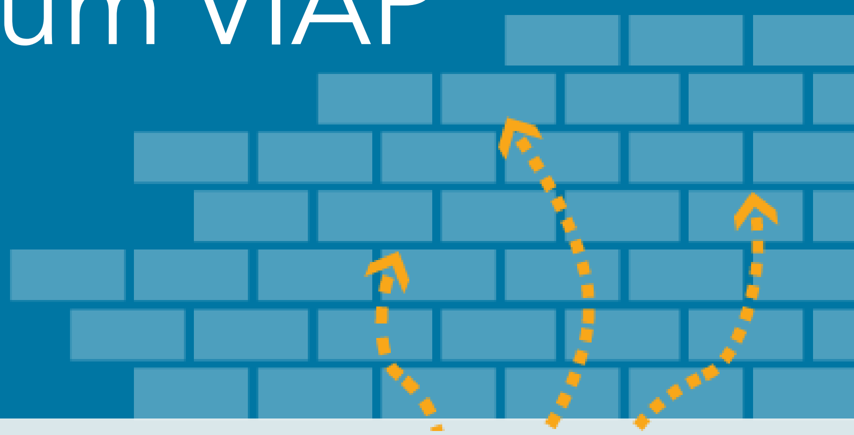
EGLE
MICHIGAN DEPARTMENT OF
ENVIRONMENT, GREAT LAKES, AND ENERGY

Guidance Document for the Volatilization to the Indoor Air Pathway (VIAP)

Volume 4:
Investigative approach for petroleum VIAP



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This guidance document was developed to promote a consistent and informed approach by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) to the volatilization to the indoor air pathway (VIAP). This document is a ready-reference tool for anyone trying to address the VIAP in Michigan. The information contained in this document is drawn from existing manuals, various reference documents, and a broad range of colleagues with considerable practical experience and diverse educational backgrounds. The information provided in this document is available as a technical reference to assist any party conducting investigations and evaluating the VIAP to support risk management decisions.

NOTE: The use of the information in this guidance requires that the data collected be representative of the actual conditions and for the purpose that it is intended. It is the user's responsibility to understand the strengths and weakness of the sampling method prior to utilizing and that the resulting data is what the decision is based on.

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Volume 4 Executive Summary

Petroleum vapor intrusion (PVI) is a unique subdivision of the volatilization to indoor air pathway (VIAP) distinguished by the influence of aerobic biodegradation in degrading volatile petroleum hydrocarbon (PHC) vapors over short distances. As a result, unacceptable risks from PVI are generally only observed where: 1) non-aqueous phase liquid (NAPL) is near or entering a structure; 2) NAPL has entered a utility that is connected to a structure; or 3) groundwater above the volatilization to indoor air criteria (VIAC) is entering a structure.

The risk evaluation associated with PVI should focus on contaminated groundwater at the surface (i.e., top) of the zone of saturation and areas where the non-aqueous phase liquid (NAPL) body is located above the saturation zone or where mobile NAPL intersects and may enter an underground conduit that can transport vapors to a structure. For PVI, risk evaluation can often be carried out through application of nationally supported separation distances and/or strategic placement of representative soil gas samples above and around the NAPL body and contaminated groundwater.

1. Introduction

PVI and the direct volatilization of a petroleum hydrocarbon into a structure is a subdivision of the VIAP and is the process by which PHCs volatilize into vapors and migrate into a structure with the potential to pose an unacceptable exposure risk to human health.

This document uses a scientifically based approach that has been supported by empirical data and is based on the ITRC Petroleum Vapor Intrusion – Fundamentals of Screening, Investigation, and Management (PVI -1) (ITRC 2014) so that decisions can be made to confidently screen out any area, place, parcel or parcels of a property, or portion of a parcel of a property and focus limited resources on the small fraction of petroleum-contaminated properties that warrant further evaluation, vapor control, or an additional response activity to prevent unacceptable exposure risks. This document is drafted to specifically address only PVI and is consistent with Part 201. However, the approaches found in this document are applicable and can be used under Part 213 though the terminology will be different due to the use of a Risk-Based Corrective Action program consistent with ASTM International E1739.

> **NOTE:** The use of the information in this volume requires that the data collected be representative of the actual conditions and for the purpose that it is intended. It is the user's responsibility to understand the strengths and weakness of the sampling methodology prior to utilizing and that the resulting data is what the decision is based on.

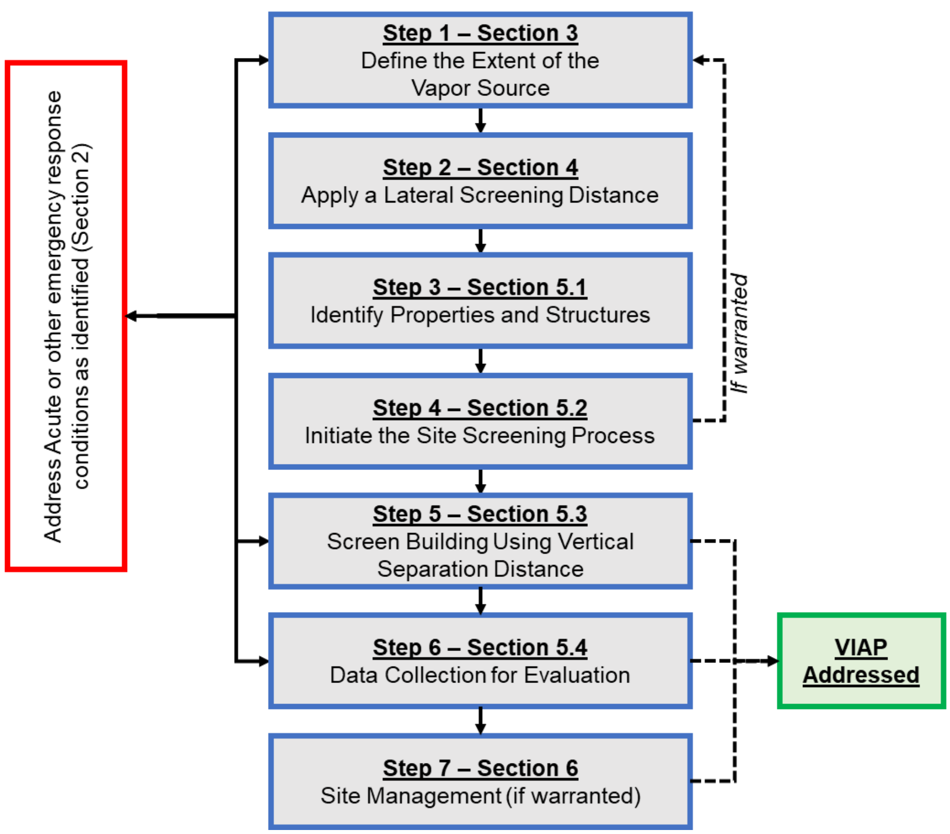
1.1. About this Volume

This volume is intended for petroleum releases that are sufficiently characterized and has data to develop a conceptual site model (CSM) for use in making risk-based decisions to identify and evaluate vapor sources that rapidly biodegrade in the presence of oxygen (O_2) relative to receptor locations. It does not address chlorinated volatile organic compounds (CVOCs) or other aerobically recalcitrant non-petroleum hydrocarbons compounds above the VIAC. The screening method and evaluation is applicable to petroleum releases in general and is not limited to the use of a property. This document is applicable whether the petroleum release occurred from an underground storage tank (UST); aboveground storage tank (AST); manufactured gas plant (MGP); petroleum industrial terminal, refinery, pipeline; or any other type of petroleum release.

If the release is mixed with CVOCs or has aerobically recalcitrant non-petroleum hydrocarbons compounds above the VIAC, the approach identified in **Volume 3 – Investigation Approach for Volatilization to the Indoor Air Pathway (VIAP)** should be consulted. However, if a no further action report (see Sec. 20114d) is addressing only the petroleum release that occurred or those compounds that will biodegrade in the presence of O_2, regardless of if the release is mixed with CVOCs or has other aerobically recalcitrant non-petroleum hydrocarbons compounds, this approach may be utilized.

The VIAP assessment strategy is based upon the following step approach as shown in Figure 1-1.

Figure 1-1
Generalized Approach to the VIAP for Aerobically Degradable Hazardous Substances



1.2. PVI and Vapor Intrusion (VI)

The defining feature of PVI that distinguishes it as a unique subdivision of VI is the rapid rate of attenuation of PHCs because of aerobic biodegradation. With PVI, vapor concentrations generally decrease with increasing distance from a subsurface vapor source due to aerobic biodegradation, and eventually at some distance, the concentrations become negligible (USEPA 2015a and 2015b). The extent and rate to which this natural biodegradation process occurs is strongly influenced by several factors cited by Lahvis and Baehr (1996), Suarez and Rifai (1999) and USEPA (2015a) and include: the concentration of the vapor source, the distance the vapors must travel to potential receptors, and the presence of O_2. Petroleum vapors are not expected to migrate more than 15 feet (ft) from any source with most vapors being degraded within inches to a few feet.

