MICHIGAN DEPARTMENT OF
ENVIRONMENT, GREAT LAKES, AND ENERGY

Michigan Risk-Based Corrective Action (MIRBCA)

Technical Guidance

July 2025

This guidance document was developed to promote a consistent and informed approach by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) for the implementation of the ASTM International Risk-Based Corrective Action (RBCA) process at petroleum leaking underground storage tank (LUST) sites.

This document is available as a technical reference for conducting corrective actions at petroleum release sites regulated under Part 213, Leaking Underground Storage Tanks, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, according to the RBCA process. The document is explanatory and does not contain any regulatory requirements. It does not establish or affect the legal rights or obligations for conducting corrective actions at petroleum LUST sites. It does not have the force or effect of law and is not legally binding on the public or the regulated community. Any regulatory decisions made by EGLE regarding the implementation of the RBCA process at petroleum LUST sites will be made by applying the governing statutes and ASTM International standards to relevant facts.

Approved: ______________________________

Mike Neller, Director
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Contents

Figures (within the text)

Tables (within the text)

Equations (within the text)

Tables

Appendices

Abbreviations

ADF	Advective diffusive flow
ASTM	ASTM International
BEA	Baseline Environmental Assessment
BFS	Michigan Department of Licensing and Regulatory Affairs, Bureau of Fire Services
CAP	Corrective Action Plan
COC	Chemical of concern
CP	Certified Professional
CR	Closure Report
CSM	Conceptual site model
DAF	Dilution attenuation factor
ECF	Equilibrium conversion factor
ED	Exposure domain
EGLE	Michigan Department of Environment, Great Lakes, and Energy
ELA	Environmental license agreement
EM	Exposure model
FAR	Final Assessment Report
FID	Flame ionization detector
FOC	Fractional organic carbon
GSI	Groundwater-surface water interface
HI	Hazard index
HQ	Hazard quotient
IAR	Initial Assessment Report
IELCR	Individual excess lifetime cancer risk
J&E	Johnson and Ettinger model (USEPA, 2001)
LARA	Michigan Department of Licensing and Regulatory Affairs
LIZ	Lateral inclusion zone
LUST	Leaking underground storage tank
MCL	Maximum contaminant level
MCL	Michigan Compiled Laws
MDOT	Michigan Department of Transportation
MGS	Michigan Geological Survey
MIOSHA	Michigan occupational safety and health act, 1974 PA 154, MCL 408.1001 to 408.1094, and the rules promulgated under that act
MIRBCA	Michigan risk-based corrective action
MLE	Multiple lines of evidence
MS4	Municipal Separate Storm Sewer Systems

MTWS	Mass transfer from water surface
MUSTA	Michigan Underground Storage Tank Authority
NPDES	National Pollution Discharge Elimination System
NAPL	Nonaqueous-phase liquid
NCA	Notice of corrective action
NREPA	Natural Resources and Environmental Protection Act, 1994 PA 451, as amended
O/O	Owner or operator that is liable under Part 213
OSHA	Occupational and safety health act of 1970, Public Law 91 596, 84 Stat 1590, and the regulations promulgated under that act
PE	Professional Engineer
PEAS	Pollution Emergency Alerting System
PHIC	Public highway institutional control
PID	Photoionization detector
POC	Point of compliance
POE	Point of exposure
QC	Qualified underground storage tank consultant
RA	Risk assessment
RBCA	Risk-based corrective action
RBSL	Risk-based screening level
RBTL	Risk-based target level
RC	Restrictive covenant
RIDE	Remediation Information Data Exchange database
RM	Risk management
ROW	Right-of-way
RRD	Remediation and Redevelopment Division
RSL	USEPA Regional Screening Levels
SA	Site assessment
SSTL	Site-specific target level
TAPS	Technical assistance and program support
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground storage tank
VIAP	Volatilization to indoor air pathway

1.0 Introduction and Background

1.1 Introduction

Part 213*, Leaking Underground Storage Tanks,* of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), requires corrective actions to be conducted in accordance with the process outlined by the ASTM International (ASTM) risk-based corrective action (RBCA) standards. These standards are: *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (E-1739-95), Standard Guide for Risk-Based Corrective Action (E-2081-00)*, and *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface (E-2531-06)* (collectively referred to as "RBCA" in this document).

In 1995 ASTM published the E-1739-95 standard that provides a technically defensible, environmentally protective and efficient decision-making framework to manage risk related to releases at petroleum leaking underground storage tank (LUST) sites. This ASTM standard was incorporated by reference into Part 213 soon after the standard was published and continues to be incorporated into the statute by reference. However, the lack of a written protocol for the implementation of RBCA in Michigan has hindered the widespread and consistent implementation of this process. This guidance document fills that void by providing a technically defensible procedure for the customization and implementation of the RBCA process for petroleum releases at LUST sites regulated under Part 213. This process is referred to as the Michigan RBCA (MIRBCA) process.

1.2 Applicability

The intent of this MIRBCA guidance document is to (i) ensure that petroleum releases regulated under Part 213 are adequately characterized, (ii) provide a means for applying the generic risk-based screening levels (RBSLs) developed pursuant to Part 201 at petroleum releases regulated under Part 213, and (iii) provide a method to develop and apply site-specific target levels (SSTLs) that are protective of public health, safety, welfare, and the environment under current and reasonably anticipated future conditions. This guidance document provides a technically defensible procedure for investigating releases and for developing and consistently applying RBSLs and SSTLs at petroleum releases regulated under Part 213.

The MIRBCA process is applicable at all petroleum LUST sites regulated under Part 213 irrespective of the current phase of corrective action being conducted at the site. Since the MIRBCA process can be implemented at any point after the confirmation of a release, sites currently under assessment should be carefully evaluated to ensure that data of sufficient quantity and quality are available to complete the MIRBCA evaluation. Sites that have previously submitted a Corrective Action Plan (CAP) should be evaluated to determine if the proposed corrective action goals are appropriate based on the MIRBCA process. If the corrective action goals are not consistent with MIRBCA, the CAP may be updated.

Although all releases regulated under Part 213 are required to be addressed by the RBCA process, this guide offers an approach specifically for ***petroleum releases*** regulated by Part 213. Non-petroleum LUST releases and waste oil releases should be handled on a case-by-case basis; the applicability of this guide at non-petroleum LUST and waste oil release sites will depend on the substance released and site-specific conditions. The user is encouraged to contact the Department of Environment, Great Lakes and Energy (EGLE) regarding the implementation of corrective actions at non-petroleum and waste oil LUST release sites. This guide is not intended to be used at facilities regulated under Part 201, *Environmental Remediation*, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as Amended (NREPA). The ASTM RBCA standards are not incorporated into Part 201.

This guide is advisory in nature and does not have the force of law but provides an EGLE-accepted approach to implement Part 213 according to the RBCA process. This guide is intended to represent a comprehensive approach for conducting corrective actions at petroleum LUST sites regulated under Part 213 and should be used as the primary guidance document in conjunction with other cited documents. This document has been developed for environmental professionals with working knowledge and experience in the areas of site assessment (SA), risk assessment (RA), and risk management (RM) under Part 213. Technical information is included that describes the MIRBCA program and its elements, including SA, RA, RM, and the closure process as developed by EGLE. Since the development of SSTLs is an integral part of the overall MIRBCA process and has not been described in other state guidance documents, it is described at length in this manual. ***This manual is not, however, intended as a general guide to every aspect of RA or the RBCA process*.** Prior experience or training will be necessary for an individual to correctly implement the MIRBCA process.

For consistency, this document references the owner or operator (O/O) that is liable under Section 21323a of the NREPA (O/O) as the person implementing the MIRBCA process. It is understood that although the O/O is responsible for conducting corrective actions under Part 213, the implementation of the MIRBCA process will be undertaken by a Qualified Underground Storage Tank Consultant (QC), described in Section 1.4.

1.3 Liability to Conduct Corrective Actions

An O/O of the real property and/or the UST system at the time of a release is liable to conduct corrective actions. A person or legal entity who purchased a property after March 6, 1996, is considered liable for corrective actions related to any past release if they fail to conduct and submit a baseline environmental assessment (BEA) to EGLE within the statutorily required timeframes if no other exemption to liability exists. Information related to BEAs can be found at Michigan.gov/egle/about/organization/remediation-and-redevelopment.

This document is not intended to provide legal advice or guidance related to liability to conduct corrective actions. Refer to Section 21323a of Part 213 for information on liability as well as BEAs and additional exemptions to liability.

1.4 Qualifications for Underground Storage Tank Consultants

The MIRBCA process requires that the personnel implementing the process be experienced in the concepts and procedures of SA, RA and RM. Section 21325 of Part 213 lists the required qualifications for a QC:

- Has experience in all phases of underground storage tank work, including RBCA, tank removal oversight, SA, soil removal, feasibility analysis, design of remedial systems, installation of remedial systems, remediation management activities, and site closure.
- Possesses or employs at least one of the following:
  - A licensed professional engineer (PE) with three or more years of relevant corrective action experience, preferably involving underground storage tanks,
  - A professional geologist certification or a similar approved designation such as a professional hydrologist or a certified groundwater professional, with 3 or more years of relevant corrective action experience, preferably involving underground storage tanks,
  - A person with a master's degree from an accredited institution of higher education in a discipline of engineering or science and eight years of full-time relevant experience or a person with a baccalaureate degree from an accredited institution of higher education in a discipline of engineering or science and ten years of full-time relevant experience. This experience shall be documented with professional and personal references; past employment references and histories; and documentation that all requirements of the occupational safety and health act of 1970, Public Law 91-596, 84 Stat 1590, and regulations promulgated under that act (OSHA), and the *Michigan Occupational Safety and Health Act*, 1974 PA 154, MCL 408.1001 to 408.1094, and rules promulgated under that act (MIOSHA) have been met, or
  - A person that was certified by EGLE as an underground storage tank professional pursuant to Section 21543 of the NREPA on May 1, 2012.
- Has all the following insurance policies written by carriers authorized to write such business, or approved as an eligible surplus lines insurer, by this state and which are placed with an insurer listed in AM Best with a rating of no less than B+ VII:
  - Worker's compensation insurance,
  - Professional liability errors and omissions insurance. This policy may exclude bodily injury, property damage, or claims arising out of pollution for environmental work and shall be issued with a limit of not less than $1,000,000 per occurrence,

  - Contractor pollution liability insurance with limits of not less than $1,000,000 per occurrence, if not included under the professional liability errors and omissions insurance listed above. The insurance requirement under this point is not required for consultants who do not perform contracting functions,
  - Commercial general liability insurance with limits of not less than $1,000,000 per occurrence and $2,000,000 aggregate, and
  - Automotive liability insurance with limits of not less than $1,000,000 per occurrence.

- Has demonstrated compliance with OSHA and MIOSHA and is able to demonstrate that all such rules and regulations have been complied with during the person's previous corrective action activity.

1.5 Fundamental Differences Between Part 213 and Part 201

Michigan's environmental laws administered by EGLE's Remediation and Redevelopment Division (RRD) include Part 201, *Environmental Remediation*, and Part 213, *Leaking Underground Storage Tanks*, of the NREPA. Part 213 uses processes and procedures separate and distinct from Part 201. Whereas corrective actions conducted under Part 213 must be implemented in accordance with the process outlined by RBCA, response activities conducted under Part 201 are not implemented in accordance with the RBCA process. The user is advised to refer to the environmental statute that is applicable at the site in question for statutory requirements.

1.5.1 Exposure Model

One of the main differences between the implementation of Part 213 and Part 201 is related to the exposure model (EM). Part 201 defines a generic EM that is applicable for facilities regulated under Part 201. For example, R.299.10(4) of the Michigan Administrative Code requires the point of exposure (POE) for the application of generic criteria for groundwater, based on ingestion/drinking of groundwater, to be any point in the affected aquifer, and R.299.20(4) requires that the criteria for direct contact of soil are applicable without regard to depth at facilities regulated under Part 201.

Part 213 allows a tiered approach, including the development of an EM based on site conditions. A Tier 1 RBCA evaluation utilizes a generic EM similar to Part 201. In contrast, a Tier 2 or 3 evaluation requires that an EM be developed based on site conditions, including the location of a site-specific POE rather than a generic POE. In a Tier 2 evaluation, SSTLs can be developed for points of compliance (POC) located between the source and the POE. Such SSTLs account for the site-specific attenuation of the groundwater plume. This results in Tier 2 and/or Tier 3 corrective action goals that are uniquely site-specific and depend on the location of the POC. Refer to Section 5.1 for more information regarding the development of an EM.

1.5.2 Exposure Pathway Language

The terminology for exposure pathway evaluation differs between Part 201 and Part 213. Whereas an evaluation under Part 201 would determine if a pathway is relevant or not relevant, a similar evaluation under Part 213 would determine if an exposure pathway is complete or not complete. A "relevant" pathway under Part 201 is the equivalent of a "complete" pathway under Part 213. Although the language differs between Part 213 and Part 201, the pathway evaluation process and comparison to criteria or risk-based target levels (RBTLs) is the same.

Note that **RBTL** is a generic term that includes any target level calculated based on risk. RBTLs include Tier 1 RBSLs, Tier 2 and 3 SSTLs. In this document the term RBTL is used to refer to one or all of these.

The terminology for the exposure pathways commonly evaluated in the MIRBCA process differs from the terms used in Part 201 as shown in Table 1-1.

Table 1-1. MIRBCA exposure pathways and corresponding generic criteria

MIRBCA Exposure Pathway	Part 201 Generic Criteria
Groundwater protection	Drinking water
Surface water protection	Groundwater surface water interface
Direct contact	Direct contact
Ambient air inhalation	Volatile soil inhalation; particulate soil inhalation
Volatilization to indoor air	Volatilization to indoor air inhalation

Unlike Part 201, in the MIRBCA process, the vadose zone soil is divided into surficial soil (0 to 2 feet in depth) and subsurface soil (greater than 2 feet in depth). Certain exposure pathways are evaluated specifically for surficial soil, subsurface soil, or vadose zone soil. Refer to Section 5.1.2 for more information about evaluating exposure pathways.

1.5.3 Other Differences

In Part 201 the term "criterion" is used for the corresponding term "corrective action goal" in the MIRBCA process. Corrective action goal is an umbrella term defined in ASTM E-2081 as a concentration or other condition, e.g., plume stability, that when achieved at a site, demonstrates no further action is necessary to protect human health and the environment. Corrective action goals include RBTLs that may include Tier 1 RBSLs or Tier 2 or Tier 3 SSTLs, all of which are protective of human health and the environment if developed and applied in accordance with this document. It is the O/O's choice whether to use Tier 1 RBSLs or Tier 2 or 3 SSTLs as the corrective action goals.

Under Part 201, a person conducting response activities is allowed to develop site-specific criteria that are submitted to EGLE for review and approval. Both site-specific criteria development as well as EGLE's review and approval process is governed by Section 20120b of the NREPA. However, 20120b does not apply to SSTLs developed under the RBCA process at Part 213 sites. In Part 213, SSTLs are developed as part of the MIRBCA process, and EGLE has the authority to audit Final Assessment Reports (FARs) and Closure Reports (CRs). A FAR or CR that contains SSTLs developed by an O/O would be subject to EGLE audit. The proposed SSTLs would be evaluated by EGLE as a part of the audit, although the audit would result in a decision on the report in question and not an "approval" or "denial" of the SSTLs themselves.

Other terminology differences include a distinction between the Part 201 term "facility" and the corresponding Part 213 terms of "site" and "property." This guide will use the word "site" in a generic sense rather than the term as defined by Part 213. Whereas Part 201 regulates impacts from all chemicals released into the environment on a property, Part 213 regulates only chemicals released from a LUST system. Thus, not all contamination at a Part 213 site is regulated under Part 213 but only the contamination that was released from the LUST system. Furthermore, not all chemicals that were released from a LUST system are evaluated under Part 213 but only certain indicator parameters, referred to as chemicals of concern (COCs) and included in Table 1 in this manual (refer to Section 4.3.3 for more information).

This document provides guidance for petroleum releases from leaking underground storage tanks and is specific to these sites only. This document references several other technical documents created by EGLE for programs administered by the RRD, and these technical documents were written to apply broadly to all Michigan's environmental cleanup programs. There may be differences in terminology, assumptions, and legal requirements between the MIRBCA process and various other EGLE technical guidance documents. The terminology used in the MIRBCA guidance document should be adopted when implementing the MIRBCA process on petroleum LUST releases regulated under Part 213.

2.0 Overview of the MIRBCA Process

2.1 Introduction

The MIRBCA process begins with the discovery of a release of regulated substances from a regulated UST system and continues until an O/O submits a CR that is approved by EGLE or by operation of law, or until EGLE otherwise determines that no unacceptable risk remains to public health, safety, welfare, or the environment related to the confirmed release. After release discovery and initial response actions, the MIRBCA process requires the following types of activities:

- **Site assessment (SA)**, including characterization and delineation of impacts in vadose zone soil, groundwater, and soil gas, as applicable. Information related to current and future land use, groundwater use, characteristics of the impacted media, COCs, current and future onsite receptors, and offsite receptors must be collected. This information is used to develop a conceptual site model (CSM) that includes an EM,
- **Risk assessment (RA)** at the Tier 1, Tier 2, and Tier 3 level, as applicable. Tier 1 requires the use of generic RBTLs whereas Tier 2 and Tier 3 allow the calculation of SSTLs and representative concentrations. These are discussed in Section 5.2 and Appendix A, and

> A **representative concentration** is the value for each COC and each complete exposure pathway that is compared to an applicable RBTL to determine if the risk is acceptable or unacceptable. It is generally a maximum concentration in Tier 1 and an average concentration in Tier 2 (refer to Section 5.7).

- **Risk management (RM)**, including the development and implementation of a CAP to meet the RBTLs developed as a part of the RA. This step ensures the protection of public health, safety, welfare, and the environment from site-specific impacts under both current and reasonably anticipated future use on and near the site.

The above activities are fundamentally technical and rely on a variety of scientific disciplines (e.g., geology, hydrogeology, engineering, chemistry, toxicology, land use planning, etc.). These activities also entail assumptions and implementation choices that must be consistent with existing environmental laws, including Part 213 of the NREPA. These implementation choices and the specific steps of the MIRBCA process are briefly described in this section. Subsequent sections of this document describe the details of each step.

2.2 Risk-Based Corrective Action Process

2.2.1 Introduction

The MIRBCA process is illustrated in Figure 2-1 and briefly described below. A detailed explanation of the MIRBCA process and the data requirements is provided in the remaining sections of this document.

2.2.2 Initial Response Actions

After a release from a regulated UST system is confirmed and reported to the Michigan Department of Licensing and Regulatory Affairs (LARA), the O/O must immediately implement initial response actions required by Section 21307 of Part 213 to prevent further release into the environment and address any immediate threats. Further details of initial response actions are described in Section 3.4.

If initial response actions have sufficiently addressed all risks related to the confirmed release, the O/O can submit a CR and omit the remaining steps in the MIRBCA process.

2.2.3 Initial Site Assessment and Development of a Conceptual Site Model

If concentrations of COCs exceed applicable Tier 1 RBSLs, additional characterization is required to develop and validate a CSM. A CSM qualitatively and to a limited extent quantitatively describes all the relevant site-specific factors that affect the risk to public health, safety, welfare, and the environment and provides the framework for the overall management of a site. The CSM includes narrative descriptions, figures, cross sections, tables, and flow charts, as appropriate. The CSM is a living document and is updated as additional site information is collected.

Key elements of the CSM include:

- The location and date of chemical release, source(s), and COCs,
- Spatial and temporal distribution of COCs and trends in the various impacted media,
- Site stratigraphy and hydrogeology with an emphasis on determining the groundwater flow direction and velocity, and the fate and transport of COCs,
- Current and future onsite/offsite land use, groundwater use, and characteristics of surface water bodies that may potentially be affected by the COCs,
- Description of existing or proposed land or resource use restrictions,
- Details of any active remediation conducted to date, and
- An EM that identifies the receptors, complete exposure pathways, and routes of exposure under current and reasonably anticipated future conditions.

Refer to Section 4.3.3 and Table 1 for the COCs relevant for petroleum products. Since most petroleum LUST plumes are less than 500 feet long, current and future off-site land use information for about 500 feet from the property boundary is sufficient for most sites.

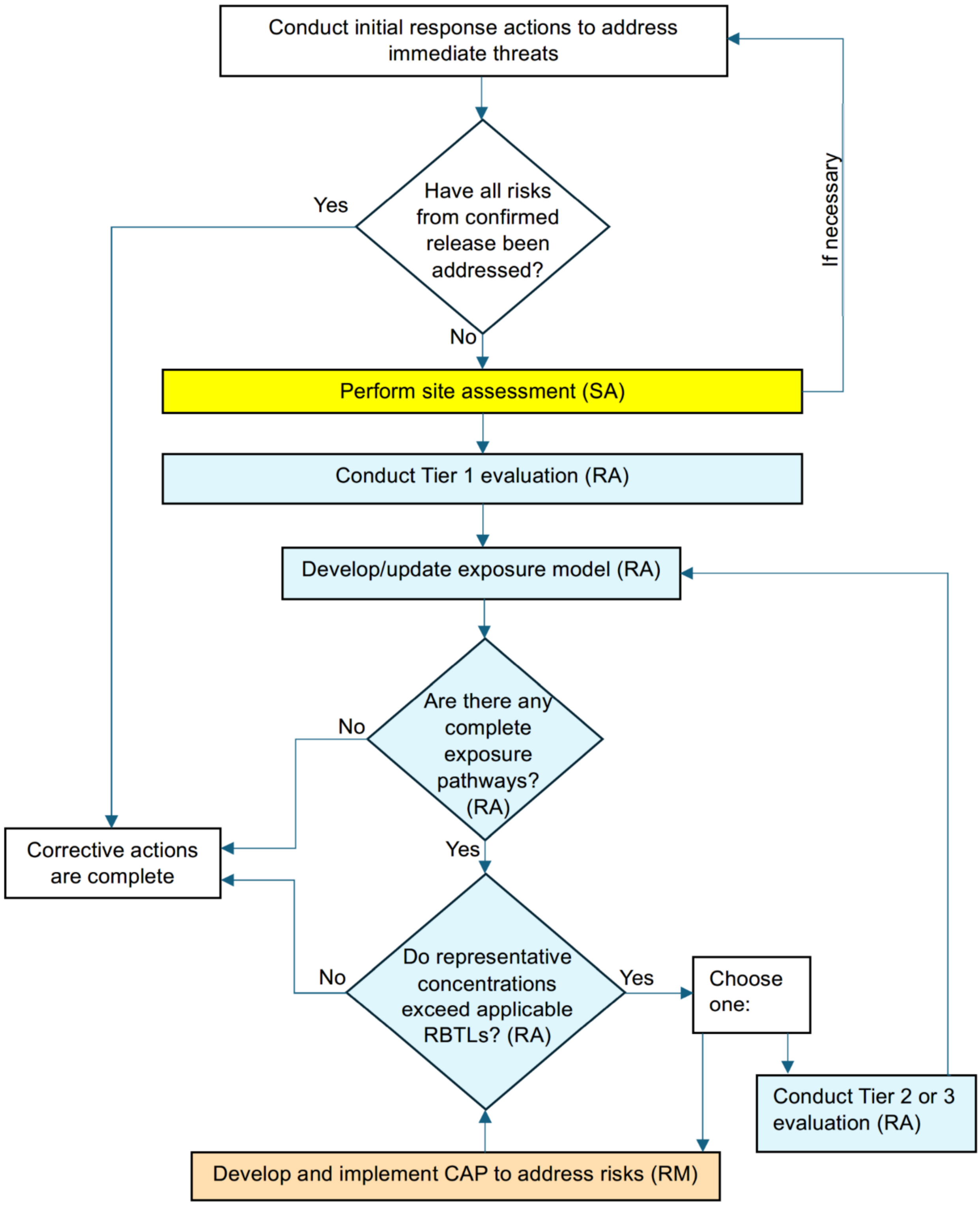


Figure 2-1. Simplified overview of the MIRBCA process

yellow (SA) = site assessment
blue (RA) = risk assessment
orange (RM) = risk management

An important part of the SA is the validation of the CSM through the collection of site-specific data. The validation process is like the traditional site investigation step in that it may involve the installation and sampling of monitoring wells and collection of soil data both onsite and offsite. Additionally, validation involves the determination of current and potential future land use and the development of an EM. At sites that are currently undergoing investigation or corrective action, this step may involve the compilation of relevant historic data, identification of data gaps, evaluation of temporal and spatial trends in the COCs, and the collection of missing data so that a tiered risk evaluation can be completed.

2.2.4 Site Classification

Based on the site information and the CSM, sites must be classified based on the urgency for corrective actions. Site classification is used internally by the RRD to determine and communicate to the public the overall level of risk at a site and to prioritize sites for audits, compliance assistance, enforcement, and state-funded corrective action. Site classification must be documented in the site classification form and must be included in the IAR, FAR, CR, and in any report that denotes a change in site classification. Site classification must be updated as more site information becomes available or as corrective actions are implemented to address unacceptable risk.

2.2.5 Tier 1 Evaluation

Within MIRBCA RA can consist of a Tier 1, Tier 2, or Tier 3 evaluation. A Tier 1 evaluation includes (i) the selection of applicable Tier 1 RBSLs, and (ii) the comparison of recent maximum soil, groundwater and soil gas concentrations to the RBSLs. Tier 1 RBSLs will be selected for each COC, each complete exposure pathway, and each medium of concern identified in the EM. The Tier 1 RBSLs are provided in Tables 3 through 6.

Based on the comparison of maximum concentrations to the applicable Tier 1 RBSLs for all complete exposure pathways, one of the following three options is possible:

1. Submit a CR to EGLE if maximum concentrations do not exceed the applicable Tier 1 RBSLs and all other required conditions discussed in Section 6.0 have been met,
2. Adopt Tier 1 RBSLs as the corrective action goals and develop and implement a CAP to achieve these levels, or
3. Perform a Tier 2 or Tier 3 evaluation for COCs, receptors and exposure pathways that do not meet the Tier 1 levels.

The specific option chosen must be documented and submitted to EGLE using the Tier 1 MIRBCA report forms. Upon completion of the Tier 1 evaluation, the O/O must provide their recommendations to EGLE.

For additional details refer to Section 6.0.

2.2.6 Tier 2 Evaluation

A Tier 2 evaluation allows for the use of an EM consistent with current and reasonably anticipated future conditions and the use of site-specific fate and transport parameters to calculate Tier 2 SSTLs that are compared with representative concentrations. A Tier 2 evaluation is conducted only for the COCs, receptors and exposure pathways that have not been eliminated in Tier 1. Depending on the results of the comparison, the following three options are possible:

1. Submit a CR to EGLE if representative concentrations do not exceed the applicable Tier 2 SSTLs for all COCs, receptors and complete exposure pathways that were not eliminated in Tier 1, and if all other required conditions discussed in Section 7.0 have been met,
2. Adopt Tier 2 SSTLs as the corrective action goals and develop and implement a CAP to achieve these levels, or
3. Perform a Tier 3 evaluation.

The specific option chosen must be documented and submitted to EGLE using the Tier 2 MIRBCA report forms. For additional details refer to Section 7.0.

2.2.7 Tier 3 Evaluation

A Tier 3 evaluation allows considerable flexibility to the O/O. Except for the surface water protection pathway, this document does not provide specific guidance for conducting a Tier 3 evaluation because Tier 3 evaluations are very flexible and can include any technically defensible approach. It is recommended that the O/O contact EGLE to discuss the proposed Tier 3 evaluation and submit a Tier 3 work plan to receive EGLE feedback prior to implementing a CAP based on a Tier 3 evaluation. Such feedback may streamline the Tier 3 process and lead to an effective outcome.

After the Tier 3 SSTLs have been developed, they will be compared with representative concentrations of COCs for each complete exposure pathway. Depending on the results of the comparison, the following two options are possible:

1. Submit a CR to EGLE if representative concentrations do not exceed the applicable Tier 3 SSTLs for all COCs, receptors, and complete exposure pathways that were not eliminated in previous tiers, and if all other required conditions discussed in Section 8.0 have been met, or
2. Adopt Tier 3 SSTLs as corrective action goals and develop and implement a CAP to achieve these levels.

For additional details refer to Section 8.0.

2.2.8 Risk Management

RM involves the development and implementation of a CAP to achieve the corrective action goals for the release. The CAP must include one or a combination of the following items if they are applicable to the site:

- Implementation of active remediation
- Monitoring to demonstrate plume stability
- Recording of land or resource use restrictions
- Alternative mechanisms to eliminate exposure pathways
- A monitoring plan to demonstrate effectiveness of the CAP
- A contingency plan to be implemented if the CAP is not effective
- A reporting schedule
- Anticipated time to complete the CAPDuring the implementation of the CAP, sufficient data must be collected and analyzed to allow for an appropriate evaluation of the performance of the CAP so that modifications can be made as appropriate.

2.2.9 Reporting Requirements

Reporting requirements under Part 213 do not coincide with MIRBCA tiered evaluations. Regardless of where an O/O is in the MIRBCA evaluation process, an IAR is due 180 days after discovery of the release and a FAR is due 365 days after discovery of the release. The IAR must include the results of a Tier 1 evaluation but may also include a Tier 2 evaluation, if conducted. The FAR must include the final tiered evaluation for the release. Refer to Section 11.0 for information on reporting requirements.

2.2.10 Release Closure

CAP activities must continue until the O/O determines that, based on site-specific data, the corrective action goals have been met, specified land use or resource use restrictions are in place if required, and the residual impacts are stable or decreasing. A CR must be submitted upon completion of corrective actions, and EGLE may audit the report.

Refer to Section 11.0 for information on reporting requirements and audits.

2.3 Risk-Based Target Levels within the MIRBCA Process

Under the MIRBCA process, RBTLs used for RA include Tier 1 RBSLs, Tier 2 SSTLs, and Tier 3 SSTLs (Figure 2-2). Any one or a combination of these may be selected by the O/O as the corrective action goals.

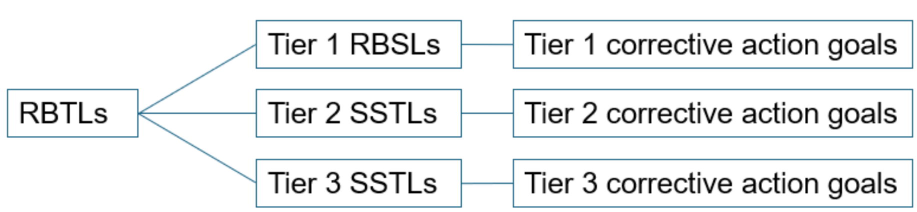


Figure 2-2. Categories of RBTLs in the MIRBCA framework

The difference between the three RBTLs is discussed below (refer to Table 2-1).

- **Tier 1 RBSLs.** These are generic screening levels developed by EGLE pursuant to Part 201 and included in Tables 3 through 6. These values are developed using conservative default parameters that depend on the receptor, medium, pathway, and route of exposure.
- **Tier 2 SSTLs.** These differ from Tier 1 RBSLs in that they are based on (i) fate and transport models included in Appendix A (not necessarily the same as those used for the development of Tier 1 RBSLs), (ii) updated chemical-specific input parameters, (iii) site-specific parameters as opposed to generic parameters used to develop Tier 1 RBSLs. Tier 2 SSTLs are calculated using site-specific data and the guidelines included in this document. Typically, but not always, Tier 2 SSTLs will be higher than the corresponding Tier 1 RBSLs.
- **Tier 3 SSTLs.** These are calculated using site-specific data and provide considerable technical flexibility to the O/O. Compared with Tier 2 SSTLs, Tier 3 SSTLs may potentially be based on the application of fate and transport models other than those presented in Appendix A.

Table 2-1. The differences between the RBTLs within the MIRBCA framework

Factors	Tier 1 RBSLs	Tier 2 SSTLs	Tier 3 SSTLs
Toxicity values	R. 299[1]	Table 7	Table 7 or other justifiable values
Physical/chemical properties	R. 299[1]	Table 8	Table 8 or EGLE-accepted values
Exposure factors	R. 299[1]	Table 9	Table 9 or EGLE-accepted values
Fate and transport and building parameters	R. 299[1,2]	Site-specific	Site-specific
Fate and transport models	R. 299[1,2]	Appendix A	Acceptable to EGLE
Representative concentration	Maximum	Average[3]	Average[3]
Individual excess lifetime cancer risk	1 in 100,000	1 in 100,000	1 in 100,000
Groundwater protection target level at the POE[4]	More stringent of MCL or aesthetic criteria[5] (Table 13)	More stringent of MCL or aesthetic criteria[5] (Table 13)	More stringent of MCL or aesthetic criteria[5] (Table 13)
Hazard quotient (HQ)	1	1	1

[1]Rule 299 of the Michigan Administrative Code.

[2]Models and default parameters for certain situations in the VIAP are discussed in Section 5.3 and included in Appendix A.

[3]Refer to Section 5 for exceptions.

[4]Tier 1 POE is any point in the affected aquifer.

[5]If an MCL or aesthetic criterion is not available the target level is a calculated value.

Tier 1 RBSLs are also used as delineation criteria as explained below:

> **Delineation Criteria.** All confirmed releases must be adequately characterized as part of the SA, and the extent of contamination must be delineated. The delineation criteria are the most conservative Tier 1 RBSLs for each medium and are presented in Table 2. Site characterization and delineation ensure that (i) adequate data are available for a tiered risk assessment and (ii) parties impacted above a residential RBSL are notified.

2.4 Rationale and Characteristics of Tiered Approach

Despite the differences between the three tiers, there is one significant similarity: RA within each tier will result in cleanup levels that satisfy the same acceptable risk and therefore provide acceptable protection to public health, safety, welfare, and the environment. The process provides considerable flexibility and a variety of options to manage site-specific risks. The O/O can thus select the optimal strategy based on site-specific considerations.

As the evaluation moves through the tiered process, the following can be anticipated:

- Higher tiers will require the collection of more site-specific data, which will increase data collection, data analysis, labor time, and costs,
- In general, the calculated Tier 2 SSTLs will be higher than the Tier 1 RBSLs and the Tier 3 SSTLs will be higher than the Tier 2 SSTLs. This is because lower tier target levels are calculated using more conservative assumptions than higher tier target levels. Thus, the cost of RM activities at higher tiers should generally be lower,
- The need for, and extent of, regulatory oversight and review will increase as the site moves from Tier 1 to Tier 3, and
- The level of uncertainty and conservatism will decrease as the evaluation progresses from Tier 1 to Tier 3 due to the availability of more site-specific data.

2.5 Documentation of the MIRBCA Process

To facilitate and allow decisions to be made that are protective of public health, safety, welfare, and the environment, the MIRBCA process requires the collection of a considerable amount of data. The outcome of the MIRBCA process may be of interest to a variety of stakeholders, including but not limited to EGLE, landowners, developers, lending agencies, cities, and municipalities. Therefore, the process by which data are collected, analyzed, and important decisions that potentially affect human health and the environment are made, must be as transparent as possible via adequate and clear communication between the O/O and EGLE. Such communication must occur throughout the MIRBCA process, from release discovery to the closure of a confirmed release, so that interested parties can determine if decisions made, and activities undertaken during the MIRBCA process are sufficient to adequately protect human health and the environment.

The method and format by which the O/O reports data developed under the MIRBCA process must be consistent (across the state) and unambiguous so that interested parties can readily understand the:

- Data collected to understand and quantify the problem,
- Sequence of actions taken to address the problem,
- Process used to develop a plan of action to address the problem,
- Results of the action taken, and
- Demonstration that the actions taken are protective of public health, safety, welfare, and the environment under current and reasonably anticipated future conditions.

To facilitate the documentation of these activities and to ensure consistency across sites, EGLE has developed forms and tables that must be used pursuant to Section 21316 of the NREPA. These forms are included in Appendix E and on EGLE's Leaking Underground Storage Tanks website. Brief instructions to complete the forms are provided in Appendix F. The forms must be used to submit reports required under Part 213. Reporting requirements are described in Section 11.0 of this document.

3.0 Release Discovery and Initial Response Actions

3.1 Introduction

The MIRBCA process starts when the release of a regulated substance from an UST system regulated under Part 211 is confirmed. After a release is confirmed, the O/O must first prevent further release of the regulated substance, address any immediate threats related to the release, and abate any immediate threats to human health and the environment. Following the control of immediate threats, an SA will be necessary to collect relevant data to delineate the impacts and to perform a RA (refer to Sections 4.0 and 5.0). Note that MIRBCA data collection activities are secondary to addressing all immediate threats posed by the confirmed release.

3.2 Reporting a Release

Both Part 211, Underground Storage Tank Regulations, and Part 213, Leaking Underground Storage Tanks, of the NREPA, require the reporting of releases from regulated UST systems within 24 hours of discovery of the release.

Release reporting is regulated under Part 211, which is administered by LARA, Bureau of Fire Services (BFS), Storage Tank Section. Suspected and confirmed releases must be reported to LARA within 24 hours of discovery either by e-mail or fax on form BFS-3826. A suspected release can be reported based on a positive indication from field monitoring equipment such as photoionization detectors (PID), flame ionization detectors (FID), H-Nu meters, organic vapor analyzers, combustible gas detectors, or inventory discrepancies. The owner/operator of an UST system (defined in Section 21101 of Part 211) is not limited to reporting a suspected release but may report a confirmed release anytime they believe one has occurred. Suspected releases must be cancelled or upgraded to confirmed within 14 business days. Reporting of a confirmed release is required when an UST owner/operator finds visible or olfactory evidence of regulated substances in the UST excavation or along piping runs, or if analytical results from soil or groundwater samples are above detection limits. "Visible evidence" includes the presence of a product sheen on water or stained soils. "Olfactory evidence" includes the smell of product odors in soils or water within the tank or piping excavation. There are certain exceptions, for example: conducting an UST site assessment at a location with a previously closed LUST release; visible evidence of contamination in overburden soils from UST removal. Refer to LARA guidance at the link below for details.

Note that the requirements for UST site assessments and UST closure are administered by LARA and are different from the requirements for characterization of soil and groundwater to evaluate risk under Part 213. Additional information, including applicable laws, rules, and required forms, can be found at LARA's website at Michigan.gov/lara/bureau-list/bfs/storage-tanks/underground/related-links/release-reporting-underground-storage-tanks. After a release from an UST has been confirmed, the O/O that is liable under Part 213 must perform corrective actions under Part 213, administered by EGLE, to protect public health, safety, welfare, and the environment.

3.3 MUSTA Reimbursement

An UST owner/operator may be eligible for reimbursement for corrective action activities through the Michigan Underground Storage Tank Administration (MUSTA) Underground Storage Tank Cleanup Fund. The Underground Storage Tank Cleanup Fund allows eligible refined petroleum UST owners or operators to be reimbursed up to $1 million per claim (minus the appropriate deductible) of eligible costs for corrective action and/or indemnification costs incurred for confirmed releases that were discovered and reported on or after December 30, 2014. The deductible amount for UST owners or operators of seven refined petroleum USTs or fewer is $2,000 per claim. The deductible amount for UST owners or operators of eight or more refined petroleum USTs is $10,000 per claim.

Claims must be submitted on an Underground Storage Tank Fund Claim Submittal Form. The facility and owner or operator information on the Claim Submittal Form must match that shown on the current underground storage tank registration form on file with LARA for the site. Along with the claim application, proof as to how the owner or operator was able to demonstrate they had the ability to meet their deductible amount (also known as financial responsibility) at the time of the discovery of the release is required.

There are certain eligibility requirements to receive reimbursement from MUSTA:

- The claim must be filed by an owner or operator of a refined petroleum UST system who owned or operated the system at the time of reporting the release,
- The release from which the corrective actions or indemnification arose was discovered and reported on or after December 30, 2014,
- At the time of the release, the UST was in compliance with the registration and fee requirements of Part 211,
- The O/O confirmed the release within 24 hours after its discovery,
- The O/O is not the United States Government,
- The claim is not for a release from an UST system closed prior to January 1, 1974,
- The O/O was in compliance with their financial responsibility requirements at the time of the discovery and the reporting of the release(s) for which the claim was filed, and
- The total amount of reimbursement does not exceed the claims limit or claim period aggregate limit applicable to the claim.

Additional information, applicable laws, rules, and forms can be found at MIchigan.gov/MUSTA.

3.4 Initial Response Actions

After confirming a release from an UST system, an O/O must first implement initial response actions required under Section 21307 of Part 213. The objective of the initial response actions is to take appropriate steps to safeguard human health and the environment and to prevent further release of the regulated substances to the environment. The O/O must immediately begin and expeditiously perform all the following initial response actions:

- Identify and mitigate immediate fire, explosion hazards, and acute vapor hazards,
- Prevent further release of the regulated substance into the environment including removing the regulated substance from the UST system that is causing the release,
- Take steps necessary and feasible to address unacceptable immediate risks regarding NAPL (see Section 5.8.1),
- Excavate and contain, treat, or dispose of soils above the water table that are visibly impacted with a regulated substance if the impact is likely to cause a fire hazard,
- Take any other action necessary to abate an immediate threat to public health, safety, or welfare, or the environment,
- Visually inspect the areas of any above ground releases or exposed areas of below ground releases and prevent further migration of the released substance into surrounding soils, groundwater, and surface water, and
- Continue to monitor and mitigate any additional immediate fire and safety hazards posed by vapors or NAPL that have migrated from the UST system excavation zone and entered subsurface structures.

4.0 Data Requirements for the MIRBCA Process

4.1 Introduction

This section presents the SA data necessary to implement the MIRBCA process for petroleum LUST releases regulated under Part 213. These data would typically be collected after the confirmation of a release as part of the SA required for the IAR and FAR. The specific data requirements for these reports are listed in Sections 21308a and 21311a of Part 213 and within applicable sections of ASTM RBCA standards E-1739-95, E-2081-00, and E-2531-06.

The objective of the data collection effort is to ensure that data of sufficient quality and quantity are available to:

- Develop a CSM,
- Develop a site-specific EM,
- Compare maximum site concentrations with the applicable Tier 1 RBSLs,
- Develop Tier 2 and Tier 3 SSTLs, if necessary,
- Compare representative concentrations to applicable SSTLs, and
- Develop a CAP.

Risk assessment, including Tier 1, 2 or 3 evaluations, follows SA and should be completed after sufficient relevant data have been collected and a CSM including an EM has been developed. To achieve the above objectives, the following information is required:

- Chronology of relevant site events,
- Nature, magnitude, and location of the release (including identification of COCs),
- Site information (e.g., location of UST system related infrastructure, land use, etc.),
- Adjacent land use and receptor information including location and depth of storm drains, utility lines, any surface water bodies,
- Vadose zone soil characteristics,
- Saturated zone and groundwater characteristics,
- Distribution of the COCs in soil, groundwater, and soil gas, and
- Information about corrective action measures conducted and planned.

As part of the MIRBCA evaluation, the O/O must carefully review all existing data and identify any data gaps. Additional data may be necessary depending on the tier evaluation and site-specific conditions. After all the necessary data have been collected, the O/O can proceed with the tiered evaluation.

4.2 Chronology of Relevant Site Events

A comprehensive chronology of events related to the release, including investigation and remediation of the release, will help create a comprehensive picture of the activities conducted at the site and identify any data gaps. The chronology includes information regarding events such as:

- The date the USTs were installed, removed, and/or upgraded,
- The date and circumstances when the release was discovered,
- Whether any contaminated soil was excavated and disposed of off-site,
- Dates when monitoring wells were installed, gauged, sampled, and abandoned,
- Dates when soil gas points were installed, sampled, and abandoned,
- Dates when soil samples were collected,
- Dates when any land use restrictions were imposed, and
- Dates when any active remediation was conducted.

The intent of this step is to develop a clear understanding of all relevant site activities as they may impact current and potential future risk. Development of chronology is a means to understand past and current relevant site conditions.

4.3 Nature, Magnitude, and Location of Release

Knowledge about the nature, magnitude, and location of the release is necessary to identify the NAPL, soil, groundwater, and soil gas impacts and to identify the COCs. The O/O shall collect as much of the following information as is available for each release:

- Location and date of release,
- Quantity of the product released,
- Type of product released, and
- Any corrective actions performed with respect to each release.

Release-related information can be obtained by a variety of means, including reviewing inventory records, interviewing past and current onsite employees, and reviewing historic release reports filed with LARA.

4.3.1 Location and Date of Release

Identifying the location of a release helps define the source area that affects the extent of NAPL, soil, groundwater, and soil gas impacts. Likely release locations at petroleum LUST sites include (i) corroded or damaged tanks, (ii) pipes, especially at pipe bends and joints, and (iii) dispenser islands below the shear valve.

Identifying the date of the release is necessary to determine the COCs. If the release was from an UST system that operated prior to 1996, compounds related to leaded gasoline (i.e., lead and lead scavengers) must be included in the COCs. If a gasoline release was from an UST system that operated prior to 2003, methyl-tert-butyl-ether (MTBE) must be included in the COCs. Based on the chronology, the person performing the work shall review the operational history of the site to determine the location of the release and the dates the release was discovered and reported to LARA. Often the exact location and date of the release will not be known. In such cases, soil and groundwater data, including field screening data collected using a PID and visual observations, can be used to identify the likely location of the release.

Note for property owners: An owner of contaminated property has due care obligations under Section 21304c of the NREPA to undertake corrective action necessary to mitigate any unacceptable exposures. This includes but is not limited to ensuring that there are no unacceptable exposures to lead or leaded compounds that may have originated from current or historic USTs on the site property. Owners of contaminated property are advised to sample groundwater for lead and lead scavengers if there is a potential for an unacceptable exposure.

4.3.2 Quantity of Release

The MIRBCA process does not necessarily require knowledge of the exact quantity of the release. Often this information is not known. However, having a general idea of the amount released can assist in evaluating the severity of site conditions and the likely extent of COCs. Information regarding the amount released is typically based on inventory records.