Studies have documented the subsurface biodegradation of PHC vapors (McAlary et al. 2007; Ririe et al. 2002; Hers et al. 2000; Ostendorf et al. 2000; Lahvis et al. 1999). Recent evaluations of empirical soil gas data have demonstrated that biodegradation can limit the migration of PHC vapors from a subsurface vapor source (USEPA 2013; Lahvis et al. 2013; Davis 2009). These studies show that the potential for PVI is reduced because biodegradation minimizes the flux of PHC vapors in soil gas from a vapor source to overlying buildings.

General differences between PVI and VI for PHCs and CVOCs are discussed in Table 2-1 ITRC (2014) which is based on USEPA (2012a). These differences form the basis for the PVI-specific facility screening approach discussed and detailed in this volume.

1.3. Biodegradation

Aerobic biodegradation is the most important fate and transport mechanism for understanding PVI and is the basis for the screening strategy presented in Sections 4 and 5. The processes of partitioning, diffusion, advection, and mixing are the same for PHCs and other compounds, including CVOCs. Further details on these processes, its uniqueness to PVI, and the biogeochemical behavior of PHCs is discussed in Appendix C - Chemistry of Petroleum and Appendix M - Fate and Transport of Petroleum Vapors in ITRC (2014). A brief summary of the processes of the biodegradation is provided below.

The Process of Biodegradation

PHC-degrading bacteria are found in biologically active soil in most environments (USEPA 2015a) in Michigan. PHC-degrading bacteria can consume hydrocarbons rapidly in the presence of O_2. This process limits the transport of PHC vapors. Although PHCs can be biodegraded in the absence of O_2, the most rapid rates of biodegradation typically occur under aerobic conditions. The vadose zone above an area contaminated by a petroleum NAPL is normally an aerobic environment in which O_2 can be readily replenished from the atmosphere. USEPA (2013 and 2015b) identified a total petroleum hydrocarbon (TPH) concentration of 250,000 micrograms per kilogram (µg/kg) as a metric for clean, biologically active soil absent of NAPL. EGLE uses a multiple lines of evidence approach for evaluation of when NAPL is absent (see EGLE's Non-Aqueous Phase Liquid – Petroleum Releases Characterization, Remediation, and Management Guidance dated June 2023) to identify clean, biologically active soil. The rates of petroleum vapor biodegradation typically exceed the rates of petroleum vapor transport via diffusion; therefore, petroleum vapors are often fully attenuated by aerobic biodegradation processes in the vadose zone. This process is fundamental in understanding why unsaturated soil that does not contain NAPL does not pose a risk to the VIAP.

Environmental Effects on Biodegradation

While there is the general reliability of aerobic biodegradation in reducing the potential for an unacceptable risk for PVI, are some environmental factors can hinder this process, such as lack of soil moisture (USEPA 2015a), which are not common in Michigan. The most significant factor in biodegradation is the availability of O_2, which is a necessary electron acceptor and enzyme reactant in the aerobic biodegradation of PHCs. Roggemans et al. (2001) showed O_2 concentrations of 2% by volume to be supportive of aerobic biodegradation. Other factors that can limit the biodegradation are described in ITRC (2014). In Michigan, these factors can often be found by the lack of O_2 present in the subsurface.

1.4. PVI Conceptual Site Model (CSM)

A CSM provides an iterative representation of the site data and information collected from the property or properties and guides the decision-making process. The CSM should be refined throughout the life of the project as new information is acquired. Because of the importance of biodegradation to PVI, the CSM for any petroleum release should incorporate biodegradation. Information to construct the CSM is acquired from historical research, facility characterization (e.g., sample collection), and an understanding of contaminant behavior, among other sources. Additional information on the development of a CSM can be found in ASTM International E1689-95 (2008) Standard Guide for Developing Conceptual Site Models for Contaminated Sites.

Vapor Source for a Petroleum Release

CSMs assist in defining and depicting the nature and extent of the vapor source and identifying where a potentially unacceptable risk for the VIAP may occur to guide further evaluation or response actions. Site data shows that when petroleum is most likely to pose a risk to the VIAP it is limited to NAPL being close to structures (e.g., less than 15 feet); dissolved phase PHCs or NAPL in direct contact with or entry into building foundations (e.g., basements, elevator pits, etc.); and NAPL entering into subsurface utilities (McHugh et al. 2010). The vapor source is key to understanding and identifying where potentially unacceptable risks for the VIAP may occur and is generally associated with the applicable unrestricted criterion. The applicable unrestricted VIAC can also be used to understand the full extent of a person's obligations that exist under Part 201. See **Volume 6 – Volatilization to the Indoor Air Criteria** for more information.

For the risk evaluation of the VIAP associated with a petroleum release, only the applicable unrestricted groundwater VIAC and NAPL is used because of the aerobic biodegradation of PHC vapors in clean biologically active soil (soil without residual NAPL). Petroleum-contaminated soil in exceedance of appliable unrestricted residential soil VIAC that has been determined through multiple lines of evidence to be without NAPL will not be utilized in PVI risk evaluations.

NOTE: If an evaluation is made in accordance with Rule 299.14(5) and Rule 299.24(5) using more representative data such as soil gas, the soil gas data can be used to show compliance with the VIAC and that an unacceptable risk will not occur for a specific structure. The need for land or resource use restrictions will be highly dependent on-site conditions, how or where the soil gas samples were collected in relation to the vapor source, and if future land uses can be evaluated with representative soil gas samples. See **Section 6** and **Attachment D.4** for more details.

2. Addressing Acute Vapor Risks

Unacceptable risks for VIAP may pose both immediate threats to safety (e.g., fire or explosion potential from petroleum vapors or methane) and possible short-term adverse health effects (acute) from inhalation of toxic chemicals. While rare, the potential for these to occur is often the greatest after a new release but should be initially evaluated in the investigative process for structures within the lateral inclusion zone (LIZ).

NOTE: If strong petroleum odors are detected or combustible, explosive, or O_2-deficient conditions are found to exist inside a building, then first responders should be contacted immediately.

The following scenarios are site conditions when short term or acute health effects are possible and need to be evaluated:

- NAPL is less than 5 feet from a structure,
- Soil vapor above the time-sensitive interim action screening levels (TS MSSLs),
- Petroleum odors have been identified within a structure, or
- NAPL has entered an underground conduit that can transport vapor directly to a structure.

Additional Information is provided in **Attachment A.4** on the acute vapor risks associated with petroleum.

3. Define Extent of the Vapor Source – Step 1

Delineation of the vapor source for a petroleum release is necessary to identify which buildings and properties are within the LIZ (**Section 4**) and if there is sufficient vertical separation distance to screen out buildings (**Section 5**). The delineation required for the VIAP risk evaluation associated with a petroleum release will be the delineation of groundwater to the applicable unrestricted groundwater VIAC and the delineation of the NAPL body.

Additional information on vapor source delineation can be found in **Attachment B.4** and additional information on NAPL evaluation can be found in EGLE's Non-Aqueous Phase Liquid – Petroleum Releases Characterization, Remediation, and Management Guidance dated June 2023.

NOTE: Structures and properties outside of the LIZ require no further evaluation. Conduits and utilities outside of the LIZ only require evaluation if they have mobile NAPL that entered the utility within the LIZ and are found to be transporting NAPL or vapors beyond the LIZ.

4. Apply a Lateral Screening Distance – Step 2

Once the delineation of the groundwater to applicable unrestricted residential VIAC and the NAPL body is complete, a LIZ can be applied. The LIZ is used to evaluate whether a structure or a property is close enough to a vapor source to be considered a potential risk to the VIAP and require further evaluation. For petroleum, the LIZ includes the extent of the groundwater and/or NAPL vapor source as well as the applicable screening distances beyond the delineated extent of the petroleum vapor source.

NOTE: The LIZ distances and vertical screening distances should be the same because the physical processes acting on PHC vapor sources (mass flux from the source, O_2 demand, and biodegradation) are the same in the vertical and horizontal directions (ITRC 2014).

The vertical screening distances can be applied laterally in the absence of preferential pathways (natural or man-made). Structures, properties, and utilities located within the distance established by the LIZ (including those structures above a vapor source) require further evaluation as discussed in **Section 5**. For a well characterized vapor source, the following distances may be applied:

- 15-feet from NAPL beginning at a location where NAPL is not located
- 5-feet for groundwater contamination (i.e., dissolved-phase sources), can be measured or drawn from the edge of the delineated groundwater plume

For a petroleum release, a 30-feet LIZ may be applied for a facility that is not well characterized, when there are physical features or obstructions (e.g., a road) that require long spatial distances between the borings or sampling locations, and the extent of contamination is interpolated. If warranted, the use of statistical methods, such as Kriging, can provide a means for justification of interpolated extent. EGLE recommends that, where possible, sufficient delineation is completed to use the smallest LIZ rather than apply the 30-foot LIZ distance.

In some cases, a person may wish to reduce the LIZ distance further than the distances identified above. It may be possible with a petroleum release to reduce the LIZ to the extent of groundwater and/or NAPL vapor source with supporting data. This can be done through a representative soil gas investigation that shows PHC vapors are not migrating past the sampling location.

Alternatively, if a representative soil gas sample cannot be collected, a demonstration that includes a site-specific evaluation of O_2 in soil gas at the extent of the LIZ can be conducted. If the O_2 in the soil gas is greater than 2%, then there is sufficient O_2 to support rapid aerobic degradation and a reduction in the LIZ may be established. However, the LIZ cannot be less than the extent of the vapor source.