4.3.3 Product Released and Chemicals of Concern

Identification of the specific product(s) released is important to identify the chemicals of concern. Part 213 allows for the use of indicator parameters, also referred to as the COCs, to evaluate risk from leaking UST systems. Petroleum products are composed of a variety of hydrocarbon compounds and additives whose physical and chemical properties and percent composition in the product vary considerably. Further, the environmental behavior (mobility, persistence, and intermedia transport) and toxicity of the product depend on the properties of each constituent and its concentration in the product.

EGLE, like most other state cleanup programs for petroleum sites, recommends focusing on a limited set of chemicals that pose most of the risk for each product. These are known as the recommended parameters for petroleum products and are referred to in this guidance document as COCs. The meaning of the term COCs used in this guidance document may differ from its use in other programs or documents.

Table 1 contains the major product types found in UST systems in Michigan and the corresponding COCs for each confirmed product type released. This table should be utilized in the planning and implementation of site activities including sampling of various media and the application/calculation of target levels. This guidance document is intended primarily for gasoline and diesel releases. COCs for releases from waste oil or unknown USTs are listed in Table 1, however, only COCs related to gasoline or diesel releases are included in the remaining tables within this document. If the release is from a waste oil or unknown UST, the use of this guidance document may or may not be appropriate for the release and will be determined on a site-specific basis. For further details about COCs, including recommended analytical methods and target detection limits, refer to *Application of Target Detection Limits and Designated Analytical Methods* Resource Materials.

4.3.4 Initial Response Actions

Initial response actions are described in Section 3.4 of this document and in Section 21307 of Part 213 and include corrective actions that may have removed all or part of the product and related COCs released. Soil and groundwater data collected prior to such removal activities may not be representative of current conditions and should not be used in the tiered evaluation. At such sites additional soil and groundwater concentration data should be collected after the completion of the initial response actions. Data collected prior to the initial response actions may be used to determine the locations where additional data should be collected.

4.4 Site Information

The following onsite and offsite information is necessary to complete the MIRBCA evaluation:

- A site location map,
- A site map,
- Ground surface conditions,
- Location of and depth of utilities on and adjacent to the site,
- Land use and receptors within 500 feet of the site,
- Onsite and area groundwater use, and
- Local hydrogeology and aquifer characteristics.

The above information can be obtained by a (i) site visit, (ii) review of engineering drawings showing the layout of the site, (iii) review of regional information, and (iv) review of files at EGLE related to the site or adjacent sites. A brief discussion of each of the above items is presented below.

4.4.1 Site Location Map

A site location map should be prepared using either a United States Geological Survey (USGS) 7½ minute topographic map or an aerial imagery as a base. The site location should be centered and clearly marked on the map that must include a scale bar and a north arrow.

4.4.2 Site Map

A detailed site map must be prepared that shows the following, as appropriate.

- Property boundaries,
- Layout of past and current site features such as USTs, piping, dispensers, paved and unpaved areas, canopy, station building, etc.,
- Onsite and offsite monitoring wells, soil gas monitoring points, soil borings,
- Water supply wells (public and private) within at least 500 feet of the site,
- Wellhead protection areas within at least 500 feet of the site,
- Surface water features within at least 500 feet of the site,
- Buildings, including the foundation type, presence of basement and sump, if any,
- Remediation wells and system layout,
- Soil excavation areas, if any, and
- Area/location of release(s).

At sites where it is anticipated that the impacts may extend beyond 500 feet, the survey and corresponding site map must extend beyond 500 feet to encompass the entire area impacted by the release. As appropriate, multiple maps showing these features may be prepared. Site maps must be made to scale with a scale bar and a north arrow.

4.4.3 Ground Surface Conditions

The site map should identify the portion of the affected area (onsite and offsite) that is paved, unpaved, or landscaped. The type, extent, and general condition of the pavement should also be noted. The unpaved areas (for example, vegetated, gravel, or bare soil) should be described. The direction in which the surface slopes and any relevant topographic features should be noted.

4.4.4 Location and Evaluation of Onsite and Adjacent Offsite Utilities

Utility evaluation involves primarily four potential concerns that may require evaluation and corrective action:

- Preferential flow of impacted groundwater and/or mobile NAPL in utility backfill material,
- Fire and explosion hazards,
- Mobile NAPL migration into conduits, and
- Migration of impacted groundwater and NAPL through storm sewers to surface water bodies.

Due to the above concerns, an assessment of potential and actual migration and impact of COCs to underground utilities must be performed. Utilities include, but are not limited to, communication lines, water lines, sanitary sewers, storm sewers, combined sewers, and natural gas lines. Conduits, a subset of utilities in which mobile NAPL has the potential to enter and migrate within it, should also be identified. A combination of site observations, knowledge of buried utilities, and discussions with utility representatives and the property owner should be used to determine the locations of site utilities.

As appropriate, the following must be performed:

- Locate all underground utility lines and conduits within the known or likely impacted area, both onsite and offsite, where the release may have migrated or may migrate in the future,
- Identify the utility lines/conduits on a figure that also shows the extent of NAPL, soil, and groundwater impacts, including depths of impact relative to the depths of utilities,
- Determine depth of the utility lines/conduits relative to the depth of groundwater and mobile NAPL (if present). Seasonal fluctuations of the water table relative to the depth of utilities must be carefully evaluated. A cross-sectional figure should be provided illustrating the depth to groundwater, location of the NAPL body and mobile NAPL, if any, and the locations and depths of utility lines and conduits,
- If mobile NAPL is in contact with a utility, as a first step, screen the utilities and manholes using either a combustible gas detector, PID, or a four-gas meter. If explosive conditions are encountered immediately inform the local fire department and the EGLE PEAS hotline (800-292-4706), and
- A possibility of explosion exists if a utility is threatened or NAPL has entered a utility. Appropriate measures to eliminate fire, explosive conditions, or vapor hazards must be immediately undertaken.

4.4.4.1 Preferential Flow in Utility Backfill Material

At sites where the surrounding lithology is less permeable than utility backfill material, the backfill can act as a preferential flow pathway for groundwater and mobile NAPL. If conditions exist where preferential flow of mobile NAPL or dissolved groundwater contamination is likely, it should be evaluated. Any monitoring wells that are installed within utility backfill must be installed with great caution to avoid damaging the utilities. It is recommended to consider the risks of such an evaluation versus the potential data/information that may be gained and the need for the data to evaluate risk to human health and the environment. Soil gas should be evaluated if the utility backfill has the potential for connecting a source of vapors (e.g., mobile NAPL) with a structure that is inside the lateral screening distances. Refer to Section 5.3 and the EGLE's *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP* for additional information.

4.4.4.2 Fire and Explosion Hazards

Evaluating potential fire and explosion hazards due to vapors accumulating in a structure is generally considered an initial response action required when a release from a LUST system has first been identified. The potential for this situation is greatest when mobile NAPL is in contact with an unpressurized utility, such as a sewer. The assessment of fire and explosion hazards is performed by monitoring confined spaces using an appropriately calibrated field meter (e.g., four-gas meter).

Additional information related to fire and explosion hazards can be found in EGLE's *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP*.

4.4.4.3 NAPL and Vapor Migration within Utilities

Mobile NAPL in contact with unpressurized utilities has the potential to enter and migrate in the utilities and allow vapors to migrate within the utilities. It is important to identify any unpressurized utilities that are in contact with mobile NAPL to assess whether NAPL has entered the utility. The direction of flow within the utility should be assessed for potential NAPL migration within the utility; however, vapors can flow in any direction within the utility if the utility has headspace. It should be determined if there are any structures connected to the utilities where exposure or the accumulation of vapors could occur. Refer to EGLE's *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP* for additional information.

4.4.4.4 Storm Sewer and Surface Water Impacts

If mobile NAPL or impacted groundwater is in contact with a storm sewer, the sewer must be evaluated to determine if it is impacted and if a surface water body could be impacted above Tier 1 groundwater-surface water interface (GSI) RBSLs. The surface water protection pathway is considered complete if impacted groundwater or mobile NAPL is in contact with a storm sewer. However, the surface water protection pathway may be determined to be incomplete by demonstrating a storm sewer is sufficiently tight to prevent inflow of groundwater or that the sewer is otherwise impervious based on industry standards. Suggested lines of evidence include demonstrating that the sewers:

- Have been designed to prevent infiltration of water into the sewer,
- Have a permeability that would prevent infiltration of groundwater into the sewer (typically less than $1x10^{-7}$ cm/second, overall (including joints)),
- Have a design life that is either the replacement time determined by the municipality or thirty years, whichever is longer, and
- Are compatible with the COCs such that the COCs will not significantly affect the permeability of the sewer pipes over the design life.

To comply with the requirements of Part 213 and RBCA, compliance with the Tier 1 RBSLs for surface water protection must be met at the storm sewer outfall. This can be demonstrated by evaluating water at the storm sewer outfall but is usually demonstrated at locations prior to the outfall, including soil or groundwater in proximity to the storm sewer or water within the storm sewer. Evaluating impact to a storm sewer may consist of evaluating base flow conditions (i.e., sampling storm sewer water not immediately following a rain event or snow melt) at locations in the storm sewer on the site property as well as upstream and downstream to assess the LUST site's potential contribution and attenuation of the contaminants prior to the outfall.

Note that public entities that are owners of municipal separate storm sewer systems (MS4) must comply with permits issued under the National Pollutant Discharge Elimination System (NPDES) program. The discharge of any detectable concentration of COCs into a storm sewer is considered an illicit discharge in accordance with Part 31, Water Resources Protection, of the NREPA. MS4 permittees are required to detect, eliminate, and effectively prohibit illicit discharges into their MS4. Information about the MS4 program, including areas regulated under the MS4 program, can be found at: https://www.michigan.gov/egle/about/organization/water-resources/municipal-stormwater.

An O/O's obligation to address risks related to a LUST release does not include achieving compliance with another party's NPDES permit under the MS4 program. However, an O/O should inform a permit holder in the MS4 program of any impact to the storm sewer. EGLE and MDOT have established a process required for an O/O for situations when a storm sewer within an MDOT right of way is impacted by a LUST release. A conditional environmental license agreement (ELA) from MDOT must be obtained. MDOT will require certain conditions, including: (i) the submittal of a CR within one year of issuance of the ELA, (ii) EGLE audit and approval of the CR, and (iii) EGLE determination that the COCs are naturally attenuating over time. Additional information about an ELA through MDOT, including required forms and guidance documents, can be found Michigan.gov/mdot/business/contractors/environmental-license-agreement. For additional information on evaluating storm sewers and surface water impacts refer to EGLE's resource, *Groundwater-Surface Water Interface Pathway Compliance Options*.

4.4.5 Area Land Use and Receptors

The land use and potential receptors for current and future use must be identified on the onsite property and all potentially affected offsite properties (typically within 500 feet of the property boundary) as either residential or nonresidential to evaluate risk. The risk assessment for current use should be based on actual property use (i.e., a gas station should be evaluated as nonresidential for current use). Future risk assessments must be based on residential land use unless the land use is restricted by either a notice of corrective action or a restrictive covenant. If the risk assessment for future use is based on nonresidential land use and receptors, information related to zoning must be gathered to determine if land use assumptions in the local zoning ordinance are consistent with land use assumptions used to develop the nonresidential RBTLs.

4.4.6 Onsite and Offsite Groundwater Use

The current and former site owners and operators, if available, should be interviewed to determine how water is supplied to the site and whether a water well is/was located on the site. If a water well is identified, construction details of the well should be obtained to the extent such information is available. At a minimum, the location of the well, total depth of the well, casing depth, screen or open interval, static and/or pumping level, and use of water from the well must be determined. If a well is not currently in use or not likely to be used in the future, it must be properly plugged in accordance with EGLE requirements, unless it will be used for future sampling as part of a corrective action plan for the site (refer to *Michigan Groundwater Quality Rules*, R 325.1601 et seq.). Any onsite water use well is considered a POE for current use and must be sampled.

Any onsite water supply well must be sampled. If the well is impacted, corrective actions are necessary to address any unacceptable risk.

A water well survey must be conducted to locate all water supply wells within 500 feet of the site property boundary. A larger distance may be required if the dissolved plume is or is likely to be greater than 500 feet. Information sources include RRD's RIDE Mapper application, EGLE's Wellogic online groundwater database, MGS publications, local health departments, water system operators, municipal billing records, interviews with local residents, mailer surveys (refer to Appendix D for model form letter), and door-to-door surveys. The level of effort required to identify water supply wells is dependent on the potential for a property to be impacted and a supply well to be present on the property. To the extent that such information is available, well characteristics (including age, depth to water, total well depth, screened depths if present, method of construction, casing depth), amount of water pumped, and water use should be documented. Any water supply well that is potentially impacted by the dissolved plume is a POE for current use and must be sampled and appropriate corrective actions conducted if the well is impacted by the release.

A map must be generated and submitted to EGLE in the MIRBCA report forms (refer to Appendix E) that shows all potable and other supply wells within 500 feet of the site property boundary. Wellhead protection area boundaries within 500 feet of the site property boundary must also be included on this map. Note that RIDE Mapper has various features that can assist with this analysis, including allowing a user to easily add external data sets such as water well data and wellhead protection areas to RIDE Mapper, and allowing a user to create a custom buffer of e.g., 500 feet from a point. RIDE Mapper can be accessed at Michigan.gov/egle/maps-data/ride-mapper. Refer to Section 5.4 to determine the data necessary to evaluate the groundwater protection pathway.

4.4.7 Municipal Water

For municipal water to be considered available for a property, the property must either be connected to municipal water or have a water main within 50 feet of the property boundary. The local municipality should be contacted to determine that all properties within the designated area are receiving municipal water, if applicable. Local ordinances that require a mandatory tie-in to the municipal water supply system or prohibit the installation of potable wells must be promulgated by the municipality or municipalities with jurisdiction over the properties within the surrounding area of the LUST site. Refer to Section 5.4 for information on assessing the groundwater protection exposure pathway.

4.4.8 Local Hydrogeology and Aquifer Characteristics

Local hydrogeology, soil types, and aquifer characteristics should be evaluated to determine the type and depth of aquifers in the area and whether they are confined, semi-confined, or unconfined. Published literature, including USGS publications, MGS publications, USDA soil surveys, and reports for any investigations at nearby release sites can be reviewed to determine local aquifer characteristics and to assist in the planning of site-specific data collection. Such information is useful to the extent it helps evaluate the hydrogeology within the impacted area.

The review discussed above must also locate surface water bodies (e.g., lakes, rivers, wetlands, etc.) located within approximately 500 feet of the site (or other appropriate distance if the dissolved plume exceeds 500 feet in length) that could be affected by the confirmed release.

4.5 Vadose Zone Soil Characteristics

Vadose zone soil is a medium through which COCs can migrate to groundwater and through which vapors can migrate upward to ambient air or into an enclosed space. The following vadose zone parameters and their variability across the impacted area significantly affect the movement of chemicals through the vadose zone soil:

- Thickness of vadose zone,
- Dry bulk density,
- Porosity,
- Volumetric water content, and
- Fractional organic carbon content.

Except for the thickness of the vadose zone, these parameters are often collectively referred to as the soil geophysical or geotechnical parameters and affect the partitioning of the chemicals in the vapor, dissolved, and solid phase. For Tier 1 evaluations, EGLE has assigned conservative default values to these parameters (refer to Table 10). For Tier 2 and Tier 3 evaluations, site-specific values based on data collected from the site should be used. If circumstances at a site are such that site-specific geotechnical properties listed above were not determined, the O/O may use appropriate, justifiable literature values or may use the default values if they are appropriate for the site.

When collecting site-specific geotechnical data (i.e., dry bulk density, porosity, volumetric water content, fractional organic carbon content), careful consideration must be given to the location of COCs relative to receptors and the effect of the specific geotechnical parameter on the transport of COCs. For example, to develop SSTLs for the volatilization to indoor air pathway (VIAP), geotechnical data from the soil zone between the source of vapors and the building foundation is needed. However, to develop SSTLs for the leaching pathways, the geotechnical data of most relevance are from the zone of soil impact/source area. These types of considerations must be kept in mind when collecting and using geotechnical soil data.

Of the parameters listed above, **fractional organic carbon content must be determined using soil samples not impacted by the release.** Since the organic carbon content varies with depth, whenever appropriate, samples representative of vadose and saturated zones should be collected. For measuring porosity and the bulk density of soil, an undisturbed sample is necessary. Such a sample can be collected using a Shelby Tube. Consideration must be given to collecting multiple samples if multiple lithologies are present that might affect the transport of COCs.

The vadose zone soil parameters listed below are required for evaluating fate and transport in groundwater leaching pathways. In many cases, especially with newly discovered releases, it is necessary to evaluate soil contamination to determine the likely concentrations that could leach into groundwater at a POE or leach into groundwater and migrate to a POE. The groundwater protection pathway can be evaluated with representative groundwater concentrations in lieu of soil concentrations if sufficient time has passed such that the dissolved plume is stable or decreasing. Refer to Sections 4.7.4 and 10.2 for more information.

4.5.1 Thickness of Vadose Zone and Depth to Groundwater

The thickness of the vadose zone represents the distance from the ground surface to the depth at which the water table is encountered. It can be determined based on information presented on boring logs and/or measurements taken from monitoring wells or piezometers. For MIRBCA evaluations, the capillary fringe thickness is not considered part of the vadose zone. Depth to groundwater is used to estimate soil gas migration from groundwater and to determine the vadose zone attenuation factor, if required.

For sites where the water table fluctuates considerably, the available data must be evaluated to determine whether the fluctuations are seasonal or represent a consistent upward or downward regional trend. For sites with significant seasonal fluctuations, the average depth to groundwater and the average thickness of the vadose zone (as determined by groundwater elevation measurements) should be used in the development of Tier 2 and Tier 3 SSTLs. Averages can be determined by groundwater level measurements during a year. These averages should not be used in the development of site-specific potentiometric maps or any other activities that require specific knowledge of fluctuations in groundwater flow direction(s). At sites with consistent, long-term (greater than one year) upward or downward water level trends that do not appear to represent seasonal fluctuations, the most recent data should be used to estimate the depth to groundwater and the thickness of the vadose zone.

4.5.2 Dry Bulk Density

Dry bulk density is the dry weight of a soil sample divided by its field volume. An accurate measurement of bulk density requires determining the dry weight and volume of an undisturbed sample. An undisturbed soil core sample may be collected using a Shelby Tube, a thin-walled sampler, or equivalent method. The sample must not be disturbed prior to laboratory analysis.

Dry bulk density is estimated using the ASTM Method D2937-94, *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method.*

4.5.3 Porosity

Porosity is the ratio of the volume of voids to the volume of the soil sample. Many laboratories use dry soil bulk density and specific gravity to calculate porosity using the following:

$$\theta_{Tv} = 1 - \frac{\rho_b}{\rho_s} \qquad (4\text{-}1)$$

where,

θ_{Tv} = porosity (cc/cc)
ρ_b = dry soil bulk density (g/cc)
ρ_s = specific gravity or particle density (g/cc)

Thus, specific gravity and dry bulk density are needed to estimate porosity.

The *Standard Test Method for Specific Gravity of Soil*, ASTM Method D854, may be used to determine specific gravity. If specific gravity or particle density is not available, then 2.65 g/cc can be assumed for most mineral soils. Note, however, that use of this value must be justified.

If a site-specific porosity value cannot be determined, literature values consistent with the site lithology may be used, provided the source(s) of the value(s) is cited and appropriately justified. Where the total and effective porosities differ, the effective porosity value must be used.

4.5.4 Volumetric Water Content/Moisture Content

Volumetric water content is the ratio of volume of water to the volume of soil. The ASTM Method D2216-10, *Standard Test Method for Laboratory Determination of Water [Moisture] Content of Soil and Rock* is a gravimetric oven drying method that may be used to measure the water content of vadose zone soils. However, the water content value used in most models is the volumetric water content. Hence, if a gravimetric method is used to measure water content, the following conversion equation should be used to obtain the volumetric value:

$$\theta_{wv} = \theta_{wg} \times \frac{\rho_b}{\rho_l} \qquad (4\text{-}2)$$

where,

θ_{wv} = volumetric water content (cm^3 of water/cm^3 of soil)
θ_{wg} = gravimetric water content, typically reported by the laboratory (g of water/g of soil)
ρ_b = dry bulk density (g of dry soil/cm^3 of soil)
ρ_l = density of water (g/cm^3)

Multiple samples from across the site and at varying depths must be analyzed for water content to estimate a representative water content value for the vadose zone. Typically, every soil sample analyzed for one or more COCs must be analyzed for water content since the laboratory must provide COC concentrations on a dry weight basis. Thus, water content data are readily available for these samples. In addition, water content values representative of each of the lithologic units that comprise the vadose zone must be determined. Professional judgment should be used for applying the water content values if there is significant variability (refer to Section 7.2.1 for a discussion of variability in geotechnical parameters). When using professional judgment, it is important to consider that the intent is to use a value representative of the long-term conditions for the site. For example, a water content value collected immediately after a storm event may be discarded in calculating the representative water content value.

Water content data should be carefully reviewed prior to being used to calculate Tier 2 SSTLs. The volumetric water content of a sample cannot exceed the porosity of that same sample and possibly for any other sample collected from the same soil. If the laboratory report indicates this to be the case, an inquiry should be made of the laboratory to determine which value is in error.

4.5.5 Fractional Organic Carbon Content

Fractional organic carbon (FOC) content is the weight of organic carbon in the soil divided by the weight of the soil and is expressed either as a ratio or as a percent. **FOC must be determined using soil samples not impacted by petroleum or other anthropogenic chemicals**. Therefore, FOC samples must be collected from soil borings or probe holes away from areas of contamination but to the extent possible, from similar stratigraphy. Prior to collecting samples for FOC analysis, a PID reading should be taken to confirm that the sample has not been impacted by petroleum products or other anthropogenic contaminants. As an alternative, laboratory data from the same boring or a nearby boring may be used to confirm that contamination is not present.

In general, soil samples from the saturated zone do not need to be collected for FOC analysis. FOC analysis in the saturated zone is necessary; however, if the saturated soil type is different from the vadose zone soil and there is the potential for COCs to migrate to a POE in an unimpacted area.

Data from multiple borings or probe holes from non-impacted locations are required to accurately determine FOC for the site. In addition, multiple samples from each boring or probe hole may be required if there are different types of soils in the vadose zone.

Prior to shipping samples to a laboratory for analysis, subsamples of the same soil type collected from different borings or probes may be combined into a single composite sample for laboratory analysis. For instance, if three different soil types underlie a site and a sample of each is collected from four different borings, the samples from each soil type may be combined into a single composite sample for that soil type. This would result in three samples for FOC analysis rather than twelve.

Fractional organic carbon content may be estimated using the Walkley Black Method (Page et al., 1982) or the method outlined in *Determination of Total Organic Carbon in Sediment (Lloyd Kahn Method)*, July 27, 1988, or a similar method. However, some laboratories may not be familiar with these methods. If the laboratory is not equipped to conduct either of these methods, an alternative, though less preferred, method is ASTM Method 2974, *Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils*. Method 2974 measures the organic matter content of a sample. When using the method, the fractional organic carbon value can be calculated by Equation 4-3:

$$F_{oc} = \frac{F_{om}}{1.724} \qquad (4\text{-}3)$$

where,

F_{oc} = fractional organic carbon
F_{om} = fractional organic matter

If the laboratory results are reported as a percent, fractional organic carbon content may be obtained by dividing the result by 100. The FOC analytical method must be identified in the MIRBCA report submitted to EGLE.

FOC data should be carefully reviewed prior to being used to calculate Tier 2 or Tier 3 SSTLs and prior to submission to EGLE. Data indicating unexpectedly high FOC should be verified through discussion with the analytical laboratory and, if warranted, via collection and analysis of additional samples.

4.6 Saturated Zone Characteristics

COCs reach the water table by travelling vertically through the vadose zone. COCs that reach the water table primarily travel horizontally in the saturated zone, although vertical transport is possible when a vertical gradient exists between shallow and deeper saturated zones. Saturated zone characteristics that determine the rate, magnitude, and direction of migration of COCs in groundwater include the following:

- Horizontal hydraulic conductivity,
- Hydraulic gradients (magnitude and direction),
- Thickness of capillary fringe and residual mass in the capillary fringe,
- Saturated zone soil geotechnical characteristics (fractional organic carbon content, porosity, and bulk density), and
- Factors that determine the rate of natural attenuation.

Of the characteristics listed above, the properties typically having the greatest influence on COC migration are hydraulic conductivity and hydraulic gradient.

Note that quantification of the above characteristics will be required only at sites where it is necessary to quantify the movement of water or the COCs by using a model. If a quantitative evaluation is not necessary, a qualitative understanding of these parameters is sufficient.

4.6.1 Hydraulic Conductivity

Hydraulic conductivity is the discharge of water per unit area per unit hydraulic gradient in a subsurface formation. Reliable estimates of site-specific hydraulic conductivity can be obtained by pump tests or slug tests. In the absence of these tests, literature values corresponding to the type of soil in the saturated zone may be used. When a literature value is used, adequate reference and justification for the value chosen must be provided. When using literature values, all predominant soil types composing the saturated zone must be considered. Hydraulic conductivity may also be estimated based on the grain size distribution of the formation when data from pump tests or slug tests are not available.

4.6.2 Hydraulic Gradient

The magnitude and direction of the hydraulic gradient is estimated by comparing static water levels measured in monitoring wells across a site. A contour map must be prepared, either manually or using a computer program, using field measured static water level data, corrected to elevations relative to mean sea level (preferably) or other established datum. These contour maps can be used to estimate both the direction and magnitude of the hydraulic gradient. When drawing contour maps, care should be taken to ensure that measurements from monitoring wells screened in the same interval or hydrogeologic unit are used. For sites where wells are screened in multiple zones, a contour map for each zone must be developed. Data from wells screened in different zones should not be combined to draw one contour map.

For sites that have seasonal variation in the hydraulic gradient and/or the predominant flow direction, estimates of the average hydraulic gradient for each season and each flow direction can be used in the modeling efforts. A horizontal groundwater gradient can be calculated using the USEPA tool (EPA On-line Tools for Site Assessment Calculation) located at www3.epa.gov/ceampubl/learn2model/part-two/onsite/gradient4plus-ns.html.

At sites with multiple groundwater zones, vertical gradients should also be determined via a comparison of water levels in wells screened at different intervals. EGLE will consider exceptions to this requirement on a site-specific basis.

4.6.3 Thickness of Capillary Fringe

The capillary fringe is the zone immediately above the saturated zone where capillary forces cause upward movement of water molecules from the saturated zone into the soil above. This zone is distinct in that it has characteristics of both the vadose zone and saturated zones. For purposes of the MIRBCA process, the thickness of the capillary fringe may be measured or a default value may be used. Because accurate field measurement of the thickness of the capillary fringe can be difficult, literature values based on the soil type immediately above the water table may be used to assign a site-specific value for the capillary fringe thickness.

4.6.4 Saturated Zone Soil Geotechnical Characteristics

The saturated zone soil characteristics include fractional organic carbon content, porosity, and bulk density. These parameters are required to estimate the extent of the migration of COCs, including the retardation factor that "slows" the movement of chemicals within the saturated zone. These parameters are also necessary when estimating future concentrations or performing contaminant mass balance calculations using models that include a finite source or biodegradation (See Appendix C for details). The laboratory methods to measure these parameters are discussed in Section 4.5.

4.6.5 Natural Attenuation

Natural attenuation includes all processes that cause a reduction in the concentration of COCs in groundwater. These include dilution due to surface recharge, three-dimensional molecular diffusion, three-dimensional mechanical dispersion, sorption, volatilization from groundwater, and biodegradation.

Natural attenuation may be evaluated at a site by monitoring appropriate indicators (such as chemical concentrations, geochemical indicators, electron acceptors, microorganisms, or carbon dioxide). Such measurements may be required when natural attenuation is proposed as a principal element of the CAP. Indicators of natural attenuation can be broadly classified into three groups: primary, secondary, and tertiary lines of evidence. Data collected under each line of evidence are used to qualitatively and quantitatively evaluate the rate of natural attenuation.

The **primary** line of evidence is a demonstration that a reduction in concentration or mass of COCs is occurring at a site. The primary line of evidence is best determined by:

- Plotting COC concentrations as a function of distance along the plume center line,
- Plotting COC concentrations in each well as a function of time,
- Comparing COC concentration contour maps at various times (e.g., Ground Water Spatio-Temporal Data Analysis Tool (GWSDAT) [http://gwsdat.net/]),
- Performing concentration mass balance calculations, and
- As appropriate, generating three-dimensional depictions of plumes and their migration over time.

In performing the above analysis, other factors that could influence the data, such as seasonal water level or flow direction fluctuations, should be considered.

A **secondary** line of evidence is necessary when the primary line of evidence is insufficient, or when a secondary line of information is necessary to design a remedial system (for example, the addition of oxygen). The secondary line of evidence involves measuring geochemical indicators such as dissolved oxygen, dissolved nitrates, manganese, ferrous iron, sulfate, and methane. These indicators must be measured in at least three wells located along the plume center flow line. The wells must be located to represent conditions at:

- A background or upgradient location,
- An area within the plume near the source, and
- An area within the plume downgradient of the source.

Developing a **tertiary** line of evidence involves performing microbiological studies to identify and quantify microorganisms within and near the plume. A tertiary line of evidence is seldom used at petroleum LUST sites.

The commonly used methods to estimate natural attenuation include (i) mass balance analysis for expanding, stable, or shrinking plumes, and (ii) plume concentration vs. distance plots.

At most LUST sites, the development of secondary and tertiary lines of evidence is usually not necessary. However, at most sites, groundwater sampling data should be plotted to evaluate temporal trends. These trends can be used to determine whether the plume is expanding, stable, or decreasing. EGLE will require that the groundwater plume be stable or decreasing prior to approving a closure for the release.

4.7 Delineation and Distribution of COCs

4.7.1 General Requirements for Delineation

Part 213 and the MIRBCA process require the extent of contamination to be determined so that the risk related to the confirmed release can be evaluated and members of the public directly impacted by the confirmed release can be notified.

The delineation criteria are the most stringent Tier 1 RBSLs in each medium regardless of the tier evaluation and are listed in Table 2. The delineation criteria are not used for risk assessment but are used to estimate the extent of contamination as required by 21308a and 21311a of Part 213 and to notify parties impacted above a residential Tier 1 RBSL as required by 21309a(3) of Part 213. The extent and distribution of COCs must be known so that a CSM and an EM can be developed.

Delineating the extent of contamination is a necessary data-gathering step as part of a **site assessment** in the MIRBCA process and is a required precursor to risk assessment. The precision for delineation is unique for each site and should be driven by the potential for exposure to occur.

In most cases it will be necessary to delineate COCs laterally until soil borings or monitoring wells confirm COC concentrations below the delineation criteria. The actual depicted extent of COCs on a figure may be reasonably estimated. For example, the extent of contamination between a sampling point where COCs exceed the delineation criteria and a sampling point where COCs do not exceed the delineation criteria may be interpolated between the two points provided that the depicted extent is reasonable and that a different interpretation of the extent of contamination does not appreciably change the CSM or any risk decision. In some cases, extrapolation of site data to estimate the extent of contamination may be appropriate, if justified. Knowledge of site conditions, age of release, groundwater flow direction, concentration gradients, concentration levels with respect to the delineation criteria, location of or lack of nearby points of exposure, potential impact to additional offsite properties should be considered when determining the required precision of delineation.

Soil, groundwater, and soil gas samples should be analyzed to target detection limits and designated analytical methods as described in *Application of Target Detection Limits and Designated Analytical Methods* Resource Materials.

4.7.2 Distribution of COCs in Soil

The objective of soil characterization is to delineate the vertical and horizontal extent of COCs related to the confirmed LUST release and characterize the distribution of COCs so that (i) representative concentrations (including maximum concentrations in Tier 1) can be determined for exposure domains (EDs) of each complete exposure pathway, (ii) the soil source dimensions can be estimated, (iii) the extent of residual NAPL in the vadose zone can be determined, and (iv) the contaminant distribution within MDOT and public highway ROWs can be determined.

A site assessment in the MIRBCA process requires that a thorough assessment of source areas be performed to ensure that maximum concentrations of COCs are detected at the site. The number and locations of soil borings necessary to adequately characterize and delineate a site will vary from site to site depending on various factors, such as size and complexity of site, age of release, proximity to receptors, distribution of COCs, site stratigraphy and hydrogeology, etc. For historic releases,

The amount of data needed to conduct a risk assessment at a petroleum LUST site should be driven by site conditions and the likelihood of exposure. In the MIRBCA process, sufficient data should be collected to calculate Tier 2 and as appropriate, Tier 3 SSTLs, calculate representative concentrations, and demonstrate plume stability. If collection of additional data would likely not change a risk-based decision, the additional data may not be necessary. The degree of uncertainty in the CSM should be balanced by site conditions, including age of release, the general lifecycle of petroleum contamination in the environment, and the conservative nature of the assumptions used to develop the exposure model and the RBTLs.

recent soil data may not be necessary in most cases because the leaching to groundwater pathways (groundwater protection, surface water protection) are better assessed through groundwater data, and the VIAP is better assessed through soil gas data.

4.7.3 Distribution of COCs in Groundwater

Adequate groundwater samples must be collected to (i) delineate the extent of the dissolved COC plume in all directions, and (ii) determine representative concentrations for the complete exposure pathways. The precision of data needed for characterization and delineation is site-specific and dependent on various factors, such as proximity to receptors and age of release (refer to Section 4.7.1). Properly installed and developed permanent monitoring wells are generally required for collecting repeated representative groundwater data. Representative groundwater data can also be collected from temporary wells. Temporary wells may be useful, for example, (i) if repeated sampling at the given point is not necessary, (ii) if access issues do not allow the installation and sampling of a permanent monitoring well, (iii) for delineation or characterization if the dissolved plume is likely stable based on age of the release, and (iv) for collecting groundwater samples to determine a location of a permanent monitoring well. Part 213 requires that groundwater samples for closure verification be collected utilizing a low-flow technique or other method approved by EGLE. Technical resources for monitoring well installation are available in the literature (e.g., *Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM D-5092)).

4.7.4 Determination of Plume Stability

To assess plume stability, groundwater monitoring must be conducted for a period sufficient to show a reliably consistent trend in the concentrations of COCs. For the MIRBCA process, such a trend must be apparent over a monitoring period of one to three years, with samples generally collected on a quarterly basis. The default assumption is that two years of quarterly data will be necessary to evaluate plume stability; however, in cases where less than two years of data demonstrate a clearly declining or stable plume, no further monitoring will be required. In some cases where two years of monitoring does not clearly show a stable or declining plume, additional data may be required. Greater than three years of monitoring without a conclusion of stability would indicate that the plume is not stable. For historic releases with multiple years of groundwater data, plume stability can be demonstrated by semi-annual or annual data, if the data set is adequate. The age of the release, volume and duration of the release, proximity to receptors, and other lines of evidence can be considered to determine plume stability. The footprint of dissolved petroleum plumes often stabilizes within a short period of time (e.g., a few years) after the release has been stopped. For historic releases where it is likely that the dissolved plume is stable, an evaluation of site-specific conditions should be conducted to determine if additional groundwater sampling is necessary. Factors to consider include age of the release, concentration and distribution of COCs, and likelihood of exposure to the COCs.

Methods to evaluate plume stability include evaluating concentration trends for each COC in each monitoring well, plume area, average plume concentration, plume mass, and plume center of mass. Several of these analyses are described in published literature (e.g., Gibbs et al., 2002; Ricker, 2008; Vanderford, 2010). Plume trends can be evaluated by means of an appropriate statistical trend test such as linear regression or Mann-Kendall analysis (e.g., EPA, 2009; ITRC, 2013). If the data exhibit seasonal variations, the Mann-Whitney test may be a more appropriate method for evaluating the data than the Mann-Kendall because the Mann-Kendall evaluation is not appropriate for data sets that are cyclic or exhibit seasonal trends (ITRC, 2013). In general, plume stability analysis for smaller sites and simpler datasets can be accomplished with well-by-well analysis methods, whereas more complex sites and larger data sets may require plume-based analysis methods. This is not to be construed that plume-based analysis methods cannot be used for smaller sites.

At all sites, the groundwater system is very dynamic due to variability in weather (amount of precipitation, water table elevation fluctuations, barometric pressure fluctuations, temperatures, etc.). Fluctuations in groundwater concentrations are the norm rather than the exception. Therefore, plume stability requires considerable professional judgment; the focus must be on the overall trends and not just a portion of the data.

4.7.5 Distribution of COCs in Soil Gas

Soil gas samples are not collected and analyzed for the purpose of delineation but rather solely as an indirect means to evaluate indoor air inhalation risk. Soil gas samples should be collected in locations that represent the potential for vapors to migrate vertically into an existing or potential future structure and that adequately characterize soil gas emitted from a source. If samples within an exposure domain (refer to Section 5.1.5 for a discussion on determining the exposure domain) are collected from multiple media (e.g., soil gas, soil, and groundwater), the risk evaluation should be conducted using soil gas data.

5.0 General Considerations for Risk Assessment

A tiered risk-based evaluation requires the consideration and understanding of several factors common to the three tiers. These factors include, but are not limited to:

- Development of an EM,
- Calculation of RBTLs,
- Protection of groundwater use and surface water bodies,
- Estimation of representative concentrations of COCs, and
- Evaluation of nonaqueous-phase liquid (NAPL).

This section briefly discusses each of these factors and their application for the management of LUST sites.

5.1 Development of an Exposure Model

An EM identifies the exposure pathways that are complete under current conditions or may become complete under future conditions. An EM identifies the media of concern, receptors of concern, migration of COCs from the impacted media to the receptor (exposure pathway), and routes of exposure. The EM presents a working hypothesis of how the COCs migrate from the source to the POE where the COCs contact the receptors and exposure occurs. For each complete exposure pathway, each receptor, and each COC, RBTLs must be developed. For a list of COCs refer to Table 1. If exposure to the COCs is not possible under current or reasonably anticipated future conditions (e.g., due to engineering controls or land or resource use restrictions), there can be no adverse health risk. Thus, for risk to be present at a site, at least one exposure pathway must be complete under current use or in the future.

An EM is a qualitative evaluation based on information collected during SA. Typically, for each site, EMs for two time periods will be developed: (i) current use, and (ii) long-term (i.e., several years) reasonably anticipated future use, to ensure that the site concentrations are protective of both current and potential future receptors. At sites where the current and future use will be the same, EMs for current and future use would be identical.

The MIRBCA process does not consider short-term exposures such as for construction workers because short-term exposures to petroleum chemicals, at concentrations typically observed at LUST sites, would not likely result in an unacceptable risk. A RA that considers short-term exposure would involve recalculating Tier 1 RBSLs based on much lower exposure frequency and duration and sub-chronic toxicity values. For petroleum compounds these RBTLs would be less stringent than the RBTLs for chronic, long-term exposures.

Development of an EM requires knowledge of land use, receptors, exposure pathways, routes of exposure, and exposure domains. Each of these elements is discussed in the following sections.

5.1.1 Land Use and Human Receptors

Within the MIRBCA process, land use is categorized as either (i) residential or (ii) nonresidential. These land use categories determine the appropriate receptors and associated exposure assumptions. Thus, the RBTLs are generally based on either residential or nonresidential exposure assumptions. Residential land generally results in lower target levels and cleanup to these levels allows for unrestricted residential use.

Descriptions of residential and nonresidential land uses are presented below:

- **Residential** – Includes land uses where people reside and/or children or other sensitive subpopulations are present on a regular basis (greater than intermittent). Examples include, but are not limited to, homes, apartments, hospitals, nursing homes, schools, and childcare centers, etc.
- **Nonresidential** – Includes land uses where healthy adult workers can be expected to be on site less than 12 hours a day and five days a week. Examples include, but are not limited to, retail facilities, industrial and manufacturing operations, fleet operations, offices, etc.

In Tier 1 and Tier 2, the following human receptors are considered:

- **Residential** – Child, adult, and age-adjusted individual (considered only for direct contact of surficial soil in Tier 1 and for all pathways in Tier 2)
- **Nonresidential** – Adult worker

> RBTLs for future use must be based on residential land use assumptions unless nonresidential land use restrictions apply to the impacted properties (refer to Section 10.1 and 10.2).

The age-adjusted individual is one who lives at a site continuously from birth to age 26. For residential land use, the lowest of the three RBTLs (child, age-adjusted, and adult) is applicable. Other receptors may be considered in a Tier 3 evaluation.

Other nonresidential receptors such as visitors, maintenance workers, or construction workers will generally have less exposure than those listed above (due to lower exposure frequency and duration) and, therefore, for these receptors it is not necessary to calculate RBTLs.

The MIRBCA process requires that human receptors present on both onsite and offsite impacted areas be considered. A plume moving offsite might impact multiple land uses and multiple receptors. For example, a plume whose source is a nonresidential property, with recorded restrictions that limit the property to nonresidential land use, may have migrated offsite below an unrestricted residential area. In this case, both nonresidential and residential land uses must be considered when developing the EM. For simplification, the following definitions should be used:

- **Onsite** – The property located within the legal property boundaries within which the release occurred.
- **Offsite** – Any property located outside the boundaries of the onsite property and onto which COCs associated with the release have or are likely to migrate.

In the MIRBCA process, both current and future use must be determined for all affected properties. The evaluation of current use should be based on the actual land use, which could be residential or nonresidential. If the O/O chooses to rely on nonresidential target levels for future use, Part 213 requires that either a notice of corrective action or a restrictive covenant that restricts land use to nonresidential conditions be recorded on the property deed. Regardless of land use, delineation (conducted as part of **site assessment**) must be completed to the delineation criteria, which is the most stringent Tier 1 residential RBSLs for each medium (refer to Section 4.7). Refer to Section 10.1 and 10.2 for information related to land use restrictions.

5.1.2 Human Exposure Pathways and Routes of Exposure

A receptor comes in contact with COCs only if a complete exposure pathway exists under current or reasonably anticipated future use. For an exposure pathway to be complete, there must be a chemical source, a mechanism by which the chemical is released from the source, a medium through which the chemical travels from the point of release to the receptor location, a point of exposure where the receptor is exposed to the chemical, and a route of exposure by which the chemical enters the receptor's body and potentially causes adverse health effects (Figure 5-1). When all elements of an exposure pathway are present for current or future use, the exposure pathway is complete and must be evaluated by comparing representative concentrations to applicable RBTLs. If any element of the exposure pathway is missing, the exposure pathway is not complete, and concentrations need not be compared to target levels for that exposure pathway. EGLE has developed generic criteria under Part 201 for residential and nonresidential human receptors and for the protection of surface water. The generic criteria are used as Tier 1 RBSLs (refer to Tables 3 through 6).

> If an exposure pathway is incomplete for current and reasonably anticipated future use, RBTLs for that pathway are not applicable and there is no need to compare representative concentrations to RBTLs. Since exposure is not likely to occur, there can be no adverse health risk.

Figure 5-1. Elements of an exposure pathway

In the MIRBCA process, the following media and exposure pathways must be evaluated:

Surficial Soil

Surficial soil is defined as soil that extends from the ground surface to two feet in depth (Figure 5-2). For surficial soil, the following pathways must be evaluated:

- Dermal contact and incidental ingestion of soil. This pathway is termed **direct contact**.
- Volatilization of vapors and emission of particulates to ambient air. This pathway is termed **ambient air inhalation**. In Tier 1, inhalation of vapors and particulates are considered two different pathways. Thus, in Tier 1 the ambient air inhalation pathway is evaluated by comparing representative surficial soil concentrations to the (two) applicable RBSLs, i.e., soil volatilization to ambient air and soil particulate inhalation.
- In Tier 2 and Tier 3 evaluations, the inhalation of outdoor vapors and particulates is combined with dermal contact and incidental ingestion of soil and is evaluated using a single SSTL for each COC. However, it is highly unlikely that there will be an unacceptable risk for the ambient air inhalation or direct contact pathway in either a Tier 1 or Tier 2 evaluation.

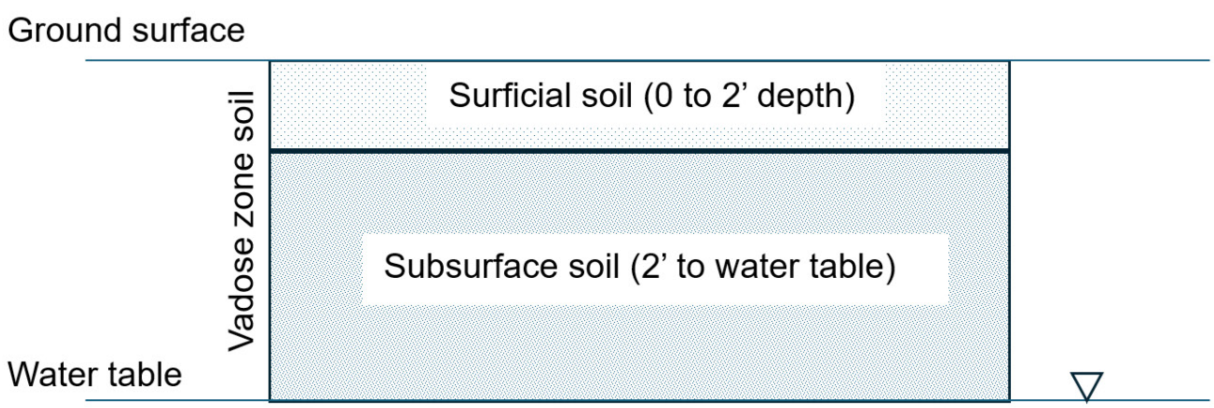


Figure 5-2. Soil zones within the MIRBCA process

Subsurface Soil

Subsurface soil is defined as soil that extends from below the surficial soil to the water table. Refer to vadose zone soil for the pathways that must be evaluated.