NOTE: The LIZ cannot be less than the extent of the vapor source, which is the NAPL body and the dissolved phase groundwater contamination in exceedance of applicable unrestricted residential VIAC. If an evaluation is made in accordance with Rule 299.14(5) using more representative data such as soil gas, the soil gas data can be used to show compliance with the groundwater VIAC.

5. Evaluate Within the Extent of the Liz – Steps 3 – 6

Any structure or property within the LIZ (including those above a vapor source) require an evaluation of the potential for an unacceptable risk to human health. In some cases, it may not be possible to determine a final LIZ until the investigation is complete. The evaluation and screening process identified below should begin immediately for structures within the preliminary or assumed LIZ.

5.1. Identify Properties, Structures, and Utilities – Step 3

All properties, buildings, utilities, and preferential pathways within the LIZ must be identified. The utilities consist of any conduits that NAPL can enter, and the preferential pathways consists of any utility backfill that is more permeable than the surrounding materials that may alter the migration of the vapor source. Details on what information should be obtained is provided in Table 5-1.

NOTE: The evaluation of utilities and preferential pathways is limited to the vapor source migration. The migration of PHC vapors in utility backfill or the migration of vapors to a utility doesn't warrant additional consideration for the risk assessment as the PHC vapors will rapidly degrade as outlined in **Section 1.3.**

Table 5-1

Information on the Buildings, Properties, and Utilities Required

Building, Property, or Utility	Information required
Properties	• Lot lines • Current use or property restrictions
Structures	• Depth below grade of current structure • Construction materials and methods • Foundation • Presence of the sump or other features that may allow for the direct volatilization to occur
Utilities	• Location • Depth below ground • Ability to transport vapors and have a mobile NAPL vapor source enter into it
Backfill surrounding the Utilities	• Type of soil found at the property and throughout the facility

5.2. Initiating the Screening Process – Step 4

The screening process should begin as soon as a structure is identified within the LIZ (see **Section 5.1** above), even if the LIZ is not completely established.

The screening process is implemented by first evaluating if there is sufficient data to determine if the vertical screening distances may be applied to a structure in the LIZ. In order to complete this evaluation, data that was collected in Section 4.0 and **5.1** is evaluated to confirm that the following questions can be answered:

- Is the depth of groundwater known?
- What is the depth of the building foundation below grade?
- Is the location of the vapor source known?
- Is the distance between the vapor source and the structure known?
- Where are conduits located in relation to the mobile NAPL (if present)?
- Can the mobile NAPL enter the conduit?

If the questions cannot be answered, additional data collection is warranted. If the questions can be answered, a person should then proceed to Step 5 and screen the building(s) using the vertical separation distances discussed in **Section 5.3** below. Sampling methods are further described in **Section 5.4** and **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP).**

Additional Considerations

The VIAP can only pose an unacceptable risk if there is a structure present. Therefore, a person implementing their due care obligations under Sec. 20107a should focus on any current or planned structure when evaluating the site. However, when closure or a no-further action is sought, future use must also be considered, which could include a future development or changes to the current structure. See Attachment D.4 for when land and resource use restrictions may be needed.

NOTE: If a party is using the site-specific VIAC provided by EGLE: Under Sec. 20120b**,** alternate site specific evaluations that better reflect the best available information concerning the toxicity, exposure risk posed by the hazardous substance, or other factors that support an unacceptable risk will not occur may be proposed for review and approval to EGLE.

Petroleum vapor sources that remain and are deeper than the bottom of a future structure and greater than 5 feet below grade are typically able to be assessed. However, shallow vapor sources (<5-feet) are often difficult to assess. Modeling done by the USEPA (2012b and 2013) suggest that if a sufficient mass of contaminants remain and soil gas concentrations are high, the construction of a building can change the soil gas concentrations or create an oxygen shadow and may cause an unacceptable risk to the VIAP, even though soil gas sampling data prior to construction may not indicate it. In areas where a structure is not present, but a shallow vapor source remains, a response action that uses a restricted closure or no-further action may use a land or use restriction in lieu of further assessment.

5.3. Screen Building Using Vertical Separation Distance – Step 5

Assess whether further investigation is necessary (in **Section 5.4**) based on the measured vertical separation distance between the building foundation (including the slab and the depth of any sumps that may allow for the direct volatilization to occur) and the top of the groundwater and/or NAPL vapor source. Vertical separation distances can be used to screen out a facility without any further vapor sampling. This evaluation may need to be reviewed on a seasonal basis to confirm the initial findings, especially when a CSM has required modification based on new data, the NAPL body is not stable (see EGLE 2023 Petroleum NAPL guidance), dissolved vapor source in the groundwater that has large elevational fluctuations, or vapor sources beneath the groundwater become exposed with groundwater fluctuations. The vertical separation distance should be based on the top of the vapor source and the bottom of the structure foundation – this distance should not be estimated.

For a facility with a petroleum release, the following initial screening distances may be applied:

- 15-feet for NAPL
- 5-feet for groundwater contamination (i.e., dissolved-phase sources)

If these vertical separation distances are met, then no additional data collection is warranted for the VIAP. If the structure cannot screen out, or if there are utilities that need to be further evaluated, a person should see **Section 5.4** for sampling or **Section 7** to consider an alternate method for evaluating the VIAP.

5.4. Data Collection and Evaluation – Step 6

If a structure or property is not able to be screened out using the vertical separation distances identified in Section 5.3 or if there are utilities that may directly transport vapors to a structure, then representative data will need to be collected. The data collection should be based on where the NAPL and/or groundwater vapor source is in relation to the structure.

Additional information on data collection for the following scenarios is provided in **Attachment C.4**:

- Structure over a Vapor Source
    - Vapor Source not in Contact with a Structure
    - Vapor Source in Contact with a Structure
- Structure adjacent to a Vapor Source
- Conduit in Contact with mobile NAPL
- Structures are Not Currently Present

6. Site Management – Step 7 (When Warranted)

With the rapid aerobic degradation, most structures will screen out and site management other than possible land use controls are typically not needed. As discussed in Section 4 and 5, unacceptable risks associated with petroleum are typically limited to:

- NAPL that is within the separation distances described in Sections 4 and 5,
- NAPL or a dissolved source of petroleum-contaminated groundwater above the applicable VIAC entering a structure, or
- A direct pathway for vapors to migrate into a structure, such as an underground conduit line (see Attachment C.4, Section 3.2).

When warranted, most strategies and approaches are dependent upon site-specific factors and cannot universally be applied across the entire property. In several areas of the state, especially where groundwater is less than 10-feet below grade, the approach is very different than those where deeper vapor sources will remain. Furthermore, the need for land or resource use restriction will be highly dependent on-site conditions, if a vapor source remains, how and where representative soil gas samples are collected in relation to the vapor source.

For petroleum, **Attachment D.4** can be used as a guide for the evaluation and when land or resource restrictions or an alternate evaluation will be necessary. Detailed management strategies including the use of either a land and resource use restriction, when they may or may not be appropriate, response activity and more is further described in Volume 5 – Response Activity. Many of the site management activities are applicable to VIAP regardless of if the vapor source only contains petroleum and describes additional approaches that may be appropriate for only petroleum.

7. Alternative evaluation approaches

There are many different approaches that may be utilized for the evaluation of the potential risks associated with petroleum and the VIAP than what is described in this document. An alternate approach that may be more cost efficient or save time could be considered, especially if the site doesn't screen out using the steps outlined in **Sections 3 through 6**. Many of the approaches that can be applied are site-specific, which is why they are not described in detail in this document. The obligation to identify an alternative approach and provide justification on why the approach meets the obligations of Part 201 is required of the person proposing the response activity.

Example site conditions that may be encountered and alternative or site-specific evaluation approaches are provided and discussed in **Attachment E.4**.

Attachment A.4 - Addressing Acute Vapor Risks

The VIAP may pose unacceptable risks as immediate threats to safety (e.g., fire or explosion potential from petroleum vapors or methane) and adverse health effects from inhalation of hazardous substances that represent short-term or acute (i.e., less than chronic) exposure concerns. While rare, the potential for these to occur is greatest after a new release but should be evaluated initially in the investigative process with old releases for structures within the LIZ to verify that the conditions do not exist. The evaluation is described below and in ASTM E2993-23 *Standard Guide for Evaluating Potential Hazard in Buildings as a Result of Methane in the Vadose Zone*.

Fire and Explosion

The risk from fire and explosion associated with petroleum is greatest shortly after the release has occurred and when mobile NAPL has been found to be in contact or has entered a structure. These risks should be assessed after a new petroleum release has been discovered, when the NAPL vapor source is either in contact or has entered a current structure, or vapors are found to be either migrating to or into a structure.

The assessment from fire and explosion is done using an appropriately calibrated field meter (e.g., four gas meter) until either the vapor source has been addressed through a response action, or there is sufficient information collected that affirms that the petroleum release does not pose a potential fire or explosion risk. Groundwater and soil gas data may also be used. The monitoring frequency of the explosive conditions should be established on a case-by-case basis and be based on the site conditions present and the potential that concentrations exceed the lower explosive limit (LEL).

Table A-1 provides example LEL readings and concentrations for commonly identified compounds in gasoline. Additional LELs for other hazardous substances are available in **R 299.50** Toxicological and Chemical-Physical Properties under Part 201. When concentrations in indoor air or soil gas are found near a structure at a site that are approximately 10% of the LEL, constant monitoring and ongoing assessment of the potential of fire and explosion should begin. The installation of calibrated gas leak detectors and alarms may be appropriate in situations that require frequent monitoring and can reduce the need to complete constant physical monitoring.

Table A-1: Lower Explosive Limit (LEL %) at 25° Celsius of Commonly Detected Hazardous Substances in Gasoline

Hazardous Substance	LEL %	LEL (ppm)	10% LEL (ppm)	LEL (µg/m^3)	10% LEL (µg/m^3)
Gasoline	1.4	14,000	1,400	4.1 E+07	4.1 E+06
Benzene	1.2	12,000	1,200	3.8 E+07	3.8 E+06
Ethanol	3.3	33,000	3,300	6.2 E+07	6.2 E+06
Ethyl Benzene	0.8	8,000	800	3.5 E+07	3.5 E+06
Hexane	1.1	11,000	1,100	3.9 E+07	3.9 E+06
Toluene	1.1	11,000	1,100	4.1 E+07	4.1 E+06

Note: Additional hazardous substances are available in R 299.50

Methane is commonly associated with the anaerobic biodegradation of petroleum or other organic material and is likely to be found on a facility where a petroleum release has occurred. However, methane will aerobically degrade, and the presence of methane alone may not indicate a risk from fire and explosion. When methane is present, an evaluation of the degradation, mass, concentration, and pressure should be completed as part of the analysis to determine the potential need for immediate interim response actions. If concentrations of approximately 10% of the LEL are identified near a structure, constant monitoring, and ongoing assessment of the potential of fire and explosion should begin to ensure no unacceptable risk occurs in the future.

Short Term and Acute Health Effects

Because of rapid biodegradation, potential exposure to petroleum hazardous substances that represent short term or acute adverse health effects (not associated to fire and explosion) for petroleum is very rare. In addition, the screening levels, and criteria for the majority of the hazardous substances associated with petroleum releases are based on 30-year (chronic) exposures.

In 2016, the Toxics Steering Group (TSG) VIAP Workgroup was tasked by EGLE and the Michigan Department of Health and Human Services (MDHHS) to evaluate and develop indoor air screening levels for volatile substances that are protective against human health effects that may result from ongoing VIAP exposures and was revised in 2020. Specific to petroleum releases, EGLE’s TSG found that toluene, n-propylbenzene, diisopropyl ether, and ethanol represent short-term or acute exposure risks at concentrations less than levels that present chronic risks (EGLE, 2020). In addition, the TSG report also identified concentrations for which exceedances of benzene, ethylbenzene, n-hexane, trimethylbenzenes (inclusive of all three isomers), and/or xylenes pose short-term or acute exposure risk concerns at concentrations above chronic exposure risks. The TSG report (EGLE, 2020) includes recommended interim action screening levels (RIASLs) and time sensitive RIASLs (TS RIASLs) for indoor air. The TS RIASLs represent elevated concentrations that pose short-term or acute exposure concerns even for those hazardous substances that are typically considered a chronic exposure concern. Based on those findings, EGLE developed media-specific volatilization to indoor air interim action screening levels (MSSLs) and time-sensitive MSSLs (TS MSSLs) for soil, shallow groundwater, groundwater not in contact, and soil gas and can be found in **Volume 6 –Volatilization to the Indoor Air Criteria**. As discussed in the document, soil that does not contain NAPL will not be used for risk evaluations at petroleum release sites and groundwater above applicable TS MSSLs does not represent an acute risk but rather require further evaluation if it does not screen out with vertical separation distances.

The following scenarios are site conditions when short term or acute health effects are possible and need to be evaluated:

- NAPL is less than 5 feet from a structure,
- Soil gas above the TS MSSLs,
- Petroleum odors have been identified within a structure, or
- NAPL has entered an underground conduit that can transport vapor directly to a structure.

If any of these situations have been identified, it is critical to immediately assess the risks and identify if there are response actions that must be immediately implemented to abate the unacceptable risks. The response actions should identify the vapor source causing the potential short term and acute health effects and prevent vapors from continuing to be within the structure.

NOTE: Indoor air RIASLs and TS-RIASLs are identified in the TSG Report (EGLE 2020) that may be used as part of a line of evidence for the potential VIAP risks. Compliance decisions and long-term protectiveness for VIAP must be based on applicable VIAC.

Prior to implementing interim response actions resulting from exceedances of applicable shallow groundwater or groundwater not in contact VIAC or TS MSSLs, representative soil gas sampling or sub-slab soil gas sampling is recommended and may also include indoor air sampling. If an evaluation is made in accordance with Rule 299.14(5) using more representative data such as soil gas, the soil gas data can be used to show compliance with the groundwater VIAC.

If indoor air samples are collected, they should be paired with a representative number of sub-slab samples or a conduit vapor sample (when appropriate). Though indoor air samples alone in Michigan do not allow for closure, it does provide a line of evidence and allows for an evaluation of the potential exposure at the time of sampling and/or the effectiveness of any implemented corrective or response actions. See **Attachment C.4** for the number of sampling locations, number of sampling rounds, and sampling frequency.

Attachment B.4 - Vapor Source Delineation for Petroleum

Under Part 201, NAPL, the presence of shallow groundwater, and certain foundation types prevent the use of the generic groundwater volatilization to indoor air inhalation criteria and soil volatilization to indoor air inhalation criteria for the evaluation of the VIAP. Therefore, the location where any one of these conditions exist, the determination of the extent of a vapor source requires the development of site-specific criteria and are referred to as the VIAC. Once the criteria have been established, the extent of the vapor source should be defined using appropriate sampling methodology.

For petroleum releases, the vapor source is limited to where the NAPL is located (i.e., residual, mobile, and migrating) above the zone of saturation and the location where the dissolved phase groundwater contamination above the applicable unrestricted residential VIAC is present at the top of the aquifer. The extent of the NAPL body will be determined using multiple lines of evidence as discussed in EGLE's June 2023 Non-Aqueous Phase Liquid – Petroleum Releases Characterization, Remediation, and Management Guidance, which will likely include the chemical analysis of soil samples.

NOTE: If an evaluation is made in accordance with Rule 299.14(5) using more representative data such as soil gas, it is possible to show compliance with the groundwater criteria or screening levels, which can aid in the delineation of the vapor source. Soil gas data may also be used to show that the NAPL does not represent a vapor intrusion risk for a current structure or future structure. The need for land or use restrictions will be highly dependent on-site conditions, how or where the soil gas samples were collected in relation to the vapor source, and if future structures can be evaluated with the soil gas samples. See **Attachment D.4** for more details.

Investigation methods are further described in **Section 5** and **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP).**

For NAPL and dissolved-phase petroleum sources in the groundwater, understanding the NAPL body and groundwater plume stability is a key factor in establishing the extent of the vapor source. This document is not intended to fully address how stability is established; however, in general stability is determined by:

- Stable footprint over time,
- Stable or decreasing concentrations in the groundwater, and
- If mobile NAPL is present, residual NAPL located beyond where mobile NAPL is located in the NAPL body.

Additional considerations for the vapor source delineation are provided below.

Analytical

The chemicals selected for analysis at a potential PVI facility depend on the petroleum product released and type of contamination, as well as the objectives of the investigation. A list of the recommended parameters for petroleum products can be found in Appendix B of the *Application of Target Detection Limits and Designated Analytical Methods* RRD Resource Materials, 2016.

If vapor samples are collected, an assessment of biodegradation should be conducted and include the analysis of O_2, CO_2, and methane. After O_2 is depleted, methanogenic bacteria convert petroleum hydrocarbons to methane and carbon dioxide. If methane is above 1% by volume, then conditions are anaerobic and is indicative that the sampling is likely near a petroleum NAPL source. Additionally, nitrogen may be collected as an indicator as to whether there is replenishment of atmospheric air or an advective flow of soil gas that flushes out the air. If nitrogen is displaced (much less than 79% by volume), then either the bulk soil gas is migrating, or the sample was collected under a vacuum. (ITRC, 2014).

Geology and Hydrogeology

Geologic and hydrogeologic information should be collected throughout the investigative process and incorporated into the CSM until there is an adequate understanding of the facility conditions and where the vapor source is located. The processes, methodology, and sampling density necessary to understand a facility is not discussed as part of this document. Each of these items is highly dependent upon the actual facility conditions, the variability that is present within the geology and hydrogeology in the area where the petroleum release occurred, and the potential risks being evaluated. The key for evaluating the VIAP is utilizing the data that is collected and evaluating how that data changes the CSM, impacts the need for additional information or evaluation, or may impact the way vapors from a vapor source migrate into a structure, as well as evaluating what potential risks may be present currently or in the future.

Vertical Distribution of Contaminant Concentrations Below the Water Table

Groundwater or NAPL, as a subsurface vapor source, will be influenced by the vertical distribution of contaminant concentrations in the upper reaches of the water table and by seasonal fluctuations in the groundwater table (McAlary et al., 2011; ITRC's PVI-1, 2014; and USEPA, 2015a and 2015b). Vapor sources that are beneath the water table at depths greater than 5 feet below the seasonal low-water elevation (10-feet may be assumed if the water table variation is unknown) do not need further evaluation for the VIAP. Seasonal evaluations will need to be made for NAPL bodies that are beneath the groundwater and could be exposed to the vadose zone with elevational changes to the groundwater surface. The need for a land or use restriction may be applicable if land use changes could result in an unacceptable exposure or an evaluation cannot be made for future land uses. This is further discussed in **Volume 5 – Response Activity**.