Vadose Zone Soil

Vadose zone soil is defined as soil that extends from the ground surface to the average depth of the water table and includes both surficial soil and subsurface soil. For vadose zone soil, the following pathways must be evaluated:

- Volatilization of soil gas from vadose zone soil and migration of vapors into indoor air. This pathway is termed the **VIAP**. The evaluation of this exposure pathway is discussed in Section 5.3.
- Migration of COCs from vadose zone soil to groundwater and potential ingestion of groundwater. This pathway is termed **groundwater protection**. The evaluation of this exposure pathway is discussed in Section 5.4.
- Migration of COCs from vadose zone soil to groundwater and potential migration to a surface water body. This pathway is termed **surface water protection**. The evaluation of this exposure pathway is discussed in Section 5.5.

Soil Gas

Soil gas refers to gas in the vadose zone soil and vapors within utilities or conduits. The source of soil gas may be NAPL, impacts to soil, and/or impacts to groundwater. For soil gas, the following pathway must be evaluated:

- Migration of soil gas to indoor air. This pathway is termed the **VIAP** and is discussed in Section 5.3.

Groundwater

Groundwater refers to water present in the saturated zone in the subsurface. For groundwater, the following pathways must be evaluated:

- Volatilization from groundwater and migration of vapors to indoor air. This pathway is termed the **VIAP** and is discussed in Section 5.3.
- Migration of groundwater to a well where water is ingested. This pathway is termed **groundwater protection** and is discussed in Section 5.4.
- Migration of groundwater to surface water. This pathway is termed **surface water protection** and is discussed in Section 5.5.

5.1.2.1 Determining Exposure Pathway Completeness

The commonly encountered exposure pathways, exposure media, and exposure routes listed above must be evaluated. A receptor comes in contact with COCs through a complete exposure pathway. For an exposure pathway to be complete, there must be a (i) source of chemical, (ii) mechanism by which the chemical is released, (iii) medium through which a chemical travels from the point of release to the receptor location, (iv) point of exposure, and (v) route of exposure by which the chemical enters the receptor's body and potentially causes adverse health effects. Items (i), (ii), (iii) and (iv) are critical to determine the ED for each complete exposure pathway. The ED is specific to the complete exposure pathway and is the three-dimensional volume of contaminated media that contributes COCs for that exposure pathway. For each complete exposure pathway, the MIRBCA process requires collection of sufficient data within the ED to estimate the representative concentrations of COCs. Refer to Sections 5.1.5, 5.1.6, and 5.1.7 for a discussion on ED, POE, and POC.

The following provides some guidance to determine if an exposure pathway is complete.

Direct contact: The exposure pathway is complete for current use on areas of the property that are unpaved. The exposure pathway is not complete for current use on paved areas of the property. This exposure pathway is considered complete for future use regardless of the current pavement unless engineering controls and a mechanism (i.e., restrictive covenant) is in place to ensure the continuance of the pavement. The POE is assumed to be anywhere within the upper two feet of soil. Concentrations below two feet in depth are not evaluated for this pathway. If there is no evidence of impact within the upper two feet of the site (e.g., field screening does not indicate impact within the upper two feet of vadose zone soil), then the exposure pathway is incomplete, and no further evaluation is required. Note that there are separate non-risk-based requirements for characterizing and addressing impacted soil within MDOT and public highway ROWs (refer to Section 10.5 and 10.6).

Groundwater protection: The exposure pathway is complete for current use if there are any water supply wells that are potentially impacted by the release. The exposure pathway is complete for future use if groundwater is in an aquifer or COCs can migrate to an aquifer. The pathway is not complete for future use in the following circumstances (Figure 5-3):

- If groundwater is not in an aquifer and is not able to migrate to an aquifer, or
- If groundwater is in a shallow, isolated aquifer where the bottom of the aquifer is less than 15 feet from the ground surface and the aquifer is not in hydraulic communication laterally or vertically with a continuous aquifer that extends deeper than 15 feet from the ground surface, ***and*** no water supply wells exist on the property or within 300 feet of the site property boundary.

Refer to Appendix B for the conditions necessary to eliminate the groundwater protection pathway for future use.

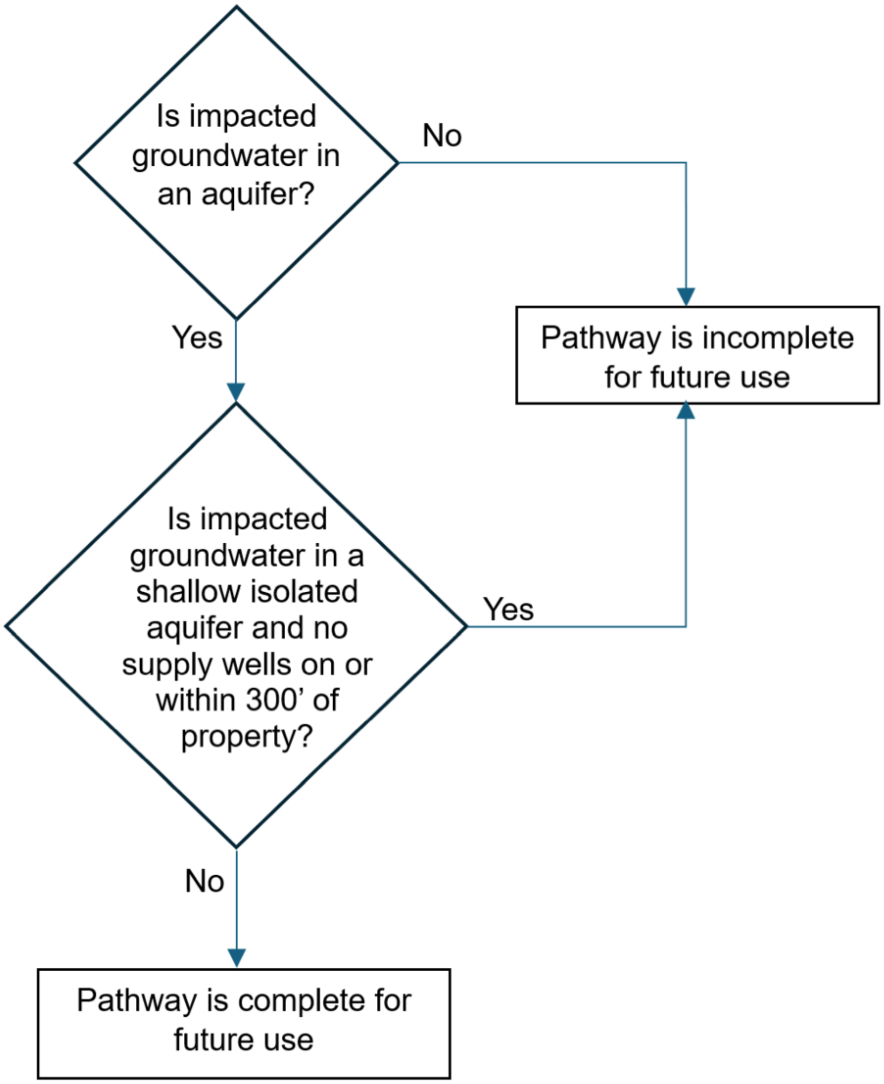


Figure 5-3. Determining future use pathway completion for the groundwater protection pathway

Surface water protection: This exposure pathway is complete when COCs in groundwater are likely to discharge to surface waters of the state, including the following circumstances:

- If impacted groundwater discharges or is likely to discharge directly to a surface water body, or
- If a storm sewer line is in a saturated zone impacted by a confirmed release, i.e., the storm sewer is below the average depth of groundwater within the dissolved contaminant plume.

Combined sewers are not evaluated for the surface water protection pathway because the influent is treated and discharged to a surface water body that is regulated with an NPDES permit.

Ambient air inhalation: The exposure pathway is complete for current use on areas of the property that are unpaved. The exposure pathway is not complete for current use on paved areas of the property. This exposure pathway is considered complete for future use regardless of the current pavement unless engineering controls and a mechanism to ensure the maintenance of the engineering controls are in place.

If there is no evidence of impact within the upper two feet of the site (e.g., field screening does not indicate the presence of volatile COCs related to the release), then the exposure pathway is not complete and does not require further evaluation. Concentrations below two feet in depth are not evaluated for this pathway. If there is evidence of impact within the upper two feet of the vadose zone, the thickness of the impacted soil must be determined so that applicable Tier 1 RBSLs for the soil volatilization to ambient air can be selected (i.e., infinite source, 5-meter source thickness, or 2-meter source thickness).

If there is evidence of impact within the upper two feet of vadose zone soil, the thickness of the impacted soil must be determined so that applicable Tier 1 RBSLs for soil volatilization to ambient air can be selected (i.e., infinite source, 5-meter source thickness, or 2-meter source thickness.

VIAP: The exposure pathway is complete for current use if there is a building partially or completely within the footprint of the vapor source and lateral inclusion zone (LIZ). Similarly, the exposure pathway is complete for future use if there could be a building within the vapor source and LIZ. The vapor source is defined as the area where concentrations exceed applicable Tier 1 RBTLs. The size of the LIZ varies depending on the level of certainty within the area of impact (refer to Section 5.3.2 for a discussion of the LIZ and to Section 5.1.5 for assumptions regarding the location and construction of future buildings).

If the VIAP is complete for current or future use, all buildings potentially impacted by vapors should be identified, including foundation type and whether a sump is present. The subsurface within the applicable vertical and lateral screening distances should be sufficiently characterized to identify the presence of utilities and any potential preferential pathways. For information, refer to Section 4.4.4 of this guidance and to the *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP*.

5.1.2.2 Other Exposure Pathways

Each of the above exposure pathways must be considered when developing the EM for current and potential future conditions. If it is determined that an exposure pathway is incomplete, the pathway can be eliminated from further evaluation.

The O/O developing the EM must consider all other pathways and routes of exposure that may be complete at a site. At some sites, other routes of exposure such as ingestion of produce grown in impacted soils or exposure associated with the use of groundwater for irrigation purposes must be considered. These routes of exposure are significant only in rare cases for LUST releases and will be evaluated in Tier 3.

5.1.2.3 Development of a Conceptual Exposure Model

For all complete exposure pathways, a conceptual EM for current use and future use must be developed. The conceptual EM is based on a reasonable potential exposure scenario, defined as a situation with a credible chance of occurrence where a receptor may become directly or indirectly exposed to the COC, without considering extreme or essentially impossible circumstances (ASTM International, 1995). Exposure to COCs occurs at a POE and the source is an ED. Therefore, EDs and POEs for current and future use must be determined for each complete exposure pathway.

The following POEs must be determined for a risk assessment of current use:

- The POE for the groundwater protection pathway is potentially impacted water supply wells,
- The POE for the surface water protection pathway is located where groundwater discharges to a surface water body and at the storm sewer outfall,
- The POE for the VIAP is indoor air in buildings,
- The POE for the direct contact pathway is unpaved surficial soil to which a receptor comes into contact, and
- The POE for the ambient air inhalation pathway is the ambient air.

The risk assessment for future use is based on the reasonable potential exposure scenario and the assumptions within the tiered evaluation. A Tier 1 evaluation includes conservative, generic assumptions, and thus the **POEs for future use in a Tier 1 evaluation include the following:**

- The POE for the groundwater protection pathway is any point in the affected aquifer,
- The POE for the surface water protection pathway is located where groundwater discharges to a surface water body and at the storm sewer outfall (Tier 1 future use POE for the surface water protection pathway is the same as the current use POE),
- The POE for the VIAP is indoor air in a future building that could be constructed within the LIZ,
- The POE for the direct contact pathway is surficial soil to which a receptor comes into contact, regardless of pavement (Tier 1 assumption is that surficial soil may be unpaved in the future unless a restrictive covenant that assures the presence and maintenance of the pavement is recorded on the property deed), and
- The POE for the ambient air inhalation pathway is the ambient air.

In a Tier 2 evaluation, the EM is based on where POEs could reasonably be located in the future. **POEs for future use in a Tier 2 evaluation include the following:**

- The POE for the groundwater protection pathway is a reasonable location of a water supply well,
- The POE for the surface water protection pathway is located where groundwater discharges to a surface water body and at the storm sewer outfall (Tier 2 POE for the surface water protection pathway is the same as Tier 1 POE),
- The POE for the VIAP is indoor air in a future building within the LIZ (Tier 2 assumption is a building with foundation type and location based on a site-specific evaluation),
- The POE for the direct contact pathway is surficial soil (Tier 2 assumption is that surficial soil may be unpaved in the future unless a restrictive covenant that assures the presence and maintenance of the pavement is recorded on the property deed), and
- The POE for the ambient air inhalation pathways is the ambient air.

The main difference between a Tier 1 and Tier 2 evaluation of future use is in the groundwater protection pathway and the VIAP. When developing a Tier 1 EM, the POEs for these pathways are generic and conservative. When developing a Tier 2 EM, the POEs for these pathways are based on site-specific information and therefore require additional data to complete the EM. For the groundwater protection pathway, information related to the presence of municipal water in the area, properties connected to the municipal water system, and information about municipal ordinances that require hookup to the system or prohibit the installation of new wells is necessary to develop the Tier 2 EM for the groundwater protection pathway. Refer to Section 5.4 for more information.

For the VIAP, an evaluation of the likely location and construction of a future building is required for a Tier 2 EM. For example, the evaluation can determine if it is reasonable that a future building would be constructed with a basement or with slab-on-grade construction. A reasonable location of a building can also be determined, based on factors such as development patterns in surrounding properties, local setback requirements, plans for future development on the property, etc. If multiple future building locations are possible, the risk evaluation for future use must be based on a reasonable location that poses the greatest VIAP risk based on the existing contamination.

EGLE considers ROWs as areas where there is no reasonable potential chronic exposure scenario for most exposure pathways. ROWs can include public roads, highways, railroads, gas pipelines, and other similar features. It is not reasonable to expect a supply well or a building to be constructed in a ROW, nor is it reasonable to expect chronic exposure to surficial soil or ambient air within a ROW, and therefore there are no POEs in ROWs for these pathways. MDOT and public highway ROWs are evaluated primarily to assist the ROW owner with management of contaminated soil and are discussed in Sections 5.1.4, 10.5, and 10.6.

5.1.3 Ecological Risk Evaluation within the MIRBCA Process

Based on nationwide experience, ecological risk assessment, other than the protection of surface water bodies, is typically not required at petroleum LUST sites because such sites are typically located in high traffic areas, are small in size, and ecological receptors are rarely a concern. If groundwater concentrations at the surface water protection POE exceed Tier 1 RBSLs (which are protective of ecological receptors) or if there are other significant ecological risks at a site, they will be evaluated in Tier 3.

5.1.4 Evaluation of Public Rights of Way

The MIRBCA process requires the O/O to evaluate impacts within road and highway rights of way (ROWs) controlled by the Michigan Department of Transportation (MDOT) or local units of government. This evaluation differs from the risk-based process described in the MIRBCA guidance document and is required by Section 21310a(3) of Part 213 primarily to assist MDOT and public highway ROW owners with managing contaminated soil, groundwater, and NAPL within the construction zone in public highway ROWs. Impacted soil, groundwater, or NAPL within the ROW may require a notification or an alternative mechanism. Refer to Sections 10.5 and 10.6 for more information.

5.1.5 Exposure Domain

A key part in the development of an EM is the determination of the size and location of the ED for each pathway, route of exposure, and receptor. The ED is the three-dimensional volume of a medium that contributes to the receptor's exposure via a specific pathway and route of exposure. In Tier 1, since the evaluation is based on the maximum observed concentration in a medium, the implication is that the entire impacted portion of the site property is an ED. The offsite ED must be identified for each complete exposure pathway if offsite properties are impacted. In Tier 2, the ED is site-specific and unique for each complete exposure pathway.

The following offers reasonable exposure domains for each exposure pathway:

Direct contact: The ED is the volume of soil with which a receptor could come into contact. It is assumed that a receptor can come in contact with the upper two feet of the unpaved portion of the site. For a Tier 1 evaluation, the maximum soil concentration measured in the upper two feet of unpaved soil is considered. Thus, the exposure domain would be the impacted top two feet of the site that is unpaved or likely to be unpaved in the future. Engineering controls that ensure the permanence of the pavement may be used to reduce the ED for future use to the portion that may be unpaved.

Ambient air inhalation: The ED is the volume of soil that contributes to particulate matter and volatilization of COCs to ambient air. This is the upper two feet of vadose zone soil. For current conditions, the top two feet of the unpaved area should be evaluated. Engineering controls that ensure the permanence of the pavement may be used to reduce the ED for future use to the portion that may be unpaved.

Groundwater protection: For a Tier 1 evaluation, the ED is the point at which a potable well is located or could exist in the future. In this case the future well is hypothetical. Thus, in Tier 1, the ED is a single point located at the POE. For a Tier 2 evaluation, the ED refers to the soil source area or the groundwater source area as discussed in detail in Section 7.2.2.

Surface water protection: For Tier 1, the concept of ED is not very relevant because this exposure pathway evaluates the transport of impacted groundwater to a single point (the POE), where Tier 1 RBSLs must be met. For a Tier 2 evaluation, the ED refers to the soil source area or groundwater source area as in the case of the groundwater protection pathway and is discussed in detail in Section 7.2.2.

VIAP: The ED is the area from which NAPL, groundwater, and soil gas contribute vapors to an indoor air space. There will likely be multiple EDs for the VIAP. For current use, the ED is the area of each building footprint within lateral and vertical separation distances. As appropriate, data collected up to ten feet beyond the building footprint can be used to estimate the representative concentration for the ED (refer to Section 5.7 for a discussion on estimating the representative concentration).

In Tier 1, the ED for future use is assumed to be the entire property for the site and for each impacted offsite property (Figure 5-4). The future use scenario is evaluated in Tier 1 assuming a potential building with a basement at eight feet depth with concrete block or poured concrete walls and floor and built over the maximum concentrations on each impacted property.

In a Tier 2 evaluation, the ED for future use can be determined based on a site-specific evaluation and is the footprint of a building of reasonable size and construction located in a likely location on each impacted property. If the location of a future building is unknown, multiple locations of buildings may have to be evaluated (Figure 5-5).

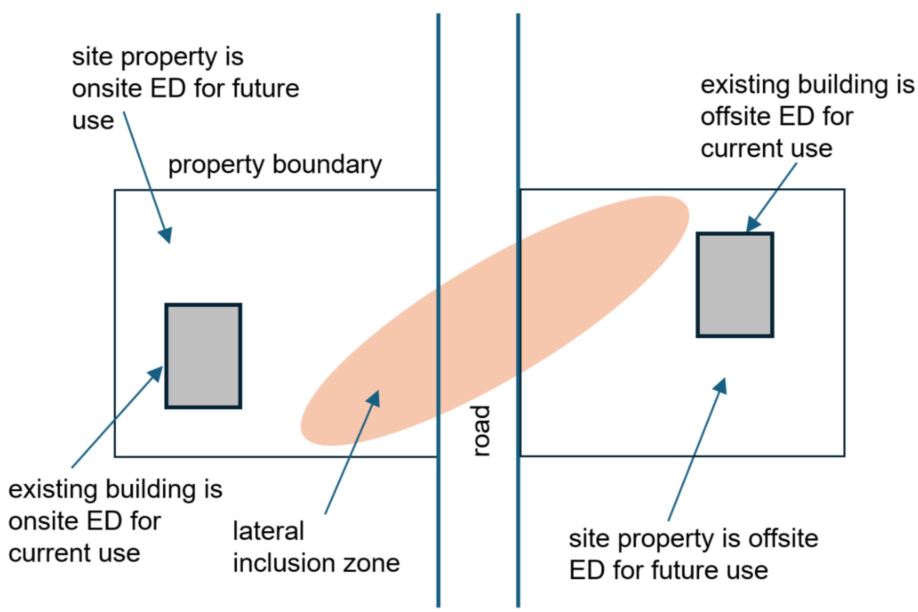


Figure 5-4. Tier 1 ED for the VIAP

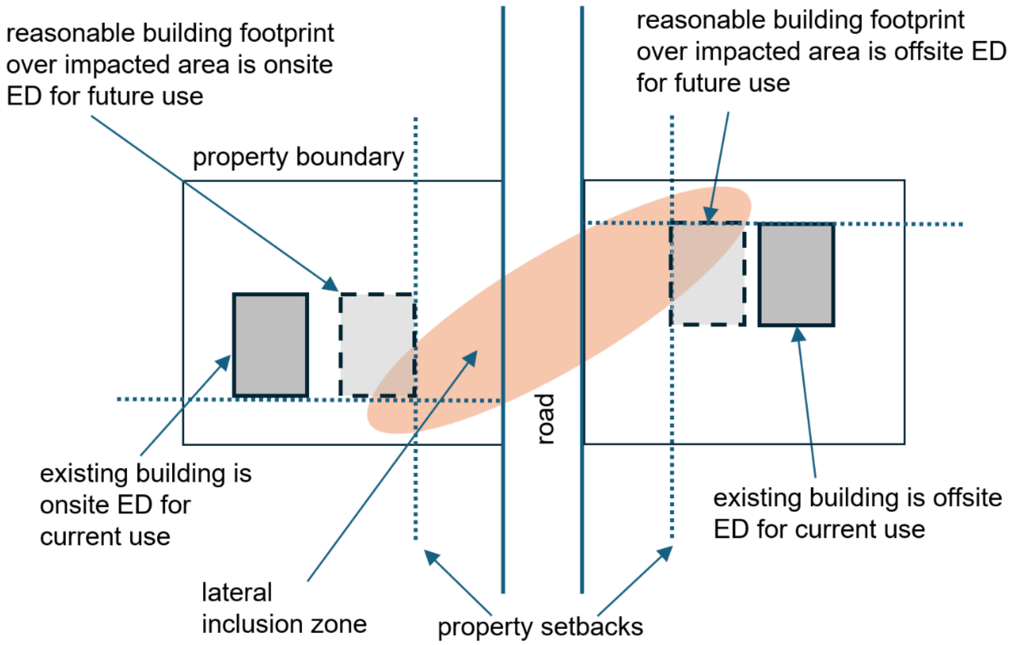


Figure 5-5. Tier 2 ED for the VIAP

5.1.6 Point of Exposure

A POE is the location where a receptor comes in contact with COCs under current and reasonably anticipated future conditions. A POE is associated with each complete route of exposure. For direct routes of exposure, the POE is located at the source of the COCs. For example, for the direct contact of surficial soil, the POE is located at the same location as the source. For indirect routes of exposure, the POE and the source of COCs are physically separate. For example, in the case of indoor inhalation of vapors from groundwater, the POE is the breathing space inside the building whereas the source is the groundwater or NAPL below the building. For each complete route of exposure, the O/O must identify the source and the POE, which may be different for different tiers.

Direct exposure RBTLs are developed using chemical uptake equations and are applicable at the POE. **Indirect exposure** RBTLs applicable at the POCs and the source area are developed using the acceptable POE concentration (i.e., the chemical uptake equations) and fate and transport models.

5.1.7 Point of Compliance

A POC is located between the source and the POE where concentrations are measured to demonstrate that the concentrations at the POE would be acceptable. At the POC there is no exposure and the acceptable concentrations at the POC are higher than the acceptable concentrations at the POE. The difference in concentrations represents the attenuation of COCs between the POC to the POE. In the MIRBCA process, POC monitoring points are selected between the source and the POE to serve as sentinel or guard wells for the protection of the POE in the groundwater protection and the surface water protection pathways. For the VIAP, soil gas and groundwater (and soil, if used for risk evaluation in Tier 1) concentrations are POC concentrations. In Tier 2, SSTLs are developed that are unique to each POC and COC based on fate and transport considerations. Additional information about how points of compliance are used in the groundwater protection and surface water protection pathways is available in Section 5.4 and 5.5.

5.1.8 Documentation of the Exposure Model

A complete and accurate discussion of the exposure model is critical to the MIRBCA evaluation. Therefore, EGLE has developed forms pursuant to Section 21316 of Part 213 that must be completed to document the EM. The forms can be downloaded from at michigan.gov/egle/about/organization/remediation-and-redevelopment. A copy of the forms and brief instructions for completing the forms is available in Appendix E.

5.2 Calculation of Risk-Based Target Levels

This section presents the development of target levels, and the default data used to develop Tier 1 RBSLs.

Applicable RBTLs: RBTLs are applicable when an exposure pathway is complete and when fate and transport assumptions used to develop the RBTLs are met. Direct exposure RBTLs (e.g., Tier 1 GSI RBSLs, Tier 1 groundwater ingestion RBSLs) are applicable only at the POE. SSTLs that are developed based on distance to the POE are applicable only at the distance or point for which they were developed.

5.2.1 Target Risk Level

Development of RBTLs requires a target or acceptable risk level for carcinogenic and non-carcinogenic adverse health effects. The target risk levels are specified in Part 213. For carcinogenic effects, the MIRBCA process uses an **individual excess lifetime cancer risk (IELCR)** of 1×10^{-5} as the target risk and for non-carcinogenic effects a **hazard quotient (HQ)** of one (1). These target risk levels must be used for all tiers and for current and future receptors.

The estimation of cumulative risk or the hazard index (HI, sum of HQs) is not required in the MIRBCA process for the following reasons:

- There are a limited number of COCs at most regulated LUST release sites,
- The MIRBCA process uses conservative exposure factors, fate and transport models, and target risk levels, and
- The models used to estimate the RBSLs and SSTLs include numerous conservative assumptions.

5.2.2 Quantitative Toxicity Factors

For COCs with carcinogenic adverse health effects, toxicity is quantified using slope factors for dermal and ingestion exposures and a unit risk factor for inhalation exposures. For COCs with non-carcinogenic adverse health effects, toxicity is quantified using reference doses for dermal and ingestion exposures and a reference concentration for inhalation exposures.

Toxicity values used in the calculation of Tier 1 RBSLs are listed in Table 4 of R.299.50 of the Michigan Administrative Code. EGLE requires the use of the updated toxicity values presented in Table 7 of this guidance document for the calculation of Tier 2 RBTLs, which are the most recent values published in the USEPA Regional Screening Levels (RSLs). For Tier 3 evaluations, alternate toxicity values that can be justified and are acceptable to EGLE may be used. As of the publication of this document, Table 7 presents the toxicity values that must be used in calculating RBTLs for the COCs (USEPA, 2024). The USEPA updates toxicity values two times per year. Toxicity values for most petroleum chemicals are unlikely to change significantly. If a toxicity value changes between the time an SSTL is calculated and the time a CR is submitted, the SSTL will be considered protective. If the toxicity change results in an SSTL that should be an order of magnitude lower, EGLE may require recalculation of the SSTL.

5.2.3 Exposure Factors

Exposure factors describe the physiological and behavioral characteristics of the receptor and are typically not measured at a site and instead literature values are used. Exposure factors used to derive the Tier 1 RBSLs are listed in R.299.10 through R.299.26 of the Michigan Administrative Code. For reference these exposure factors are presented in Table 9 that also includes the Tier 2 exposure factors. For a Tier 3 evaluation, alternate exposure factors may be used with adequate technical justification. Part 213 requires either a notice of corrective action or a restrictive covenant for any evaluation that relies on nonresidential exposure assumptions for future use.

5.2.4 Fate and Transport Parameters

Fate and transport parameters are necessary to estimate the RBTLs for the indirect routes of exposure. These factors characterize the physical site properties (such as depth to groundwater, soil porosity, and infiltration rate) and building characteristics (such as the height of a building and the air exchange rate). For calculating Tier 1 RBSLs, EGLE has established conservative default fate and transport values presented in Tables 10 and 11. For Tier 2, a combination of site-specific and default values may be used. However, all the values used must be justified based on site-specific considerations.

5.2.5 Physical and Chemical Properties

The development of RBTLs requires the physical and chemical properties of the COCs and are listed in Table 8. Several of the physical and chemical properties are experimentally determined; hence their values are not exact and include a certain amount of variability. Physical and chemical properties used to derive the Tier 1 RBSLs are listed in Table 4 of

R.299.50 of the Michigan Administrative Code. For Tier 2 and Tier 3 evaluations, EGLE requires the use of values presented in Table 8 of this guidance document. However, for Tier 3 evaluations, these values may be modified with justification provided to EGLE.

5.2.6 Mathematical Models

Two types of models, or equations, namely the (i) uptake equations, and (ii) fate and transport models, are required to calculate RBTLs. Uptake equations are used to calculate the dose based on the exposure factors and POE concentrations. Fate and transport models are required for indirect routes of exposure which involve the migration of chemicals within a medium or across media. Such models relate the POE concentration with the source concentration. For indirect exposure routes the two equation types are often combined together.

Uptake equations and fate and transport models used to derive the Tier 1 RBSLs are listed in R.299 of the Michigan Administrative Code and in the *Guidance Document for the VIAP, Volume 6 – Volatilization to Indoor Air Criteria*. For Tier 2 evaluations, EGLE has selected the models and equations presented in Appendix A. These models are commonly used across the nation for RBCA evaluations. These models have been programmed into the MIRBCA computational software that can be used to develop the Tier 2 SSTLs. For Tier 3 evaluations, an O/O can use this software or may propose alternative models. A guide to the selection of an appropriate fate and transport model is *ASTM (1999) RBCA Fate and Transport Models: Compendium and Selection Guide*, or *USEPA (1990) 625/6-90/016a: Groundwater Volume I: Groundwater and Contamination*.

5.3 Volatilization to Indoor Air Inhalation

If the VIAP is complete for current or future use, it must be evaluated as described below. To determine if the VIAP is complete and for determining the appropriate ED for current and future use, refer to Sections 5.1.2, 5.1.5, and to the *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP*.

5.3.1 Determine the Extent of the Vapor Source

The first step is to determine the extent of the vapor source. The vapor source is assumed to be NAPL above the water saturated zone and the soil and groundwater impacts above the applicable Tier 1 residential RBSLs (Tables 3 through 6). The applicable RBSLs depend on the VIAP Scenario (refer to Section 5.3.6), which is a function of the depth to groundwater in relation to the floor of a building and the mechanism by which vapors enter a building. Residential RBSLs should be used unless the land use is restricted to nonresidential use by a restrictive covenant or notice of corrective action.

The extent of the vapor source can be depicted on a map by:

- Extending to sample locations where concentrations are below applicable Tier 1 ,
- Interpolating the extent between sample locations where concentrations are below applicable RBSLs and sample locations where concentrations are above applicable RBSLs, or
- Estimating between borings where NAPL has been shown to be present and where it has been determined to be absent.

If supported by site data and if it is unlikely to change a risk decision, the extent of the vapor source can be extrapolated beyond a sample location where concentrations are above the applicable RBSLs. An example of this is when there is no current or reasonable future building in the direction where the vapor source extent is estimated by extrapolation.

For determining the extent of the vapor source, recent data (defined as the recent five years of soil data and the recent two years of groundwater data) should be used if available (refer to Section 5.7). The extent of NAPL is determined as discussed in Section 5.8.

NAPL and soil and groundwater concentrations above applicable Tier 1 residential RBSLs are assumed to be a source that could result in unacceptable indoor air concentrations. Soil gas samples below applicable Tier 1 RBSLs can be used to demonstrate that NAPL, soil, or groundwater is not a vapor source or to limit the area that represents a vapor source. Soil gas concentrations below applicable Tier 1 RBSLs that are collected from the location(s) that represent the highest soil gas concentrations can be used to demonstrate that NAPL, soil or groundwater is not a vapor source (refer to Section 5.3.8 and 5.3.9 regarding the quantitative evaluation of the VIAP).

Soil gas concentrations below applicable Tier 1 RBSLs that are collected from the location(s) that represent the highest soil gas concentrations can be used to demonstrate that NAPL, soil or groundwater is not a vapor source.

If sufficient soil, groundwater, or NAPL data are not available to determine the extent of the vapor source and where the pathway is complete, then soil gas data can be collected to determine the potential extent of vapors that could pose an unacceptable indoor air risk. This process should be done iteratively by first collecting soil gas data at the source (i.e., at the highest detected concentrations of soil or groundwater or where NAPL is present) and comparing it with Tier 1 RBSLs. Soil gas samples should be collected at a depth that represents potential concentrations at which vapors could enter a building.

5.3.2 Application of a Lateral Screening Distance

The second step is to add a lateral screening distance around the vapor source to account for any uncertainties to estimate the maximum potential area within which soil gas can migrate into buildings above unacceptable levels.

The applicable lateral screening distance is determined based on the vapor source type (i.e., NAPL, soil, or groundwater) and the precision of determining the extent of the vapor source (i.e., extending to points with concentrations below RBTLs, estimated by interpolating or extrapolating). The lateral screening distance is also called the lateral inclusion zone (LIZ) and is determined based on the level of confidence and the amount of data available to depict the vapor source, as explained below. Note that the LIZ is determined based on a conservative estimate of the lateral distance that soil gas can migrate from a soil, groundwater, or NAPL vapor source. If soil gas data are available that either (i) demonstrate that indoor air concentrations would not be above acceptable levels, or (ii) limit the area that could result in unacceptable indoor air concentrations, then it is not necessary to establish a LIZ or it can be based on site-specific soil gas data.

- If the vapor source is conservatively depicted as extending to sample locations where soil or groundwater concentrations are below the applicable RBTLs for soil or groundwater, then the LIZ is five feet, extending beyond the sample locations where concentrations are below the applicable soil or groundwater RBTLs (Figures 5-6a, 5-6b).

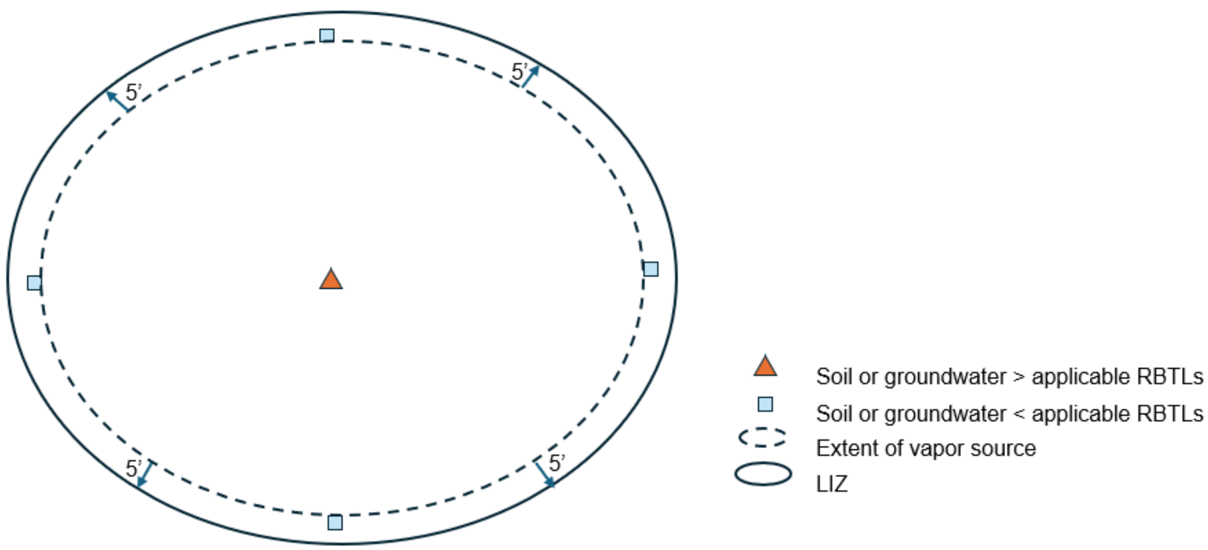


Figure 5-6a. 5-foot LIZ from a soil or groundwater vapor source (plan view)

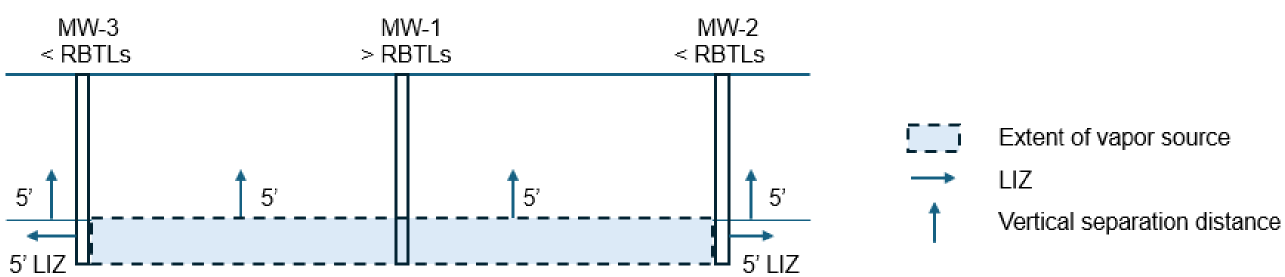


Figure 5-6b. 5-foot LIZ from a soil or groundwater vapor source (cross section)

- If the vapor source is based on the extent of NAPL, the LIZ is 15 feet that extends outward from the sample locations where NAPL is absent (Figures 5-7a, 5-7b).

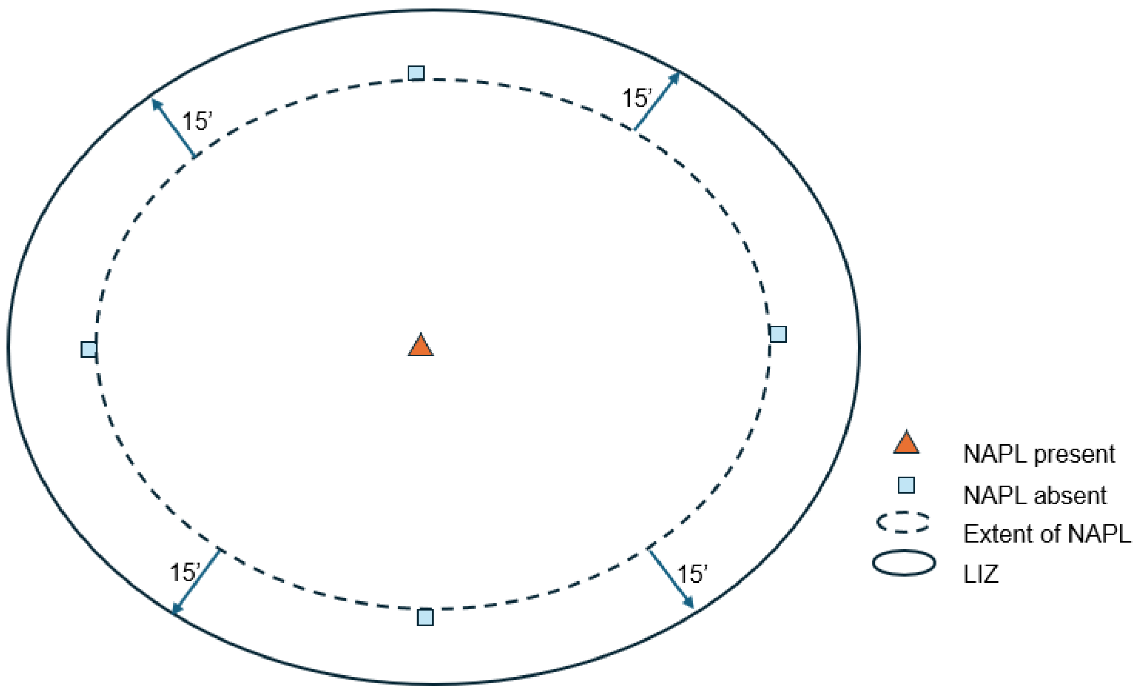


Figure 5-7a. 15-foot LIZ from a NAPL vapor source (plan view)

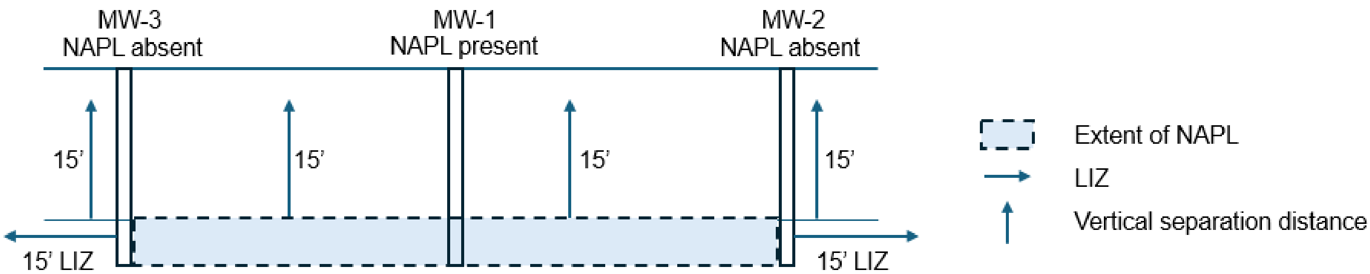


Figure 5-7b. 15-foot LIZ from a NAPL vapor source (cross section)

- If the extent of the vapor source is based on interpolation or estimation between sampling locations or extrapolating beyond a sampling location (for a soil, groundwater, or NAPL vapor source), then the LIZ would be 30 feet beyond the interpolated or estimated vapor source (Figures 5-8a, 5-8b, 5-9a, 5-9b).

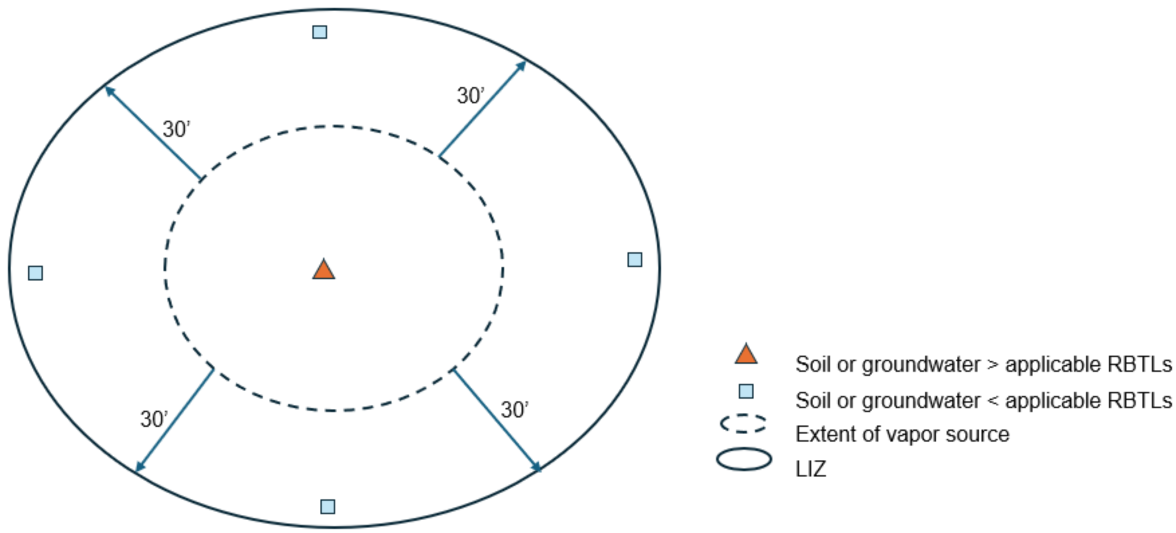


Figure 5-8a. 30-foot LIZ from a soil or groundwater vapor source (plan view)

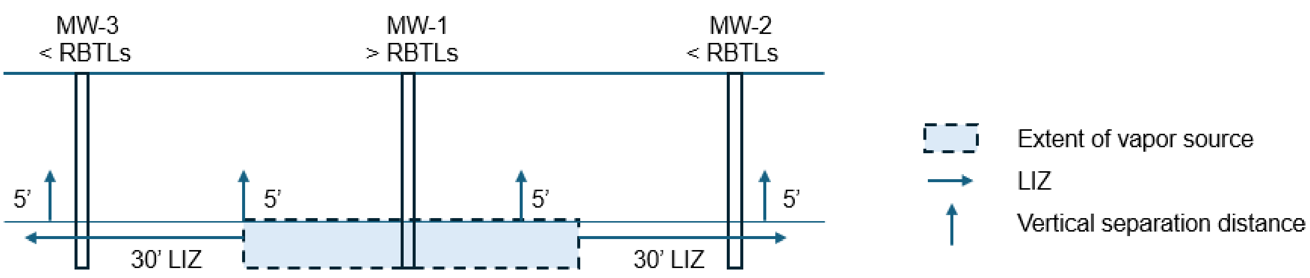


Figure 5-8b. 30-foot LIZ from a soil or groundwater vapor source (cross section)

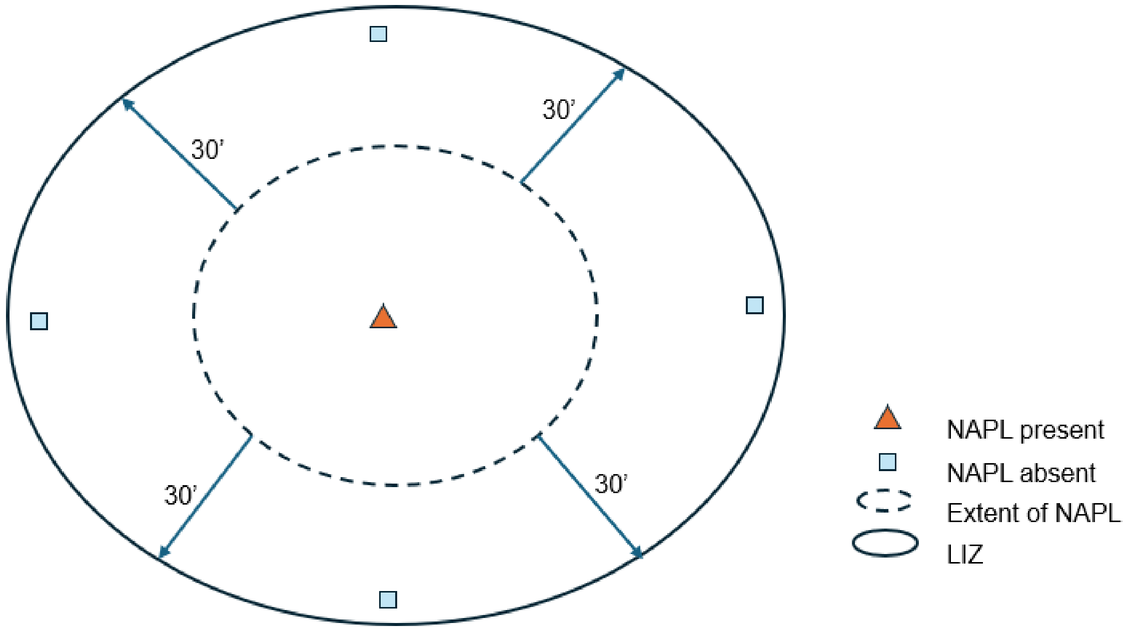


Figure 5-9a. 30-foot LIZ from a NAPL vapor source (plan view)

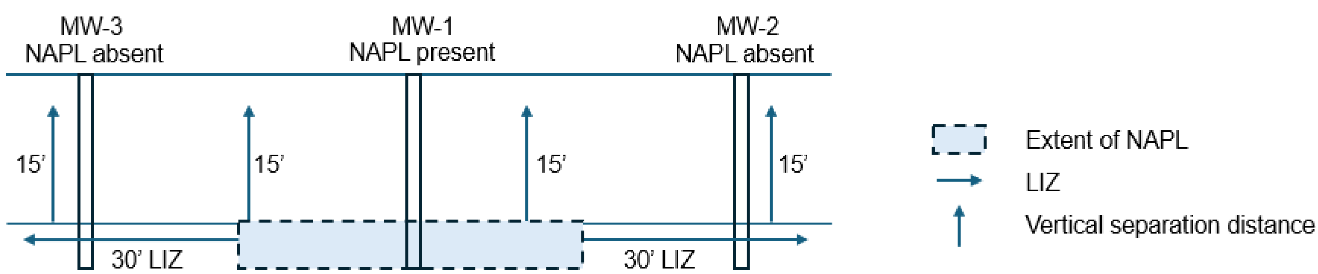


Figure 5-9b. 30-foot LIZ from a NAPL vapor source (cross section)

The area within the LIZ (including the area of the vapor source) is the area that could pose an unacceptable indoor air inhalation risk and thus is the area within which the VIAP is complete for current and future use and must be evaluated. The indoor air inhalation risk must be evaluated for all current and potential future buildings located partially or completely within this area.