Utility Backfill and Conduits that can Transmit Vapor or a Vapor Source Considerations

The utilities and utility corridor must intersect the vapor source for there to be alterations in migration routes of the vapor source or direct transport. For the utility corridors, it is important when defining the vapor source to identify utility corridors that may have more porous and permeable material than the adjacent native soil as well as a vapor source that can migrate (e.g., mobile NAPL and dissolved phase). For the utilities, it is important to identify the utilities where the vapor source of mobile NAPL can directly enter, and the utility then may serve as a conduit to directly transport vapors into a structure.

NOTE: Utilities that are pressurized (e.g., water and gas lines), or that are documented to not connect to structures (e.g., dedicated storm sewers), are not necessary to evaluate beyond supplying supporting documentation. Supporting documentation should include the type and location of the utility.

Consideration of the backfill material as a preferential pathway for the vapor source is limited to facilities that have site soils that consist of finer grain soil materials (e.g., silts and clays) that were backfilled during the installation of the utility with coarser grain materials (e.g., gravels and sands). For the backfill to act as a preferential pathway, the NAPL or groundwater vapor source must be able to enter the backfill material and then migrate along the utility corridor.

NOTE: Backfill in a utility corridor that is similar in grain size and permeability to the native material is not necessary to evaluate beyond supplying supporting documentation commonly obtained through standard soil sampling techniques and documentation.

Attachment C.4 - Data Collection and Evaluation for Petroleum Sites

If a facility or property is located within the lateral inclusion zone (LIZ) and is not able to be screened out using the vertical separation distances, if a site-specific approach is implemented, or if there are utilities that mobile NAPL may enter and can directly transport vapors to a structure, then data collection is needed to evaluate risks. The data collection should be based on where the vapor source is in relation to the structure and is discussed in detail in the following sections:

- Structure over a Vapor Source (**Section C.1.0**)
    - Vapor Source not in Contact with a Structure (**Section C.1.1**)
    - Vapor Source in Contact with a Structure (**Section C.1.2**)
- Structure adjacent to a Vapor Source (**Section C.2.0**)
- Utilities (**Section C.3.0**)
    - C.3.1 Petroleum Vapor Source within Utility Backfill Material (**Section C.3.1**)
    - C.3.2 Petroleum Vapor Source in an Underground Conduit (**Section C.3.2**)
- Structures are Not Currently Present (**Section C.4.0**)

Types of Soil Gas Samples

At facilities that don't screen out, the investigation approach after the vapor source has been adequately delineated will include soil gas sampling. Representative soil gas data allows for better risk-based decisions since soil gas data reflect the processes that are occurring in the vadose zone (e.g., partitioning, sorption, biodegradation) from the vapor source to the overlying receptor at the location being sampled. Three primary options are available for characterizing soil gas which differ by the sampling location relative to the structure under investigation (if present):

- *Subslab Soil Gas.* These sampling points are located *within the footprint* of a building and are installed by drilling through the slab. They are not located outside of a building and require an actual structure to be present. Sampling depths are less than 1-foot below the bottom of the slab. They are the most representative and predictive of vapors located beneath the structure and their potential to cause an unacceptable health risk.

> **NOTE:** Subslab soil gas samples are preferred over exterior samples for a PVI building evaluation unless the lateral migration of vapors is being evaluated. More information and methods for collecting soil gas samples and additional factors in sample placement are described in **Volume 2 – Investigation Methods for the Volatilization to Indoor Air Pathway (VIAP)**.

- *Exterior Soil Gas.* These subsurface sampling points are located at some distance (usually 10 linear feet or more) away from the building. Sample points are installed within the vadose zone and at least 5 feet below the ground surface. Factors considered for selecting sampling depth include (1) fluctuations in water table depth; (2) thickness of capillary fringe; (3) a minimum sampling depth; and (4) depth of the vapor source. See **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)** for other depth considerations.
- *Near-Slab Soil gas.* These subsurface sampling points are located around the perimeter of the building (typically less than 5 feet from a building). In addition to the sampling depth considerations for external soil gas points, building features (such as depth of foundation) should be considered when selecting near-slab sampling depths. Subslab soil gas samples are preferred in evaluating petroleum over near-slab soil gas samples unless lateral migration is being evaluated. Near-slab samples are typically used to evaluate the fill associated with a utility line or the lateral migration of vapors (see **C.2.0**).

NOTE: Pressure differential readings, as well as O_2, CO_2, and methane, should be collected prior to any samples being collected to aid in CSM development and to ensure that the pressure gradient is from the subsurface into the structure.

General advantages and disadvantages for each type of vapor sampling method for the investigation of a petroleum release are provided in **Table C-1**. More information is available in **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)**.

Table C-1: Advantages and Disadvantages of Various Investigative Strategies

Measurement	Advantages	Disadvantages	Comments
Subslab soil gas	• Gives concentrations immediately below building and receptors • Most reliable predictor of the potential exposure for the VIAP when the vapor source is not directly entering the structure	• May have contaminants from interior sources • Highly intrusive; requires building access and drilling through slab/floor	Preferred approach for evaluating current structures.

Measurement	Advantages	Disadvantages	Comments
Near-Slab Soil Gas **(e.g., typically, less than 5 feet from a building)**	• Less chance of short-circuiting by atmospheric air • Temporal variations in concentration minimal at depth greater than 5 feet below ground surface. • Data can be collected outside the building • Can evaluate the lateral migration of a vapor source towards a structure.	• May not reflect subslab concentrations • Requires an understanding of the building construction and size • Typically requires larger equipment to reach depths below a basement	Concentrations are likely to be different than those collected directly beneath the structure.
Exterior Soil Gas **(>5 feet below grade)**	• Less chance of short-circuiting with atmospheric air • Temporal variations in concentrations are minimal the deeper the soil gas is collected	• Does not account for aerobic biodegradation in soil layers less than 5 feet below ground • May not be representative of future uses where groundwater or shallow petroleum sources are present	Soil gas data can provide evidence of biodegradation as a function of vertical transport distance, can verify lateral migration, and reliably provide oxygen data.
Exterior Shallow Soil Gas (<5 feet below grade)	• At some sites, this is the only data able to be collected. • Will reliably provide information on oxygen and verify lateral migration. • May provide an evaluation of aerobic degradation in shallow soil	• The closer the borings get to the surface, the greater the chance for short circuiting. • Subject to temporal variations with atmospheric dilution • May not represent future uses nor vapor concentrations beneath a structure	Concentration of the vapor source, presence of NAPL, and depths should be considered when evaluating shallow soil gas samples – see **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)** for more details.

Vertical soil gas profiles can be acquired by installing a series of nested or clustered exterior or near-slab soil gas points at a range of depths. Such soil gas data may be useful for defining the zone of active biodegradation and demonstrating that the decrease in PHC concentrations with distance from the source is due to biodegradation. This may be useful in development of site-specific risk evaluations. Additional information on vertical soil gas profiles can be found in **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)**.

C.1.0 Structure Over a Vapor Source

There are two (2) scenarios that must be considered when a structure directly overlies a vapor source. **Section C.1.1** describes the data collection and evaluation that should be conducted for a facility where the vapor source is not in contact with a structure and **Section C.1.2** describes where it is in contact with a structure.

C.1.1 Vapor Source Not in Contact with a Structure

A vapor source is not in contact with a structure when, after considering seasonal variation to the depth to groundwater and the capillary fringe, a measurable distance of vadose zone between the vapor source and the structure is maintained. The structure is measured from the bottom of the slab; or the depth of footings if they can transport vapor into the structure (poured footings cannot); or the subsurface utilities (including the sump) if they can transport vapor or the vapor source.

When the vapor source directly underlies a building, subslab soil gas samples should be collected based on the number of sampling locations and frequency described in **Tables C-2** and **C-3**. Exterior soil gas samples in lieu of subslab soil gas samples are appropriate for structures when all of the following apply:

- The vapor source concentration is within one-order of magnitude on all sides of the structure,
- There is no conduit or preferential pathway that connects the vapor source to the structure that must be evaluated,
- The soil gas sampling point can be installed using proper techniques at a depth >5 feet below the ground surface and greater than the depth of the structure considering capillary zone, depth of footings, and subsurface utilities (including the sump),
- The structure is less than 1,000 feet^2 or is a single-family structure, and
- A soil gas sample is collected from at least two opposing sides of the structure.

Other soil gas sampling approaches that utilize exterior soil gas samples in lieu of subslab soil gas samples may be appropriate and considered by EGLE if it can be demonstrated that the data provided will account for the spatial and/or temporal variability associated with the facility. Example scenarios of site conditions that may warrant exterior soil gas include, but are not limited to:

- Vapor source partially under a structure,
- The structure is less than 9,500 feet^2 and there is at least 5 feet of separation between the vapor source and building foundation, or
- The total volatile organic compound concentration of the exterior soil gas is less than 10,000 µg/m^3 and all compounds below VIAC or screening levels.