The LIZ extends outward from the edge of the vapor source. Current and future buildings within the LIZ must be evaluated for the VIAP.

5.3.3 Identification of Potentially Affected Current Buildings

All buildings currently located within the LIZ must be identified and their relevant characteristics tabulated using the tables in the MIRBCA forms. Such tabulation will include the building location and construction details (e.g., slab on grade, poured concrete walls and foundations, basement, presence of a sump, etc.).

In addition to current buildings within the LIZ, utilities and preferential pathways must also be identified. The utilities consist of any conduits that mobile and migrating NAPL can enter, and the preferential pathways consist of any utility backfill that is more permeable than the surrounding materials that may alter the migration of mobile NAPL or impacted groundwater. Residual NAPL cannot move and therefore does not need to be evaluated any further with utilities or utility backfill. More information related to evaluating utilities and preferential pathways can be found in the *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP*.

5.3.4 Identification of Potentially Affected Future Buildings

To evaluate risk for future use, a hypothetical building will be assumed on each property within the LIZ. The characteristics of the potential building include:

- Tier 1: A hypothetical residential building with an 8-foot-deep basement. It is assumed that the basement will have a sump if the average depth to groundwater is less than eight feet below grade and that the basement will not have a sump if the average depth to groundwater is greater than eight feet below grade.
- Tier 2: A hypothetical building with size and construction details based on a site-specific evaluation.

In a Tier 1 evaluation, the building would be located anywhere on each impacted property. In a Tier 2 or 3 evaluation, the construction, foundation type, and location of the building would be based on a site-specific evaluation. If multiple potential future building locations are possible, the risk assessment for future use must be based on the location that would result in the greatest risk (refer to Section 5.1.5).

5.3.5 VIAP Evaluation using Vertical Separation Distance

For the buildings identified within the LIZ, a semi-quantitative evaluation of indoor air inhalation risk is performed by utilizing a vertical separation distance between the vapor source and the floor of the building, as explained below:

- If the distance between the bottom of the slab of the lowest floor of the building and the top of a soil or groundwater vapor source is greater than five feet and greater than 15 feet from a NAPL vapor source, no further evaluation is necessary for the given building (i.e., the VIAP is complete for current use but the given building screens out and does not require a quantitative evaluation of indoor air inhalation risk using soil concentrations, groundwater concentrations, or soil gas concentrations). The vertical screening evaluation must be performed for all buildings within the LIZ.

- A similar evaluation must be performed to assess the indoor air inhalation risk related to potential future buildings within the LIZ (refer to Section 5.1.5 and 5.3.4 for assumptions related to a hypothetical future building).

The indoor air inhalation risk must be quantitatively evaluated for any current building within the LIZ that does not screen out using the applicable vertical separation distance and for all areas within the LIZ that could have a potential future building that does not meet the applicable vertical separation distance. For all current and potential future buildings outside the LIZ, the VIAP is considered incomplete unless there is a known preferential pathway from the source to the building.

5.3.6 Conceptual Model for the VIAP

The quantitative evaluation of the VIAP requires the development of a robust conceptual model for depicting how vapors enter a building. Figures 5-10, 5-11, and 5-12 describe three commonly encountered scenarios by which soil gas may enter a building. In these scenarios, the source of vapors is either contaminated soil/residual NAPL in the vadose zone (Scenario 1a and 2a) or contaminated groundwater (Scenario 1b, 2b and 3). Further, as discussed below, Scenarios 1 or 2 may also have a foundation drain and sump.

Scenario 1: Groundwater not in contact with the building floor and NAPL not present.

Scenario 1 (Figure 5-10) represents a building with either slab-on-grade construction or a basement with concrete block or poured concrete walls and floor and the soil source of vapors (Scenario 1a) or the groundwater source of vapors (Scenario 1b) is not in contact with the building floor. Scenario 1 applies when NAPL is absent between the soil or groundwater vapor source and the building floor.

For this scenario, the transport mechanisms for vapors to enter the building consist of (i) diffusive flow of vapors from the source through the overlying vadose zone soil up to the floor of the building and advective flow into the building, and (ii) intrusion of these vapors into the building through dirt-filled cracks and any other openings in the floor. Advective transport occurs if there is a pressure difference across the building's subsurface envelope that consists of the area of the floor of the building (for slab-on-grade construction and for buildings with basements). It is assumed that advective diffusive flow of vapors through the subsurface walls is negligible. The VIAP evaluation is described below.

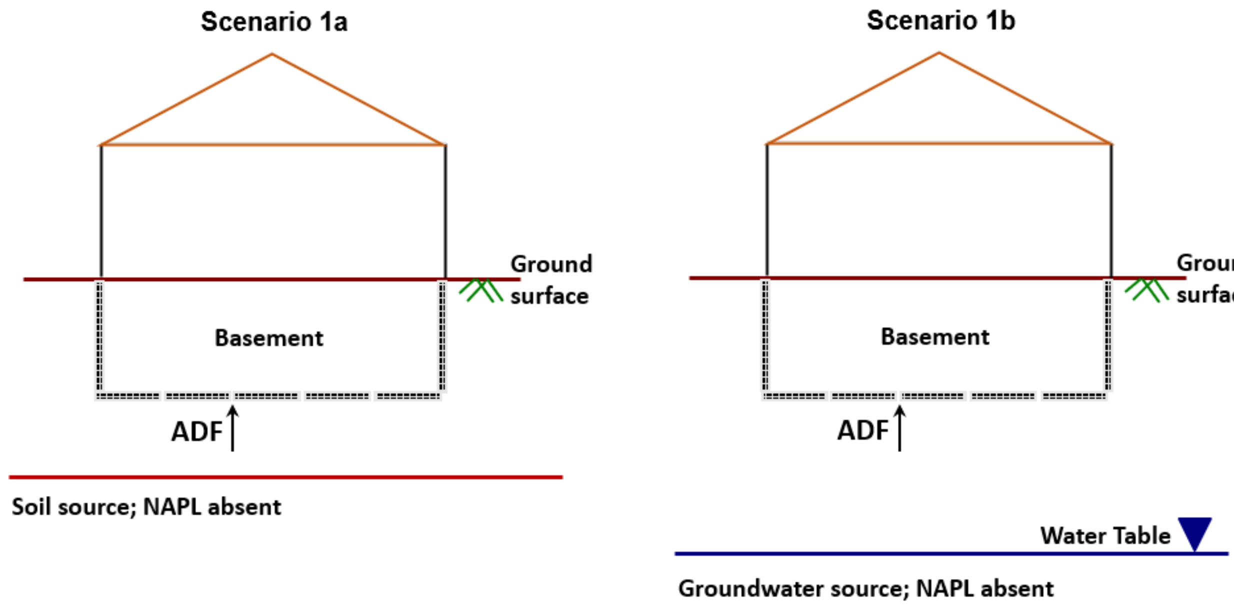


Figure 5-10. Conceptual model for VIAP Scenario 1

ADF: Advective diffusive flow of mass from the source and subsequent migration to indoor air

For a Tier 1 evaluation:

- The soil gas RBSLs listed in Tables 5 and 6 are applicable and should be used if the risk evaluation is conducted using soil gas data. The Tier 1 RBSLs for soil gas are derived by dividing acceptable indoor air concentrations by a conservative, default attenuation factor of 0.03, or
- The soil and groundwater RBSLs in Tables 3 and 4 are applicable if NAPL is absent within the ED and if there is at least 1 cm separation from the building floor to the soil source and approximately 2 feet separation from the building floor to the groundwater source. If there is less than 2 feet from the building floor to the average depth of groundwater the risk to the building should be evaluated either by soil gas data or by calculating Tier 2 groundwater SSTLs using the Johnson & Ettinger (J&E) model.

For a Tier 2 evaluation, the J&E model can be used with site-specific inputs to calculate SSTLs for soil gas. The soil gas concentrations can be used with the applicable equilibrium partitioning equations to calculate SSTLs for groundwater or soil. The J&E model and equilibrium equations are included in Appendix A. For Tier 3, SSTLs may be developed using an alternative model with site-specific inputs.

In some areas of the state, there may be a sump present in Scenario 1, even though the building floor is not in contact with groundwater. Typically, such sumps will be present if the vadose zone consists of finer grained lithologies and lower permeabilities causing surface water to drain into the sump. In such situations, the foundation drain may capture the soil gas and act as a preferential pathway to transmit vapors into the structure. Such a situation must be evaluated in Tier 3 by the collection of soil gas samples that represent what could be entering the foundation drain or collection of sump and foundational drain head space samples.

Scenario 2: Groundwater not in contact with the building floor and NAPL present.

Similar to Scenario 1, Scenario 2 (Figure 5-11) represents a building with either slab-on-grade construction or a basement with poured concrete walls and floor where the source of vapors is either residual NAPL in the vadose zone (Scenario 2a) or residual or mobile NAPL at or near the water table (Scenario 2b), but NAPL is not in contact with the building. For this scenario, like Scenario 1, the transport mechanisms for vapors to enter the building consist of (i) diffusive flow of vapors from the source through the overlying vadose zone soil up to the subsurface building envelope and advective flow into the building, and (ii) intrusion of these vapors into the building through dirt-filled cracks and any other openings in the floor. The area of the subsurface building envelope consists of the area of the floor of the building (for slab-on-grade construction and for buildings with basements.

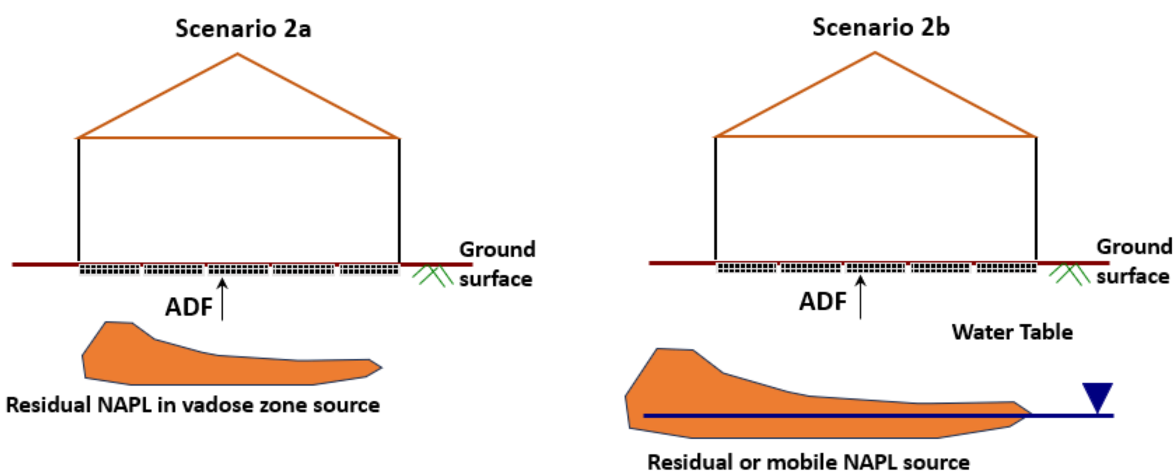


Figure 5-11. Conceptual model for VIAP Scenario 2

ADF: Advective diffusive flow of mass from the source and subsequent migration to indoor air

Scenario 2 should be evaluated with soil gas data and not with soil or groundwater data because the equilibrium partitioning equations to convert soil gas SSTLs to soil or groundwater SSTLs do not account for the presence of NAPL. In a Tier 1 evaluation, the soil gas RBSLs listed in Tables 5 and 6 are applicable and should be used. For a Tier 2 evaluation, the J&E model can be used with site-specific inputs to calculate SSTLs for soil gas. The J&E model and equilibrium equations are included in Appendix A. For Tier 3, SSTLs for soil gas may be developed using an alternative model with site-specific inputs.

As with Scenario 1, if a basement has a sump, the indoor air inhalation risk must be evaluated in Tier 3 by the collection of soil gas samples that represent what could be entering the foundation drain or collection of sump and foundational drain head space samples.

Scenario 3: Building with a basement and sump with a portion of the building envelope below the groundwater.

In Scenario 3 (Figure 5-12), contaminated water is in contact with the building floor and with a portion of the basement walls and a foundation drain, and a sump is present. Often this scenario will occur in areas with lower permeability soil and the sump is used to keep the basement dry by dewatering the foundation. The amount of water that is present and pumped out of the sump will depend on the hydraulic conductivity of the porous media surrounding the sump and the depth to groundwater. In Scenario 3, vapors do not intrude through cracks in the building envelope, rather, water immediately surrounding the building drains into foundation drains and collects into the sump. COCs within the foundation drain and sump water volatilize into the sump and drainpipes and intrude directly into the structure where they mix with the indoor air.

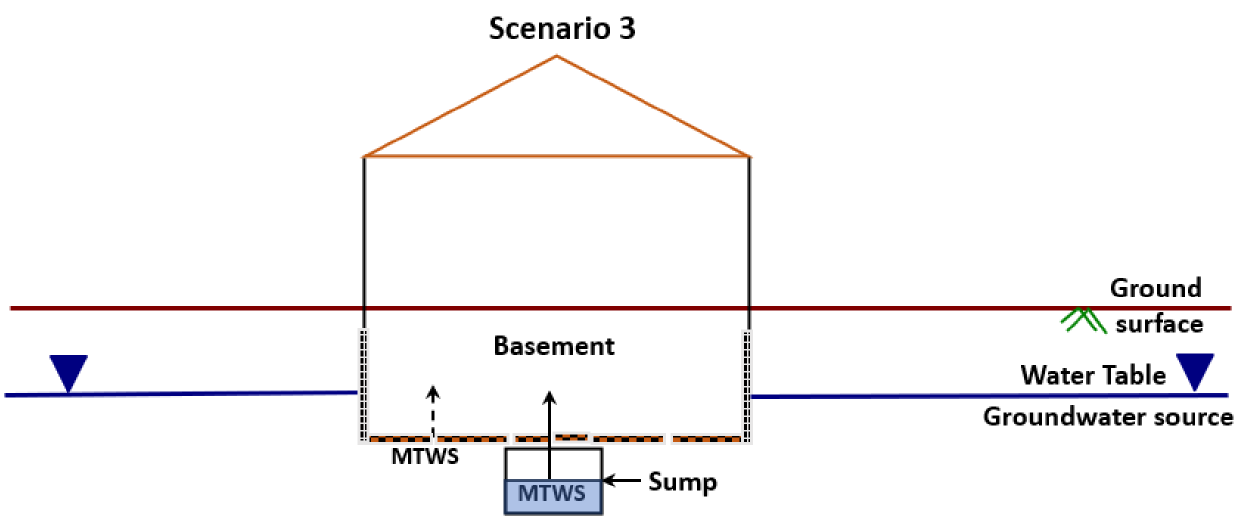


Figure 5-12. Conceptual model for VIAP Scenario 3

MTWS: Mass transfer from water surface and subsequent migration to indoor air, assumed to be negligible through cracks in the floor

Scenario 3 must be evaluated using the water-air interface mass transfer model (i.e., the "sump model") with default assumptions in Tier 1 (Tier 1 RBSLs are given in Tables 5 and 6), or with site-specific values in Tier 2 (refer to Table 5-1). Scenario 3 can be evaluated with an alternative model in Tier 3. Appendix A provides the water-air interface mass transfer model that can be used to develop Tier 2 or Tier 3 SSTLs for Scenario 3 with site-specific data.

Table 5-1. Applicable RBTLs and models for calculating SSTLs for the VIAP

Scenario	Medium	Tier 1	Tier 2	Tier 3
Scenario 1a and 1b	Soil gas	Table 5, 6	J&E model	Acceptable to EGLE
	Groundwater	Table 3, 4	J&E model + equilibrium partitioning equation	Acceptable to EGLE
	Soil	Table 3, 4	J&E model + equilibrium partitioning equation	Not recommended
Scenario 2a and 2b	Soil gas	Table 5, 6	J&E model	Acceptable to EGLE
	Groundwater	N/A	N/A	Acceptable to EGLE
	Soil	N/A	N/A	N/A
Scenario 3	Soil gas	N/A	N/A	N/A
	Groundwater	Table 5, 6	Sump model	Acceptable to EGLE
	Soil	N/A	N/A	N/A

5.3.7 Development of RBTLs for the VIAP

The RBTLs (Tier 1, Tier 2 or Tier 3) for the VIAP are back-calculated using a combination of:

1. A chemical uptake equation is used to calculate the receptor- and chemical-specific acceptable indoor air (POE) concentration for each COC. Tier 1 and Tier 2 acceptable POE concentrations are presented in Tables 5 and 6.

2. The POC concentration is calculated by dividing the acceptable POE concentration, calculated in Step 1, by an attenuation factor. The attenuation factor may be empirically estimated or calculated using a model such as the J&E model.

3. The acceptable soil gas POC concentration (item two above) can be used to calculate the acceptable (i) soil POC concentration, and (ii) groundwater POC concentration. These calculations use the assumption of equilibrium between the three phase concentrations (soil gas, soil, and groundwater). Since the equilibrium partitioning does not include a free-phase component (i.e., NAPL), soil and groundwater RBTLs for POCs cannot be calculated by these equations if NAPL (residual, mobile, or migrating) is present. Thus, if NAPL is the vapor source (i.e., NAPL is present within the ED), the VIAP should be evaluated by soil gas data.

4. If the source of indoor vapors is groundwater in contact with the structure and the direct volatilization of vapors from contaminated water in a sump and foundation drain (Scenario 3), acceptable groundwater concentrations are calculated by a mass transfer-based model. Such a model also uses the acceptable POE concentration (Item 1) to calculate RBTLs for water in the sump. These RBTLs are also applicable for groundwater data collected from monitoring wells located close to the sump or within the footprint of the building.

The equations required to calculate the Tier 2 RBTLs are included in Appendix A.

Care should be taken to ensure that (i) model assumptions, and (ii) input parameters used to implement the models are applicable to the site. In the MIRBCA process, generally the concentrations at the POE are not measured unless site data warrant and instead concentrations at POCs (soil gas, subslab soil gas, soil, groundwater, sump water) are measured to evaluate the VIAP risk.

The fate and transport model requires several factors including, but not limited to the (i) indoor air exchange rate, (ii) distance between the building floor and the POC, (iii) properties of the media between the POC and the building floor, (iv) transport mechanism(s) between the POC and the building floor, (v) dimensions of openings by which soil gas enters a building, (vi) pressure difference between the building interior and the POC, and (vii) building characteristics (e.g., slab on grade, or building with basement).

Ideally, the VIAP is best evaluated using the POE concentrations. However, this is not always practical and often sufficient data are not available to account for variability associated with the POE. Within MIRBCA, the VIAP evaluation using POE concentrations is limited to specific situations (refer to Section 5.3.8).

Soil gas concentrations are a better predictor of indoor air risk than soil or groundwater concentrations because the latter require modeling the partitioning of the soil gas concentrations to soil and groundwater concentrations that introduces an additional set of assumptions. **Thus, whenever possible, the VIAP should be evaluated based on soil gas concentrations rather than the soil or groundwater concentrations.** If NAPL is present within the exposure domain for a current or future building, the VIAP must be evaluated based on soil gas concentrations because the equilibrium partitioning equations to calculate groundwater or soil RBTLs are not valid when NAPL is present.

Note that while there are Tier 1 RBSLs available for evaluating VIAP risk from soil, soil concentrations are generally a poor indicator of indoor air concentrations. The VIAP risk related to impacted soil or residual NAPL in the vadose zone should be evaluated using soil gas data. If both soil data and soil gas data are available, the risk assessment should be based on the soil gas data. Refer to the process outlined in *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP*.

The following sections discuss the use of various POC concentrations for the evaluation of the VIAP.

5.3.8 Quantitative VIAP Assessment for Current Use

The VIAP risk must be quantitatively evaluated for all current buildings that are completely or partially within the LIZ (including the vapor source) that do not have adequate vertical separation distance from a soil, groundwater, or NAPL vapor source. This evaluation can be performed using soil gas concentrations from samples collected from subslab soil gas points in the building (preferably) or with representative soil gas concentrations, groundwater concentrations, or soil concentrations within the exposure domain (refer to Section 5.1.5 and 5.7). The VIAP assessment for a building can use data collected within the building footprint and up to 10 feet from the building. The risk evaluation is performed by comparing the representative concentration within the exposure domain of each building to applicable RBTLs. If representative concentrations are available for multiple media within the exposure domain (e.g., representative soil gas, groundwater, and soil concentrations within the exposure domain are available), the risk decision should be prioritized in the following order:

1. Subslab soil gas
2. Soil gas
3. Groundwater
4. Soil

For example, if the representative concentration of subslab soil gas is below applicable RBTLs but the representative concentration of groundwater exceeds applicable RBTLs, the risk decision should be made based on subslab soil gas concentrations.

There are certain situations that require indoor air to be evaluated to determine if the concentrations at the POE are acceptable: if representative subslab soil gas concentrations exceed target levels or if representative groundwater samples in contact with the building (Scenario 3) exceed target levels. In addition, if impacted groundwater or NAPL is present in a sump, the POE must be evaluated.

The POE can be evaluated by collecting samples of the indoor air. To ensure samples are representative, subslab soil gas samples should be collected at the same time as indoor air samples, and pressure differentials across the slab should also be measured and evaluated. Ideally, the indoor air samples should be collected when vapor intrusion is “turned on” or the pressure is greater in the subslab than in the building. Representative indoor air data can be used to verify that the risk at the POE is acceptable and if sufficient data are collected, indoor air data can be used to understand the building-specific attenuation factor to develop SSTLs for the subslab soil gas POCs. A risk decision can be made based on direct evaluation of the VIAP (i.e., indoor air concentrations) regardless of concentrations in other media, provided that the indoor air concentrations provide a better representation than concentrations in other media of a receptor’s potential exposure and accounts for the variability that occurs with indoor air data.

5.3.9 Quantitative Evaluation of VIAP for Future Use

The VIAP must be quantitatively evaluated for any potential future building that is either partially or completely within the LIZ (including the vapor source) that does not have adequate vertical separation distance from a soil, groundwater, or NAPL vapor source. In a Tier 1 evaluation, it is assumed that a building with an 8-foot-deep basement could be constructed anywhere within the LIZ. If the average depth to groundwater is equal to or less than eight feet below grade, the future building will be assumed to have a sump in the basement. In a Tier 2 or 3 evaluation, the location and construction (e.g., basement, slab-on-grade, etc.) of the building can be determined based on a site-specific evaluation. For example, property setback requirements can be used to determine that a future building would not reasonably be constructed in certain areas on the property. If multiple locations are possible for a future building, the location that results in the greatest risk must be evaluated for each property where a building could be constructed within the LIZ. If representative concentrations are available for multiple media within the exposure domain (e.g., representative soil gas, groundwater, and soil concentrations within the exposure domain are available), the risk decision should be prioritized in the same order listed in Section 5.3.8.

5.4 Groundwater Protection

Within the MIRBCA process, all current and reasonably anticipated future use of groundwater must be protected. Impacts to groundwater and potential exposures via the groundwater protection pathway are of significant concern in Michigan since groundwater is the primary source of drinking water in many areas of the state. The evaluation process and groundwater protection measures are intended to be used in cases where groundwater has been impacted or is likely to be impacted by a petroleum LUST release. This process has the following objectives:

- To protect all current and reasonably anticipated future use of groundwater, and
- To provide a technically defensible basis for incorporating site-specific characteristics into the determination of groundwater RBTLs.

A key consideration in developing RBTLs is whether the groundwater protection pathway is complete under current or reasonably anticipated future conditions. Refer to Section 5.1 for general information on determining pathway completeness and to Appendix B for the conditions needed to eliminate the groundwater protection pathway.

When complete, the groundwater protection pathway is evaluated using the following four steps:

- Step 1: Identification of the critical POE,
- Step 2: Determination of RBTLs at the POE,
- Step 3: Identification of POC wells, and
- Step 4: Calculation of soil and groundwater RBTLs.

The **groundwater protection exposure pathway** includes the evaluation of direct exposure via groundwater ingestion at the POE and the calculation of acceptable concentrations at other locations (e.g., groundwater at POCs and groundwater and soil in the source area) that are protective of the POE. No exposure occurs at the POC or at the source area. If a groundwater use other than ingestion must be protected, it can be evaluated in Tier 3.

Step 1: Identification of the critical POE. The critical POE is defined as the closest location to the source area where direct exposure to groundwater is possible (Table 5-2). Concentrations acceptable at the POE are discussed in Step 2. The location of the POE is determined as follows:

In any tiered evaluation (i.e., Tier 1, 2 or 3), the POE for current use is any existing water supply well that may be impacted by the release. Refer to Section 4.4.6 for a discussion on identifying existing water supply wells. In Tier 1, regardless of any other characteristics, the POE for future use is conservatively assumed to be any point in the affected aquifer, excluding restricted areas or ROWs. Examples of ROWs include but are not limited to, an active railroad ROW, a gas pipeline ROW, an active road or highway ROW.

In a Tier 2 or Tier 3 evaluation, the POE for future use is determined based on a site-specific evaluation of where a water supply well could reasonably be installed, which could be at multiple locations. Of these locations, the nearest downgradient location is chosen as the critical POE for future use as described in the scenarios below. Note that the critical POE may be a real well or a hypothetical future supply well, and in some cases, multiple POEs are necessary.

Table 5-2. POE determination for the groundwater protection exposure pathway

POE	***Tier 1***	***Tier 2 and Tier 3***
POE for current use	Potentially impacted water supply well(s)	Potentially impacted water supply well(s)
POE for future use	Any point in the affected aquifer, excluding restricted areas and ROWs	Site-specific[1]

[1]Refer to the three scenarios below.

For a Tier 2 evaluation, the location of the POE for future use is one of the three scenarios shown in Figure 5-13 and discussed below. If the conditions for Scenario 1 are not met, the POE for future use will be either Scenario 2 or Scenario 3, depending on conditions on the site property.

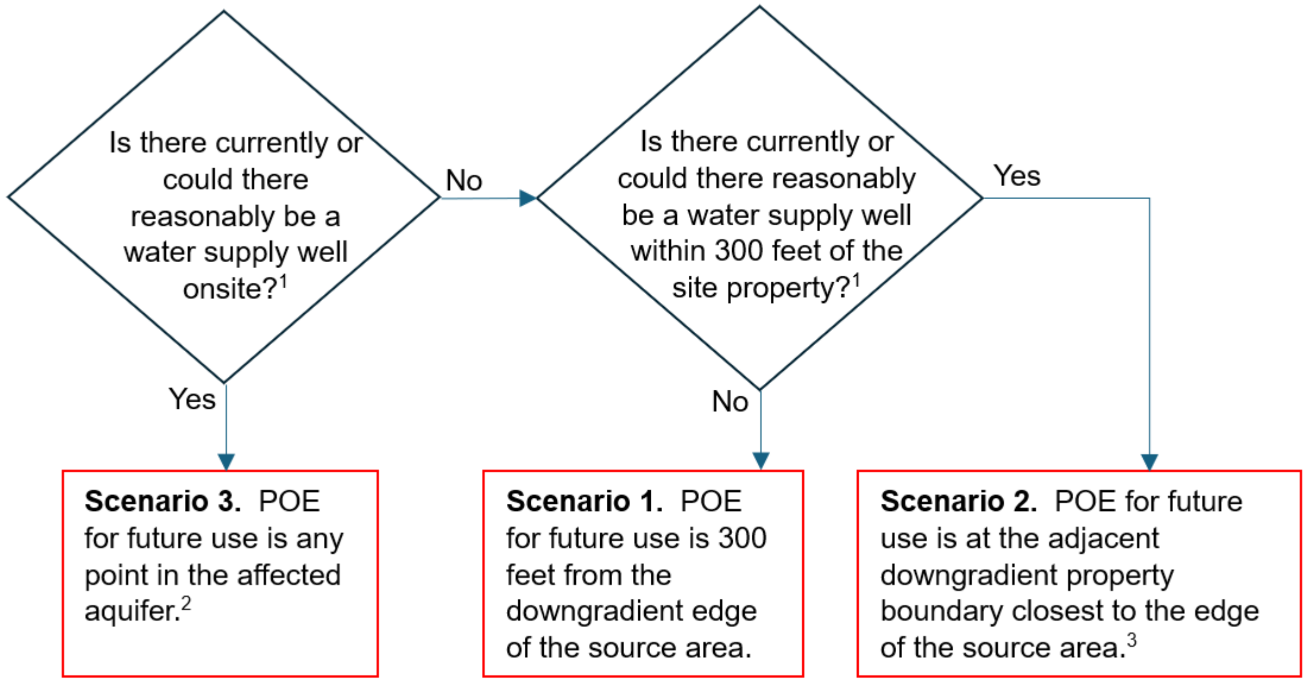


Figure 5-13. Determining a Tier 2 POE for the groundwater protection pathway

[1]Refer to the three bullet points listed in Scenario 1 to determine if a future water supply well could reasonably be installed.

[2]Excluding restricted areas and ROWs.

[3]The POE is located in the affected aquifer, at a point closest to the source area on the adjacent property boundary, excluding restricted areas and ROWs. Refer to the discussion in Scenario 2, below.

Scenario 1. The POE for future use is 300 feet from the downgradient edge of the source area (Figure 5-14).

Scenario 1 applies when (i) there is no water supply well onsite or within 300 feet of the site property boundary, and (ii) a water supply well cannot reasonably be installed onsite or within 300 feet of the site property boundary.

A water supply well cannot reasonably be installed on a property if ***one*** of the following situations is true:

- The property is connected to a municipal water system,
- Municipal water is available to the property and there is an ordinance or other legal mechanism either (i) requiring hookup to the municipal system or (ii) prohibiting the installation of new wells (refer to Section 4.5.3 for municipal water availability), or
- Groundwater use on the property is reliably restricted pursuant to Section 21310a of the NREPA.

If a site-specific POE of 300 feet from the downgradient edge of the source area is determined to be appropriate for the site, documentation must be provided to EGLE to demonstrate that the above conditions are met (refer to Sections 4.4 and 4.5).

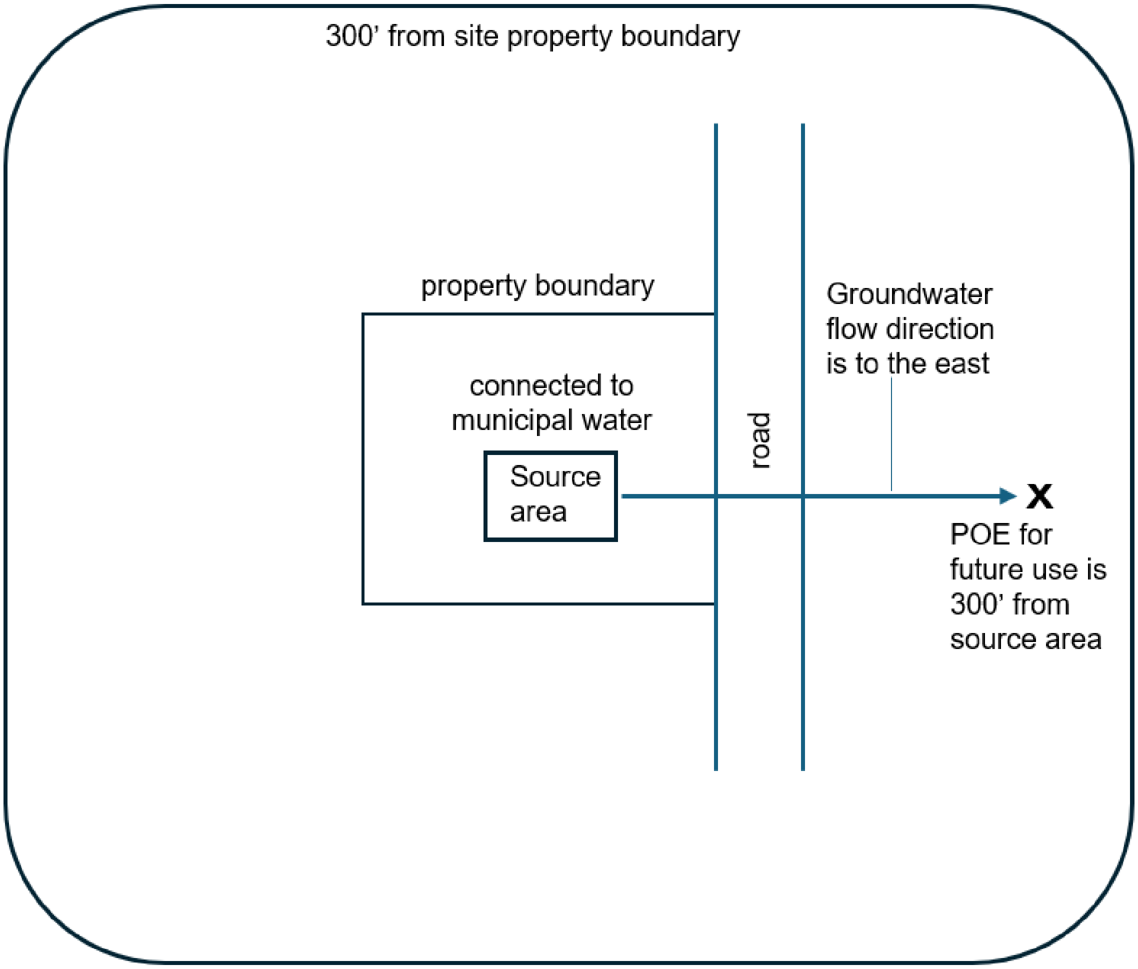


Figure 5-14. Tier 2 groundwater protection POE for future use in Scenario 1

The distance of 300 feet for the MIRBCA process is (i) consistent with other nearby states (e.g., Ohio), (ii) protective of the majority of dissolved petroleum plumes based on several studies indicating most petroleum plumes are smaller than this distance (e.g., API, 1998), and (iii) consistent with the requirements of the Michigan Groundwater Quality Control Rules, R 325.1601 et seq., that potable wells must be installed at least 300 feet from an underground storage tank system. Sites with dissolved plumes longer than 300 feet may be addressed in a Tier 3 evaluation by establishing a site-specific POE at a distance greater than 300 feet from the downgradient edge of the source area, if it is protective. It is highly recommended to discuss a proposed Tier 3 evaluation with the EGLE project manager prior to implementation.

Note that a Tier 2 evaluation for the groundwater protection exposure pathway is not precluded if the dissolved contaminant plume is within a wellhead protection zone. The Tier 2 evaluation would be conducted as outlined in this section irrespective of a wellhead protection zone.

Scenario 2. The POE for future use is at a point in the affected aquifer on the adjacent downgradient property boundary closest to the source area, excluding restricted areas and ROWs (Figure 5-15). Multiple POEs are required under certain circumstances, discussed below (Figure 5-16).

Scenario 2 applies when the following situation is true:

- There is no water supply well onsite, and a water supply well cannot reasonably be installed onsite in the future, and
- Either a water supply well is present within 300 feet of the site property boundary, or a future water supply well could reasonably be installed within 300 feet of the site property boundary.

Refer to the three bullet points listed in Scenario 1 for conditions when a water supply well cannot reasonably be installed.

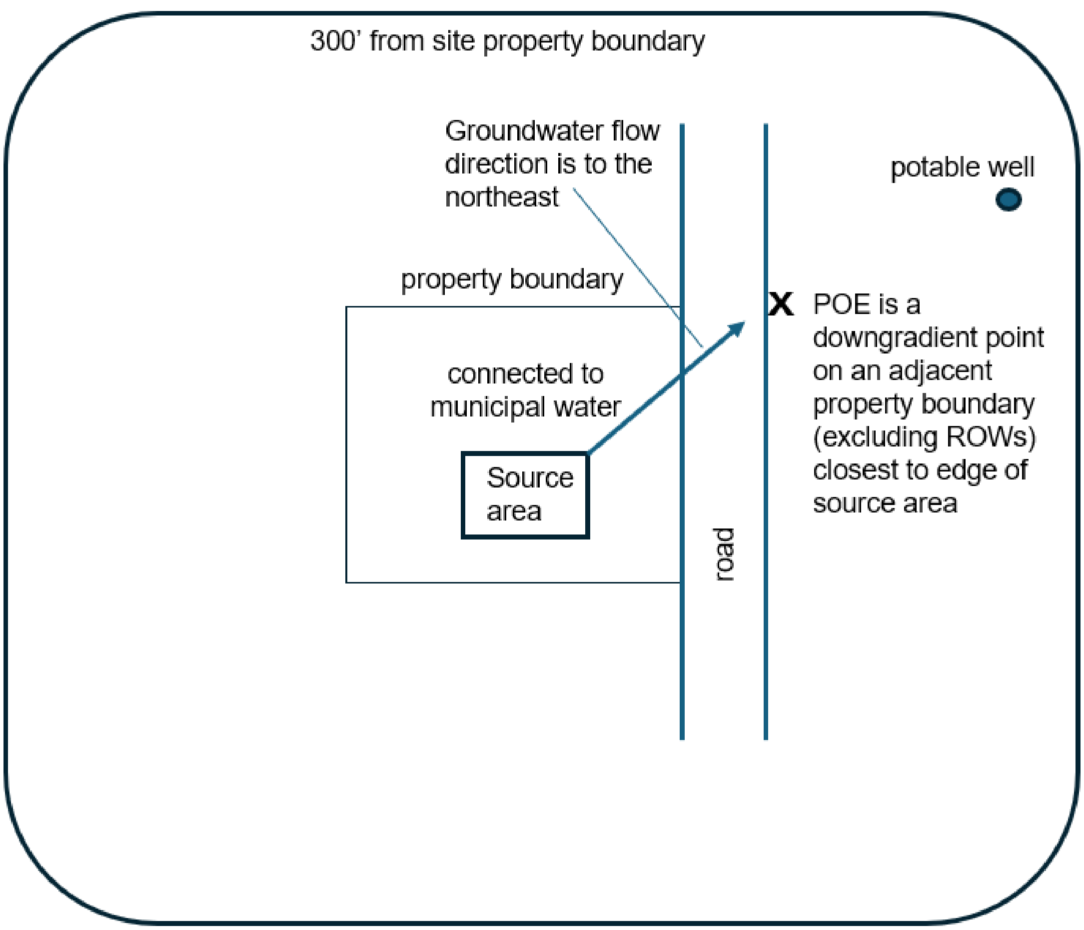


Figure 5-15. Tier 2 groundwater protection POE for future use in Scenario 2a

In addition to the POE at the downgradient property boundary, additional POEs are required to address any of the following:

- Significant variability or uncertainty in the groundwater flow direction, or
- There is a property that has or could reasonably have a water supply well and the distance between the property boundary and the source area is less than the distance between the downgradient POE and the source area.

If either of these situations or another situation that would require protection exists, a POE must be established at the nearest property boundary either in a potential secondary groundwater flow direction or at the nearest property boundary that has or could have a future water supply well. If the distance to the POE is sufficient to establish POCs between the source and the POE, then these POCs must be established.

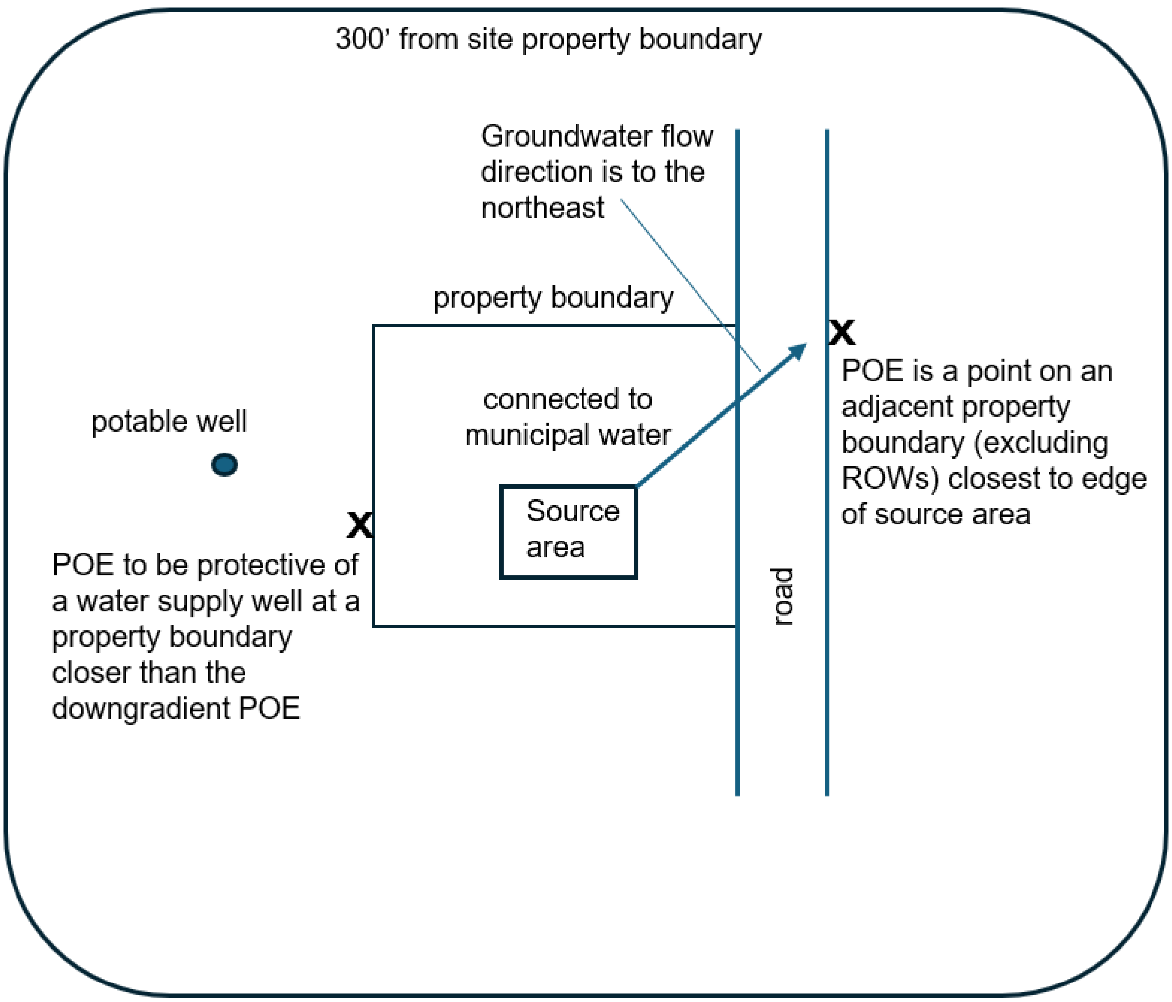


Figure 5-16. Tier 2 groundwater protection for future use in Scenario 2 with multiple POEs

Scenario 3. The POE for future use is any point in the affected aquifer, excluding restricted areas and ROWs (Figure 5-17).

Scenario 3 applies if a water supply well is present onsite or could reasonably be installed onsite. Refer to the three bullet points listed in Scenario 1 for conditions when a water supply well cannot reasonably be installed. In Scenario 3, the representative concentration is the maximum of the recent average for each COC. To determine this value, first calculate the recent average concentration for each COC at each relevant monitoring well, and second, identify the maximum average value for each COC. Note that the maximum recent average for one COC could be located in a different monitoring well from another COC.