If there are exceedances of the VIAC, then a party should proceed with continued evaluation, or an appropriate response activity as further detailed in **Section 6**.

Number of Sampling Locations

The actual number of subslab soil gas sample points should be justified and based on the overall aerial extent of the vapor source beneath the structure, number of slabs or multiple levels in contact with the soil (e.g., multiple slabs-on-grade in a large warehouse), and foundation type (e.g., combined basement and slab-on-grade in a residence). A standard number of sampling points based on the size of the structure and assuming that the vapor source is under the entire structure is detailed in **Table C-2**.

To obtain the most representative results, collect vapor samples at least 5 feet inside foundation edges and towards the center of the structure or over where the vapor source is located. In addition, subslab soil gas samples should be collected during periods where vapor intrusion is turned on – there is a higher pressure below the structure than in the structure as that is representative of what can enter the structure. Additional samples should be collected near utility trenches (i.e., vapor source transport) that intersect plumes of contamination. It is understood that a sample location may need to be adjusted to accommodate the actual structure and building layout. More information can be found in **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)**, including information that may allow for a reduction in sampling points.

Table C-2: Number of Sample Locations

Building Size	Sample Density	Minimum Number of Sampling Locations
Less than 1,000-ft^2	Not Applicable	2
1,000-feet – 10,000-ft^2	3 + one additional sample per 1,500 ft^2 of building over 1,000 ft^2	3
Greater than 10,000-ft^2	9 + one additional sample per 2,500 ft^2 of building over 10,000 ft^2	9

Number of Sampling Events

The number of soil gas sampling events for petroleum should be justified and based on the presence and the distance of NAPL and/or the dissolved source petroleum-contaminated groundwater above the VIAC. The general number of soil gas sampling events required for a petroleum release is identified in **Table C-3** below.

Table C-3: Number of Sample Events for Petroleum Sites

Potential Vapor Source and Distance to Receptor	Soil Gas Sample Results	Minimum Number of Rounds
NAPL ≤ 5-feet	< VIAC	4
NAPL 5 – 10-feet	< VIAC	3
NAPL 10 – 15-feet	< VIAC	2
Dissolved Groundwater Source	< VIAC	1

Prior to use in any decision-making process, the data should be evaluated for whether the data is of sufficient quality to complete the evaluation. If the data does not meet established data quality requirements, additional data collection may be warranted. **Table C-3** provides minimum rounds of samples, and data trends should be evaluated to determine the actual number of rounds of samples. For example, if the data trends suggest the concentrations, either in the vapor source or soil gas, are increasing, additional sampling may be warranted.

Additional information can be found in **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)** about the data evaluation process. If soil gas data exceeds the VIAC, continued evaluation and/or appropriate response actions will be necessary. For more information see **Section 6.0 Response Activity, Attachment D.4, Section 7 - Alternate Evaluation Approaches,** and **Attachment E.4** for more information.

C.1.2 Vapor Source in Contact with a Structure

A vapor source in contact with a structure occurs when there is either 1) NAPL in contact with a structure or 2) there is a shallow groundwater vapor source above applicable unrestricted residential VIAC in contact with or entering a structure. A vapor source is in contact with a structure when, after considering seasonal variation to the depth to groundwater and the capillary fringe, there is not a measurable distance between the vapor source and the structure. The structure is measured from the bottom of the slab; the subsurface utilities (including the sump) if they can transport the vapor source and result in direct volatilization to the structure, or subsurface utilities that mobile NAPL has entered, and vapors can migrate in the utility to the structure.

When a vapor source is in contact with a structure, direct volatilization is likely and will need to have an appropriate response activity implemented to evaluate the risks and likely to prevent the direct volatilization into the structure (see **Section 6**). For the evaluation of immediate risks when this scenario occurs, EGLE's preference is the sampling of indoor air (**Volume 2** – **Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)**). To account for the variations in indoor air, EGLE recommends continuous indoor air monitoring. If the vapor source is being transported via utilities and sumps, EGLE recommends sampling the media in the utilities and sumps, as well as sampling the head space for vapor.

C.2.0 Structure Adjacent to the Vapor Source

Near-slab soil gas or soil gas samples outside of a structure is the primary way to evaluate the VIAP when the vapor source is adjacent to and not beneath a structure. For petroleum, soil gas samples are collected for the evaluation of O_2 and chemical analysis as described in Appendix B in the March 2016, *Application of Target Detection Limits and Designated Analytical Methods.* Oxygen concentrations can be measured with calibrated field screening instruments.

If the O_2 in the soil gas is greater than 2%, then there is sufficient O_2 to support rapid aerobic degradation and a reduction in the LIZ may be established. Chemical analysis collected should affirm this. The number of sampling events required for a petroleum release for a structure that is adjacent to a vapor source is found in **Table C-3**.

C.3.0 Utilities

A vapor source may travel from the petroleum source area to a receptor along a preferential pathway such as utility corridors, which could include, but not be limited to, sewer and septic system piping, drains, water and gas lines, and electrical conduits. It may also enter into the utility itself that will act as an underground conduit that can transport vapor and allow direct entry into a structure. Both scenarios are described in more detail in **C.3.1 Petroleum Vapor Source within Utility Backfill Material** and **C.3.2 Petroleum Vapor Source within an Underground Conduit**.

C.3.1 Petroleum Vapor Source within Utility Backfill Material

Backfill material in utility corridors can be more permeable than the adjacent native soil and, when it is, it may result in a vapor source migrating preferentially along these pathways. The characterization and evaluation for the VIAP associated with a release or migration of petroleum vapor source in utility backfill material around utility corridors is limited to utilities that have all the conditions below:

- Soil types surrounding the utility corridor are less permeable than the utility backfill material that creates preferential migration pathways for the vapor source.
- Mobile NAPL or contaminated groundwater above the appropriate VIAC are directly within the utility backfill, and
- The utility backfill with the mobile NAPL or contaminated groundwater above the appropriate VIAC in it leads to a structure.

If the mobile NAPL or contaminated groundwater above the appropriate unrestricted residential VIAC has entered into the more permeable utility backfill, it is more likely to migrate beyond the extent of the LIZ and may require additional characterization.

A vapor source that is in the utility backfill material and is directly beneath a structure is evaluated using the sampling methods described in **C.1.0**. This includes the use of subslab soil gas samples within the backfill material beneath the structure and alongside the path of the utility. The number sampling events is described in **Table C-3**.

A vapor source that is in the utility backfill material that is adjacent to a structure and within screening distances described in **Section 4** is evaluated using either near-slab soil gas or soil gas wells similar to the approach in **C.2.0**. For this scenario, the near-slab soil gas or soil gas wells are placed directly in the backfill between the mobile NAPL and the structure. The structure can be evaluated using the approach described in **C.1.0**. The number of sampling events is described in **Table C-3**.

C.3.2 Petroleum Vapor Source in an Underground Conduit

This section is only relevant when all three conditions exist:

1. Mobile NAPL is in contact with and can directly enter a conduit,
2. The conduit can transport vapor or mobile NAPL within it, and
3. The conduit directly connects to a structure.

Where the CSM and data identify that mobile NAPL is in contact with an underground conduit, an evaluation is necessary to ensure that petroleum vapors are not preferentially migrating directly into a structure.

The initial step in determining whether an underground conduit needs to be evaluated is to understand whether mobile NAPL can enter into a conduit and if the conduit directly connects to a structure. If either of these cannot occur, no further evaluation of the utility is warranted. Though many underground utilities that are under pressure, such as force main sewer lines, gas lines, or water lines, may screen out, others, such as combined sewer lines, sewer lines, and other utilities that have a void space, may screen in.

The next step is to determine whether the mobile NAPL has entered into the conduit. If the mobile NAPL has entered into a conduit, it is more likely to migrate beyond the extent of the LIZ and may require additional characterization. If mobile NAPL enters into a utility, then there is a potential for acute risks at the site that must be evaluated. See **Attachment A.4** for more information.

An underground conduit is initially screened using a photo ionization detector (PID) to aid the evaluation. Video is often used to evaluate the integrity of the conduit and whether the mobile NAPL is in or can enter into the conduit. Once this evaluation is completed, the next step in the evaluation is the collection of vapor samples from manholes or other direct access points, such as conduit cleanouts. The analytical sampling should include the same parameters associated with the release (Appendix B in the March 2016, *Application of Target Detection Limits and Designated Analytical Methods*) and should include location(s) upstream of where the mobile NAPL entered into the conduit. A standard operating procedure for the collection of vapor samples is provided in **Volume 2 – Investigation Methods for the Volatilization to the Indoor Air Pathway (VIAP)**.

The number of sampling events is based on whether the mobile NAPL is known to have entered into the conduit or not, and because of the high variability associated with conduits, increased sampling frequency is needed when it is known to be entering. Conduit sampling frequencies are identified in **Table C-4**. Detections in the conduit necessitates development and approval of applicable preferential conduit vapor site-specific VIAC (SSVIAC) to evaluate risk. Concentrations above the applicable preferential conduit vapor SSVIAC specifically for the entry of mobile NAPL into a conduit requires that access points are investigated until the extent is defined using the applicable SSVIAC. In addition, the responsible party should immediately implement response activity to prevent the further entry of mobile NAPL into a conduit and may need to mitigate conduit vapors to prevent entry into structures. If mobile NAPL is not entering a utility conduit, then the prevention of a future infiltration of the mobile NAPL vapor source into a conduit must occur. Further discussion on the response activities can be found in **Volume 5 – Response Activity**.