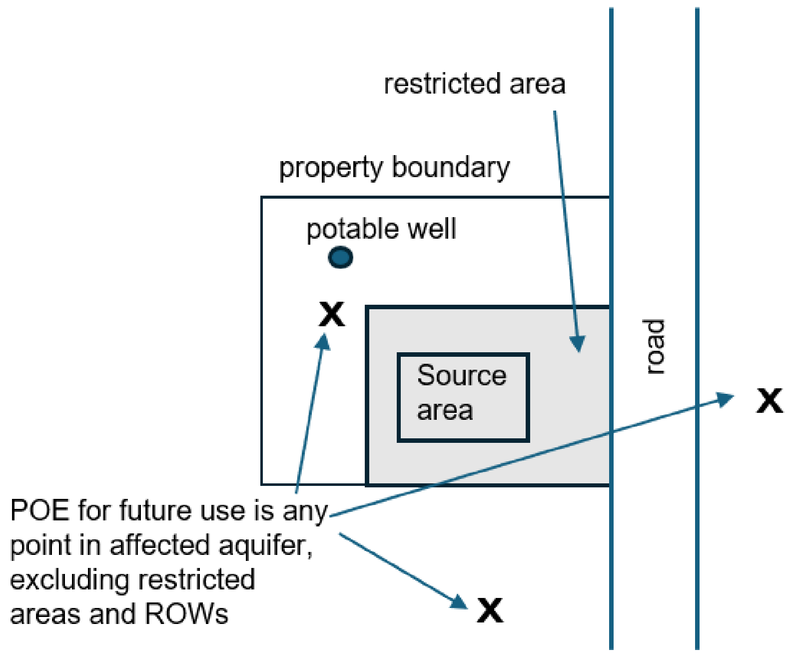


Figure 5-17. Tier 2 groundwater protection POE for future use in Scenario 3

Step 2: Determination of RBTLs at the POE. Section 21304a(4) of Part 213 requires the RBTL at the POE in all tiers to be the more stringent of the MCL or aesthetic criterion if available for each COC. For COCs that do not have an MCL or aesthetic criterion, the RBTL at the POE in Tier 1 is the value listed in Table 3 for residential use and Table 4 for nonresidential use.

In Tier 2, the RBTL at the POE for COCs that do not have an MCL or aesthetic criterion is calculated according to the equations for ingestion of water in Appendix A and the inputs in Tables 7 through 9. For residential use, the RBTL is the minimum of the carcinogenic and non-carcinogenic value for a child, age-adjusted resident, and an adult. If the calculated RBTL exceeds the solubility of the COC, the calculated value is used at the POE. For nonresidential land use, the RBTL at the POE is calculated using nonresidential exposure assumptions for the ingestion of water. A land use restriction is required if the risk assessment for future use is based on nonresidential exposure assumptions. Risk cannot be quantitatively evaluated for COCs that do not have oral toxicity values. Tier 1 and Tier 2 RBTLs that are applicable at the POE are listed in Table 13.

Step 3: Identification of POC wells. In Tier 2 and Tier 3, in addition to the POE, one or more groundwater monitoring wells located between the POE and the edge of the source area should be designated as the POC wells. A POC is a groundwater monitoring well where concentrations are measured to confirm that the concentrations at the POE will not exceed the groundwater standards (refer to Step 2). This is necessary because it may not be possible to measure the concentrations at the POE to evaluate this pathway. Note that at the POC there is no exposure to groundwater and the acceptable concentrations would be higher than the acceptable concentrations at the POE. If multiple POEs are established for a release, it may be necessary to establish POCs to evaluate risk related to each POE.

Step 4: Calculation of soil and groundwater RBTLs. The quantitative evaluation of this pathway requires the selection or calculation of RBTLs for (i) groundwater concentrations at the POE, (ii) groundwater concentrations at the POC(s), (iii) groundwater concentrations in the source area, and (iv) soil concentrations in the soil source area. Representative concentrations at these locations must be compared to the corresponding applicable RBTLs to make risk management decisions.

RBTLs for POCs and the source areas are calculated as indicated in Section 5.6.

5.5 Surface Water Protection

Potential impacts to surface waters of the state from a LUST release must be evaluated and surface water quality protected according to the standards established under Part 31 of the NREPA. Surface water is defined in 21303(n) as the Great Lakes and their connecting waters, all inland lakes, rivers, streams, impoundments, and does not include groundwater or enclosed sewers, other utility lines, storm water retention basins, or drainage ditches.

The **surface water protection exposure pathway** is evaluated in Tier 1 by comparing the representative concentrations at the POE to Tier 1 RBSLs. In Tier 2, the pathway can be evaluated by comparing representative concentrations at POCs and the source area to SSTLs that are protective of the POE. In Tier 3, representative concentrations can be compared to other appropriate direct exposure target levels (e.g., GSI-based mixing zone criteria) at the POE. The POE is the groundwater immediately prior to discharge or mixing with surface water.

If the surface water protection pathway is determined to be complete, it must be quantitatively evaluated like the groundwater use pathway as follows:

Step 1: Identification of the critical POE. The POE is in the groundwater immediately prior to discharge or mixing with surface water at the nearest surface water body (i.e., the groundwater at the GSI) and at the storm sewer outfall. The location of the storm sewer outfall is irrelevant if compliance can be demonstrated at a point prior to the outfall (e.g., with a water sample within the storm sewer or a groundwater sample collected in close proximity to the storm sewer, etc.). At the POE, the surface water protection standards presented in Table 3 are applicable.

Step 2: Determination of RBTLs at the POE. The Tier 1 surface water protection RBSLs are applicable at the POE. In Tier 1, recent maximum concentrations must be below Tier 1 RBSLs at the POE and in Tier 2 recent average concentrations must be below the Tier 1 RBSLs at the POE to demonstrate compliance with Part 31.

Step 3: Identification of POC wells and calculation of SSTLs at the POC. POC wells are located between the source and the POE for the purpose of monitoring COC concentrations in groundwater to evaluate whether the concentrations at the POE would be exceeded. This is necessary because the acceptable concentrations at the POC are based on fate and transport models. Note that Steps 3 and 4 are generally not applicable if concentrations are measured in the storm sewer. However, they are valid if groundwater concentrations are measured adjacent to the sewer.

Step 4: Calculation of soil and groundwater COC RBTLs in the source area. RBTLs for soil and groundwater source areas are calculated as indicated in the following Section 5.6.

5.6 Calculation of Acceptable Concentrations Protective of Groundwater Use and Surface Water

This section provides the methodology used to develop the various acceptable concentrations protective of groundwater use and surface water in a Tier 2 and possibly Tier 3 evaluation.

5.6.1 Calculation of Soil Source Concentrations

Figure 5-18 shows a schematic of the leaching of COCs from the soil source area to the POC and POE. The movement of impacted groundwater from the soil source area to the POE is divided into three zones discussed below. As the COCs migrate from the soil source to the POE, their concentrations decrease in three zones:

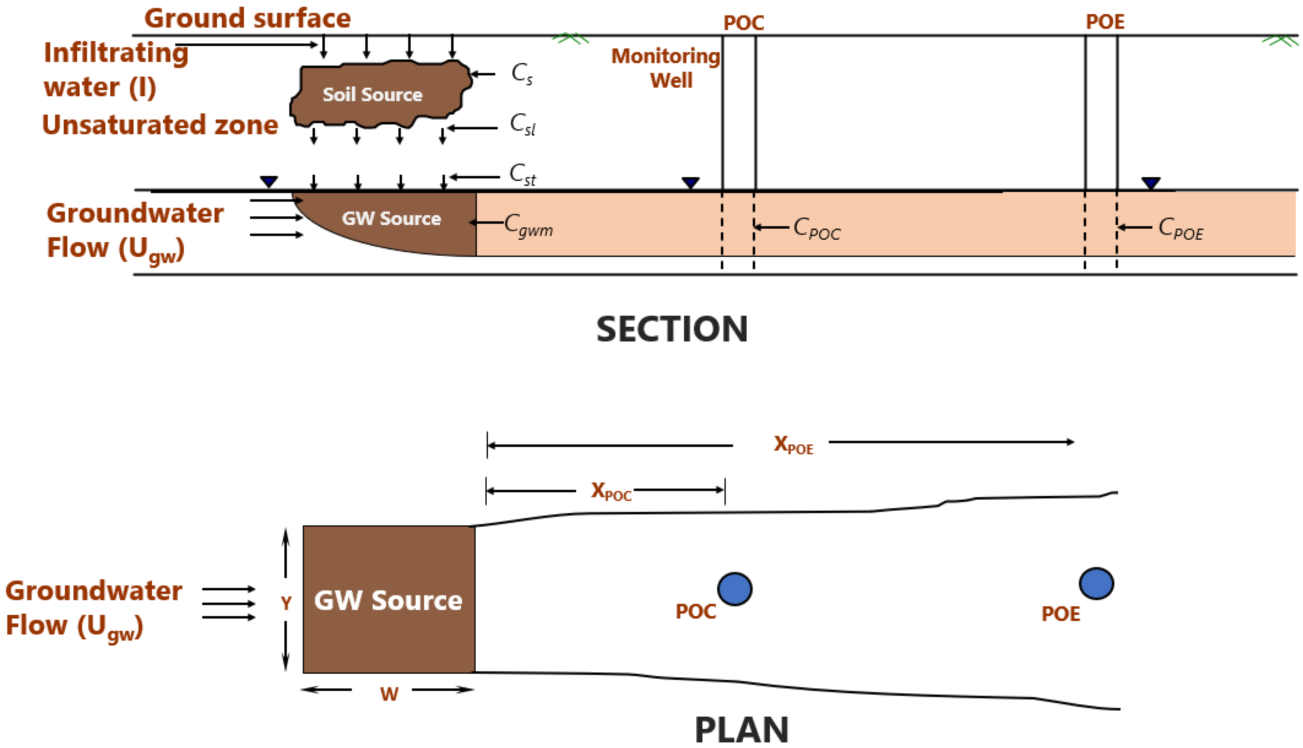


Figure 5-18. Schematic of the groundwater protection pathway

- **In the unsaturated zone**, due to natural attenuation processes that occur as the chemicals migrate from the point of release to the water table. The ratio of the concentration leaching out of the soil source (C_{sl}) to the concentration that reaches the water table (C_{st}) is referred to as the unsaturated zone dilution attenuation factor, DAF_{unsat},

- **Groundwater mixing zone at the groundwater table**, due to mixing of the contaminated (infiltrating) solution with the clean regional uncontaminated groundwater. The ratio of the concentration that reaches the water table (C_{st}) to the concentration at the downgradient edge of the groundwater mixing zone (C_{gwm}) is referred to as the mixing zone dilution attenuation factor, DAF_{mix}, and

- **In the saturated zone**, due to natural attenuation processes that occur as the dissolved plume moves downgradient in the saturated zone. The ratio of the concentration at the edge of the mixing zone (C_{gwm}) to the concentration at a point in the saturated zone, e.g., the POE, is referred to as the saturated zone dilution attenuation factor, DAF_{sat}. Note that DAF_{sat} may be DAF_{POE} or DAF_{POC} depending on the distance used to calculate the DAF_{sat}.

Based on the process described above, soil source area concentrations protective of groundwater use can be calculated using the following equation:

$$C_{sl} = DAF_{unsat} \times DAF_{mix} \times DAF_{sat} \times C_{POE} \quad (5\text{-}1a)$$

$$C_s = C_{sl} \times ECF \quad (5\text{-}1b)$$

where,

- C_s = soil source concentration
- C_{sl} = leachate concentration at the bottom of the soil source
- C_{st} = leachate concentration at the water table
- DAF_{unsat} = dilution attenuation factor in the unsaturated (vadose) zone
- DAF_{sat} = dilution attenuation factor in the saturated zone
- DAF_{mix} = dilution attenuation factor in the mixing zone
- C_{POE} = concentration at the POE
- C_{POC} = concentration at the POC
- C_{gwm} = concentration at the edge of the groundwater mixing zone
- ECF = equilibrium conversion factor
- U_{gw} = groundwater Darcy velocity
- I = infiltration rate
- W = dimension of groundwater source area parallel to the groundwater flow direction
- Y = dimension of groundwater source area perpendicular to the groundwater flow direction
- X_{POE} = distance from the downgradient edge of the groundwater source area to the POE
- X_{POC} = distance from the downgradient edge of the groundwater source area to the POC

Refer to Appendix A for the units of each of these variables.

The dilution attenuation factors (DAFs), as discussed above, represent the reduction in concentration as the COCs (i) travel from the soil source area to the water table (DAF_{unsat}), (ii) mix with the clean groundwater (DAF_{mix}), and (iii) travel from the groundwater source area (DAF_{sat}) to the POE. This reduction in concentration is a result of the combined effect of several physical, chemical, and biological factors including advection, diffusion, dispersion, dilution, adsorption, and biodegradation processes.

In Equation 5-1, the equilibrium conversion factor (ECF) converts the leachate concentration (C_{sl} in µg/L) to a soil concentration (C_s in µg/kg), assuming equilibrium conditions.

In general, there are two ways to estimate the DAFs: (i) using fate and transport models, or (ii) using field data, i.e., by calculating the ratio of the concentrations measured at the different locations if the plume is stable. The second method is rarely used due to temporal variations in the groundwater concentrations measured at any point in the aquifer. Thus, the first method, i.e., the use of groundwater models, is used in MIRBCA. The Summers model and the Domenico model are used to estimate DAF_{mix} and DAF_{sat}, respectively. The specific equations used to calculate each of the DAFs are presented in Appendix A.

For Tier 1 evaluations, the DAF_{unsat} is assumed to be one, i.e., attenuation within the unsaturated zone is neglected. This is reasonable and conservative due to the relatively shallow depth to groundwater at most LUST sites in Michigan. This assumption would likely be applicable for Tier 2 evaluations at most sites in Michigan due to shallow groundwater depth. At sites where the vertical distance between the bottom of the source and the water table is large (e.g., greater than 20 feet), the user may either select an unsaturated fate and transport model to calculate the DAF_{unsat} or consult with EGLE to use an empirical DAF_{unsat}.

A Tier 1 evaluation does not require the calculation of DAFs because every point in the aquifer is potentially a POE. For a Tier 2 evaluation, the DAFs should be calculated using data specific to the site. This is further discussed in Section 7.0. Tier 2 evaluations can calculate SSTLs using biodegradation if the biodegradation rate is supported by site data. For Tier 3 evaluations, DAFs may be calculated using site-specific monitoring data or an alternative fate and transport model implemented using site-specific data.

5.6.2 Calculation of POC SSTLs

A step-by-step procedure to develop SSTLs for the POC well(s) located between the POE and the groundwater source, is presented below:

Step 1: Identify the POE(s) and the distance between the downgradient edge of the source area/groundwater mixing zone and the POE. Refer to Sections 5.4 and 5.5 for guidelines on location of POE(s).

Step 2: Establish target levels for the POE. The groundwater quality standards that must be met for the groundwater protection pathway are listed in Table 13 and for the surface water protection pathway are listed in Tables 3 and 4.

Step 3: Identify POC wells and the distance between the edge of the source area/groundwater mixing zone and the POC. Refer to Section 5.4 for guidance to select POCs for the groundwater protection exposure pathway. Refer to Section 7.2 for guidance on establishing source area dimensions.

Step 4: Calculate target concentrations (i.e., SSTLs) for POC wells. Since the POCs are located between the source area and the POE, the POC SSTLs will be higher than the POE target concentrations. The difference reflects the attenuation in concentration of the COCs as they migrate from the POC to the POE. Note there is no human exposure at the POC.

Specifically, the target concentration at the POC is estimated using:

$$C_{target}^{POC} = C_{target}^{POE} \frac{DAF_{POE}}{DAF_{POC}} \tag{5-2}$$

where,

C_{target}^{POC} = Target concentration at the POC (µg/L)

C_{target}^{POE} = Target concentration at the POE (µg/L)

DAF_{POE} = Dilution attenuation factor between the POE and the source [(µg/L)/ µg/L)]

DAF_{POC} = Dilution attenuation factor between the POC and the source [(µg/L)/ µg/L)]

If both the groundwater protection and surface water protection pathways are complete and SSTLs are developed for POCs, risk at each POE is determined by the more stringent SSTL for each COC at each POC.

5.7 Estimation of Representative Concentrations

5.7.1 Background

A representative COC concentration is the concentration for each complete route of exposure that is compared to an applicable RBTL to determine if the risk is acceptable or unacceptable. An exceedance of a representative concentration relative to the applicable RBTL in soil, groundwater, or soil gas indicates an unacceptable risk. The representative concentration is calculated using concentration data within an ED and accounts for the spatial and temporal variability in the concentrations within the ED.

The application of the MIRBCA process results in the selection (in Tier 1) or calculation (in Tier 2 and Tier 3) of RBTLs for each COC and each complete exposure pathway identified in the EM. For corrective action decisions, the RBTLs must be compared to applicable representative concentrations. Thus, the outcome of a risk assessment critically depends on the representative concentrations.

A receptor would typically be exposed to COCs over a defined geographical area (i.e., the ED), or at a specific POE, for a specified exposure duration, and through one or more routes of exposure. Because COC concentrations typically vary within the ED and the exposure duration, it is necessary to estimate a representative COC concentration using data collected within the ED. The representative concentrations are compared with the applicable RBTLs to determine the next course of action, as explained in Sections 6, 7, and 8.

A **representative concentration** of soil, groundwater, or soil gas, in the MIRBCA process, is the concentration used for each COC, complete pathway, and route of exposure to make a risk-based decision. A representative concentration accounts for the spatial variability of concentrations within the ED and to a limited extent, the temporal variability over the exposure duration.

A representative COC concentration at the POE is the concentration to which the receptor is exposed over the specified exposure duration, for a specific route of exposure that has a defined ED. In most risk assessments, the concentration is assumed to be constant over the exposure duration, in effect disregarding the temporal variability in concentrations.

The calculation of representative concentrations is complicated due to the following factors:

- Spatial variability in the concentrations over the ED,
- Temporal variability in concentrations over the exposure duration (often neglected), and
- Lack of sufficient concentration data collected within the ED

Further, complications arise because environmental data are typically obtained through biased sampling in that the sampling is focused on identifying the source areas and extent of contamination and does not consist of samples collected randomly over the entire ED. In addition, the concept of a representative concentration is often mistakenly associated with the site as opposed to a complete exposure pathway and receptor. Because there may be several receptors and several complete exposure pathways for each receptor, several representative concentrations, one for each complete exposure pathway, each COC, and for each receptor, must be estimated. The following sections discuss the methodology used to estimate the representative concentrations for each complete route of exposure.

5.7.2 Types of Representative Concentrations

The appropriate representative concentration must be selected based on the tiered evaluation. Consistent with ASTM E-1739-95, maximum concentrations are selected as the representative concentrations in Tier 1 evaluations. Tier 2 evaluations under the MIRBCA process allow for additional data evaluation. EGLE considers average concentrations within the ED as acceptable representative concentrations in Tier 2 evaluations, with the exception of groundwater protection in Scenario 3 in which the representative concentration is the maximum average (refer to Section 5.4). In Tier 3, an O/O may use a maximum concentration, an average concentration, or an alternative value with justification as the representative concentration.

In a risk assessment, the representative concentration is an estimate of the concentration to which a receptor would be exposed over the assumed exposure duration. Note that for indirect exposure pathways, the representative concentration is not necessarily measured at the POE but may be measured at the POC where no exposure occurs. Further, the POE concentration and the POC concentration may be in different media.

5.7.2.1 Maximum Concentrations

The MIRBCA process requires the maximum concentration to be used as the representative concentration for all exposure pathways in Tier 1 evaluations. When utilizing a maximum value, the O/O must determine the specific maximum concentration to use. Depending on the pathway and the receptor, the MIRBCA process allows the use of a historical maximum (using the entire historical data set) or a recent maximum value for a particular period of record. The decision to utilize the appropriate type of maximum value should be based on the stage at which the site data are being evaluated.

The historical maximum is the highest detection ever recorded for each COC anywhere on each impacted property. The historical maximum should first be used to see if there is an exceedance of a Tier 1 RBSL. If the historic maximum is not exceeded, no further evaluation may be necessary.

However, if the historical maximum is exceeded, the maximum concentration based on recent data (i.e., a recent maximum concentration) may be used.

The appropriate periods for recent maximum concentrations in soil, groundwater, and soil gas are listed below (Table 5-3). Different maximum concentrations must be used for the onsite exposure scenario and the offsite exposure scenario.

Table 5-3. Period of record for recent maximum concentrations in Tier 1

Medium	Period of record
Soil	Recent five years
Groundwater	Recent two years
Soil gas / subslab soil gas	Recent two years

For soil, the Tier 1 representative concentration for each COC is the recent maximum concentration (if available) or the historic maximum concentration in the ED for each complete exposure pathway. Where two separate soil sampling investigations occurred during different time frames and both sets of data represent the site adequately, the maximum concentration of the more recent soil data may be utilized. Note that it is not necessary to replicate every historic soil sample for the more recent soil data to be used in place of the historic soil data. If the more recent soil data are representative of site conditions, such data should be used in the evaluation.

For groundwater, the Tier 1 representative concentration should be the recent maximum concentration, which is the highest detection for each COC during the past two years of data or the most recent eight sampling events, whichever yields more data.

The Tier 1 representative concentration for soil gas should also be the recent maximum concentration, which is the highest detection for each COC during the past two years of data. Refer to the *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP* for recommended sampling frequency.

The above recommended periods of record apply to risk evaluations of new releases (e.g., a release within the past five years). Flexibility is allowed when evaluating a historic release provided that the period of record is justified and results in a risk assessment that is protective.

5.7.2.2 Average Concentrations

The recent average concentration for each COC for each complete exposure pathway should be used as the representative concentration in Tier 2 and possibly Tier 3 evaluations. Representative concentrations must be calculated for each COC and each ED for the onsite and offsite complete exposure pathways. Separate representative concentrations may need to be determined for current and future use. Prior to calculating the average concentration for each combination of COC and complete exposure pathway, the ED for each complete exposure pathway must be determined (see below). The average concentration is the sum of concentrations available within an ED for each COC divided by the total number of samples.

For groundwater samples, the average of the most recent two years or eight quarters of samples should be used. For soil gas, the average of the most recent available data should be used. The appropriate periods for recent average concentrations in soil, groundwater, and soil gas are listed below (Table 5-4).

Table 5-4. Period of record for recent average concentrations in Tier 2 and Tier 3

Medium	Period of record
Soil	Recent five years
Groundwater	Recent two years
Soil gas / subslab soil gas	Recent two years

The periods of record cited in Tables 5-3 and 5-4, above are recommendations for new releases. Flexibility and professional judgment is allowed for determining the appropriate period of record for historic releases.

Due to the nature of petroleum LUST sites, including site limitations in data collection, biased sampling strategies, there is no minimum number of samples required to calculate an average concentration over a spatial area (e.g., in an ED) for use as a representative concentration. Care should be taken to confirm that each ED has been adequately characterized. The exception to this is for evaluating the VIAP through soil gas or subslab samples. There should be a minimum of three sampling points for a residential-sized ED and additional sampling points based on ED dimensions (refer to the *Guidance Document for the VIAP, Volume 4: Investigative Approach for Petroleum VIAP* for recommended number of sampling points).

5.7.2.3 Other Concentrations (averages obtained by incremental sampling methodologies, area-weighted averages, etc.)

Due to the nature of the typical LUST site, which often consists of an active or former gas station, a relatively small property that is paved and contains a building, canopy, underground storage tanks, dispensers, piping, and numerous utilities, the application of incremental sampling methodologies is usually not implementable. Other states have attempted to require methods that would potentially result in a representative sample that are conceptually more accurate than an average (e.g., area-weighted average) but have found during implementation that risk decisions have little to no change compared to using an arithmetic average concentration regardless of the substantial increase in effort involved in generating the representative concentrations. An O/O may in Tier 3 propose a different methodology to calculate a representative concentration other than an average but experience from other states that have implemented the RBCA process since the late 1990s to early 2000s have shown little to no increased benefit.

5.7.3 Steps for Calculation of the Representative Concentrations

The calculation of the representative concentrations requires the following steps for each complete exposure pathway:

1. Identification of the ED for each medium and each complete route of exposure
2. Identification of the available COC concentration data within the ED for each medium
3. Calculation of the representative concentration

Since the representative concentration is an average concentration, the concentration should not be artificially lowered or “diluted.” To avoid this, the following should be kept in mind:

- Clearly understand and document the ED for each complete exposure pathway,
- Do not use data outside the ED to calculate the representative concentration,
- Within the ED, replace any concentrations that are non-detect with concentrations equal to half the reporting limit, assuming the reporting limits are reasonable,
- When calculating the representative groundwater concentration, if multiple wells are located within the ED, first estimate the average concentration in each well based on recent data, then use the average of each well to estimate the representative concentration,
- If multiple soil samples are collected from a single boring, the representative concentration should be calculated by first calculating the average concentration of each COC in each boring and then determining the average COC concentrations from all borings within the ED,
- Within each ED the maximum concentration for each COC should be less than 10 times the average concentration for that COC. If this condition is not satisfied, carefully evaluate the data to confirm that the calculations are correct and that sufficient data have

been collected within the ED. Note, a ratio exceeds 10, is merely a “red flag” that should trigger a review of the assumptions and does not mean the data are incorrect or insufficient,

- If mobile NAPL is present in a monitoring well, use the effective solubility of each COC as the groundwater concentration of each COC at that point. The effective solubility concentrations presented in Table 12 are calculated using mole fractions of COCs that are representative of fresh gasoline and fresh diesel. These values may not be representative of historic releases since various weathering processes preferentially degrade chemicals with lighter molecular weights and thus alter the relative percentage of each chemical within the mixture. The equation to estimate the effective solubility is presented in Appendix A,
- If a site has a long history of groundwater data but no recent data, data from the most recent two years or 8 quarters of sampling at the site should be used to calculate representative concentrations,
- For a Tier 2 evaluation, representative groundwater concentrations must be calculated at the POE well(s) (if present), at the POC(s), and at the groundwater source. Further, soil concentrations have to be calculated for the soil source area,
- For evaluating the VIAP using groundwater data, use data collected near the first encountered water table from monitoring wells located within the building footprint and up to ten feet beyond the building perimeter, and
- For the direct contact and the ambient air inhalation pathways, use soil data from the upper two feet of vadose zone soil. The calculation of a representative concentration for these exposure pathways is necessary only if there is field evidence of impact in surficial soil related to the LUST release.

5.8 Evaluation of Nonaqueous-Phase Liquid (NAPL)

NAPL released from a LUST system must be managed according to Section 21307 and 21308a of Part 213 and according to the process outlined in ASTM E-2531-06, *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface*. The following NAPL objectives must be met:

- The release must be stopped at the source and all immediate threats must be evaluated and abated,
- The extent of the NAPL body must be determined,
- Risks to human health and the environment related to NAPL must be evaluated and addressed,
- Both the NAPL body and its associated dissolved-phase plume must be stable or decreasing in size, and
- If the recovery of mobile NAPL is necessary to abate an unacceptable risk, the mobile NAPL must be recovered.

When data collected under the MIRBCA process demonstrate that these goals have been achieved, no further evaluation or removal of NAPL will be required. If NAPL has been sufficiently characterized and the conditions above have been met, EGLE may grant closure of a release when NAPL remains at the site.

Detailed information about evaluating NAPL can be found in EGLE's *Non-Aqueous Phase Liquid – Petroleum Releases: Characterization, Remediation, and Management Guidance* available under Resource Materials for the Part 201 and Part 213 Programs. A brief discussion of each of these objectives is presented below.

5.8.1 Evaluate and Abate Immediate Threats

After the release of NAPL from a LUST has been stopped, immediate threats related to the NAPL must be evaluated. Conditions, receptors, and/or exposure pathways that must be evaluated to ensure NAPL or its associated COCs are not creating an immediate threat include:

- Fire and/or explosion (immediate threat – abate immediately upon discovery),
- Acute vapor hazards – COC vapors in indoor air at concentrations above acceptable acute levels (immediate threat – abate immediately upon discovery),
- Drinking water wells in the vicinity of the release,
- Ponding of NAPL on the ground surface that may cause direct contact,
- Sumps in buildings near the release location where NAPL may collect and cause indoor vapor inhalation,
- NAPL entering a storm or sanitary sewer or petroleum vapors in a structure, and
- Surface water bodies where NAPL may migrate.

When an immediate threat has been identified, an initial response action appropriate to abate the threat in accordance with Part 213 must be implemented.

5.8.2 Determine the Extent of the NAPL Body

The extent of the NAPL body, including all states or occurrence of the NAPL (residual, mobile, and/or migrating as defined by Part 213) must be determined. A single line of evidence can be utilized to conservatively infer the presence of NAPL. To verify the absence of NAPL, multiple lines of evidence (MLE) should be used. The multiple lines of evidence should be collected at borings and/or monitoring wells near the edges of the NAPL body rather than in the source area (where it can be assumed that NAPL is present) or at the outermost extent of the dissolved-phase plume (where NAPL is often absent). Potential lines of evidence are listed below:

General NAPL Line of Evidence

- Adjacent to (e.g., within 20 feet) a known or suspected NAPL release area or petroleum equipment
- Current or historic presence of NAPL

Soil NAPL Line of Evidence

- Observed or visible NAPL
- Ultraviolet fluorescence (UV) or laser-induced fluorescence (LIF) response in NAPL range
- TPH-GRO, TPH-DRO, or TPH-ORO greater than 250,000 µg/kg
- Benzene > 10,000 µg/kg
- PID or FID readings for a recent release > 500 parts per million
- Field screening tests positive (e.g., dye test or shake test)

Groundwater NAPL Line of Evidence

- Observed NAPL, including sheen (e.g., in monitoring wells or other discharges)
- Near effective solubility in dissolved phases
- Dissolved plume persistence and center-of-mass stability
- TPH-GRO > 30,000 µg/L in groundwater
- Benzene > 1,000 µg/L
- Sum of benzene, toluene, ethylbenzene and total xylenes > 20,000 µg/L

Vapor NAPL Line of Evidence

- Near volatility limits in vapor phase
- Oxygen less than 4% by volume
- Hexane concentrations > 100,000 µg/m^3

Note that the Part 201 generic criteria for "Csat" are not applicable in the MIRBCA process at Part 213 sites because Csat concentrations are developed using a single chemical's aqueous solubility limit. The MIRBCA process, however, is developed for mixtures of chemicals, such as gasoline and diesel, rather than releases of a single chemical.

Refer to EGLE's NAPL guidance document for further information related to these lines of evidence, including references, considerations, and limitations. Any line of evidence can be used to support the conclusion that NAPL is absent. Not using a line of evidence, for example, not considering the concentration of hexane in soil gas because data are not available or not considering the historic presence of NAPL because the confirmed release is recent and there are no historic data or observations available, cannot be considered as a line of evidence. A minimum of 5 lines of evidence should be included in evaluations to determine where NAPL is not present. For releases greater than five years old with all sources of COCs previously removed, 3 lines of evidence can be used to make the evaluation. EGLE's NAPL guidance, cited above, provides additional details on determining the extent of the NAPL body. An MLE table to assist in the evaluation can be found in the MIRBCA report forms and also in the NAPL guidance document.

5.8.3 Evaluate Risks Related to the NAPL

Risks related to NAPL are generally evaluated via the medium through which exposure could occur (e.g., soil gas for inhalation risks, groundwater for ingestion risks, soil for direct contact risks). Risks related to NAPL should be evaluated using either a Tier 1, 2, or 3 evaluation. This will require the comparison of representative concentrations for each exposure pathway, each COC, and each medium to the applicable RBTLs.

5.8.4 Evaluate Stability of the NAPL Body

Migrating NAPL can occur in the early stages of a release from a LUST and is characterized by a NAPL body that is observed to spread or expand laterally (most common) or vertically. NAPL can migrate only if the NAPL is of sufficient saturation to be mobile, and only if there is a driving force "pushing" the NAPL. Generally, once the release has stopped, the migration of NAPL continues for a short duration and is a self-limiting process. The assessment of NAPL stability in the MIRBCA process generally involves determining the extent of NAPL and determining that its associated dissolved-phase plume is stable or decreasing. Lines of evidence to demonstrate that the NAPL body is stable include:

- Stable NAPL footprint over time,
- Stable or decreasing dissolved-phase plume in the groundwater, and
- Residual NAPL beyond the footprint of mobile NAPL.

5.8.5 Determine if NAPL Must be Recovered to Abate an Unacceptable Risk

As outlined in Part 213, if the recovery of mobile NAPL is necessary to abate an unacceptable risk, then mobile NAPL recovery is required to the maximum extent practicable. If there are no unacceptable risks associated with mobile NAPL, there are no statutory requirements for mobile NAPL recovery. Refer to EGLE's NAPL guidance cited above for further information on NAPL recoverability.

6.0 Tier 1 Evaluation

A Tier 1 evaluation requires the following steps:

STEP 1: Compilation of data and identification of data gaps,

STEP 2: Development of Tier 1 EM,

STEP 3: Collection of data to fill data gaps, if any,

STEP 4: Determination of exposure pathway-specific maximum concentrations of COCs,

STEP 5: Selection of Tier 1 RBSLs and comparison with appropriate representative concentrations,

STEP 6: Recommendation for the next course of action, and

STEP 7: Documentation of the Tier 1 evaluation.

The details of these steps are presented below.

6.1 Step 1: Compilation of Data and Identification of Data Gaps

The objective of this step is to compile available relevant data, evaluate the data, and identify any data gaps. Data requirements for the MIRBCA process are discussed in Section 4.0. The MIRBCA process requires the data to be compiled in the data tables developed as a part of the MIRBCA report forms included in Appendix E. It is recommended that this step and Step 2 be completed simultaneously since the development of an EM may also help in the identification of any data gaps.

Examples of Tier 1 data gaps include:

- Lack of a current land use map,
- Lack of soil or groundwater COC concentrations representative of current conditions (e.g., soil or groundwater data might be too old or not representative of current conditions),
- Lack of an adequate water well search,
- Insufficient characterization, delineation, or absence of relevant data (e.g., soil gas data), and
- Lack of soil, groundwater, or soil gas data for certain COCs.

After all the data gaps have been identified, additional investigation or evaluation must be conducted to collect the necessary data. Refer to Section 4.0 for a discussion on the nature, amount, and precision of data required for the MIRBCA process.

6.2 Step 2: Development of Tier 1 Exposure Model

This step is necessary to identify exposure pathways at a site that are currently complete or that are reasonably likely to become complete in the future. Note, if COCs have migrated offsite, the affected offsite properties must also be considered in developing the EM. Receptors and pathways should be considered for the entire impacted area or area likely to be impacted in the future. Thus, prior to determining exposure pathways that must be evaluated, sufficient SA must be conducted such that the horizontal and vertical extent of COCs have generally been determined. Otherwise, pathways that are of concern might be excluded or pathways not of concern might be erroneously included in the evaluation. Section 5.1 provides general information related to the development of an EM. For each exposure pathway that is determined to be complete, the following must be identified:

- The exposure domain,
- The monitoring points located within the ED,
- Concentrations collected from the monitoring points included in the ED,
- Representative concentrations for each ED, and
- The POE and POC if applicable, for each complete exposure pathway.

If an exposure pathway is determined to be incomplete for current and future use, no further evaluation of the pathway is necessary.

To facilitate development of the EM, EGLE has developed standardized Tier 1 evaluation report forms. These report forms list the routes of exposure typically considered at a LUST site. On these forms, the O/O must indicate whether the pathway is complete or not complete and provide the rationale for the choice. **The MIRBCA report forms are required for all reporting under Part 213.**

6.3. Step 3: Collection of Data to Fill Data Gaps

This step will be necessary only if data gaps are identified in Step 1. Upon completion of this step and with appropriate documentation of the fieldwork, the O/O will proceed with Step 4.

6.4 Step 4: Determination of Exposure Pathway-Specific Representative Concentrations

For a Tier 1 evaluation, the recent maximum concentrations for soil, soil gas, and groundwater are considered the representative concentrations for the complete exposure pathway. For details on determining the representative concentrations, refer to Section 5.7.

Using the data compiled in Steps 1 and 3, the O/O will select the recent maximum concentration for each complete pathway, on each impacted property, and for each complete route of exposure. There include recent maximum soil, groundwater, and soil gas concentrations. Note that these maximum concentrations are the Tier 1 representative concentrations.

6.5 Step 5: Comparison of Tier 1 RBSLs with Tier 1 Representative Concentrations

In this step, the applicable Tier 1 RBSLs for the complete exposure pathways identified in Step 2 are compared with the representative COC concentrations for each complete exposure pathway from Step 4. The Tier 1 RBSLs are presented in Tables 3 through 6. These Tier 1 RBSLs are included in the Tier 1 Report Forms.

6.6 Step 6: Recommendations for the Next Course of Action

The next course of action is determined from the following alternatives based on the results of the comparison in Step 5:

Alternative 1: If the representative concentrations do not exceed the Tier 1 RBSLs for all complete exposure pathways and the following three conditions are met, a CR may be submitted to EGLE to document that corrective actions are complete.

- **Condition 1:** Confirmation that the dissolved plume is stable or decreasing (refer to Section 4.7.4). If this condition is not satisfied, compliance monitoring must be conducted until the plume is demonstrably stable and/or additional corrective action must be implemented to hasten plume stability.
- **Condition 2:** Assurance that the land use assumptions used in the MIRBCA evaluation will not be violated in the future. The need for such assurance may require documentation of land or resource use restrictions or other institutional controls on the site property or other impacted properties. Such documentation must be properly recorded as discussed in Section 10.1 and 10.2.
- **Condition 3:** Appropriate notification under Section 21309a and 21310a of Part 213 has been provided to all affected parties (refer to Section 9.3).

Alternative 2: If one or more representative concentrations exceed the applicable Tier 1 RBSLs, the O/O must recommend one of the following:

- Adopt the Tier 1 RBSLs as the corrective action goals and remediate and/or monitor until representative concentrations achieve these levels,
- Eliminate the necessary exposure pathways by restrictive covenants or alternative mechanisms under Section 21310a of Part 213, or
- Perform a Tier 2 evaluation for the COCs and exposure pathways that do not meet the Tier 1 RBSLs.

Nationwide experience suggests that, unless the corrective action is limited, it is more efficient to manage a site under Tier 2 than under Tier 1 even considering the cost of additional data collection and analysis for a Tier 2 evaluation.

6.7 Step 7: Documentation of Tier 1 Evaluation

To facilitate and streamline the documentation and review of the Tier 1 evaluation, EGLE has developed standardized report forms (refer to Appendix E). The Tier 1 evaluation must be appropriately documented and submitted to EGLE as a part of an IAR, FAR, CAP, or CR. If a Tier 2 evaluation is conducted, both the Tier 1 and Tier 2 evaluations may be submitted simultaneously.

7.0 Tier 2 Evaluation

A Tier 2 evaluation would typically be conducted if the release does not close under Tier 1. At sites where a preliminary review of data indicates that the COCs will not meet the Tier 1 RBSLs, a Tier 2 evaluation may be performed directly without performing and submitting a Tier 1 report.

A Tier 2 evaluation requires the following steps:

STEP 1: Development of Tier 2 exposure model,

STEP 2: Compilation of site-specific fate and transport parameters,

STEP 3: Calculation of Tier 2 SSTLs,

STEP 4: Calculation of representative concentrations,

STEP 5: Comparison of Tier 2 SSTLs with representative concentrations,

STEP 6: Recommendations for the next course of action, and

STEP 7: Documentation of the Tier 2 evaluation.

The details of each of these steps are presented below.

7.1 Step 1: Development of Tier 2 Exposure Model

Similar to Tier 1, all exposure pathways and COCs must be evaluated to determine the pathways that are complete under current conditions or could be complete under reasonably anticipated future conditions. Exposure pathways and COCs that are eliminated in Tier 1 because representative concentrations do not exceed the applicable RBSLs need not be evaluated in Tier 2. Section 5.1 provides general information related to the development of an EM. For each exposure pathway that is determined to be complete, the following must be identified:

- The exposure domain,
- The monitoring points located within the ED,
- Concentrations collected from the monitoring points included in the ED,
- Representative concentrations for each ED, and
- The POE and POC if applicable, for each complete exposure pathway.

To facilitate the development of the Tier 2 EM, EGLE has developed standardized Tier 2 evaluation report forms (refer to Appendix E).

7.2 Step 2: Compilation of Site-Specific Fate and Transport Parameters

A Tier 2 evaluation allows for the application of site-specific fate and transport parameters to develop Tier 2 SSTLs. Fate and transport parameters will be considered site-specific if they are:

- Correctly measured on site at the appropriate location using approved methods,
- Literature values that can be justified as being representative of site conditions, or
- Documented values obtained from a nearby site in a similar hydrogeologic setting.

This section discusses the fate and transport parameters that must be modified unless the default values can be justified as being representative of the site (refer to Tables 10 and 11). The evaluator must review the site information and select values for each of these parameters and provide justification for the selection of each specific value. To help in the documentation and to provide justification, EGLE has developed standardized forms. Refer to Appendix E for these forms. For some fate and transport parameters, literature values consistent with the site stratigraphy may be used in lieu of field measurements.

7.2.1 Vadose Zone Soil Parameters

Depth to Vadose Zone Soil Source Below Grade

Tier 2 allows for the use of the actual depth of contaminated soils in developing Tier 2 SSTLs using the J&E model. This is the distance from the ground surface to the top of the first zone of contaminated soil. Conservatively, the measured depth to vadose zone soil source may be the shallowest detected contamination or an average depth of the shallowest detected contamination from multiple borings within the ED.

Depth to Soil Gas Measurement

At sites where soil gas data are available and will be used to estimate Tier 2 SSTLs using the J&E model, this parameter equals the average depth where the soil gas concentrations are measured.

Thickness of Capillary Fringe

This parameter is used to calculate the attenuation factor from a groundwater source to indoor air if the J&E model is used to evaluate the VIAP. The J&E model first estimates the attenuation factor and then uses it to calculate the groundwater SSTL for the VIAP. The thickness of the capillary fringe must be representative of the site soils and is primarily dependent on soil pore size. Typically, the thickness of the capillary fringe is based on literature values because direct measurement is impractical. Table 7-1 may be used to estimate the capillary zone thickness:

Table 7-1. Capillary fringe thickness estimated from soil type

U.S. Soil Conservation Service (SCS) Soil Texture	Thickness of Capillary Fringe (cm)
Clay	81.5
Silt	163.0
Sand	17.0

Source: Table 10 of USEPA (2004)

Thickness of Vadose Zone

This parameter is used by the J&E model to calculate the attenuation factor for groundwater volatilization to indoor air inhalation. The thickness of the vadose zone is calculated by subtracting the capillary fringe thickness from the depth to groundwater using Equation 7-1:

$$L_{gw} - h_c = h_v \quad (7\text{-}1)$$

where,

L_{gw} = depth to groundwater

h_c = capillary fringe thickness

h_v = thickness of vadose zone

Vadose Zone Dry Soil Bulk Density

This parameter is used for the calculation of SSTLs for all indirect exposure pathways that involve equilibrium calculations between various phase concentrations. Examples include groundwater protection (to convert soil leachate concentrations to soil concentrations), surface water protection (to convert soil leachate concentrations to soil concentrations), and volatilization to indoor air inhalation from soil (to convert soil gas concentrations to soil concentrations). If multiple measurements from the vadose zone are available, the average value should be used. If site data are not available, an appropriate value from Table 7-2 may be used with justification. See Section 4.5.2 for a discussion related to the determination of soil dry bulk density.

Fractional Organic Carbon Content in Vadose Zone

This parameter is used for the calculation of SSTLs for indirect exposure pathways that involve equilibrium calculations between various phase concentrations, as discussed above. See Section 4.5.5 for a discussion of sample collection and laboratory methods. If measurements of fractional organic matter (not the same as fractional organic carbon) are available, the value must be converted to fractional organic carbon as discussed in Section 4.5.5. Where soil lithology is significantly heterogeneous, samples should be collected at each change in lithology and may be composited into one sample for fractional organic carbon content analysis. If multiple measurements from the vadose zone are available, the average value should be used. If site data are not available, an appropriate value from Table 7-2 may be used with justification.

Porosity in Vadose Zone

This parameter is used to calculate SSTLs for indirect exposure pathways that involve equilibrium calculations between various phase concentrations. It is also used to calculate the effective vapor diffusion coefficient of the COC in the vadose zone. Both Tier 1 and Tier 2 evaluations assume that the porosities of the vadose zone, capillary fringe, and soil that fills the foundation or wall cracks are identical. This assumption is necessary because measuring porosity in the capillary fringe and in foundation and wall cracks is generally not practical. See Section 4.5.3 for a discussion of methods used to estimate porosity. If multiple porosity values are available, an average value should be used. Where total and effective porosity differ or are expected to differ, the effective porosity value must be used. If site data are not available, an appropriate value from Table 7-2 may be used with justification.

Volumetric Water Content in Vadose Zone

This parameter is used to calculate the SSTLs for indirect exposure pathways that involve equilibrium calculations between various phase concentrations and to calculate the effective vapor diffusion coefficient of COCs in the vadose zone. Volumetric water content is typically measured as discussed in Section 4.5.4. An average value based on multiple representative samples should be used. Care should be exercised to make sure that water content measurements from the capillary fringe are not assumed to be values representative of the vadose zone. Water content values may be obtained from soil samples being analyzed for COCs. The O/O must direct their laboratories to report soil COC concentrations on a dry weight basis and the water content of each sample. The laboratory will likely report the gravimetric water content that must be converted to a volumetric water content.

Volumetric Air Content in Vadose Zone

This parameter is used for the calculation of risk from indirect exposure pathways that involve equilibrium calculations between various phase concentrations and to calculate the effective vapor diffusion coefficient of COCs in the vadose zone. Volumetric air content in the vadose zone is rarely measured but can be calculated as the difference between the total soil porosity and the volumetric water content in the vadose zone using Equation 7-2:

$$\theta_{Tv} - \theta_{wv} = \theta_{av} \qquad (7\text{-}2)$$

where,

θ_{Tv} = total soil porosity in the vadose zone

θ_{wv} = volumetric water content in the vadose zone

θ_{av} = volumetric air content in the vadose zone

Volumetric Water Content in Capillary Fringe

This parameter is used to estimate the effective vapor diffusion coefficient of COCs in the capillary fringe. Volumetric water content in the capillary fringe is estimated as 90% of the total vadose zone soil porosity (Equation 7-3). Total soil porosity in the capillary fringe is assumed to be equal to the total vadose zone porosity.

$$\theta_{wcap} = 0.9 \times \theta_{Tv} \quad (7\text{-}3)$$

where,

θ_{wcap} = volumetric water content in the capillary fringe

θ_{Tv} = total soil porosity in the vadose zone

Volumetric Air Content in Capillary Fringe

This parameter is used for the calculation of the effective diffusion coefficient of COCs in the capillary fringe. Volumetric air content in the capillary fringe is rarely measured but can be calculated as the difference between the total soil porosity in the capillary fringe and the volumetric water content in the capillary fringe using Equation 7-4:

$$\theta_{Tcap} - \theta_{wcap} = \theta_{acap} \quad (7\text{-}4)$$

where,

θ_{Tcap} = total soil porosity in the capillary fringe

θ_{wcap} = volumetric water content in the capillary fringe

θ_{acap} = volumetric air content in the capillary fringe

Volumetric Water Content in Foundation or Wall Cracks

This parameter is used to calculate the effective vapor diffusion coefficient of COCs in soil that fills the foundation or wall cracks. The volumetric water content in soil that fills foundation or wall cracks is assumed to be the same as the volumetric water content of the soil in the vadose zone and can be calculated using Equation 7-5:

$$\theta_{wcrack} = \theta_{wv} \quad (7\text{-}5)$$

where,

θ_{wcrack} = volumetric water content in foundation or wall cracks

θ_{wv} = volumetric water content of vadose zone soil

Volumetric Air Content in Foundation or Wall Cracks

This parameter is used to calculate the effective vapor diffusion coefficient of COCs in the foundation or crack walls. The volumetric air content in foundation or wall cracks is assumed to be the same as the volumetric air content of the soil in the vadose zone and can be calculated using Equation 7-6:

$$\theta_{acrack} = \theta_{av} \qquad (7\text{-}6)$$

where,

θ_{acrack} = volumetric air content in foundation or wall cracks

θ_{av} = volumetric air content of vadose zone soil

Variability in Vadose Zone Soil Parameters

The spatial variability in the soil geotechnical parameters (fractional organic carbon content, porosity, volumetric water content, and volumetric air content) of the vadose zone soil can be evaluated by taking multiple measurements. If multiple values are available, and if technically appropriate, the average value should be used. Average values should generally be collected from within the soil gas or leachate transport zones and the soil source zone.

For example, assume that soil is impacted between 10 to 15 feet below ground surface (bgs) and the water table is at 25 feet bgs. If three soil samples at 5, 12, and 20 feet bgs have been collected for geotechnical parameters, it would not be appropriate to average the values across all three zones. For the evaluation of indoor inhalation from soil, the sample collected at 20 feet is irrelevant because the sample was taken from below the contaminated zone i.e., the source of soil gas. Hence, the average of the values from the samples at 5 and 12 feet may be used. Similarly, for soil leaching to the groundwater, the sample collected at 5 feet should not be used because the sample at 5 feet is from above the contaminated soil. This concept would apply to all the soil geotechnical parameters – fractional organic carbon content, porosity, volumetric water content, and volumetric air content.

Table 7-2. Geotechnical parameters

Parameter	Unit	Sand	Silt	Silty clay	Clay
Total porosity	cm^3/cm^3	0.25-0.5[a] (0.38)	0.35-0.5[a] (0.49)	0.481	0.4-0.7[a] (0.46)
Volumetric water content	cm^3/cm^3	0.053-0.055 (0.05[b])	0.05-0.28 (0.17[b])	0.11-0.32 (0.22[b])	0.10-0.33 (0.22[b])
Dry soil bulk density	g/cm^3	1.66	1.35	1.38	1.43
Fractional organic carbon content	g/g	0.001-0.006 (0.002[b])	0.001-0.006 (0.002[b])	0.001-0.006 (0.002[b])	0.001-0.006 (0.002[b])

Notes:

Values obtained from *User's guide for evaluating subsurface vapor intrusion into buildings* (USEPA, 2004) unless noted.

Value in parenthesis is an average value unless noted.

[a] Values obtained from *Groundwater* (Freeze and Cherry, 1979).

[b] Default value for USEPA (2004).

cm^3: cubic centimeter; g: gram

7.2.2 Groundwater Parameters

Depth to Groundwater

This parameter is used by the J&E model to estimate the attenuation factor for the indoor air inhalation risk from groundwater. Because the depth to groundwater fluctuates seasonally, the average depth to groundwater should be used based on the available data. Thus, calculating an average depth to groundwater using data collected from several monitoring events over an extended period is preferable. If such data are available for multiple wells in an ED, first the average depth should be calculated for each well. Second, the average of the average depth to groundwater of all the wells should be calculated and considered the average depth to groundwater. In areas where there is a systematic long-term water level rise or fall, only recent data should be used.

Width and Length of Groundwater Source Area Perpendicular to Groundwater Flow Direction

These parameters are required by models to estimate the DAF to evaluate the groundwater protection and surface water protection pathways. This parameter is necessary only in cases where the mixing of leachate with groundwater (quantified by the Summers model) and the horizontal migration of COCs in the saturated zone (quantified by the Domenico model) is being evaluated. The Tier 2 risk assessment assumes that COCs migrate vertically downward from the area of release to groundwater. Thus, the soil source and the groundwater source areas are identical. Figure 5-18 shows a schematic of the soil and groundwater source area that is considered by the Domenico groundwater model. The length (W) and width (Y) of the soil source and groundwater source are estimated as follows:

1. Determine the area where the product was released. This determination requires a thorough knowledge and review of the site history and the available data. Use the soil and groundwater data collected during site characterization to help estimate the soil source location. The area may be irregularly shaped but for the purposes of “modeling” the source area must be approximated as a square or rectangle and marked on a map. Mark the primary direction of groundwater flow on the map based on static water level elevations. At sites where the flow direction varies or if the flow is radial, multiple flow direction arrows may be drawn.

2. Use the map showing the source and the flow direction to estimate the source size. This includes estimating the “Y” and “W” that are measured perpendicular and parallel to the flow direction. If the projected area is not aligned with the flow direction, adjust the measurement to ensure they are perpendicular for Y and parallel for W. The model conservatively neglects lateral dispersion and assumes that the COCs migrate vertically downward from the source to the water table and assumes no lateral spreading. Thus, the spatial dimensions of the soil source and groundwater source are identical.

> The dimensions of the source area should be reasonably estimated based on the known or suspected release area or area of NAPL. Precision in the dimensions of the source area is not critical for determining RBTLs. Source area size is inversely proportional to RBTLs that are developed for the source area.

Groundwater Source Mixing Zone Thickness

Mixing zone thickness is used by the Summers and Domenico models to estimate the dilution attenuation factors in the mixing zone and saturated zone, respectively. The groundwater mixing zone thickness is a measure of the thickness over which COCs have mixed within the saturated zone, primarily due to water table fluctuations. While difficult to estimate accurately, the mixing zone thickness may be approximated based on either (i) PID readings, (ii) soil concentrations measured in borings extending below the water table, or by measuring (iii) groundwater concentrations at different depths below the water table, or (iv) the USEPA’s Soil Screening Guidance (1996, page 31, Equation 12). For easy reference this equation is included in Appendix A, Equation Number 29. The mixing zone thickness should not exceed the thickness of the aquifer. The Tier 1 default value of 200 cm should be considered a minimum.

Porosity in Saturated Zone

Porosity in the saturated zone is required when biodegradation is considered in the horizontal migration of COCs, e.g., using the Domenico model. If the unsaturated and saturated zone stratigraphies are similar, the saturated zone porosity may be assumed equal to the vadose zone porosity. If the stratigraphies of the vadose and saturated zone soils are significantly dissimilar, the porosity of the saturated zone must be measured in the field. If a literature value is used, it must be justified based on site-specific conditions. Where total and effective porosity differ or are expected to differ, the effective porosity value must be used.

Saturated Zone Dry Soil Bulk Density

An accurate estimate of the dry soil bulk density in the saturated zone is essential only when biodegradation is considered in the horizontal migration of COCs, e.g., using the Domenico model. If the unsaturated and saturated zone stratigraphies are similar, the saturated zone dry soil bulk density may be set equal to the vadose zone dry soil bulk density. If multiple values are available, an average should be used. If the stratigraphies of the vadose and saturated zone are significantly dissimilar, the dry soil bulk density of the saturated zone must be measured, or an appropriate literature value used.

Fractional Organic Carbon Content in Saturated Zone

An accurate estimate of the fractional organic carbon content in the saturated zone is essential only when biodegradation is considered in the horizontal migration of COCs, e.g., using the Domenico model. If a site-specific value for saturated zone fractional organic carbon content is to be used at Tier 2 or Tier 3 levels, the value must be determined based on field samples collected below the water table or by choosing a justifiable literature value.

Groundwater Darcy Velocity

Groundwater Darcy velocity is used by the Summers model to estimate the DAF in the groundwater mixing zone and by the Domenico model to estimate the DAF in the groundwater. For a Tier 2 evaluation, the groundwater Darcy velocity must be calculated as the product of the saturated zone hydraulic conductivity (K) and the site-specific hydraulic gradient (i) as shown below:

$$U_{gw} = K \times i \tag{7-7}$$

where,

U_{gw} = groundwater Darcy velocity
K = hydraulic conductivity
i = hydraulic gradient

Site-specific hydraulic conductivity can be estimated based on the results of pump tests or slug tests, if available, or using literature values based on site-specific lithology. The hydraulic gradient should be estimated (as the average gradient) using groundwater elevation data not more than two years old. At sites where the groundwater flow direction shows marked variations, the hydraulic gradient and, hence, the Darcy velocity may need to be estimated for more than one direction. If site data are not available, an appropriate value from Table 7-3 may be used with justification.

Table 7-3. Saturated zone hydraulic conductivity

Soil type	Range (cm/s)*	Range (cm/year)	Midpoint (cm/year)
Sand	$5x10^{-4}$ – 1.0	15,768 – 31,536,000	15,775,884
Silt	10^{-7} – 10^{-3}	3.15 – 31,536	15,770
Clay	10^{-10} – 10^{-7}	0.00315 – 3.15	1.577

Notes:
cm/s: centimeters per second.
cm/year: centimeters per year.
*Obtained from Table 2.2 of *Groundwater* (Freeze and Cherry, 1979).

Infiltration Rate (I)

The Summers model uses the infiltration rate (I) to estimate the DAF in the groundwater mixing zone. Unless site-specific information is available, the infiltration rate may be estimated at 10% of the average annual rainfall for an unpaved soil source area and 1% of the average annual rainfall if the soil source area is paved. Average annual rainfall values are based on a 30-year average and may be obtained from literature.

Biodegradation Rate

This parameter is used by the Domenico model to calculate the DAF in the saturated zone. In a Tier 1 evaluation, the biodegradation rate is assumed to be zero. In a Tier 2 or Tier 3 evaluation, a site-specific non-zero biodegradation rate may be used. The use of biodegradation requires site-specific data to justify the proposed value. If a biodegradation rate is proposed in a Tier 2 or Tier 3 evaluation, an evaluation without the application of a biodegradation rate should also be presented in the event the evaluation using the biodegradation rate is not acceptable. Refer to Appendix C for a methodology to calculate a site-specific biodegradation rate.

7.3 Step 3: Development of Exposure Pathway-Specific Representative Concentrations

Using the site characterization data, the O/O will calculate representative COC concentrations for affected soil, groundwater, and soil gas, as discussed in Section 5.7, for each COC and for each complete pathway that is evaluated in Tier 2.

Depending on site conditions (and as discussed in Section 5.7), multiple representative concentrations may be needed for a site. For example, a site must have a representative concentration for an existing building to evaluate VIAP risk for current use and a representative concentration for a potential future building to evaluate VIAP risk for reasonable future use.

7.4 Step 4: Calculation of Tier 2 SSTLs

Using the site-specific data discussed above, Tier 2 SSTLs are calculated for each COC and each complete exposure pathway that do not meet the Tier 1 RBTLs. The Tier 2 SSTLs should be calculated using the fate and transport models, physical-chemical properties, and toxicological properties presented in Appendix A and Tables 7 through 11. These levels should preferably be developed using the MIRBCA computational software. If a different software is used, it must be provided to EGLE at no cost to EGLE.

7.5 Step 5: Comparison of Tier 2 SSTLs with Site-Specific Representative Concentrations

In this step, the Tier 2 SSTLs calculated in Step 4 are compared with the representative concentrations for each COC calculated in Step 3. Based on the results of this comparison, the O/O must recommend the path forward as discussed in Step 6, below.

7.6 Step 6: Recommendations for the Next Course of Action

The next course of action is determined from the following alternatives based on the results of the comparison in Step 5:

Alternative 1: If the representative concentrations do not exceed the Tier 2 SSTLs for any of the COCs and the following three conditions are met, a CR documenting that corrective actions are complete may be submitted to EGLE.

- **Condition 1:** Confirmation that the dissolved-phase plume is stable or decreasing (refer to Section 4.7.4). If this condition is not satisfied, compliance monitoring must be continued until the plume is demonstrably stable and/or actions to hasten plume stability may be undertaken.
- **Condition 2:** Assurance that the land use assumptions used in the MIRBCA evaluation will not be violated in the future. The need for such assurance may require land or resource use restrictions or other institutional controls on the site property or other impacted properties.

- **Condition 3:** Appropriate notification under Section 21309a and 21310a of Part 213 has been provided to all required parties (refer to Section 9.3).

Alternative 2: If one or more representative concentrations exceed the Tier 2 SSTLs, the O/O may select one of the three options below:

- **Option 1:** Select Tier 2 SSTLs as the corrective action goals and perform remediation and/or monitoring until representative concentrations achieve these levels,
- **Option 2:** Record restrictive covenant(s) or alternative mechanisms to eliminate the exposure pathway(s) for which the COCs exceeded the Tier 2 SSTLs, or
- **Option 3:** Perform a Tier 3 evaluation.

7.7 Step 7: Documentation of the Tier 2 Evaluation

To facilitate the review of a Tier 2 evaluation by EGLE and other interested stakeholders, the RA must be clearly documented. If a Tier 1 evaluation is also conducted, both Tier 1 and Tier 2 evaluations may be submitted as one report. Refer to Section 11.0 and Appendix E for reporting requirements under Part 213. At a minimum, the Tier 2 evaluation report must include the following:

- Site background and chronology of relevant events,
- Conceptual site model, including the exposure model,
- Data used to perform the evaluation,
- Documentation and justification of all fate and transport parameters used to calculate the Tier 2 SSTLs,
- Calculated SSTLs for each COC, each exposure pathway, and each receptor, and
- Recommendation based on the Tier 2 evaluation.

If corrective actions are complete, a CR summarizing corrective actions and documenting the conditions in Step 6, Alternative 1, above, are met.

8.0 Tier 3 Evaluation

A Tier 3 evaluation is a detailed, site-specific evaluation that may be conducted when Tier 2 SSTLs are exceeded and it is not cost-effective to remediate the site to Tier 2 SSTLs. As shown in Table 2-1, compared to a Tier 1 or Tier 2 evaluation, a Tier 3 evaluation provides considerable flexibility in that alternative fate and transport models and input parameters may be used with adequate justification to calculate Tier 3 SSTLs. Further, alternative representative concentrations and other site-specific analyses that are technically justified may be used.

A Tier 3 evaluation requires the following steps:

Step 1: Development of a Tier 3 work plan,

Step 2: Collection of additional data, if necessary,

Step 3: Calculation of Tier 3 SSTLs and representative concentrations,

Step 4: Comparison of Tier 3 SSTLs with representative concentrations,

Step 5: Recommendations for the next course of action, and

Step 6: Documentation of the Tier 3 evaluation.

8.1 Step 1: Development of a Tier 3 Work Plan

Since a Tier 3 evaluation allows considerable flexibility in the performance of the MIRBCA evaluation, a work plan should be prepared that provides sufficient technical justification of all aspects of the Tier 3 evaluation. The work plan should be submitted prior to the FAR. Although EGLE does not have the authority to approve or deny a Tier 3 work plan, EGLE can provide comments to streamline the Tier 3 process that may lead to an approvable FAR or CR. If GSI mixing zone-based criteria are needed as part of the Tier 3 evaluation, they should be requested from EGLE prior to developing the Tier 3 work plan. Refer to Section 8.7 for further information on the evaluation of the surface water protection pathway under Tier 3.

In Tier 3, the exposure pathways and the COCs that exceed the Tier 2 SSTLs must be evaluated. Exposure pathways that are not complete or COCs with representative concentrations that meet the Tier 2 SSTLs need not be evaluated in a Tier 3 unless new data collected after the Tier 2 evaluation indicate otherwise. Typically, a Tier 3 evaluation follows a Tier 2 evaluation although it may be appropriate based on site-specific conditions to proceed directly to Tier 3 after a Tier 1 evaluation.

The Tier 3 work plan must include the following:

- Complete exposure pathways for current and future use for each receptor that will be evaluated,
- The COCs that will be evaluated for each complete pathway and receptor,

- The fate and transport models to be used to evaluate the indirect exposure pathways. If a model different from those included in Appendix A is proposed, it must be peer reviewed, publicly available or a copy provided to EGLE at no cost. Further, the use of the model must be justified (e.g., by describing a history of use on similar projects),
- A tabulation of all the input parameters and justification for each. These may include:
  - Chemical-specific physical properties
  - Chemical-specific toxicological properties
  - Exposure factors
  - Media and fate and transport parameters required by the selected fate and transport models
- A discussion of the data and the methodology that are used to calculate the representative concentrations,
- An explanation of data gaps, if any, that may require additional fieldwork, with a plan to collect the additional data prior to completing the Tier 3 evaluation, and
- A description of any alternate methods of evaluating risk, if applicable.

8.2 Step 2: Collection of Additional Data, if Needed

This step involves the collection of additional data that may be necessary to complete the Tier 3 evaluation. Depending on the site-specific circumstances, this step may or may not be conducted iteratively with Step 1. Depending on the type of additional data needed for the evaluation, it may be appropriate to report the additional data within a FAR or within a CR upon completion of corrective action.

8.3 Step 3: Calculation of Tier 3 SSTLs and Representative Concentrations

This step involves the calculation of SSTLs for the complete exposure pathways and COCs identified in Step 1, above. The calculations must be consistent with the details provided in the work plan developed in Step 1. All models or software used to perform the calculations must be provided to EGLE, if requested, at no cost to EGLE. Further, for each COC and complete exposure pathway, the representative concentration must be calculated.

8.4 Step 4: Comparison of Tier 3 SSTLs with Representative Concentrations

In this step the representative concentrations calculated in Step 3 are compared with the Tier 3 SSTLs. Note that representative concentrations used in a Tier 2 evaluation may be used in Tier 3 unless additional data require a recalculation of the representative concentration, or a different representative concentration is proposed (e.g., 95% upper confidence interval of the mean). Based on the comparison, the O/O must recommend the next course of action.

8.5 Step 5: Recommendations for the Next Course of Action

Depending on the results of Step 4, one of the following two alternatives is available:

Alternative 1: If the representative concentrations for the complete exposure pathways do not exceed the Tier 3 SSTLs and the following three conditions are met, a CR that documents the Tier 3 evaluation and the completed corrective actions may be submitted to EGLE.

- **Condition 1:** Confirmation that the dissolved-phase plume is stable or decreasing (refer to Section 4.7.4). If this condition is not satisfied, compliance monitoring must be continued until the plume is demonstrably stable and/or actions taken to hasten plume stability may be undertaken.
- **Condition 2:** Assurance that the land use assumptions used in the MIRBCA evaluation will not be violated in the future. The need for such assurance may require land or resource use restrictions or other institutional controls on the site property or other properties.
- **Condition 3:** Appropriate notification under Section 21309a and 21310a of Part 213 has been provided to all required parties (refer to Section 9.3).

Alternative 2: If one or more representative concentrations exceed the Tier 3 SSTLs and/or if any of the above conditions are not met, the O/O must conduct additional corrective action to address the unacceptable risk. Any change in corrective action strategy will require the submittal of a CAP.

8.6 Step 6: Documentation of the Tier 3 Evaluation

Because a Tier 3 evaluation is very site-specific, the O/O must submit a report that clearly describes the data used, the methodology, key assumptions, the results, evaluation of current risk, evaluation of future risk, and recommendations regarding the path forward. Part 213 requires that a Tier 3 evaluation be included in a FAR. An O/O may request an extension of the FAR deadline if additional time is needed to collect data or perform the evaluation. Refer to Section 11.2 for information on reporting extensions. If a FAR has previously been submitted, a Tier 3 evaluation can be submitted as part of another report, as appropriate (e.g., CAP, CR). EGLE has developed Tier 1 and Tier 2 forms but has not developed standardized forms for Tier 3 evaluations because the nature of Tier 3 evaluations can vary substantially from site to site. The Tier 3 evaluation should be included as a separate attachment to the FAR and/or CR, as applicable. The O/O is encouraged to use a format like Tier 1 and Tier 2 forms to the extent possible supplemented with a traditional report.

8.7 Tier 3 Surface Water Protection Evaluation

If representative concentrations of COCs exceed or are expected to exceed the Tier 1 RBSLs at the POE for the surface water protection pathway, the O/O may either conduct corrective action to reduce the concentrations or may conduct a Tier 3 evaluation. The Tier 1 RBSLs are the water quality standards developed by EGLE pursuant to Part 31 of the NREPA and are presented in Table 3. Direct and indirect discharges to surface waters of the state are regulated under Part 31 by the Water Resources Division of EGLE.

An O/O may address venting groundwater pursuant to Section 20120e of Part 201 and ultimately must comply with Part 31. In the context of the MIRBCA process, representative concentrations that exceed the Tier 1 RBSLs at the GSI can be managed in one or more of the following ways:

- Remediation to decrease concentrations,
- Request mixing zone-based GSI criteria for the POE from EGLE, and/or
- Conduct an alternative evaluation under Section 20120e.

8.7.1 Remediation to Decrease Concentrations

Active remediation to address representative concentrations of COCs that exceed the Tier 1 GSI RBSLs at the POE is strongly recommended and may be required.

8.7.2 Request Mixing Zone Criteria

The evaluation of risk to surface water is made based on the comparison of representative concentrations at the groundwater-surface water interface to Tier 1 RBSLs (i.e., surface water quality standards). If representative concentrations (i.e., recent maximum concentrations in Tier 1, recent average concentrations in Tier 2) exceed the Tier 1 RBSLs, a request can be made for EGLE-developed site-specific mixing zone-based GSI criteria (i.e., Tier 3 SSTLs). The request should be submitted to EGLE on a Supplemental Information Report cover sheet form (EQP4001) that includes form EQP4483 (Request for mixing zone-based GSI criteria) and should be submitted prior to a FAR. EGLE will generate SSTLs and will communicate them to the O/O. If an O/O chooses to utilize the SSTLs as corrective action goals for the surface water protection pathway, the SSTLs must be included in a CAP within a FAR, and EGLE is required to audit the FAR and provide an opportunity for public comment, pursuant to Section 09a(2)(b) of Part 31.

Additional resources related to submitting a request for EGLE-developed mixing zone-based GSI criteria include *Groundwater-Surface Water Interface Pathway Compliance Options* (EGLE, April 2018) and *Request for Calculation of Mixing Zone-Based Groundwater-Surface Water Interface Criteria* (EGLE, August 2021).

8.7.3 Conduct an Alternative Evaluation under Section 20120e

Section 20120e of Part 201 outlines several options to demonstrate compliance with the surface water protection pathway (termed GSI pathway in Part 201). An O/O conducting corrective action under Part 213 is allowed to demonstrate compliance with the surface water protection pathway by any of the options listed in 20120e. These options include:

- Requesting a variance from the surface water quality standards,
- Developing site-specific target levels,
- Requesting EGLE-developed site-specific criteria,
- Demonstrating compliance at alternative monitoring points,
- Conducting an ecological assessment,
- Conducting a modeling assessment,
- Making a de minimis effect demonstration,
- Requesting a technical impracticability waiver,
- Monitored natural attenuation, and
- Conducting a use attainability analysis (wetlands).

The level of complexity, data collection and financial commitment vary greatly for these options, and it is recommended that the O/O gain a complete understanding of these factors before pursuing one compliance option over another. Details of these options can be found in Part 201, Environmental Remediation, of the NREPA, and also in the *Groundwater-Surface Water Interface Pathway Compliance Options* (EGLE, April 2018).

9.0 Corrective Action Plan

A corrective action plan (CAP) encompasses all activities necessary to manage human health and environmental risk so that representative concentrations do not exceed the acceptable risk levels under current and reasonably anticipated future land use conditions. CAP activities may include, but are not limited to, (i) active remediation, (ii) monitoring to verify the assumptions made in the risk assessment, and (iii) land or resource use restrictions.

9.1 The Requirement for a Corrective Action Plan

A CAP for the confirmed release is required if initial response actions do not result in completion of corrective action and either of the following two conditions is met:

- Representative COC concentrations for one or more complete exposure pathways for current or future use exceed the applicable RBTLs, or
- Representative COC concentrations for each complete exposure pathway do not exceed applicable RBTLs but a CAP is necessary to (i) document land or resource use restrictions or alternative mechanisms that eliminate exposure pathways, (ii) describe any land use restrictions that preserve the exposure assumptions used in the development of RBTLs, or (iii) describe the monitoring necessary to demonstrate plume stability.

A CAP is a plan for risk management that ensures:

- Site conditions related to the confirmed release are protective of public health, safety, welfare, and the environment under current and reasonably anticipated future conditions,
- Exposure assumptions made in the development of target levels are not violated and/or remain applicable in the future, and
- Sufficient monitoring occurs to demonstrate the groundwater plume is stable or decreasing.

Successful implementation of the CAP should result in the completion of corrective action to address the confirmed LUST release. When corrective action is complete, a CR must be submitted to EGLE.

9.2 Contents of the Corrective Action Plan

Once it has been determined that a CAP is required for a release, the O/O should prepare and submit a CAP to EGLE. A FAR, due 365 days after the release has been discovered, must contain a CAP. An updated CAP may also be submitted independent of a FAR if a FAR with a CAP was previously submitted. Substantial changes to the CSM since the FAR may require that the CAP be submitted in a new FAR. A CAP may include one or a combination of the following:

- Active remediation to reduce COC concentrations to meet the corrective action goals. Examples include but are not limited to, soil excavation and offsite disposal, air sparge, soil vapor extraction, dual-phase extraction, in-situ injection technologies, etc.,
- Application of land or resource use restrictions and/or alternative mechanisms to (i) eliminate exposure pathways, (ii) ensure the ongoing presence and maintenance of engineering controls, or (iii) restrict land use to non-residential land use, and/or
- The use of compliance monitoring to demonstrate plume stability or monitored natural attenuation to monitor groundwater concentrations of COCs until they reach the corrective action goals for the site.

An updated CAP may be submitted independent of a FAR. Substantial changes to the CSM since the FAR may require that the CAP be submitted in a new FAR.

A CAP should also include the following:

- Reasons why a CAP is being prepared and the specific objectives of the plan (e.g., "remediation of soil to achieve the corrective action goals (specified in the CAP)"),
- Application of technologies to reduce the mass, concentrations, and/or mobility of the COCs to meet the corrective action goals for the release,
- Description of the data that will be collected during the implementation of the CAP to demonstrate the effectiveness and progress of corrective action activities,
- Details of how and when the data will be evaluated and presented to EGLE, including a reporting schedule,
- Description of proposed land or resource use restrictions and/or alternative mechanisms or other institutional controls, including types of restrictions and area to which restrictions would apply,
- A schedule for the implementation of the CAP, including a target completion date for the CAP,
- RBTLs that will be used to demonstrate that the CAP has been successfully completed, and
- As appropriate, contingency plans if the selected remedy fails to meet the objectives of the CAP by the target completion date.

Further details including all items required to be included in a CAP can be found in Section 21309a of Part 213 of the NREPA. CAPs do not require EGLE approval prior to implementation. However, certain corrective actions require RRD to audit the FAR, and thus CAPs for the following must be submitted in a FAR:

- A CAP that includes a discharge to waters of the state (e.g., in-situ injection) requires approval of a workplan by RRD to grant a discharge permit exemption under the Part 22 Rules prior to implementation, and
- A CAP that relies on EGLE-generated mixing zone-based criteria at the groundwater-surface water interface for the surface water protection pathway. Mixing zone criteria are requested from the O/O prior to a FAR (refer to Section 8.7.2).

CAPs submitted within a FAR are subject to EGLE audit. EGLE does not have the authority to audit CAPs submitted independent of a FAR but may provide the O/O with comments. Implementing a CAP, whether the CAP was part of an approved FAR or whether the CAP was modified based on EGLE comments, does not guarantee that the CAP will result in sufficient risk management that will lead to an approved CR. All CRs are subject to EGLE audit. The audit decision of a CR is independent of a previous FAR audit decision.

9.3 Notification Requirements

Part 213 requires the following notifications as part of the CAP:

- Notice to impacted parties of corrective action (EQP4003), and
- Notice to local unit(s) of government of land use restrictions (EQP4023).

9.3.1 Notice to Impacted Parties of Corrective Action

Part 213 requires an O/O to notify parties who are impacted above a residential Tier 1 RBSL of the impact and of the proposed corrective action using form EQP4003. Impacted parties can include easement holders, utility owners, ROW owners, offsite property owners, and other parties impacted by the release. A copy of form EQP4003 and proof of providing notice must be provided to EGLE in the FAR or CR. Additional instructions related to this notice are provided within form EQP4003.

9.3.2 Notice to Local Unit(s) of Government of Land Use Restrictions

The O/O that implements corrective action activities that rely on ***land use*** restrictions must provide notice of the land use restrictions to the local unit of government in which the site is located within 30 days of filing of the land use restrictions with the county register of deeds. The notification must be provided using form EQP4023. If groundwater is impacted above residential Tier 1 RBSLs a notice should also be provided to the County/District Health Department. A copy of the notice and proof of providing the notice must be included with the CR. Additional instructions related to this notice are provided within form EQP4023. Information about land use restrictions and other institutional controls is available in Section 10.0 of this document.

10.0 Institutional Controls

Institutional controls are a commonly used corrective action tool to manage current and future risk at a site. They are particularly useful in situations where it is technically infeasible or not cost-effective to manage risk by remediation such as soil vapor extraction, pump and treat, etc. Institutional controls can be used to (i) assure the land use assumptions used in the risk assessment are not violated in the future, (ii) eliminate an exposure pathway (i.e., make an exposure pathway incomplete), and (iii) ensure that controls to prevent unacceptable exposure (e.g., direct contact barrier) are maintained in the future.

The following institutional controls are allowed under Part 213:

- Notice of corrective action (NCA),
- Restrictive covenant (RC),
- Notice of aesthetic impact (NAI),
- Local groundwater use ordinance,
- Environmental license agreement (ELA) with MDOT,
- Public highway institutional control (PHIC),
- Health department alternative mechanism, and
- Other alternative mechanisms.

Each of these is briefly described below. Each institutional control must contain a reference number assigned by EGLE to provide tracking and access to institutional controls. EGLE reference number requests should be e-mailed to EGLE-RRD@Michigan.gov. The request should include site details (e.g., institutional control type, program type, location ID#, site name, address, and parcel ID#) and requestor information (e.g., consulting company name, contact name and title, business address, phone, and e-mail address). The assigned number must be prominently displayed on the first page of the institutional control prior to final signatures and recording with the county register of deeds (as required). Reference numbers that are more than one year old prior to finalizing the control should be updated by contacting RRD at the e-mail address listed above. Additional information about various institutional controls, including required forms and model documents, is available at Michigan.gov/egle/about/Organization/Remediation-and-Redevelopment/land-or-resource-use-restrictions.

10.1 Notice of Corrective Action

A notice of corrective action (NCA) is required when corrective action activities at a site result in a final remedy that relies on nonresidential RBTLs (i.e., nonresidential RBSLs or nonresidential SSTLs) for future use. The purpose of the NCA is to ensure that assumptions relied upon in generating the nonresidential RBTLs are maintained and that any proposed change in the land use at any time in the future may necessitate further evaluation of potential risk to the public health, safety, welfare, and to the environment, and that EGLE must be contacted regarding any proposed change to the land use. The statutory requirement to record an NCA on the deed of the property can be satisfied in one of two ways: (i) recording an NCA using EQP3853, or (ii) recording an RC that restricts the ***land use*** to nonresidential use via EQP3854 (refer to Section 10.2). The NCA must be recorded with the register of deeds for the county in which the site is located and must be filed by the property owner or with the express written permission of the property owner. A person that implements corrective action activities that rely on land use restrictions such as an NCA shall provide notice of the land use restrictions that are part of the corrective action plan to the local unit of government in which the site is located within 30 days of filing of the land use restrictions with the county register of deeds using form EQP4023.

It is important to note that there is no requirement to use nonresidential RBTLs if a property is zoned commercial or industrial. A more conservative risk assessment for future use based on residential assumptions may be conducted and does not require an NCA. The O/O should carefully consider the benefits and costs of a remedy that relies on nonresidential RBTLs. A copy of the NCA and proof of recording with the register of deeds must be provided in the CR.

> A risk assessment for a property may be based on exposure assumptions that are more conservative than current or likely future land use. For example, a risk assessment at a gas station site that is zoned commercial may be based on ***residential*** exposure assumptions (and residential RBTLs). The advantage of this is that an RC or NCA would ***not*** be required to restrict the property to nonresidential land use.

10.2 Restrictive Covenant

An RC may be used (i) to address unacceptable risk when COC concentrations remain above applicable corrective action goals (resource use restriction) and/or (ii) to limit the future property to a specific land use such as nonresidential (land use restriction). The RC must be recorded with the register of deeds for the county in which the site is located and must be filed with written approval or consent of the property owner and any easement holders who are affected by the RC. The restrictive covenant model document, form EQP3854, is available at the EGLE website.

An RC can be used to address COC concentrations above applicable RBTLs by eliminating an exposure pathway. For example, when the use of groundwater is restricted via an RC, this removes any future points of exposure related to groundwater use on the given property and thus the groundwater protection exposure pathway is no longer complete for future use within the restricted area on that given property. If a subsequent release on the same property occurs, or if a release from an offsite source impacts groundwater on this property, the existing RC would eliminate the groundwater protection exposure pathway within the restricted area on the site property. Thus, additional restrictions for that pathway on the given property would not be required, provided that the existing RC is protective. If an RC is used to address an unacceptable risk and there are multiple RCs on the property deed, a review of the recorded RCs will be necessary to determine any conflicts and to determine if the RC relied upon is protective.

Even though concentrations exceed Tier 1 RBSLs on a property, an RC may not necessarily be required. An RC is not necessary in the following situations:

- If an exposure pathway is not complete for current and future use (e.g., adequate separation distance between current/likely future buildings and a vapor source with the VIAP; the groundwater protection pathway has been eliminated for current and future use (refer to Section 5.1.2.1 and Appendix B)),
- If there is no POE for current and future use on the property and representative concentrations are below SSTLs for POCs and the source area (e.g., a Tier 2 evaluation for the groundwater protection exposure pathway),
- If the exposure pathway is eliminated by another mechanism (e.g., reliance on a groundwater use ordinance pursuant to Section 21310a of Part 213 to eliminate the groundwater protection exposure pathway; reliance on a health department alternative mechanism under Section 21310a to eliminate the groundwater protection exposure pathway), or
- Representative concentrations in the medium of exposure do not exceed RBTLs whereas representative concentrations in another medium exceed RBTLs. For example:
    - Representative concentrations of soil gas are below RBTLs for the VIAP whereas representative concentrations of groundwater exceed RBTLs for the VIAP, an RC is not needed if future risk can be evaluated with the soil gas samples.
    - Representative concentrations of groundwater are below RBTLs for the groundwater protection exposure pathway whereas representative concentrations of soil exceed RBTLs for the groundwater protection exposure pathway, an RC and/or infiltration barrier is not needed if sufficient time has passed such that the dissolved plume is stable or decreasing. Dissolved petroleum plumes reach equilibrium relatively quickly and are usually limited in length. An increase in infiltration through contaminated soil or groundwater if a paved site becomes unpaved would also be accompanied by an increase in oxygen to the subsurface. Any potential change in equilibrium conditions of the dissolved plume caused by a change in pavement conditions would be minimal and would not require an infiltration barrier in most cases.

An RC may be necessary to eliminate the VIAP for future use if it is reasonably anticipated that a building of a given construction type and/or location could be present in the future that would result in an unacceptable risk. Note that the risk determination should be made with representative soil gas samples whenever possible as soil gas is a better predicter of risk than soil or groundwater concentrations. If representative soil or groundwater concentrations exceed applicable RBTLs for the VIAP but soil gas samples that are collected in locations that assess current and reasonable future use are below applicable RBTLs, then an RC is not required.

An RC can be used to ensure the integrity of a direct contact exposure barrier, which is required if representative concentrations of COCs in the upper two feet of the vadose zone soil exceed applicable direct contact RBTLs or if mobile NAPL is present within the upper two feet of the site and is proposed to remain at the site. Any pavement or other engineering control cannot be used to eliminate the direct contact pathway for future use unless there is a restrictive covenant that ensures the integrity of the exposure barrier. Risk from NAPL at depths greater than two feet should be evaluated through the medium of exposure (e.g., VIAP risk evaluated through soil gas samples; groundwater ingestion evaluated through groundwater samples) when possible and addressed appropriately. The presence of NAPL itself does not require an RC, nor does the presence of NAPL preclude closing a release if current and future risks are below target risk levels.

An RC runs with the land and is binding on all current and future property owners. EGLE, as well as any party specified in the RC, may enforce the restrictions set forth in the RC by legal action in a court of competent jurisdiction. A proposed change in the terms of the RC after it has been recorded on the property deed, including recission of the RC, is the responsibility of the party proposing the changes to demonstrate to EGLE that no unacceptable risks related to the confirmed release are present. A person that implements corrective action activities that rely on land use restrictions such as an RC shall provide notice of the land use restrictions that are part of the corrective action plan to the local unit of government in which the site is located within 30 days of filing of the land use restrictions with the county register of deeds using form EQP4023.

10.3 Notice of Aesthetic Impact

An NAI is similar to a restrictive covenant and is an appropriate mechanism to eliminate the groundwater protection exposure pathway when there is an unacceptable aesthetic impact as determined by representative groundwater concentrations of COCs that exceed aesthetic target levels but not risk-based target levels for groundwater ingestion. 21304a(4) requires that the applicable SSTL for drinking water is the more stringent of (i) the state drinking water standard or (ii) criteria for adverse aesthetic characteristics. For a COC for which either (i) or (ii) is available, the Tier 1 RBSL is the more stringent of (i) or (ii). This value is applicable at the POE as determined in the tier evaluation (refer to Section 5.4). Refer to the footnotes in Tables 3 and 4 to determine if the RBSL is based on the state drinking water standard, aesthetic criteria, or if it is derived pursuant to the algorithms in R.299.10 of the Michigan Administrative Code.

The NAI is recorded on the deed of the affected property using the EGLE form EQP3887 and runs with the land and is binding on current and future property owners.

10.4 Local Groundwater Use Ordinance

Section 21310a(3)(a) of Part 213 allows the use of alternative mechanisms, including local ordinances such as groundwater use ordinances that limit or prohibit the use of contaminated groundwater. An alternative mechanism to limit or prohibit the use of contaminated groundwater can include an amendment to an existing groundwater use ordinance or the proposal of a new ordinance to restrict use of contaminated groundwater. The ordinance must be filed with the register of deeds on the affected property or filed as an ordinance affecting multiple properties. Adopted ordinances must include a requirement within the ordinance that the local unit of government notify EGLE 30 days before adopting a modification to the ordinance or the lapsing or revocation of the ordinance. To ensure that the proposed ordinance is reliable, enforceable, and protective, and meets the requirements of Part 213, a suggested format and contents for reviewing and developing a local ordinance to limit or prohibit the use of contaminated groundwater is available at Michigan.gov/egle/about/organization/remediation-and-redevelopment/land-or-resource-use-restrictions. EGLE's institutional controls technical assistance and program support (TAPS) team is available for assistance.

10.5 MDOT Environmental License Agreement (ELA)

The requirement for an environmental license agreement (ELA) with MDOT is not primarily a risk-based requirement but rather a requirement to assist MDOT in the management of contaminated media within the construction zone of ROWs and potential increased construction costs pursuant to Section 21310a(3)(b) of Part 213. ROW construction zones typically extend to depths of 10 to 15 feet below ground surface but could extend deeper in some areas. Any soil or groundwater contamination greater than residential Tier 1 RBSLs in an MDOT ROW (regardless of depth) requires a notice to impacted parties of corrective action (EQP4003) to MDOT and all persons affected by the release (e.g., easement holders, etc.).

An MDOT ELA is required when any of the following conditions exists:

- NAPL (residual, mobile) is present within an MDOT ROW construction zone,
- Representative soil concentrations exceed residential Tier 1 RBSLs for the direct contact pathway within the construction zone in an MDOT ROW, or
- COCs related to the LUST release are present or could reasonably be present at any concentration in an MS4 storm sewer within the ROW.

Figure 10-1 is a flowchart that outlines when an MDOT ELA or a PHIC is required. Additional information related to MDOT ELA including the required forms and model documents can be obtained at Michigan.gov/mdot/business/contractors/environmental-license-agreement.

10.6 Public Highway Institutional Control

Like an ELA, a PHIC is required to address regulated substances within a ROW controlled by a local unit of government (LUG) and to assist the LUG with its management of contaminated soil, groundwater, and NAPL within the construction zone, which typically extends to depths of 10 to

15 feet below ground surface but could extend deeper in some areas. Any soil or groundwater contamination greater than residential Tier 1 RBSLs in a ROW (regardless of depth) requires a notice to impacted parties of corrective action (EQP4003) to the ROW owner and all persons affected by the release (e.g., easement holders, etc.).

A PHIC is required when any of the following conditions exists:

- NAPL (residual, mobile) is present within a ROW construction zone,
- Representative soil concentrations exceed residential Tier 1 RBSLs for the direct contact pathway within the construction zone in the ROW, or
- COCs related to the LUST release are present or could reasonably be present at any concentration in an MS4 storm sewer within the ROW.

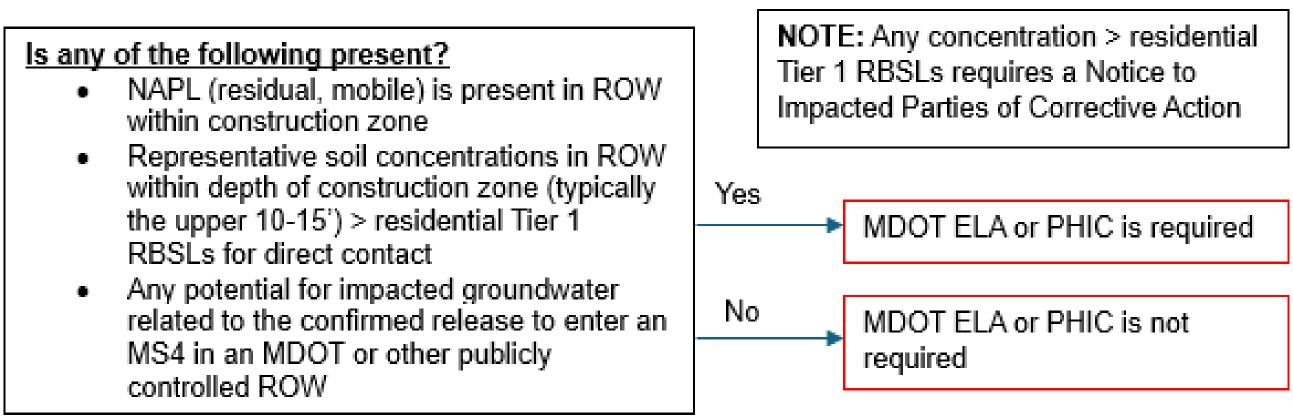


Figure 10-1. Conditions when an ELA or PHIC is required

10.7 Health Department Alternative Mechanism

An alternative mechanism that relies on the authority of the local health department in conjunction with Part 127, Water Supply and Sewer Systems, of the Public Health Code, PA 368 of 1978, as amended, to place a groundwater use restriction for water wells can be used to eliminate the groundwater protection exposure pathway for future use. Several elements are necessary to ensure that this alternative mechanism is reliable, enforceable, and protective, including:

- A report provided to the local health department that documents environmental conditions, extent and concentrations of groundwater impacts, the proposed restricted area, and the results of a survey identifying existing wells within the proposed restricted area,
- Written statement from the local health department that they will use the information to make future permit decisions in the area of the proposed restriction, and
- Notification to the affected property owner(s) within the proposed restricted area regarding contamination on the affected property and any potential due care obligations.

Recommended model documents for the health department alternative mechanism can be obtained from the Institutional Controls TAPS Team. EGLE recommends contacting the institutional controls TAPS Team district point of contact for the area where the mechanism is needed to discuss the use of this alternative mechanism and to have the point of contact initiate conversations with the local health department to start the process.

10.8 Other Alternative Mechanisms

Part 213 allows for a party to propose an alternative mechanism to restrict exposure to COCs. Such alternative mechanisms must be reliable, enforceable, and protective of public health, safety, welfare, and the environment. EGLE recommends contacting the project manager for the confirmed release to discuss any proposed alternative mechanism not listed above.