Table– C-4 – Mobile NAPL Vapor Source Entering an Underground Conduit

Known or Suspected	Sampling Frequency of Conduit Vapors	Response Action
Not in Contact	None	Not applicable
In contact and determined to not be entering utility	None	Response Actions may be needed to ensure vapor source will not enter in the future.
Suspected but unconfirmed	Quarterly for 1 year	Any detection in the conduit above the SSVIAC moves the utility into the known vapor source entering into an underground conduit. Response Actions may be needed to ensure vapor source will not enter in the future.
Known – Occurring	Weekly sampling until the vapor source is controlled. Structures connected to the utility should be evaluated for the entry of vapors and explosive conditions.	Implement immediate response activity – considered occurring until response activity is complete.
Known – post corrective or response action	Sample monthly for 3 months then quarterly for 3 additional quarters	Any detection above the SSVIAC requires sampling to return to the *Known – Occurring* sampling frequency.

C.4.0 Structures are Not Currently Present

Areas where structures are not currently present pose unique and difficult challenges for the VIAP especially when the vapor source is located less than 10-feet below the ground surface. When the vapor source is less than 10 feet below ground, a representative soil gas sample can be collected; however, reasonable future property uses must be considered. Whether or not an unacceptable risk for the VIAP will occur in a future structure requires a thorough understanding of the vapor source, what the soil gas concentrations are near the vapor source, and the actual or potential structure that will be constructed. Modeling done by USEPA (2012 and 2013) provides simplified simulation models to illustrate graphically how subsurface conditions with NAPL as a vapor source and building-specific characteristics, such as the presence or absence of a structure, is likely to impact the concentrations detected and create oxygen shadows. In addition, a change in land use could alter the exposure scenario changing the vapor source from not in contact to in contact.

Therefore, in many situations with shallow vapor sources, even when an evaluation is made, there still remains a need to place a land or use restriction on the property to ensure the exposure scenario that was evaluated remains the same or requires additional evaluation. The most common scenario where this occurs is where shallow soil gas samples are collected less than 4 feet below the ground due to the presence of shallow groundwater at concentrations above the applicable VIAC and where there currently is not a structure. Vapor data is likely to indicate that the VIAP is unlikely to pose an unacceptable risk; however, to ensure that a future property use doesn't alter the exposure scenario (e.g. changing it from VIAP to direct volatilization) institutional controls are often necessary.

However, where there is no structure present, the shallow vapor source has been addressed via remediation or other means or only a deeper vapor source of petroleum remains greater than approximately 10 feet below ground, appropriately placed and monitored soil gas samples may allow for an evaluation of current and reasonable future land uses. The soil gas sampling allows for a determination that either the NAPL or groundwater vapor source does not pose a vapor intrusion risk or per Rule 299.14(5) soil gas sampling data can be used to show compliance with the groundwater VIAC. Even if there is a vapor source still present, if greater than 10-feet below ground and soil gas verifies that it is unlikely to pose an unacceptable risk for all current and reasonable future land uses, a land or resource use restriction would not be necessary. Information on this process, when a land or resource use restriction is required, and other site management strategies is described in **Section 6, Attachment D.4,** and further detailed in **Volume 5 – Response Activity**.

Attachment D.4 – Site Management for Petroleum

Most strategies and approaches for site management of PVI are dependent upon site-specific factors and cannot universally be applied across the entire facility. In several areas of the state, especially where groundwater is less than 10 feet below grade, the approach is very different than those where deeper vapor sources remain. Furthermore, the need for land or resource use restrictions will be highly dependent on-site conditions, if a vapor source remains, how and where the soil gas samples are collected, especially in relation to the vapor source, and if future land uses can be evaluated with appropriately collected soil gas samples.

For petroleum, **Table D-1** can be used as a general guide for the evaluation of when land or resource use restrictions or controls (ICs), or an alternate evaluation, will be necessary for No Further Action under Part 201. Detailed management strategies, including the use of either a land or resource use restriction, when they may or may not be appropriate, response activity, and more is further described in **Volume 5 – Response Activity.** Many of the site management activities are applicable to the VIAP regardless of the hazardous substance released, however, **Volume 5 – Response Activity** also describes additional approaches that may be appropriate for only petroleum.

Table D-1: Vapor Source, Depth, and Common Site Management for Closure

Scenario – Assuming Vapor Source Not in Contact	Data Required	Outcome	Actions for Closure of the VIAP for petroleum releases
Vapor Source of NAPL less than 10 feet below ground	• Soil gas samples from subslab or at least 5 feet below ground (assuming the NAPL is not shallower than 5 feet below ground)	• Soil gas sampling with the appropriate number and rounds of data is below applicable VIAC (if structure is present)	• ICs required to ensure that land use changes don't result in exposure scenario that has not been evaluated (e.g., restrict construction to slab on grade)

Scenario – Assuming Vapor Source Not in Contact	Data Required	Outcome	Actions for Closure of the VIAP for petroleum releases
Vapor Source of NAPL is 10 feet or greater	• Data that supports a clean, biologically active soil between the NAPL and structure • Soil gas samples from a depth greater than 8 feet below ground	• For all reasonable land uses, vapor source not in contact will be maintained • Soil gas sampling with the appropriate number and rounds of data is below applicable VIAC	• No ICs required for PVI • Notice or other ICs may be required for NAPL or other pathways
Vapor Source of NAPL is 25 feet or greater below ground surface and above the water table	• Data that supports a clean, biologically active soil between the NAPL and structure	15-foot vertical separation will be maintained	• No ICs required for PVI • Notice or other ICs maybe required for NAPL or other pathways
Vapor Source of groundwater above applicable unrestricted residential VIAC is less than 10 feet below ground	• Data that supports a clean, biologically active soil between the groundwater vapor source and the structure • Groundwater data and soil gas samples from sub-slab or at least 5 feet below ground (assuming no vapor source is shallower than 5 feet below ground)	• Vertical separation screening distance of 5 feet or • Soil gas sampling with the appropriate number and rounds of data is below all applicable VIAC (if structure is present)	ICs required to ensure that land use changes don't result in different exposure scenario that has not been evaluated (e.g., groundwater in contact) or that 5 feet of separation is maintained

Scenario – Assuming Vapor Source Not in Contact	Data Required	Outcome	Actions for Closure of the VIAP for petroleum releases
Vapor Source of groundwater above applicable unrestricted residential VIAC is 10 feet or greater below ground	• Data that supports a clean, biologically active soil between the groundwater vapor source and the structure • Soil gas samples from a depth of at least 8 feet below ground	Soil gas sampling with the appropriate number and rounds of data is below all screening levels	• No ICs required for PVI • Notice or other ICs maybe required for other pathways
Vapor source of groundwater above applicable unrestricted residential VIAC is 15 feet or greater	• Groundwater data • Data that supports a clean, biologically active soil between the groundwater vapor source and the structure	5-foot vertical separation will be maintained	• No ICs required for PVI • Notice or other ICs maybe required for other pathways

NOTE: Per NAPL guidance, a multiple lines of evidence evaluation that supports the presence or absence of NAPL is warranted for each scenario and a determination if an IC is required. Reasonably foreseeable future construction is assumed to be a building with a standard 8-foot basement.

Attachment E.4 – Petroleum Site Conditions and CSMs that May be Encountered and Site-Specific Evaluation Approaches

There are many different alternate approaches that may be utilized for the evaluation of the potential risks associated with petroleum and the VIAP than what is described in this volume. An alternate approach that may be more representative of the actual sites risks or more cost/time efficient than the linear screening approach described in Sections 3 through 6 of document could be considered, especially if the site doesn't screen out.

Examples of different site conditions that may warrant an alternative approach include:

- **VIAC Exceedances with Limited Spatial Extent** – Exceedances of an applicable VIAC with limited spatial extent may indicate that a more site-specific approach based on actual site information is better to evaluate the potential risks the VIAP may pose to human health. Information to be considered could include the exposure assumptions used in the VIAC, the mass of contaminants, exposure domain or area over which a building is or may be located, degradation rates and source zone depletion rates of the contaminants present, etc.

- **Age of the Release** – Within a relatively short period of time after a release is stopped (e.g., typically 5 years or less), equilibrium is likely reached which can reduce the data needs for CSM development. In addition, as the release ages, volatile compounds will "weather" and degrade which reduces the potential risk to the VIAP.

- **Type of Petroleum Released** – Different refined petroleum products will consist of different compounds and some hazardous substances are less volatile than others (e.g., gasoline vs diesel release). The more volatile compounds present in the petroleum released, the greater the potential risk to the VIAP.

- **Lithology** – The less permeable the lithology, the lower the likelihood of significant mass flux from the lithology. With low permeability of the lithology, the flux from the subsurface becomes the limiting factor for the advective transport, thereby reducing the potential risks and data needs. In essence, the lower the soil permeability, the slower the transport of VOCs to indoor air and greater potential to encounter lower COC concentrations in indoor air as a result of mixing and dilution. Pneumatic testing can aid in the evaluation of permeability and ability to collect representative soil gas – see **Volume 3 – Investigation Approach for Volatilization to the Indoor Air Pathway (VIAP)** for more information.