11.0 Reporting Requirements

11.1 Required Reports and Forms

Table 11-1 lists the reports that are required under Part 213.

Table 11-1. Reports required under Part 213

Report	Due
Initial Assessment Report (IAR)	Within 180 days after a release has been discovered
Amendment to IAR	Within 30 days of discovering migrating or mobile NAPL that was not identified in an IAR
Final Assessment Report (FAR)	Within 365 days after a release has been discovered
Closure Report (CR)	Upon completion of corrective actions

Table 11-2 lists the required forms and cover sheets for reporting under Part 213.

Table 11-2. Forms and cover sheets for Part 213 reports

Form number	Form
EQP3801	Notice of On-Site Work Activity (online electronic submittal, fax pdf)
EQP4002	IAR Cover Sheet, Amendment to IAR Cover Sheet
EQP4000	FAR Cover Sheet, Revised FAR Cover Sheet
EQP4005	FAR Conditional Approval Documentation
EQP4452	CR Cover Sheet, Revised CR Cover Sheet
EQP4004	CR Conditional Approval Documentation
EQP4001	Supplemental Information Report Cover Sheet
EQP4055	CAP Cover Sheet
N/A	MIRBCA Report Forms (Tier 1, Tier 2)
EQP4056	Qualified Underground Storage Tank Consultant Affidavit for Closure Report (required for online CR submittal)
EQP4057	Affidavit of Person Submitting a Closure Report (required for online CR submittal)
EQP4032	RIDE Secondary Certification Authorization
EQP4467	Site-Specific Volatilization to Indoor Air Criteria and Site-Specific Target Levels Request
EQP4483	Request for mixing zone-based GSI criteria (include EQP4483 within a report under EQP4001 Cover Sheet)

A CR can be submitted at any time that sufficient corrective action has been undertaken to address contamination. When a CR is submitted, all remaining steps required under Part 213 and the MIRBCA process and all subsequent reports can be omitted. Note that if a CR submitted in lieu of an IAR or FAR is denied because the deficiencies are substantial such that they cannot be readily resolved with a Revised CR, it may be determined that the standard reporting requirements under Part 213 (i.e., IAR, FAR) apply. The CR must include information required in 21312a, including:

- A summary of corrective actions and the basis for concluding that corrective actions have been completed,
- Closure verification results,
- A signed affidavit from the person submitting the CR attesting that the information upon which the closure is based is complete and true to the best of that person's knowledge,
- A signed affidavit from the consultant who prepared the CR attesting that the corrective actions detailed in the report comply with all applicable requirements under the applicable RBCA standard and that the information upon which the CR is based is true and accurate to the best of that consultant's knowledge, and
- A certificate of insurance demonstrating that the consultant has obtained all the insurance required under Section 21325 of the NREPA, as described in Section 1.4 of this document.

> A Closure Report can be submitted and the subsequent steps omitted at any time corrective actions are complete.

11.2 Report Extensions

EGLE has the authority to grant extensions of reporting deadlines for the IAR and FAR. The request for an extension must be:

- From an O/O that is liable under 21323a,
- In writing,
- Received at least 15 days prior to the report deadline, and
- For good cause.

11.3 Supplemental Information Reports

Supplemental information reports may be submitted at any time using form EQP4001. Supplemental information reports can include but are not limited to groundwater monitoring reports, NAPL recovery reports, remediation system operation and maintenance reports, request for mixing zone-based GSI criteria (include EQP4483), etc. EGLE recommends that a reporting schedule be established in the CAP and that supplemental information reports be submitted on a quarterly to annual basis following the FAR.

11.4 Audits under Part 213

Part 213 is an audit-based program, in which the O/O and their QC conduct corrective actions, evaluate risk, and submit the required reports to EGLE. EGLE has the authority to selectively audit FARs and CRs, to engage in compliance assistance and enforcement against an O/O that is not in compliance with Part 213, and to conduct state-funded corrective actions.

EGLE has 180 days from the receipt of a report to audit a FAR or CR. EGLE has 90 days from the receipt of a report to decide if it will audit a FAR or CR and must notify the O/O of its intention to audit the report within 7 days of making the decision. Possible audit outcomes include (i) approved, (ii) approved with conditions, (iii) denied, or (iv) insufficient information to make a decision.

A denied report requires the audit items to be addressed in a Revised FAR/CR. A report with insufficient information can be addressed in either a Revised FAR/CR or a new FAR/CR, depending on the extent of information that is lacking. The type of report (revised vs. new) required to address audit points in an insufficient information determination will be specified in the EGLE audit letter. EGLE has 90 days to audit a Revised FAR/CR. There is no requirement for notifying the O/O of EGLE's intention to audit a Revised FAR/CR.

If an O/O disagrees with the audit determination, an O/O can submit a petition for review of scientific or technical disputes to the response activity review panel pursuant to Section 20114e and pay a fee of $300.00 or submit a petition to EGLE's Office of Administrative Hearings for a contested case hearing pursuant to Section 21332.

Any audit timeframe can be extended by mutual agreement of EGLE and the O/O. An audit timeframe extension must be documented in writing.

11.5 48-Hour Notification Requirements

In addition to the reporting requirements under Part 213, the O/O is also required to provide 48-hour notification to EGLE prior to initiating any of the following activities:

- Soil excavation,
- Well drilling, including monitoring well installation,
- Sampling soil or groundwater, or
- Construction of treatment systems.

Although not required by Part 213, the O/O is encouraged to submit 48-hour notifications to EGLE for other onsite activities (e.g., soil gas sampling, ground-penetrating radar, surveying, etc.).

11.6 Closure Procedure

The procedure for an O/O to close a confirmed release requires submitting a CR to EGLE. The CR must document that corrective action is complete and that there is no remaining unacceptable risk to public health, safety, welfare, or the environment. The risk is acceptable when all representative concentrations for COCs related to the confirmed release are below applicable target levels for all complete pathways for current use and future use and the dissolved plume and NAPL body have been demonstrated to be stable or shrinking. Note that target levels are not applicable for pathways that are incomplete or pathways that have been eliminated by resource use restrictions. EGLE has 60 days from the receipt of the CR to provide confirmation of receipt to the O/O. EGLE may select the report for audit as described above.

If the CR is approved, the confirmed release will be closed, and no further corrective action will be required of the O/O. If the CR is denied or if there is insufficient information to make a decision, additional corrective action will be required. If the CR is not selected for audit, the confirmed release will be closed 90 days after the report was received by EGLE. Following the closure of the confirmed release, the O/O should properly abandon all monitoring wells and provide notification of well abandonment to EGLE.

12.0 References

ASTM Standard E1739, 1995 (2015, Withdrawn 2024). "Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites," ASTM International, West Conshohocken, PA, 2015, www.astm.org.

ASTM Standard E2081, 2000 (2022). "Standard Guide for Risk-Based Corrective Action," ASTM International, West Conshohocken, PA, 2022, DOI: 10.1520/E2081-22, www.astm.org.

ASTM Standard E2531, 2006 (2020). "Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface," ASTM International, West Conshohocken, PA, 2020, DOI: 10/1520/E2531-06R20, www.astm.org.

ASTM, 1999. RBCA Fate and Transport Models: Compendium and Selection Guide.

ASTM Standard D2937, 1994 (2017). "Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method," ASTM International, West Conshohocken, PA, 2017, DOI: 10.1520/D2937-17E02, www.astm.org.

ASTM Standard D2216, 2010 (2019). "Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass," ASTM International, West Conshohocken, PA, 2019, DOI: 10.1520/D2216-19, www.astm.org.

ASTM Standard D854, 1945 (2023). "Standard Test Methods for Specific Gravity of Soil Solids by the Water Displacement Method," ASTM International, West Conshohocken, PA, 2023, DOI: 10.1520/D0854-23, www.astm.org.

ASTM Standard D2974, 1971 (2020). "Standard Test Methods for Determining the Water (Moisture) Content, Ash Content, and Organic Material of Peat and Other Organic Soils," ASTM International, West Conshohocken, PA, 2020, DOI: 10.1520/D2974-20E01, www.astm.org.

Buscheck, T.E., and Alcantar, C.M., 1995. "Regression techniques and analytical solutions to demonstrate intrinsic bioremediation." In: R.E. Hinchee, J.T. Wilson, and D.C. Downey (eds.), Intrinsic Bioremediation, pp.109-116. Battelle Press, Columbus, OH.

Domenico, P.A., 1987. An analytical model for multidimensional transport of a decaying contaminant species. Journal of Hydrology, 91(1-2): 49-58.

EGLE-RRD, 2014. Groundwater Modeling. Resource Material.

EGLE-RRD, 2024. Application of target detection limits and designated analytical methods. Remediation and Redevelopment Division Resource Materials.

EGLE-RRD, 2024. Groundwater not in an aquifer. Resource Materials.

EGLE-RRD, 2023. Non-aqueous phase liquid – Petroleum releases: Characterization, remediation, and management guidance.

EGLE-RRD, 2018. Groundwater-surface water interface pathway compliance options. Remediation and Redevelopment Division Resource Materials.

EGLE-RRD, 2021. Request for calculation of mixing zone-based groundwater-surface water interface criteria. Resource Material.

EGLE-RRD, 2024. Guidance document for the volatilization to indoor air pathway (VIAP). Volume 4 – Investigative approach for petroleum volatilization to the indoor air pathway (VIAP).

EGLE-RRD, under development. Guidance document for the volatilization to indoor air pathway (VIAP). Volume 6. Volatilization to the indoor air criteria.

Freeze, R.A., and Cherry, J.A., 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Gibbs, J.T., Williamson, T.K.G., Naber, S.J., and Macchiarella, T.L., 2002. Multiple methods for determining stability of attenuating MTBE groundwater plume. Journal of Environmental Engineering, 128(9): 891-901.

Interstate Technology & Regulatory Council (ITRC), 2013. Groundwater statistics and monitoring compliance: statistical tools for the project life cycle. Section 5.5.1 GSMC-1. Washington, D.C.: Interstate Technology & Regulatory Council, Groundwater Statistics and Monitoring Compliance Team. Accessed at https://projects.itrcweb.org/gsmc-1/.

Johnson, P.C., and Ettinger, R.A., 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. Environmental Science & Technology, 25, 1445-1452.

Kahn, L., 1988. Determination of total organic carbon in sediment. US EPA Region II Environmental Services Division, Edison, NJ, July 27, 1988.

Nelson, D.W., and Sommers, L.E., 1982. Total carbon, organic carbon and organic matter. p. 539-579. In: A.L. Page et al. (ed.) Methods of soil analysis: Part 2: Chemical and microbiological properties. ASA Monograph Number 9.

Ricker, J.A., 2008. A practical method to evaluate ground water contaminant plume stability. Ground Water Monitoring & Remediation, 28(4): 85-94.

Summers, K., Gherini, S., and Chen, C., 1980. Methodology to evaluate the potential for ground water contamination from geothermal fluid releases. USEPA Interagency Energy/Environment R&D Program Report. EPA-600/7-80-117.

USEPA, 2009. Statistical analysis of groundwater monitoring data at RCRA facilities – Unified Guidance. EPA 530-R-09-007, 2009.

USEPA, 2004. User's guide for evaluating subsurface vapor intrusion into buildings. Revised February 22, 2004.

USEPA, 1997. Guiding Principles for Monte Carlo Analysis. EPA/630/R-97/001.

USEPA, 1990. Groundwater Handbook, Volume I: Groundwater and Contamination, 625/690/016a.

Vanderford, M., 2010. A comprehensive approach to plume stability. Remediation, 21(1): 21-37.

Vicenc Marti et al., June 11, 2014. Water-air volatilization factors to determine volatile organic compound reference levels in water. Toxins ISSN 2305-6304.

TABLES

Michigan Risk-Based Corrective Action (MIRBCA) Evaluation

Table 1 – Chemicals of Concern for Common Petroleum Products

Chemical Group	Chemical of Concern	CAS Number	Common Petroleum Products				
			Gasoline / Racing Fuel	Diesel / Fuel Oil / Heating Oil[1]	Petroleum Solvent	Waste / Motor/ Reused Oils	Unknown
Aromatic Compounds	Benzene	71432	x	x	x	x	x
	Toluene	108883	x	x	x	x	x
	Ethylbenzene	100414	x	x	x	x	x
	Total xylenes	1330207	x	x	x	x	x
	1,2,4-Trimethylbenzene	95636	x	x	x	x	x
	1,3,5-Trimethylbenzene	108678	x	x	x	x	x
	sec-Butylbenzene	135988	x	x	x	x	x
	tert-Butylbenzene	98066	x	x	x	x	x
	n-Propylbenzene	103651	x	x	x	x	x
Aliphatic Compounds[3]	n-Hexane	110543	x	N/A	x	N/A	x
	2,2,4-Trimethylpentane	540841	x	N/A	x	N/A	x
	Pentane	109660	x	N/A	x	N/A	x
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	x	x	x	x	x
	2-Methylnaphthalene[2]	91576	x	x	x	x	x
	Acenaphthene	83329	N/A	x	x	x	x
	Acenaphthylene	208968	N/A	x	x	x	x
	Anthracene	120127	N/A	x	x	x	x
	Benzo(a)anthracene	56553	N/A	x	x	x	x
	Benzo(a)pyrene[2]	50328	N/A	x	x	x	x
	Benzo(b)fluoranthene[2]	205992	N/A	x	x	x	x
	Benzo(g,h,i)perylene[2]	191242	N/A	x	x	x	x
	Benzo(k)fluoranthene[2]	207089	N/A	x	x	x	x
	Chrysene[2]	218019	N/A	x	x	x	x
	Dibenzo(a,h)anthracene[2]	53703	N/A	x	x	x	x
	Fluoranthene[2]	206440	N/A	x	x	x	x

Table 1 – Chemicals of Concern for Petroleum Products

Chemical Group	Chemical of Concern	CAS Number	Gasoline / Racing Fuel	Diesel / Fuel Oil / Heating Oil[1]	Petroleum Solvent	Waste / Motor/ Reused Oils	Unknown
	Fluorene[2]	86737	N/A	x	x	x	x
	Indeno(1,2,3-cd)pyrene[2]	193395	N/A	x	x	x	x
	Phenanthrene	85018	N/A	x	x	x	x
	Pyrene	129000	N/A	X	X	x	x
Lead Scavengers[3]	1,2-Dichloroethane (1,2-DCA)	107062	x	N/A	N/A	N/A	x
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	x	N/A	N/A	N/A	x
Oxygenates	Ethanol[6]	64175	x	N/A	N/A	N/A	x
	Methyl-tert-butyl-ether (MTBE)[4]	1634044	x	N/A	N/A	N/A	x
Metals	Cadmium	7440439	N/A	N/A	N/A	x	x
	Chromium (III)[5]	16065831	N/A	N/A	N/A	x	x
	Chromium (VI)[5]	18540299	N/A	N/A	N/A	x	x
	Lead[3]	7439921	x	N/A	N/A	x	x

Notes:

CAS Number: Chemical Abstract Service Number

NA: Not available; N/A: Not applicable; x: Chemical of concern

1. Includes all light distillate oils, such as kerosene, and jet fuels.
2. Recommended for soil and groundwater analysis only.
3. Required for all leaded-gasoline releases. For any release from an UST system that operated prior to 1996, lead and lead scavengers should be analyzed in the first sampling event to verify they are not present from historic releases. If there is a drinking water concern, US EPA Method 8011 will be needed for analysis of EDB to achieve the appropriate detection limit.
4. Required for all UST systems and releases prior to 2003.
5. If the chromium species is unknown, analyze for total chromium and compare results to Chromium (VI). If the results exceed the RBTL analyze for Chromium (III) and Chromium (VI).
6. E15 or greater percent ethanol only.
7. Primarily associated with vapor risks; the site can still be evaluated if labs cannot immediately analyze in soil and/or groundwater.

Michigan Risk-Based Corrective Action (MIRBCA)

Table 2 - Delineation Criteria

Chemical Group	Chemical of Concern	CAS Number	Delineation Criteria	
			Groundwater [µg/L]	Soil [µg/kg]
Aromatic Compounds	Benzene	71432	5	100
	Toluene	108883	270	5,400
	Ethylbenzene	100414	18	360
	Total xylenes	1330207	49	980
	1,2,4-Trimethylbenzene	95636	17	570
	1,3,5-Trimethylbenzene	108678	45	1,100
	sec-Butylbenzene	135988	80	1,600
	tert-Butylbenzene	98066	80	1,600
	n-Propylbenzene	103651	80	1,600
Aliphatic Compounds	n-Hexane	110543	3,000	180,000
	2,2,4-Trimethylpentane	540841	2,300	110,000
	Pentane	109660	38,000	970,000
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	11	730
	2-Methylnaphthalene	91576	19	4,200
	Acenaphthene	83329	38	8,700
	Acenaphthylene	208968	52	5,900
	Anthracene	120127	43	41,000
	Benzo(a)anthracene	56553	2.1	20,000
	Benzo(a)pyrene	50328	0.2	2,000
	Benzo(b)fluoranthene	205992	1.5	20,000
	Benzo(g,h,i)perylene	191242	1	2,500,000
	Benzo(k)fluoranthene	207089	1	200,000
	Chrysene	218019	1.6	2,000,000
	Dibenzo(a,h)anthracene	53703	2	2,000
	Fluoranthene	206440	1.6	5,500
	Fluorene	86737	12	5,300
	Indeno(1,2,3-cd)pyrene	193395	2	20,000
	Phenanthrene	85018	2	2,100
	Pyrene	129000	140	480,000
Lead Scavengers[3]	1,2-Dichloroethane (1,2-DCA)	107062	5	100
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	0.05	20
Oxygenates	Ethanol	64175	1,900,000	38,000,000
	Methyl-tert-butyl-ether (MTBE)	1634044	40	800
Metals	Cadmium	7440439	5	6,000
	Chromium (III)	16065831	100	330,000,000
	Chromium (VI)	18540299	11	3,300
	Lead	7439921	4	400,000

Notes:

The delineation criteria are the minimum soil and groundwater concentrations from Table 3.

CAS Number: Chemical Abstract Service Number

Michigan Risk-Based Corrective Action (MIRBCA)

Table 3 – Tier 1 Residential Risk-Based Screening Levels

Aromatic Compounds

Chemical of Concern	Chemical Abstract Service Number	Groundwater: Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater: Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Groundwater: Surface Water Protection (Applicable at POE) [µg/L]	Soil: Groundwater Protection (Applicable at POE) [µg/kg]	Soil: Surface Water Protection (Applicable at POE) [µg/kg]	Soil: Soil Volatilization to Indoor Air [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Soil: Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
Benzene (I)	71432	5 (A)	5,600	200	100	4,000	1,600	13,000	34,000	79,000	380,000,000	180,000
Toluene (I)	108883	790 (E)	530,000 (S)	270	16,000	5,400	330,000 (C)	2,800,000	5,100,000	12,000,000	27,000,000,000	50,000,000 (C)
Ethylbenzene (I)	100414	74 (E)	110,000	18	1,500	360	87,000	720,000	1,000,000	2,200,000	10,000,000,000	22,000,000 (C)
Total xylenes (I)	1330207	280 (E)	190,000 (S)	49	5,600	980	6,300,000 (C)	46,000,000	61,000,000	130,000,000	290,000,000,000	410,000,000 (C)
1,2,4-Trimethylbenzene (I)	95636	63 (E)	56,000 (S)	17	2,100	570	4,300,000 (C)	21,000,000	500,000,000	500,000,000	82,000,000,000	32,000,000 (C)
1,3,5-Trimethylbenzene (I)	108678	72 (E)	61,000 (S)	45	1,800	1,100	2,600,000 (C)	16,000,000	380,000,000	380,000,000	82,000,000,000	32,000,000 (C)
sec-Butylbenzene	135988	80	ID	ID	1,600	ID	ID	ID	ID	ID	400,000,000	2,500,000
tert-Butylbenzene (I)	98066	80	ID	ID	1,600	ID	ID	ID	ID	ID	670,000,000	2,500,000
n-Propylbenzene (I)	103651	80	ID	ID	1,600	ID	ID	ID	ID	ID	1,300,000,000	2,500,000

Aliphatic Compounds

Chemical of Concern	Chemical Abstract Service Number	Groundwater: Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater: Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Groundwater: Surface Water Protection (Applicable at POE) [µg/L]	Soil: Groundwater Protection (Applicable at POE) [µg/kg]	Soil: Surface Water Protection (Applicable at POE) [µg/kg]	Soil: Soil Volatilization to Indoor Air [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Soil: Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
n-Hexane	110543	3,000	12,000 (S)	NA	180,000 (C)	NA	510,000 (C)	3,000,000	3,200,000	6,200,000	13,000,000,000	92,000,000 (C)
2,2,4-Trimethylpentane	540841	ID	2,300 (S)	NA	ID	NA	110,000 (C)	5,200,000	39,000,000	96,000,000	230,000,000,000	ID
Pentane	109660	ID	38,000 (S)	NA	ID	NA	970,000 (C)	37,000,000	310,000,000	580,000,000	1,200,000,000,000	ID

Table 3 – Tier 1 Residential Risk-Based Screening Levels

Polycyclic Aromatic Hydrocarbons (PAHs)

		Groundwater			Soil							
Chemical of Concern	Chemical Abstract Service Number	Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Surface Water Protection (Applicable at POE) [µg/L]	Groundwater Protection (Applicable at POE) [µg/kg]	Surface Water Protection (Applicable at POE) [µg/kg]	Soil Volatilization to Indoor Air [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
Naphthalene	91203	520	31,000 (S)	11	35,000	730	250,000	300,000	300,000	300,000	200,000,000	16,000,000
2-Methylnaphthalene	91576	260	25,000 (S)	19	57,000	4,200	2,700,000	1,500,000	1,500,000	1,500,000	670,000,000	8,100,000
Acenaphthene	83329	1,300	4,200 (S)	38	300,000	8,700	190,000,000	81,000,000	81,000,000	81,000,000	14,000,000,000	41,000,000
Acenaphthylene	208968	52	3,900 (S)	ID	5,900	ID	1,600,000	2,200,000	2,200,000	2,200,000	2,300,000,000	1,600,000
Anthracene	120127	43 (S)	43 (S)	ID	41,000	ID	1,000,000,000	1,400,000,000	1,400,000,000	1,400,000,000	67,000,000,000	230,000,000
Benzo(a)anthracene	56553	2.1	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	ID	20,000
Benzo(a)pyrene	50328	0.2 (A)	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	1,500,000	2,000
Benzo(b)fluoranthene	205992	1.5 (S)	ID	ID	NLL	NLL	ID	ID	ID	ID	ID	20,000
Benzo(g,h,i)perylene	191242	1	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	800,000,000	2,500,000
Benzo(k)fluoranthene	207089	1	NLV	NA	NLL	NLL	NLV	NLV	NLV	NLV	ID	200,000
Chrysene	218019	1.6 (S)	ID	ID	NLL	NLL	ID	ID	ID	ID	ID	2,000,000
Dibenzo(a,h)anthracene	53703	2	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	ID	2,000
Fluoranthene	206440	210 (S)	210 (S)	1.6	730,000	5,500	1,000,000,000	740,000,000	740,000,000	740,000,000	9,300,000,000	46,000,000
Fluorene	86737	880	2,000 (S)	12	390,000	5,300	580,000,000	130,000,000	130,000,000	130,000,000	9,300,000,000	27,000,000
Indeno(1,2,3-cd)pyrene	193395	2	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	ID	20,000
Phenanthrene	85018	52	1,000 (S)	2	56,000	2,100	2,800,000	160,000	160,000	160,000	6,700,000	1,600,000
Pyrene	129000	140 (S)	140 (S)	ID	480,000	ID	1,000,000,000	650,000,000	650,000,000	650,000,000	6,700,000,000	29,000,000

Table 3 – Tier 1 Residential Risk-Based Screening Levels

	Chemical Abstract Service Number	Groundwater			Soil							
		Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Surface Water Protection (Applicable at POE) [µg/L]	Groundwater Protection (Applicable at POE) [µg/kg]	Surface Water Protection (Applicable at POE) [µg/kg	Soil Volatilization to Indoor Air [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
Lead Scavengers												
1,2-Dichloroethane (1,2-DCA) (I)	107062	5 (A)	9,600	360	100	7,200	2,100	6,200	11,000	26,000	120,000,000	91,000
Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	0.05 (A)	2,400	5.7	20	110	670	1,700	1,700	3,300	14,000,000	92
Oxygenates												
Ethanol (I)	64175	1,900,000	NLV	ID	38,000,000	ID	NLV	NLV	NLV	NLV	1,300,000,000,000	1,000,000,000 (C)
Methyl-tert-butyl-ether (MTBE)	1634044	40 (E)	47,000,000 (S)	7,100	800	140,000	9,900,000 (C)	25,000,000	39,000,000	87,000,000	200,000,000,000	1,500,000
Metals												
Cadmium	7440439	5 (A)	NLV	(G)	6,000	(G)	NLV	NLV	NLV	NLV	1,700,000	550,000
Chromium (III)	16065831	100 (A)	NLV	(G)	1,000,000,000	(G)	NLV	NLV	NLV	NLV	330,000,000	790,000,000
Chromium (VI)	18540299	100 (A)	NLV	11	30,000	3,300	NLV	NLV	NLV	NLV	260,000	2,500,000
Lead	7439921	4 (L)	NLV	(G)	700,000	(G)	NLV	NLV	NLV	NLV	100,000,000	400,000

Notes:

A: Michigan drinking water standard

C: The RBSL exceeds soil saturation level

E: Aesthetic drinking water value

G: Groundwater surface water interface (GSI) RBSL depends on the pH or water hardness, or both, of the receiving surface water. The final chronic value (FCV) for the protection of aquatic life shall be calculated based on the pH or hardness of the receiving surface water. Where water hardness exceeds 400 mg CaCO3/L, use 400 mg CaCO3/L for the FCV calculation. The FCV formula provides values in units of ug/L or ppb. The generic GSI RBSL is the lesser of the calculated FCV, the wildlife value (WV), and the surface water human non-drinking water value (HNDV). The soil GSI protection RBSL for these hazardous substances are the greater of the 20 times the GSI RBSL or the GSI soil-water partition values using the GSI RBSL developed with the procedure described in this footnote.

I: Hazardous substance may exhibit the characteristic of ignitability as defined in 40C.F.R. §261.21 (revised as of July 1, 2001).

L: Refer to footnote L in R.299.49, Footnotes for generic cleanup criteria tables.

S: Calculated value exceeded solubility; therefore, solubility is shown.

ID: Insufficient data to develop RBSL

NA: Not available

NLL: Chemical is not likely to leach under most soil conditions

NLV: Not likely to volatilize under most conditions

Michigan Risk-Based Corrective Action (MIRBCA)

Table 4 – Tier 1 Nonresidential Risk-Based Screening Levels

Chemical of Concern	Chemical Abstract Service Number	Groundwater			Soil							
		Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Surface Water Protection (Applicable at POE) [µg/L]	Groundwater Protection (Applicable at POE) [µg/kg]	Surface Water Protection (Applicable at POE) [µg/kg]	Soil Volatilization to Indoor Air [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
Aromatic Compounds												
Benzene (I)	71432	5 (A)	35,000	200	100	4,000	8,400	45,000	99,000	230,000	470,000,000	840,000 (C)
Toluene (I)	108883	790 (E)	530,000 (S)	270	16,000	5,400	610,000 (C)	3,300,000	36,000,000	36,000,000	12,000,000,000	160,000,000 (C)
Ethylbenzene (I)	100414	74 (E)	170,000 (S)	18	1,500	360	460,000 (C)	2,400,000	3,100,000	6,500,000	13,000,000,000	71,000,000 (C)
Total xylenes (I)	1330207	280 (E)	190,000 (S)	49	5,600	980	12,000,000 (C)	54,000,000	65,000,000	130,000,000	130,000,000,000	1,000,000,000 (C)
1,2,4-Trimethylbenzene (I)	95636	63 (E)	56,000 (S)	17	2,100	570	8,000,000 (C)	25,000,000	600,000,000	600,000,000	36,000,000,000	100,000,000 (C)
1,3,5-Trimethylbenzene (I)	108678	72 (E)	61,000 (S)	45	1,800	1,100	4,800,000 (C)	19,000,000	460,000,000	460,000,000	36,000,000,000	100,000,000 (C)
sec-Butylbenzene	135988	230	ID	ID	4,600	ID	ID	ID	ID	ID	180,000,000	8,000,000
tert-Butylbenzene (I)	98066	230	ID	ID	4,600	ID	ID	ID	ID	ID	290,000,000	8,000,000
n-Propylbenzene (I)	103651	230	ID	ID	4,600	ID	ID	ID	ID	ID	590,000,000	8,000,000
Aliphatic Compounds												
n-Hexane	110543	8,600	12,000 (S)	NA	510,000 (C)	NA	950,000 (C)	3,500,000	3,500,000	6,400,000	5,900,000,000	300,000,000 C)
2,2,4-Trimethylpentane	540841	ID	2,300 (S)	NA	ID	NA	200,000 (C)	6,300,000	40,000,000	96,000,000	100,000,000,000	ID
Pentane	109660	ID	38,000 (S)	NA	ID	NA	180,000	44,000,000	340,000,000	600,000,000	530,000,000,000	ID
Polycyclic Aromatic Hydrocarbons (PAHs)												
Naphthalene	91203	1,500	31,000 (S)	11	100,000	730	470,000	350,000	350,000	350,000	88,000,000	52,000,000
2-Methylnaphthalene	91576	750	25,000 (S)	19	170,000	4,200	4,900,000	1,800,000	1,800,000	1,800,000	290,000,000	26,000,000
Acenaphthene	83329	3,800	4,200 (S)	38	880,000	8,700	350,000,000	97,000,000	97,000,000	97,000,000	6,200,000,000	130,000,000
Acenaphthylene	208968	150	3,900 (S)	ID	17,000	ID	3,000,000	2,700,000	2,700,000	2,700,000	1,000,000,000	5,200,000

Table 4 – Tier 1 Nonresidential Risk-Based Screening Levels

Chemical of Concern	Chemical Abstract Service Number	Groundwater: Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater: Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Groundwater: Surface Water Protection (Applicable at POE) [µg/L]	Soil: Groundwater Protection (Applicable at POE) [µg/kg]	Soil: Surface Water Protection (Applicable at POE) [µg/kg]	Soil: Soil Volatilization to Indoor Air [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Soil: Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
Anthracene	120127	43 (S)	43 (S)	ID	41,000	ID	1,000,000,000	1,600,000,000	1,600,000,000	1,600,000,000	29,000,000,000	730,000,000
Benzo(a)anthracene	56553	8.5	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	ID	80,000
Benzo(a)pyrene	50328	0.2 (A)	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	1,900,000	8,000
Benzo(b)fluoranthene	205992	1.5 (S)	ID	ID	NLL	NLL	ID	ID	ID	ID	ID	80,000
Benzo(g,h,i)perylene	191242	1	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	350,000,000	7,000,000
Benzo(k)fluoranthene	207089	1	NLV	NA	NLL	NLL	NLV	NLV	NLV	NLV	ID	800,000
Chrysene	218019	1.6 (S)	ID	ID	NLL	NLL	ID	ID	ID	ID	ID	8,000,000
Dibenzo(a,h)anthracene	53703	2	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	ID	8,000
Fluoranthene	206440	210 (S)	210 (S)	1.6	730,000	5,500	1,000,000,000	890,000,000	880,000,000	880,000,000	4,100,000,000	130,000,000
Fluorene	86737	2,000 (S)	2,000 (S)	12	890,000	5,300	1,000,000,000	150,000,000	150,000,000	150,000,000	4,100,000,000	87,000,000
Indeno(1,2,3-cd)pyrene	193395	2	NLV	ID	NLL	NLL	NLV	NLV	NLV	NLV	ID	80,000
Phenanthrene	85018	150	1,000 (S)	2	160,000	2,100	5,100,000	190,000	190,000	190,000	2,900,000	5,200,000
Pyrene	129000	140 (S)	140 (S)	ID	480,000	ID	1,000,000,000	780,000,000	780,000,000	780,000,000	2,900,000,000	84,000,000
Lead Scavengers												
1,2-Dichloroethane (1,2-DCA) (I)	107062	5 (A)	59,000	360	100	7,200	11,000	21,000	33,000	74,000	150,000,000	420,000
Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	0.05 (A)	15,000	5.7	20	110	3,600	5,800	5,800	9,800	18,000,000	430
Oxygenates												
Ethanol (I)	64175	3,800,000	NLV	ID	76,000,000	ID	NLV	NLV	NLV	NLV	560,000,000,000	1,000,000,000 (C)
Methyl-tert-butyl-ether (MTBE)	1634044	40 (E)	47,000,000 (S)	7,100	800	140,000	18,000,000 (C)	30,000,000	41,000,000	89,000,000	88,000,000,000	7,100,000 (C)

Table 4 – Tier 1 Nonresidential Risk-Based Screening Levels

Chemical of Concern	Chemical Abstract Service Number	Groundwater: Groundwater Ingestion (Applicable at POE) [µg/L]	Groundwater: Groundwater Volatilization to Indoor Air Inhalation [µg/L]	Groundwater: Surface Water Protection (Applicable at POE) [µg/L]	Soil: Groundwater Protection (Applicable at POE) [µg/kg]	Soil: Surface Water Protection (Applicable at POE) [µg/kg]	Soil: Soil Volatilization to Indoor Air [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of Infinite Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 5 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Volatile Soil of 2 Meter Source Thickness [µg/kg]	Soil: Soil Protective of Ambient Air Inhalation - Particulate Soil Inhalation [µg/kg]	Soil: Direct Contact (Ingestion, Dermal Absorption) [µg/kg]
Metals												
Cadmium	7440439	5 (A)	NLV	(G)	6,000	(G)	NLV	NLV	NLV	NLV	2,200,000	2,100,000
Chromium (III)	16065831	100 (A)	NLV	(G)	1,000,000,000	(G)	NLV	NLV	NLV	NLV	150,000,000	1,000,000,000
Chromium (VI)	18540299	100 (A)	NLV	11	30,000	3,300	NLV	NLV	NLV	NLV	240,000	9,200,000
Lead	7439921	4 (L)	NLV	(G)	700,000	(G)	NLV	NLV	NLV	NLV	44,000,000	900,000

Notes:

A: Michigan drinking water standard
C: The RBSL exceeds soil saturation level
E: Aesthetic drinking water value
G: Groundwater surface water interface (GSI) RBSL depends on the pH or water hardness, or both, of the receiving surface water. The final chronic value (FCV) for the protection of aquatic life shall be calculated based on the pH or hardness of the receiving surface water. Where water hardness exceeds 400 mg CaCO3/L, use 400 mg CaCO3/L for the FCV calculation. The FCV formula provides values in units of ug/L or ppb. The generic GSI RBSL is the lesser of the calculated FCV, the wildlife value (WV), and the surface water human non-drinking water value (HNDV). The soil GSI protection RBSL for these hazardous substances are the greater of the 20 times the GSI RBSL or the GSI soil-water partition values using the GSI RBSL developed with the procedure described in this footnote.
I: Hazardous substance may exhibit the characteristic of ignitability as defined in 40C.F.R. §261.21 (revised as of July 1, 2001).
L: Refer to footnote L in R.299.49, Footnotes for generic cleanup criteria tables.
S: Calculated value exceeded solubility; therefore, solubility is shown.
ID: Insufficient data to develop RBSL
NA: Not available
NLL: Chemical is not likely to leach under most soil conditions
NLV: Not likely to volatilize under most conditions

Michigan Risk-Based Corrective Action (MIRBCA)

Table 5 – Tier 1 Residential RBSLs for VIAP: Groundwater (Sump Model), Soil Gas, Indoor Air

Chemical.Group	Chemical Name	CAS Number	Groundwater (Sump Model) (µg/L)	Soil Gas (µg/m^3)	Indoor Air[1] (µg/m^3)
Aromatic. Compounds	Benzene	71432	10	110	3.6
	Toluene	108883	16,000	170,000	5,200
	Ethylbenzene	100414	35	340	11
	Total Xylenes	1330207	320	7,600	100
	1,2,4-Trimethylbenzene	95636	210	2,100	63
	1,3,5-Trimethylbenzene	108678	210	2,100	63
	sec-Butylbenzene	135988	1,400	14,000	420
	tert-Butylbenzene	98066	1,400	14,000	420
	n-Propylbenzene	103651	3,300	33,000	1,000
Aliphatic.Compounds	n-Hexane	110543	2,300	24,000	730
	2,2,4-Trimethylpentane[2]	540841	13,000	120,000	3,650
	Pentane	109660	3,000	35,000	1,000
Polycyclic.Aromatic. Hydrocarbons.(PAHs)	Naphthalene	91203	3	25	0.7
	2-Methylnaphthalene	91576	39	350	10
	Acenaphthene	83329	1,100	7,300	219
	Anthracene	120127	11,000	35,000	1,040
	Benzo(a)anthracene	56553	10	5.8	0.2
	Fluorene	86737	1,000	4,900	146
	Pyrene	129000	4,800	3,500	104
Lead.Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	3	33	1
	Ethylene dibromide (EDB)	106934	0.1	1.4	0.04
Oxygenates	Methyl-tert-butyl-ether (MTBE)	1634044	350	3,300	98

[1] Acceptable Indoor Air Concentrations are derived from EPA Regional Screening Levels (RSLs) unless otherwise noted
[2] No value in EPA RSLs, EGLE-derived concentrations are used
Note: If the target detection level (TDL) is higher than any RBSL, the TDL will be used as the RBSL

Michigan Risk-Based Corrective Action (MIRBCA)

Table 6 – Tier 1 Nonresidential RBSLs for VIAP: Groundwater (Sump Model), Soil Gas, Indoor Air

Chemical.Group	Chemical Name	CAS Number	Groundwater (Sump Model) (µg/L)	Soil Gas (µg/m³)	Indoor Air[1] (µg/m³)
Aromatic Compounds	Benzene	71432	90	510	16
	Toluene	108883	130,000	250,000	22,000
	Ethylbenzene	100414	310	1,600	49
	Total xylenes	1330207	2,800	22,000	440
	1,2,4-Trimethylbenzene	95636	1,700	6,100	260
	1,3,5-Trimethylbenzene	108678	1,700	6,100	260
	sec-Butylbenzene	135988	8,300	41,000	1,200
	tert-Butylbenzene	98066	8,300	41,000	1,200
	n-Propylbenzene	103651	29,000	33,000	4,400
Aliphatic Compounds	n-Hexane	110543	20,000	72,000	3,100
	2,2,4-Trimethylpentane[2]	540841	76,000	360,000	10,700
	Pentane	109660	27,000	100,000	4,400
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	28	120	3.6
	2-Methylnaphthalene	91576	250	1,000	31
	Acenaphthene	83329	6,500	21,000	644
	Anthracene	120127	65,000	100,000	3,070
	Benzo(a)anthracene	56553	190	66.0	2
	Fluorene	86737	6,200	14,000	429
	Pyrene	129000	28,000	10,000	307
Lead Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	27	150	4.7
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	1	6.6	0.2
Oxygenates	Methyl-tert-butyl-ether (MTBE)	1634044	3,300	15,000	470

1. Acceptable Indoor Air Concentrations are derived from EPA Regional Screening Levels (RSLs) unless otherwise noted
2. No value in EPA RSLs, EGLE derived concentrations are used

Note: If the target detection level (TDL) is higher than any RBSL, the TDL will be used as the RBSL

Michigan Risk-Based Corrective Action (MIRBCA)

Table 7 – Toxicity Values

Chemical Group	Chemical of Concern	CAS Number	Oral Cancer Slope Factor (SF_O) [mg/kg-day]$^{-1}$	Inhalation Unit Risk Factor (IURF) [µg/m^3]$^{-1}$	Oral Reference Dose (RfD_o) [mg/kg-day]	Chronic Inhalation Reference Concentration (RfC) [mg/m^3]	Gastrointestinal Absorption (GIABS) [unitless]	Dermal Absorption Fraction (ABS_d) [unitless]	Relative Bioavailability Factor (RBA) [unitless]
Aromatic Compounds	Benzene	71432	5.50E-02	7.80E-06	4.00E-03	3.00E-02	1	NA	1
	Toluene	108883	NA	NA	8.00E-02	5.00E+00	1	NA	1
	Ethylbenzene	100414	1.10E-02	2.50E-06	5.00E-02	1.00E+00	1	NA	1
	Total xylenes	1330207	NA	NA	2.00E-01	1.00E-01	1	NA	1
	1,2,4-Trimethylbenzene	95636	NA	NA	1.00E-02	6.00E-02	1	NA	1
	1,3,5-Trimethylbenzene	108678	NA	NA	1.00E-02	6.00E-02	1	NA	1
	sec-Butylbenzene	135988	NA	NA	1.00E-01	4.00E-01[a]	1	NA	1
	tert-Butylbenzene	98066	NA	NA	1.00E-01	4.00E-01[a]	1	NA	1
	n-Propylbenzene	103651	NA	NA	1.00E-01	1.00E+00	1	NA	1
Aliphatic Compounds	n-Hexane	110543	NA	NA	NA	7.00E-01	1	NA	1
	2,2,4-Trimethylpentane	540841	NA	NA	NA	3.50E+00[a]	1[a]	0.1[a]	NA
	Pentane	109660	NA	NA	NA	1.00E+00	1	NA	1
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	1.20E-01	3.40E-05	2.00E-02	3.00E-03	1	0.13	1
	2-Methylnaphthalene	91576	NA	NA	4.00E-03	NA	1	0.13	1
	Acenaphthene	83329	NA	NA	6.00E-02	NA	1	0.13	1
	Acenaphthylene	208968	NA	NA	6.00E-02[b]	2.10E-01[c]	1[a]	0.1[a]	NA
	Anthracene	120127	NA	NA	3.00E-01	NA	1	0.13	1
	Benzo(a)anthracene*	56553	1.00E-01	6.00E-05	NA	NA	1	0.13	1
	Benzo(a)pyrene*	50328	1.00E+00	6.00E-04	3.00E-04	2.00E-06	1	0.13	1
	Benzo(b)fluoranthene*	205992	1.00E-01	6.00E-05	NA	NA	1	0.13	1
	Benzo(g,h,i)perylene	191242	NA	NA	2.00E-03[a]	7.00E-03[a]	1[a]	0.13[a]	NA

Chemical Group	Chemical of Concern	CAS Number	Oral Cancer Slope Factor (SF_O) $[mg/kg\text{-}day]^{-1}$	Inhalation Unit Risk Factor (IURF) $[\mu g/m^3]^{-1}$	Oral Reference Dose (RfD_o) [mg/kg-day]	Chronic Inhalation Reference Concentration (RfC) $[mg/m^3]$	Gastrointestinal Absorption (GIABS) [unitless]	Dermal Absorption Fraction (ABS_d) [unitless]	Relative Bioavailability Factor (RBA) [unitless]
	Benzo(k)fluoranthene*	207089	1.00E-02	6.00E-06	NA	NA	1	0.13	1
	Chrysene*	218019	1.00E-03	6.00E-07	NA	NA	1	0.13	1
	Dibenzo(a,h)anthracene*	53703	1.00E+00	6.00E-04	NA	NA	1	0.13	1
	Fluoranthene	206440	NA	NA	4.00E-02	NA	1	0.13	1
	Fluorene	86737	NA	NA	4.00E-02	NA	1	0.13	1
	Indeno(1,2,3-cd)pyrene*	193395	1.00E-01	6.00E-05	NA	NA	1	0.13	1
	Phenanthrene	85018	NA	NA	3.00E-02[b]	1.00E-04[a]	1[a]	0.1[a]	NA
	Pyrene	129000	NA	NA	3.00E-02	NA	1	0.13	1
Lead Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	9.10E-02	2.60E-05	6.00E-03	7.00E-03	1	NA	1
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	2.00E+00	6.00E-04	9.00E-03	9.00E-03	1	NA	1
Oxygenates	Ethanol	64175	NA	NA	6.20E+01[a]	1.90E+01[a]	1[a]	0.1[a]	NA
	Methyl-tert-butyl-ether (MTBE)	1634044	1.80E-03	2.60E-07	NA	3.00E+00	1	NA	1
Metals	Cadmium (Water)	7440439	NA	1.80E-03	1.00E-04	1.00E-05	0.05	0.001	1
	Chromium (III) (Soluble Compounds)	16065831	NA	NA	NA	6.00E-05	0.013	NA	1
	Chromium (VI)*	18540299	1.60E-01	1.10E-02	9.00E-04	3.00E-05	0.025	NA	1
	Lead	7439921	NA	NA	NA	NA	1	NA	1

Notes:

NA: Not available; * Mutagenic chemical

The toxicity values were obtained from Regional Screening Level (RSL) Summary Table (USEPA, November 2024) except as indicated otherwise.