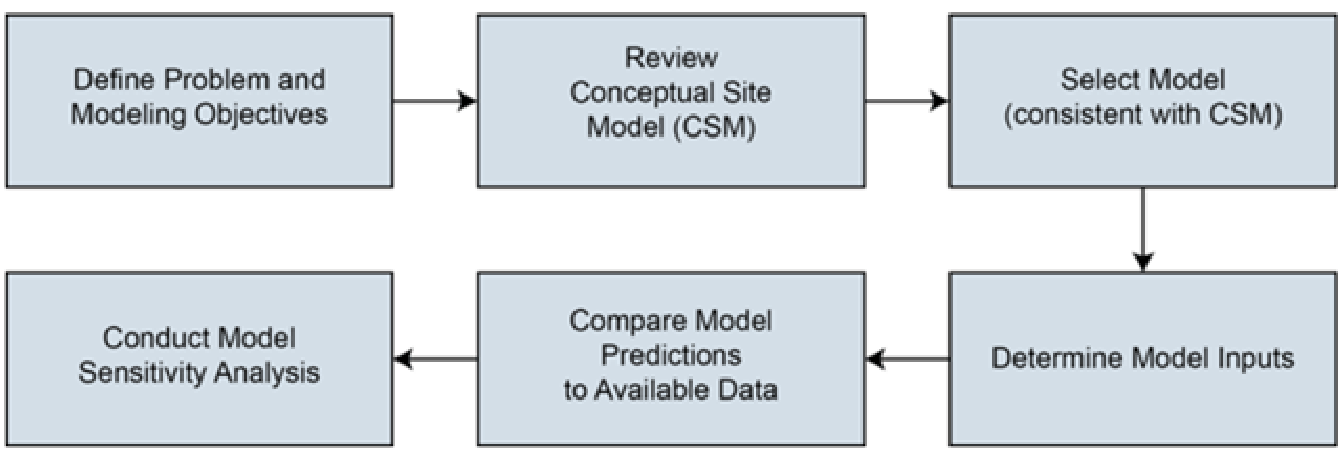
- **Structures with Natural Ventilation or High Ventilation Rates –** Air exchange rates identified by EGLE to represent the best available information in VIAC development may be conservative for buildings with consistent high air exchange rates or that are naturally ventilated and freely exchange ambient air. For buildings with high air exchange rates, SSVIAC can be developed to evaluate VIAP risks for the specific building.

Models

Alternate approaches commonly use models that evaluate and incorporate aerobic degradation or other unique site-specific conditions. The use of models can be applied as a line of evidence in the investigation process but must be field verified with data.

EGLE is not aware of any models that evaluate direct volatilization to indoor air other than the use of multiple lines of evidence that includes, as one of the lines, indoor air data collection and monitoring. The complexity of modeling applications can vary depending on the objectives of the modeling and availability of project-specific information. The steps indicated in **Figure E-1** below should be followed and documented in a Response Activity Plan submitted for EGLE review and approval.

Figure E-1: Steps in Developing a Model for Petroleum Vapor



Each of these steps, as well as different models that may be appropriate for PVI, are further described in ITRC (2014). It is important to note that though various models are described in ITRC (2014), the toxicological and chemical specific parameters utilized in the model must reflect best available information compared with generic criteria. If the goal and result of the modeling is site-specific VIAC, then the review, approval, and application of the model is done with RRD's toxicologist pursuant to Section 20120b. If the result of the model is to support sampling, fate, and transport of the vapors and does not result in site-specific VIAC, then the review and approval is done with the typical submittal process to EGLE. All other input parameters collected should be based on site-specific data and input parameters that are collected from the facility. Information on key input parameters for biodegradation modeling is provided in ITRC (2014).

If modeling is to be utilized, the documentation should include an evaluation and justification of the relevant model parameters, ranges, and parameter sensitivities, especially those that are moderate to high, and how the data supports that the model inputs are representative of the actual facility conditions and more representative than the generic criteria established by Part 201.

Lines of Evidence

The ideal outcome from collecting multiple lines of evidence is a concordant set of site-specific information that supports decisions that can be made and increases confidence in the decisions. However, based upon observations presented to RRD, the buildings where all available information agrees is typically the exception rather than the rule. Multiple lines of evidence, when used, can be data intensive efforts in making an appropriate demonstration. While it is not necessary that all data are in agreement, multiple lines of evidence supporting a single conclusion can provide confidence in proposed approaches and site-specific evaluations.

Indoor air sampling cannot be used as a sole line of evidence and alone is not sufficient to support that a response activity is not warranted, however, indoor air data does provide valuable information for the point of exposure at the moment in time when sampled. The use of indoor air samples as a line of evidence requires repeated indoor air sampling events over multiple months that supports the site-specific attenuation of the vapor source and should be only collected when the pressure inside the structure is less than the slab below. Some lines of evidence may not be definitive (e.g., indoor air varies significantly temporally). Some lines of evidence may be inconsistent with other lines of evidence and should be closely evaluated for weight of evidence when identified. When typical lines of evidence that are collected are not concordant, and the weight of evidence does not support a confident decision, it may be appropriate to collect additional lines of evidence, which may include additional samples, depending upon the CSM. For example:

- Appropriate site-specific testing can be conducted to assess the contribution of background sources of vapor-forming chemicals, including comparisons among chemicals of their relative concentrations in indoor air, outdoor air, and soil gas. Background sources of vapor-forming chemicals may help to explain situations where the indoor air concentration is higher than would be expected given the subsurface vapor source or the sub-slab soil gas data.

- Diagnostic testing of indoor air, building condition assessments or utility surveys, or supplemental hydrogeologic characterization can be used to investigate the effect of preferential migration routes. Such investigations may help to explain situations where the sub-slab or indoor air concentration appears to reflect unattenuated vapor transport from the subsurface vapor source.

- Building susceptibility to vapor intrusion can be tested through building pressure control testing, which may help to explain situations where the indoor air concentration is significantly lower than expected based upon the sub-slab soil gas data.

Vapor migration in the vadose zone can be further characterized to identify impedances to vapor migration; appropriate facility-specific attenuation factors can be considered to investigate facility-specific vapor attenuation. In some of these situations, the volatilization to indoor air pathway may be impeded due to geologic or hydrologic characteristics in the vadose zone. Aerobic degradation of the PHCs will reduce the risks at almost every site and facility-specific vapor attenuation can incorporate the microbial degradation when data exists.

Examples of different lines of evidence that may be appropriate to use for an alternate VIAP evaluation depending on the CSM and the facility conditions include:

- Data on facility geology and hydrology (e.g., soil moisture and porosity) to support the interpretation of soil gas profiles, the characterization of vadose zone permeability, and the identification of anticipated soil gas migration routes in the vadose zone or the identification and characterization of impeded migration.

- Vertical profiles of chemical vapors, electron acceptors for microbial transformations (e.g., O_2), and degradation products (e.g., CO_2, methane) to characterize attenuation due to biochemical (e.g., biodegradation) processes.

- Utility corridor assessment to identify preferential migration routes, if any, that facilitate subsurface vapor source migration between sources and buildings.

- Building construction and current conditions, including utility conduits or other preferential routes that a vapor source can enter and that can directly volatilize or transport vapor, openings for soil gas entry, heating and cooling systems in use, and any segmentation of ventilation and air handling, including instrumental (e.g., PID) readings to locate and identify potential openings for soil gas entry into buildings.

- Pressure differential data to assess the driving force for soil gas entry into building(s) via advection.
- Tracer-release data to verify openings in building foundations for soil gas entry or assess fresh air exchange within buildings.
- Indoor air sampling data to assess the presence of subsurface contaminants in indoor air.
- Building-specific indoor sources of volatile chemicals.
- Concurrent outdoor air data to assess potential contributions of ambient air to indoor air concentrations.
- Comparative evaluations of indoor air and sub-slab soil gas data, including calculation and comparison of building-specific, empirical attenuation factors to assess their consistency among subsurface contaminants to assist in identifying indoor vapors arising from vapor intrusion and the results of statistical analyses (e.g., data trends, contaminant ratios) to support data interpretation.
- Results of mathematical modeling that rely upon site-specific inputs. The relative utility of these and other lines of evidence will depend on site-specific factors, as described and documented in the CSM, and the objectives of the investigation.
- For an industrial building, indoor air testing while the heating, ventilation, and air conditioning (HVAC) system is not operating (see **Section 6.3.3**) could be useful for diagnosing vapor intrusion. On the other hand, single family detached homes can generally be presumed susceptible to soil gas entry when the HVAC systems are operating.
- Sub-slab and indoor air sampling conducted when VI or PVI is most likely to occur, (i.e., there is a higher pressure in the sub-slab than in the indoor air). This could potentially even be done by using the HVAC system to encourage flow into a structure by creating a pressure differential to have advective flow into the structure.

Any use of multiple lines of evidence requires the collection of a sufficient number of lines of evidence that support or provide evidence to the conclusion being made. It is the submitter's obligation to complete the analysis of the lines of evidence and provide an initial analysis on how the information supports the conclusion being made.