(a): Value provided by EGLE

(b): Value obtained from Texas Risk Reduction Program (TRRP) Protective Concentration Levels (PCL) Tables. Texas Commission On Environmental Quality (TCEQ, February 2025)

(c): Value obtained from New York State Brownfield Cleanup Program Development of Soil Cleanup Objectives Technical Support Document 2020 Addendum New York State Department of Environmental Conservation (NYSDEC, July 2020)

Michigan Risk-Based Corrective Action (MIRBCA)

Table 8(a) – Physical and Chemical Properties

Chemical Group	Chemical of Concern	CAS Number	Molecular Weight (MW) [g/mol]	Dimensionless Henry's Law Constant at Reference Temperature 25°C (H') [unitless]	Dimensional Henry's Law Constant at Reference Temperature 25°C (HLC) [atm-m^3/mole]	Vapor Pressure (VP) [mmHg]	Diffusivity in Air (D_a) [cm^2/s]	Diffusivity in Water (D_w) [cm^2/s]	Soil Water Partition Coefficient (K_d) [L/kg]	Soil Organic Carbon Partition Coefficient (K_{oc}) [L/kg]	Water Solubility (S) [mg/L]	Is Chemical Volatile?
Aromatic Compounds	Benzene	71432	7.81E+01	2.27E-01	5.55E-03	9.48E+01	8.95E-02	1.03E-05	NA	1.46E+02	1.79E+03	Yes
	Toluene	108883	9.21E+01	2.71E-01	6.64E-03	2.84E+01	7.78E-02	9.20E-06	NA	2.34E+02	5.26E+02	Yes
	Ethylbenzene	100414	1.06E+02	3.22E-01	7.88E-03	9.60E+00	6.85E-02	8.46E-06	NA	4.46E+02	1.69E+02	Yes
	Total xylenes	1330207	1.06E+02	2.71E-01	6.63E-03	7.99E+00	6.85E-02	8.46E-06	NA	3.83E+02	1.06E+02	Yes
	1,2,4-Trimethylbenzene	95636	1.20E+02	2.52E-01	6.16E-03	2.10E+00	6.07E-02	7.92E-06	NA	6.14E+02	5.70E+01	Yes
	1,3,5-Trimethylbenzene	108678	1.20E+02	3.59E-01	8.77E-03	2.48E+00	6.02E-02	7.84E-06	NA	6.02E+02	4.82E+01	Yes
	sec-Butylbenzene	135988	1.34E+02	7.20E-01	1.76E-02	1.75E+00	5.28E-02	7.34E-06	NA	1.33E+03	1.76E+01	Yes
	tert-Butylbenzene	98066	1.34E+02	5.40E-01	1.32E-02	2.20E+00	5.30E-02	7.37E-06	NA	1.00E+03	2.95E+01	Yes
	n-Propylbenzene	103651	1.20E+02	4.29E-01	1.05E-02	3.42E+00	6.02E-02	7.83E-06	NA	8.13E+02	5.22E+01	Yes
Aliphatic Compounds	n-Hexane	110543	8.62E+01	7.36E+01	1.80E+00	1.51E+02	7.31E-02	8.17E-06	NA	1.32E+02	9.50E+00	Yes
	2,2,4-Trimethylpentane	540841	1.14E+02[a]	1.24E+02[a]	3.03E+00[a]	4.93E+01[a]	5.74E-02[a]	7.06E-06[a]	NA	2.40E+02[a]	2.44E+00[a]	Yes
	Pentane	109660	7.22E+01	5.11E+01	1.25E+00	5.14E+02	8.21E-02	8.80E-06	NA	7.22E+01	3.80E+01	Yes
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	1.28E+02	1.80E-02	4.40E-04	8.50E-02	6.05E-02	8.38E-06	NA	1.54E+03	3.10E+01	Yes
	2-Methylnaphthalene	91576	1.42E+02	2.12E-02	5.18E-04	5.50E-02	5.24E-02	7.78E-06	NA	2.48E+03	2.46E+01	Yes
	Acenaphthene	83329	1.54E+02	7.52E-03	1.84E-04	2.15E-03	5.06E-02	8.33E-06	NA	5.03E+03	3.90E+00	Yes
	Acenaphthylene	208968	1.52E+02[a]	4.66E-03[a]	1.14E-04[a]	6.68E-03[a]	4.50E-02[a]	6.98E-06[a]	NA	5.03E+03[a]	1.61E+01[a]	Yes
	Anthracene	120127	1.78E+02	2.27E-03	5.56E-05	6.53E-06	3.90E-02	7.85E-06	NA	1.64E+04	4.34E-02	Yes
	Benzo(a)anthracene	56553	2.28E+02	4.91E-04	1.20E-05	2.10E-07	2.61E-02	6.75E-06	NA	1.77E+05	9.40E-03	Yes
	Benzo(a)pyrene	50328	2.52E+02	1.87E-05	4.57E-07	5.49E-09	2.55E-02	6.58E-06	NA	5.87E+05	1.62E-03	No
	Benzo(b)fluoranthene	205992	2.52E+02	2.69E-05	6.57E-07	5.00E-07	2.50E-02	6.43E-06	NA	5.99E+05	1.50E-03	No
	Benzo(g,h,i)perylene	191242	2.76E+02[a]	1.35E-05[a]	3.31E-07[a]	1.00E-10[a]	2.39E-02[a]	6.09E-06[a]	NA	1.95E+06[a]	2.60E-04[a]	No

Chemical Group	Chemical of Concern	CAS Number	Molecular Weight (MW) [g/mol]	Dimensionless Henry's Law Constant at Reference Temperature 25°C (H') [unitless]	Dimensional Henry's Law Constant at Reference Temperature 25°C (HLC) [atm-m^3/mole]	Vapor Pressure (VP) [mmHg]	Diffusivity in Air (D_a) [cm^2/s]	Diffusivity in Water (D_w) [cm^2/s]	Soil Water Partition Coefficient (K_d) [L/kg]	Soil Organic Carbon Partition Coefficient (K_{oc}) [L/kg]	Water Solubility (S) [mg/L]	Is Chemical Volatile?
	Benzo(k)fluoranthene	207089	2.52E+02	2.39E-05	5.84E-07	9.65E-10	2.50E-02	6.43E-06	NA	5.87E+05	8.00E-04	No
	Chrysene	218019	2.28E+02	2.14E-04	5.23E-06	6.23E-09	2.61E-02	6.75E-06	NA	1.81E+05	2.00E-03	No
	Dibenzo(a,h)anthracene	53703	2.78E+02	5.76E-06	1.41E-07	9.55E-10	2.36E-02	6.02E-06	NA	1.91E+06	2.49E-03	No
	Fluoranthene	206440	2.02E+02	3.62E-04	8.86E-06	9.22E-06	2.76E-02	7.18E-06	NA	5.55E+04	2.60E-01	No
	Fluorene	86737	1.66E+02	3.93E-03	9.62E-05	6.00E-04	4.40E-02	7.89E-06	NA	9.16E+03	1.69E+00	Yes
	Indeno(1,2,3-cd)pyrene	193395	2.76E+02	1.42E-05	3.48E-07	1.25E-10	2.47E-02	6.37E-06	NA	1.95E+06	1.90E-04	No
	Phenanthrene	85018	1.78E+02[a]	1.73E-03[a]	4.23E-05[a]	1.21E-04[a]	3.75E-02[a]	7.47E-06[a]	NA	1.67E+04[a]	1.15E+00[a]	Yes
	Pyrene	129000	2.02E+02	4.87E-04	1.19E-05	4.50E-06	2.78E-02	7.25E-06	NA	5.43E+04	1.35E-01	Yes
Lead Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	9.90E+01	4.82E-02	1.18E-03	7.89E+01	8.57E-02	1.10E-05	NA	3.96E+01	8.60E+03	Yes
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	1.88E+02	2.66E-02	6.50E-04	1.12E+01	4.30E-02	1.04E-05	NA	3.96E+01	3.91E+03	Yes
Oxygenates	Ethanol	64175	4.61E+01[a]	2.04E-04[a]	5.00E-06[a]	5.93E+01[a]	1.24E-01[a]	1.32E-05[a]	NA	1.05E+00[a]	1.00E+06[a]	Yes
	Methyl-tert-butyl-ether (MTBE)	1634044	8.82E+01	2.40E-02	5.87E-04	2.50E+02	7.53E-02	8.59E-06	NA	1.16E+01	5.10E+04	Yes
Metals	Cadmium (Water)	7440439	1.12E+02	NA	NA	NA	NA	NA	7.50E+01	NA	NA	No
	Chromium (III) (Soluble Compounds)	16065831	5.20E+01	NA	NA	NA	NA	NA	1.80E+06	NA	NA	No
	Chromium (VI)	18540299	5.20E+01	NA	NA	NA	NA	NA	1.90E+01	NA	1.69E+06	No
	Lead	7439921	2.07E+02	NA	NA	NA	NA	NA	9.00E+02	NA	NA	No

Notes:

NA: Not available

Chemical is considered volatile if either its dimensional Henry's law constant is greater than 1×10^{-5} atm-m^3/mole or vapor pressure is greater than 1 mmHg (USEPA, November 2024).

The physical chemical properties were obtained from Regional Screening Level (RSL) Parameters Table (USEPA, November 2024) except as indicated otherwise.

(a): Value provided by EGLE

Michigan Risk-Based Corrective Action (MIRBCA)

Table 8(b) – Physical and Chemical Properties for Calculation of Henry's Law Constant (HLC) at Different Temperatures

Chemical Group	Chemical Name	CAS Number	Normal Boiling Point (T_{BP}) [°K]	Critical Temperature (TC) [°K]	Enthalpy of Vaporization at the Normal Boiling Point ($\Delta H_{v,b}$) [cal/mole]
Aromatic Compounds	Benzene	71432	3.53E+02	5.62E+02	7.34E+03
	Toluene	108883	3.84E+02	5.92E+02	7.93E+03
	Ethylbenzene	100414	4.09E+02	6.17E+02	8.50E+03
	Total Xylenes	1330207	4.11E+02	6.21E+02	8.57E+03
	1,2,4-Trimethylbenzene	95636	4.42E+02	6.49E+02	9.37E+03
	1,3,5-Trimethylbenzene	108678	4.38E+02	6.37E+02	9.32E+03
	sec-Butylbenzene	135988	4.47E+02	6.79E+02	8.87E+04
	tert-Butylbenzene	98066	4.42E+02	1.22E+03	8.98E+03
	n-Propylbenzene	103651	4.32E+02	6.30E+02	9.12E+03
Aliphatic Compounds	n-Hexane	110543	3.42E+02	5.08E+02	6.90E+03
	2,2,4-Trimethylpentane[2]	540841	3.72E+02	5.44E+02	7.36E+03
	Pentane	109660	3.09E+02	4.70E+02	6.16E+03
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	4.91E+02	7.48E+02	1.04E+04
	2-Methylnaphthalene	91576	5.14E+02	7.61E+02	1.26E+04
	Acenaphthene	83329	5.52E+02	8.03E+02	1.22E+04
	Acenaphthylene	208968	5.53E+02	7.92E+02	1.17E+04
	Anthracene	120127	6.13E+02	8.73E+02	1.31E+04
	Benzo(a)anthracene	56553	7.11E+02	1.00E+03	1.60E+04
	Benzo(a)pyrene	50328	7.68E+02	9.69E+02	1.90E+04
	Benzo(b)fluoranthene	205992	7.54E+02	9.69E+02	1.70E+04
	Benzo(g,h,i)perylene	191242	7.73E+02	1.09E+03	1.77E+04
	Benzo(k)fluoranthene	207089	7.53E+02	1.02E+03	1.80E+04
	Chrysene	218019	7.21E+02	9.79E+02	1.65E+04
	Dibenzo(a,h)anthracene	53703	7.97E+02	9.90E+02	3.00E+04
	Fluoranthene	206440	6.57E+02	9.05E+02	1.38E+04
	Fluorene	86737	5.68E+02	8.70E+02	1.27E+04
	Indeno(1,2,3-cd)pyrene	193395	8.09E+02	1.08E+03	1.90E+04
	Phenanthrene	85018	6.13E+02	8.69E+02	1.29E+04
	Pyrene	129000	6.77E+02	9.36E+02	1.44E+04
Lead Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	3.57E+02	5.61E+02	7.64E+03
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	4.05E+02	5.83E+02	8.31E+03
Oxygenates	64175	3.51E+02	5.15E+02	9.22E+03	64175
	1634044	3.28E+02	4.97E+02	6.68E+03	1634044
Metals	Cadmium (Water)	7440439	1.04E+03	NA	NA
	Chromium (III) (Soluble Compounds)	16065831	2.92E+03	NA	NA
	Chromium (VI)*	18540299	2.92E+03	NA	NA
	Lead	7439921	2.02E+03	NA	NA

Notes: NA: Not available

The physical and chemical properties were obtained from EGLE.

Michigan Risk-Based Corrective Action (MIRBCA)

Table 9 – Exposure Factors

Parameter Group	Parameter	Symbol	Unit	Tier 1*	Tier 2**
Averaging Time	Averaging Time for Carcinogen	AT_c	year	70	70
	Averaging Time for Non-Carcinogen	AT_{nc}	year	=ED	=ED
Age-Dependent Adjustment Factor (ADAF) For Mutagens	Resident Age Segment 0-2	BW_{0-2}	unitless	NR	10
	Resident Age Segment 2-6	BW_{2-6}	unitless	NR	3
	Resident Age Segment 6-16	BW_{6-16}	unitless	NR	3
	Resident Age Segment 16-26	BW_{16-26}	unitless	NR	1
Body Weight	Resident Child	BW_c	kg	15	15
	Resident Adult	BW_a	kg	70	80
	Resident Age Segment 0-2	BW_{0-2}	kg	NR	15
	Resident Age Segment 2-6	BW_{2-6}	kg	NR	15
	Resident Age Segment 6-16	BW_{6-16}	kg	NR	80
	Resident Age Segment 16-26	BW_{16-26}	kg	NR	80
	Non-residential Adult	BW	kg	70	80
Exposure Duration	Resident Child	ED_c	year	6	6
	Resident Adult	ED_a	year	24	20
	Resident Age Segment 0-2	ED_{0-2}	year	NR	2
	Resident Age Segment 2-6	ED_{2-6}	year	NR	4
	Resident Age Segment 6-16	ED_{6-16}	year	NR	10
	Resident Age Segment 16-26	ED_{16-26}	year	NR	10
	Non-residential Adult	ED	year	21	25
Exposure Frequency	Resident Child	EF_c	days/year	350	350
	Resident Adult	EF_a	days/year	350	350
	Resident Age Segment 0-2	EF_{0-2}	days/year	NR	350
	Resident Age Segment 2-6	EF_{2-6}	days/year	NR	350
	Resident Age Segment 6-16	EF_{6-16}	days/year	NR	350
	Resident Age Segment 16-26	EF_{16-26}	days/year	NR	350
	Nonresidential Adult	EF	days/year	245	250
Soil Ingestion Rate	Resident Child	IR_{sc}	mg/day	200	200
	Resident Adult	IR_{sa}	mg/day	100	100
	Resident Age Segment 0-2	IR_{s0-2}	mg/day	NR	200
	Resident Age Segment 2-6	IR_{s2-6}	mg/day	NR	200
	Resident Age Segment 6-16	IR_{s6-16}	mg/day	NR	100
	Resident Age Segment 16-26	IR_{s16-26}	mg/day	NR	100
	Nonresidential Adult	IR_s	mg/day	100	100
Drinking Water Ingestion Rate	Resident Child	IR_{dwc}	L/day	NS	0.78
	Resident Adult	IR_{dwa}	L/day	NS	2.5
	Residential	IR_{dwr}	L/day	2	NR
	Resident Age Segment 0-2	IR_{dw0-2}	L/day	NR	0.78
	Resident Age Segment 2-6	IR_{dw2-6}	L/day	NR	0.78
	Resident Age Segment 6-16	IR_{dw6-16}	L/day	NR	2.5
	Resident Age Segment 16-26	$IR_{dw16-26}$	L/day	NR	2.5
	Nonresidential Adult	IR_{dw}	L/day	1	2.5

Parameter Group	Parameter	Symbol	Unit	Tier 1*	Tier 2**
Exposure Time for Indoor Inhalation	Resident Child	ET_i	hr/day	NR	24
	Resident Adult	ET_i	hr/day	NR	24
	Resident Age Segment 0-2	ET_{i0-2}	hr/day	NR	24
	Resident Age Segment 2-6	ET_{i2-6}	hr/day	NR	24
	Resident Age Segment 6-16	ET_{i6-16}	hr/day	NR	24
	Resident Age Segment 16-26	ET_{i16-26}	hr/day	NR	24
	Nonresidential Adult	ET_i	hr/day	NR	8
	Adjusted Inhalation Rate (Residential)	AIR	unitless	1	NR
	Adjusted Inhalation Rate (Non-Residential Adult)	AIR	unitless	2	NR
Exposure Time for Outdoor Inhalation	Resident Child	ET_o	hr/day	NR	24
	Resident Adult	ET_o	hr/day	NR	24
	Resident Age Segment 0-2	ET_{o0-2}	hr/day	NR	24
	Resident Age Segment 2-6	ET_{o2-6}	hr/day	NR	24
	Resident Age Segment 6-16	ET_{o6-16}	hr/day	NR	24
	Resident Age Segment 16-26	ET_{o16-26}	hr/day	NR	24
	Nonresidential Adult	ET_o	hr/day	NR	8
Skin Surface Area for Dermal Contact with Soil	Resident Child	SA_c	cm^2/day	2,670	2,373
	Resident Adult	SA_a	cm^2/day	5,800	6,032
	Resident Age Segment 0-2	SA_{0-2}	cm^2/day	NR	2,373
	Resident Age Segment 2-6	SA_{2-6}	cm^2/day	NR	2,373
	Resident Age Segment 6-16	SA_{6-16}	cm^2/day	NR	6,032
	Resident Age Segment 16-26	SA_{16-26}	cm^2/day	NR	6,032
	Nonresidential Adult	SA	cm^2/day	3,300	3,527
Soil to Skin Adherence Factor	Resident Child	AF_c	mg/cm^2	0.2	0.2
	Resident Adult	AF_a	mg/cm^2	0.07	0.07
	Resident Age Segment 0-2	AF_{0-2}	mg/cm^2	NR	0.2
	Resident Age Segment 2-6	AF_{2-6}	mg/cm^2	NR	0.2
	Resident Age Segment 6-16	AF_{6-16}	mg/cm^2	NR	0.07
	Resident Age Segment 16-26	AF_{16-26}	mg/cm^2	NR	0.07
	Nonresidential Adult	AF	mg/cm^2	0.2	0.12

Notes:
NR: Not required
NS: Not specified
=ED: Equal to the exposure duration
*: Values were obtained from Michigan Rule 299
**: Values were obtained from Regional Screening Level (RSL) User Guide (USEPA, November 2024)

Michigan Risk-Based Corrective Action (MIRBCA)

Table 10 – Fate and Transport Parameters

Parameter Group	Parameter	Symbol	Unit	Tier 1*	Appendix A Equation	Relevant Pathway
Soil Depth	Depth to base of surficial soil zone	d_s	cm	NS	No. 18	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources)
	Depth to vadose zone soil source from below grade	d_{ts}	cm	NS	No. 21	Volatilization factor for volatilization to indoor air from vadose zone soil
	Depth to soil gas measurement from below grade	d_v	cm	NR	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Surficial Soil	Total porosity	θ_{TV}	cm^3/cm^3	0.43	No. 18	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources)
	Volumetric water content	θ_{wv}	cm^3/cm^3	0.15	No. 18; No. 31	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources); Soil saturation concentration
	Volumetric air content #	θ_{av}	cm^3/cm^3	0.28	No. 18; No. 31	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources); Soil saturation concentration
	Dry soil bulk density	ρ_{bv}	g/cm^3	1.5	No. 18; No. 31	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources); Soil saturation concentration
	Fraction of organic carbon content	f_{ocv}	g/g	0.006	No. 18; No. 31	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources); Soil saturation concentration

TABLE 10 – FATE AND TRANSPORT PARAMETERS

Parameter Group	Parameter	Symbol	Unit	Tier 1*	Appendix A Equation	Relevant Pathway
Vadose Zone	Total porosity	θ_{TV}	cm^3/cm^3	0.43	No. 23	Effective diffusion coefficients
	Volumetric water content	θ_{wv}	cm^3/cm^3	0.30	No. 21; No. 23; No. 30	Volatilization factor for volatilization to indoor air from vadose zone soil; Effective diffusion coefficients; Equilibrium conversion factor to convert soil leachate concentration to soil concentration
	Volumetric air content #	θ_{av}	cm^3/cm^3	0.13	No. 21; No. 23; No. 30	Volatilization factor for volatilization to indoor air from vadose zone soil; Effective diffusion coefficients; Equilibrium conversion factor to convert soil leachate concentration to soil concentration
	Dry soil bulk density	ρ_{bv}	g/cm^3	1.5	No. 21; No. 23; No. 30	Volatilization factor for volatilization to indoor air from vadose zone soil; Effective diffusion coefficients; Equilibrium conversion factor to convert soil leachate concentration to soil concentration
	Fraction of organic carbon content	f_{ocv}	g/g	0.002	No. 21; No. 23; No. 30	Volatilization factor for volatilization to indoor air from vadose zone soil; Effective diffusion coefficients; Equilibrium conversion factor to convert soil leachate concentration to soil concentration
	Thickness of vadose zone below enclosed space floor	h_v	cm	75 (Residential); 260 (Non-residential)	No. 23	Effective diffusion coefficients
Soil in Cracks	Total porosity	θ_{TC}	cm^3/cm^3	0.43	No. 23	Effective diffusion coefficients
	Volumetric water content	θ_{wc}	cm^3/cm^3	0.3	No. 23	Effective diffusion coefficients
	Volumetric air content #	θ_{ac}	cm^3/cm^3	0.13	No. 23	Effective diffusion coefficients

TABLE 10 – FATE AND TRANSPORT PARAMETERS

Parameter Group	Parameter	Symbol	Unit	Tier 1*	Appendix A Equation	Relevant Pathway
Capillary Fringe	Total porosity	θ_{TS}	cm^3/cm^3	0.43	No. 23	Effective diffusion coefficients
	Volumetric water content	θ_{wcap}	cm^3/cm^3	0.352	No. 23	Effective diffusion coefficients
	Volumetric air content #	θ_{acap}	cm^3/cm^3	0.078	No. 23	Effective diffusion coefficients
	Thickness of capillary fringe	h_{cf}	cm	25	No. 23	Effective diffusion coefficients
Groundwater Parameters	Depth to groundwater	L_{GW}	cm	NS	No. 22	Volatilization factor for volatilization to indoor air from groundwater
	Dimension of groundwater source area parallel to the groundwater flow direction	W	cm	NR	No. 29	Groundwater mixing zone thickness
	Dimension of groundwater source area perpendicular to the groundwater flow direction	Y	cm	NR	No. 25	Dilution attenuation factor in the groundwater/saturated zone (Domenico Model)
	Total porosity	θ_{TS}	cm^3/cm^3	NR	No. 26	Retardation factor for saturated zone
	Dry soil bulk density	ρ_{bv}	g/cm^3	NR	No. 26	Retardation factor for saturated zone
	Fraction of organic carbon content	f_{ocs}	g/g	NR	No. 26	Retardation factor for saturated zone
	Aquifer thickness	d_a	cm	NR	No. 29	Groundwater mixing zone thickness
	Groundwater mixing zone thickness	δ_{gw}	cm	NR	No. 25; No. 28; No. 29	Dilution attenuation factor in the groundwater/saturated zone (Domenico Model); Dilution attenuation factor for the groundwater mixing zone (Summers Model); Groundwater mixing zone thickness

TABLE 10 – FATE AND TRANSPORT PARAMETERS

Parameter Group	**Parameter**	**Symbol**	**Unit**	**Tier 1***	**Appendix A Equation**	**Relevant Pathway**
	Hydraulic conductivity	K	cm/year	NR	No. 28; No. 29	Dilution attenuation factor for the groundwater mixing zone (Summers Model); Goundwater mixing zone thickness
	Hydraulic gradient	i	cm/cm	NR	No. 28; No. 29	Dilution attenuation factor for the groundwater mixing zone (Summers Model); Groundwater mixing zone thickness
	Infiltration rate	I	cm/day	NR	No. 28; No. 29	Dilution attenuation factor for the groundwater mixing zone (Summers Model); Groundwater mixing zone thickness
Ambient Air Parameters	Dispersion factor for 0.5-acre source for volatilization factor (VF) (infinite source, finite source, and mass balance equations)	Q/C	$(g/m^2\text{-}s)/(kg/m^3)$	82.33	No. 18	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources)
	Exposure interval for VF (infinite source and mass balance equations)	t	seconds	=ED	No. 18	Volatilization factors for emissions from surficial soil to ambient air (finite and mass limit sources)
	Dispersion factor for 0.5-acre source for wind particulate emission factor (PEF)	Q/C	$(g/m^2\text{-}s)/(kg/m^3)$	82.33	No. 19	Wind particulate emission factor for ambient air inhalation from surficial soil
	Fraction of vegetative cover	V	m^2/m^2	0.5	No. 19	Wind particulate emission factor for ambient air inhalation from surficial soil
	Mean annual wind speed	U_m	m/s	NR	No. 19	Wind particulate emission factor for ambient air inhalation from surficial soil

TABLE 10 – FATE AND TRANSPORT PARAMETERS

Parameter Group	Parameter	Symbol	Unit	Tier 1*	Appendix A Equation	Relevant Pathway
	Equivalent threshold value of windspeed at 7 m	U_t	m/s	NR	No. 19	Wind particulate emission factor for ambient air inhalation from surficial soil
	Function dependent on U_m/U_t derived using Cowherd et al. 1985	F(x)	unitless	NR	19	Wind particulate emission factor for ambient air inhalation from surficial soil

Notes:
NR: Not required NS: Not specified
ED: Exposure duration
#: Calculated value. *Volumetric Air Content = Total Porosity - Volumetric Water Content*
*: Values were obtained from Michigan Rule 299

Michigan Risk-Based Corrective Action (MIRBCA)

Table 11 – Building Parameters

Parameter Groups	Parameter	Symbol	Units	Tier 1[1]	Appendix A Equation	Relevant Pathway
Volumetric Flow Rate of Soil Gas Entering the Enclosed Space	Residential	Q_{soil}	cm^3/s	0.81	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	Q_{soil}	cm^3/s	2.1	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Building Floor Thickness	Residential	L_{crack}	cm	15	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	L_{crack}	cm	15	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Soil-Building Pressure Differential	Residential	ΔP	$g/cm\text{-}s^2$	10	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	ΔP	$g/cm\text{-}s^2$	10	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Soil Gas Permeability	Residential	k_v	cm^2	5.00E-09	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	k_v	cm^2	5.00E-09	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Air Exchange Rate	Residential	ER	1/ hr	0.25	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	ER	1/ hr	0.25	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Height of Building	Residential	H_B	cm	244	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	H_B	cm	244	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Length of Building	Residential	L_B	cm	1,056	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	L_B	cm	1,928	No. 20	Attenuation factor for volatilization to indoor air from soil gas

TABLE 11 – BUILDING PARAMETERS

Parameter Groups	Parameter	Symbol	Units	Tier 1[1]	Appendix A Equation	Relevant Pathway
Width of Building	Residential	W_B	cm	1,056	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	W_B	cm	1,928	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Depth Below Ground to Bottom of Building Floor	Residential	L_F	cm	200	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	L_F	cm	15	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Percent of Building Floor Area that is Cracked	Residential	η_c	%	1	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Nonresidential	η_c	%	1	No. 20	Attenuation factor for volatilization to indoor air from soil gas
Inputs for Sump Model	Surface area of the sump, Residential	A_{sump}	m^2	0.29	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Surface area of the sump, Nonresidential	A_{sump}	m^2	0.29	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Diameter of the perimeter foundation drain, Residential	d_d	inches	4	No. 20	Attenuation factor for volatilization to indoor air from soil gas
	Diameter of the perimeter foundation drain, Nonresidential	d_d	inches	4	No. 20	Attenuation factor for volatilization to indoor air from soil gas

Notes: NS: Not specified

NR: Not required

The software provides two options, i.e., either enter Q_{soil} or the values of the two parameters (ΔP and k_v) used to estimate Q_{soil}.

[1]Values were obtained from Michigan Rule 299

Michigan Risk-Based Corrective Action (MIRBCA)

Table 12 – Effective Solubility

Chemical Group	Chemical of Concern	Chemical Abstract Service Number	Molecular Weight (MW)[1] [g/mol]	Pure Chemical Solubility (S)[1] [mg/L]	Gasoline				Diesel			
					Weight Percent Range[2] [%]	Average Weight Fraction [unitless]	Mole Fraction[3] [unitless]	Effective Solubility[4] [mg/L]	Weight Percent Range[2] [%]	Average Weight Fraction [unitless]	Mole Fraction[3] [unitless]	Effective Solubility[4] [mg/L]
Aromatic Compounds	Benzene	71432	78	1,790	0.12-3.5	0.018	0.024	43.5	0.003-0.1	5.2E-04	1.5E-03	2.7
	Toluene	108883	92	526	2.73-21.8	0.12265	0.140	73.5	0.007-0.7	3.5E-03	8.8E-03	4.6
	Ethylbenzene	100414	106	169	0.36-2.86	0.0161	0.016	2.7	0.007-0.2	1.0E-03	2.2E-03	0.4
	Total xylenes	1330207	106	106	3.22-8.31	0.05765	0.057	6.0	0.037-1.109	5.7E-03	1.2E-02	1.3
	1,2,4-Trimethylbenzene	95636	120	57	0.66-3.3	0.0198	0.017	1.0	NA	NA	NA	NC
	1,3,5-Trimethylbenzene	108678	120	48.2	0.13-1.15	0.0064	0.006	0.3	0.09-0.24	1.7E-03	3.2E-03	0.2
	sec-Butylbenzene	135988	134	17.6	0.01-0.13	0.0007	0.001	0.01	NA	NA	NA	NC
	tert-Butylbenzene	98066	134	29.5	0.12	0.12	0.094	2.8	NA	NA	NA	NC
	n-Propylbenzene	103651	120	52.2	0.08-0.72	0.004	0.003	0.18	0.03-0.048	3.9E-04	7.5E-04	0.04
Aliphatic Compounds	n-Hexane	110543	86	9.5	0.24-3.5	0.0187	0.023	0.2	--	--	--	--
	2,2,4-Trimethylpentane	540841	114	2.44	0.32-4.58	0.0245	0.023	0.06	--	--	--	--
	Pentane	109660	72	38	5.75-10.92	0.08335	0.121	4.6	--	--	--	--
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	128	31	0.09-0.49	0.0029	0.002	0.07	0.01-0.8	4.1E-03	7.3E-03	0.2
	2-Methylnaphthalene	91576	142	24.6	NA	NA	NA	NA	0.001-1.49	7.5E-03	1.2E-02	0.3
	Acenaphthene	83329	154	3.9	--	--	--	--	NA	NA	NA	NC
	Acenaphthylene	208968	152	16.1	--	--	--	--	NA	NA	NA	NC
	Anthracene	120127	178	0.0434	--	--	--	--	0.000003-0.02	1.0E-04	1.3E-04	5.6E-06
	Benzo(a)anthracene	56553	228	0.0094	--	--	--	--	0.0000021-0.00067	3.4E-06	3.4E-06	3.2E-08
	Benzo(a)pyrene	50328	252	0.00162	--	--	--	--	0.000005-0.00084	4.2E-06	3.9E-06	6.2E-09
	Benzo(b)fluoranthene	205992	252	0.0015	--	--	--	--	0.0000003-0.000194	9.7E-07	8.9E-07	1.3E-09
	Benzo(g,h,i)perylene	191242	276	0.00026	--	--	--	--	0.0000009-0.00004	2.0E-07	1.7E-07	4.4E-11
	Benzo(k)fluoranthene	207089	252	0.0008	--	--	--	--	0.0000003-0.000195	9.8E-07	8.9E-07	7.1E-10
	Chrysene	218019	228	0.002	--	--	--	--	0.000045	4.5E-05	4.5E-05	9.1E-08
	Dibenzo(a,h)anthracene	53703	278	0.00249	--	--	--	--	NA	NA	NA	NC
	Fluoranthene	206440	202	0.26	--	--	--	--	0.0000007-0.02	1.0E-04	1.1E-04	3.0E-05
	Fluorene	86737	166	1.69	--	--	--	--	0.034-0.15	9.2E-04	1.3E-03	2.2E-03

TABLE 12 – EFFECTIVE SOLUBILITY

Chemical Group	Chemical of Concern	Chemical Abstract Service Number	Molecular Weight (MW)[1] [g/mol]	Pure Chemical Solubility (S)[1] [mg/L]	Gasoline: Weight Percent Range[2] [%]	Gasoline: Average Weight Fraction [unitless]	Gasoline: Mole Fraction[3] [unitless]	Gasoline: Effective Solubility[4] [mg/L]	Diesel: Weight Percent Range[2] [%]	Diesel: Average Weight Fraction [unitless]	Diesel: Mole Fraction[3] [unitless]	Diesel: Effective Solubility[4] [mg/L]
	Indeno(1,2,3-cd)pyrene	193395	276	0.00019	--	--	--	--	0.000001-0.000097	4.9E-07	4.1E-07	7.7E-11
	Phenanthrene	85018	178	1.15	--	--	--	--	0.000027-0.3	1.5E-03	1.9E-03	2.2E-03
	Pyrene	129000	202	0.135	--	--	--	--	0.000018-0.015	7.5E-05	8.5E-05	1.2E-05
Lead Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	99	8,600	N/A	N/A	N/A	N/A	--	--	--	--
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	188	3,910	N/A	N/A	N/A	N/A	--	--	--	--
Oxygenates	Ethanol	64175	46	1,000,000	N/A	N/A	N/A	N/A	--	--	--	--
	Methyl-tert-butyl-ether (MTBE)	1634044	88	51,000	N/A	N/A	N/A	N/A	--	--	--	--
Metals	Cadmium (Water)	7440439	112	NA	--	--	--	--	--	--	--	--
	Chromium (III) (Soluble Compounds)	16065831	52	NA	--	--	--	--	--	--	--	--
	Chromium (VI)	18540299	52	1,690,000	--	--	--	--	--	--	--	--
	Lead	7439921	207	NA	N/A	N/A	N/A	N/A	--	--	--	--

Notes:

Molecular weight of gasoline 105 g/mol — Obtained from EPA Online Tools for Site Assessment Calculation (USEPA 2021). www3.epa.gov/ceampubl/learn2model/part-two/onsite/es.html

Molecular weight of diesel 230 g/mol — Obtained from EPA Online Tools for Site Assessment Calculation (USEPA 2021). www3.epa.gov/ceampubl/learn2model/part-two/onsite/es.html

--: Not a chemical of concern

N/A: Not applicable

NA: Not available

NC: Not calculated due to lack of an input value

1: Obtained from Table 8(a) of MIRBCA (July 2025)

2: Obtained from Appendix A of Total Petroleum Hydrocarbon (TPH) Volume 3, Selection of Representative TPH Fractions Based on Fate and Transport Considerations. TPH Criteria Working Group (July 1997)

3: Calculated using the molecular weight and average weight fraction of a COC, along with the molecular weight of the petroleum hydrocarbon product (gasoline/diesel)

4: Calculated as the product of pure chemical solubility and mole fraction

Table 13 – Tier 1 and Tier 2 Groundwater Ingestion RBTLs Applicable at the Point of Exposure (POE)

Chemical Group	Chemical of Concern	CAS Number	Tier 1 RBTL at POE Residential Value [µg/L]	Tier 1 RBTL at POE Residential Source	Tier 1 RBTL at POE Nonresidential Value [µg/L]	Tier 1 RBTL at POE Nonresidential Source	Tier 2 RBTL at POE Residential Value [µg/L]	Tier 2 RBTL at POE Residential Source	Tier 2 RBTL at POE Nonresidential Value [µg/L]	Tier 2 RBTL at POE Nonresidential Source
Aromatic Compounds	Benzene	71432	5	A	5	A	5	A	5	A
	Toluene	108883	790	E	790	E	790	E	790	E
	Ethylbenzene	100414	74	E	74	E	74	E	74	E
	Total xylenes	1330207	280	E	280	E	280	E	280	E
	1,2,4-Trimethylbenzene	95636	63	E	63	E	63	E	63	E
	1,3,5-Trimethylbenzene	108678	72	E	72	E	72	E	72	E
	sec-Butylbenzene	135988	80	R. 299	230	R.299	2,000	C,NC	4,600	A,NC
	tert-Butylbenzene	98066	80	R. 299	230	R.299	2,000	C,NC	4,600	A,NC
	n-Propylbenzene	103651	80	R. 299	230	R.299	2,000	C,NC	4,600	A,NC
Aliphatic Compounds	n-Hexane	110543	3,000	R. 299	8,600	R.299	NC	--	NC	--
	2,2,4-Trimethylpentane	540841	NC	R. 299	NC	R.299	NC	--	NC	--
	Pentane	109660	NC	R. 299	NC	R.299	NC	--	NC	--
Polycyclic Aromatic Hydrocarbons (PAHs)	Naphthalene	91203	520	R. 299	1,500	R.299	6.5	AA,C	11	A,C
	2-Methylnaphthalene	91576	260	R. 299	750	R.299	80	C,NC	190	A,NC
	Acenaphthene	83329	1,300	R. 299	3,800	R.299	1,200	C,NC	2,800	A,NC
	Acenaphthylene	208968	52	R. 299	150	R.299	1,200	C,NC	2,800	A,NC
	Anthracene	120127	43	R. 299	43	R.299	6,000	C,NC	14,000	A,NC
	Benzo(a)anthracene	56553	2.1	R. 299	8.5	R.299	2.5	AA,C	13	A,C
	Benzo(a)pyrene	50328	0.2	A	0.2	A	0.2	A	0.2	A
	Benzo(b)fluoranthene	205992	1.5	R. 299	1.5	R.299	2.5	AA,C	13	A,C

Table 13 – Tier 1 and Tier 2 Groundwater Ingestion RBTLs Applicable at the POE

Chemical Group	Chemical of Concern	CAS Number	Tier 1 RBTL at POE Residential Value [μg/L]	Tier 1 RBTL at POE Residential Source	Tier 1 RBTL at POE Nonresidential Value [μg/L]	Tier 1 RBTL at POE Nonresidential Source	Tier 2 RBTL at POE Residential Value [μg/L]	Tier 2 RBTL at POE Residential Source	Tier 2 RBTL at POE Nonresidential Value [μg/L]	Tier 2 RBTL at POE Nonresidential Source
	Benzo(g,h,i)perylene	191242	1.0	R. 299	1.0	R.299	40	C,NC	93	A,NC
	Benzo(k)fluoranthene	207089	1.0	R. 299	1.0	R.299	25	AA,C	130	A,C
	Chrysene	218019	1.6	R. 299	1.6	R.299	250	AA,C	1,300	A,C
	Dibenzo(a,h)anthracene	53703	2	R. 299	2	R.299	0.3	AA,C	1.3	A,C
	Fluoranthene	206440	210	R. 299	210	R.299	800	C,NC	1,900	A,NC
	Fluorene	86737	880	R. 299	2,000	R.299	800	C,NC	1,900	A,NC
	Indeno(1,2,3-cd)pyrene	193395	2	R. 299	2	R.299	2.5	AA,C	13	A,C
	Phenanthrene	85018	52	R. 299	150	R.299	600	C,NC	1,400	A,NC
	Pyrene	129000	140	R. 299	140	R.299	600	C,NC	1,400	A,NC
Lead Scavengers	1,2-Dichloroethane (1,2-DCA)	107062	5	A	5	A	5	A	5	A
	Ethylene dibromide (1,2-Dibromoethane or EDB)	106934	0.05	A	0.05	A	0.05	A	0.05	A
Oxygenates	Ethanol	64175	1,900,000	R. 299	3,800,000	R.299	1,200,000	C,NC	2,900,000	A,NC
	Methyl-tert-butyl-ether (MTBE)	1634044	40	E	40	E	40	E	40	E
Metals	Cadmium (Water)	7440439	5	A	5	A	5	A	5	A
	Chromium (III) (Soluble Compounds)	16065831	100	A	100	A	100	A	100	A
	Chromium (VI)	18540299	100	A	100	A	100	A	100	A
	Lead	7439921	4	L	4	L	4	L	4	L

Notes:

A: Michigan drinking water standard
E: Aesthetic drinking water value
A,NC: Adult noncarcinogenic calculated SSTL
A,C: Adult carcinogenic calculated SSTL
AA,C: Age-adjusted carcinogenic calculated SSTL
--: Not calculated due to lack of toxicity
N/A: Not Applicable
C, NC: Child noncarcinogenic calculated SSTL
R.299: Rule 299 of the Michigan Administrative Code
L: Refer to footnote L in R.299.49, Footnotes for generic cleanup criteria table

APPENDICES

Appendix A	Equations Included in the MIRBCA Software for the Development of Site-Specific Target Levels (SSTLs)
Appendix B	Determining if the Groundwater Protection Exposure Pathway is Incomplete for Future Use
Appendix C	Development of a Site-Specific Biodegradation Rate
Appendix D	Model Water Well Survey Form and Letter
Appendix E	MIRBCA Forms
Appendix F	User's Guide for the MIRBCA Forms

Appendix A – Equations Included in the MIRBCA Software for the Development of Site-Specific Target Levels (SSTLs)

TABLE OF EQUATIONS

Direct Routes of Exposure

Ingestion of Groundwater for Drinking Water (Child and Adult Residents and Nonresidential Adult)

Carcinogenic effects

$$SSTL_{dwing} = \frac{TR \times BW \times AT_c \times 365 \times 10^3}{ED \times EF \times IR_{dw} \times SF_o}$$

Non-carcinogenic Effects

$$SSTL_{dwing} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_o \times 10^3}{ED \times EF \times IR_{dw}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

where:

$SSTL_{dwing}$	=	Site-specific target level for ingestion of groundwater for drinking water [µg/L]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
BW	=	Body weight [kg]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [days/year]
IR_{dw}	=	Drinking water ingestion rate [L/day]
SF_o	=	Oral cancer slope factor [$(mg/kg\text{-}day)^{-1}$]
RfD_o	=	Oral reference dose [mg/kg-day]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
10^3	=	Converts mg to µg [µg/mg]

Notes: the numerical values for exposure factors will vary for a child and adult residents, and non-resident adult.

This equation is included in Rule 299 but for the residential scenario the receptors (child or adult or age-adjusted) are not clear. Also, Rule 299 equation for non-carcinogenic effects included "relative source contribution" (RSC) but not for the carcinogenic effects equation.

Ingestion of Groundwater for Drinking Water (Age-Adjusted Resident)

Carcinogenic Effects

$$SSTL_{dwing} = \frac{TR \times AT_c \times 365 \times 10^3}{IR_{dwaa} \times SF_o}$$

Non-carcinogenic Effects

$$SSTL_{dwing} = \frac{THQ \times AT_{nc} \times 365 \times RfD_o \times 10^3}{IR_{dwaa}}$$

where,

$$IR_{dwaa} = \left[\frac{ED_c \times EF_c \times IR_{dwc}}{BW_c} + \frac{ED_a \times EF_a \times IR_{dwa}}{BW_a}\right]$$

where:

$SSTL_{dwing}$	=	Site-specific target level for ingestion of groundwater for drinking water [µg/L]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
SF_o	=	Oral cancer slope factor [(mg/kg-day)$^{-1}$]
RfD_o	=	Oral reference dose [mg/kg-day]
IR_{dwaa}	=	Age-adjusted drinking water ingestion rate for carcinogens and non-carcinogens [L/kg]
IR_{dwaam}	=	Age-adjusted drinking water ingestion rate for mutagens [L/kg]
BW_c	=	Body weight for child [kg]
BW_a	=	Body weight for adult [kg]
BW_{0-2}	=	Body weight for 0-2 years [kg]
BW_{2-6}	=	Body weight for 2-6 years [kg]
BW_{6-16}	=	Body weight for 6-16 years [kg]
BW_{16-26}	=	Body weight for 16-26 years [kg]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
ED_{0-2}	=	Exposure duration for 0-2 years [year]
ED_{2-6}	=	Exposure duration for 2-6 years [year]
ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]

Ingestion of Groundwater for Drinking Water (Age-Adjusted Resident)

continued

Mutagenic Effects

$$SSTL_{dwing} = \frac{TR \times AT_c \times 365 \times 10^3}{IR_{dwaam} \times SF_o}$$

where,

$$IR_{dwaam} = \left[\frac{EF_{0-2} \times ED_{0-2} \times IR_{dw0-2} \times 10}{BW_{0-2}} + \frac{EF_{2-6} \times ED_{2-6} \times IR_{dw2-6} \times 3}{BW_{2-6}} + \frac{EF_{6-16} \times ED_{6-16} \times IR_{dw6-16} \times 3}{BW_{6-16}} + \frac{EF_{16-26} \times ED_{16-26} \times IR_{dw16-26} \times 1}{BW_{16-26}} \right]$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299 because Rule 299 does not consider the age adjusted resident for drinking water ingestion pathway.

EF_c	=	Exposure frequency for child [days/year]
EF_a	=	Exposure frequency for adult [days/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [days/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [days/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [days/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [days/year]
IR_{dwc}	=	Drinking water ingestion rate for child [L/day]
IR_{dwa}	=	Drinking water ingestion rate for adult [L/day]
IR_{dw0-2}	=	Drinking water ingestion rate for 0-2 years [L/day]
IR_{dw2-6}	=	Drinking water ingestion rate for 2-6 years [L/day]
IR_{dw6-16}	=	Drinking water ingestion rate for 6-16 years [L/day]
$IR_{dw16-26}$	=	Drinking water ingestion rate for 16-26 years [L/day]
10	=	Age-dependent adjustment factor for 0-2 years [unitless]
3	=	Age-dependent adjustment factor for 2-6 years [unitless]
3	=	Age-dependent adjustment factor for 6-16 years [unitless]
1	=	Age-dependent adjustment factor for 16-26 years unitless]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
10^3	=	Converts mg to µg [µg/mg]

Indoor Inhalation of Vapors (Child and Adult Residents and Nonresidential Adult)

Carcinogenic Effects

$$SSTL_{ininh} = \frac{TR \times AT_c \times 365 \times 24}{ET_i \times ED \times EF \times IURF}$$

Non-carcinogenic Effects

$$SSTL_{ininh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 10^3 \times 24}{ET_i \times ED \times EF}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is included in Rule 299.

where:

$SSTL_{ininh}$	=	Site-specific target level for indoor inhalation of vapors [μg/m^3]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ET_i	=	Exposure time for indoor inhalation [hours/day]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [days/year]
IURF	=	Inhalation unit risk factor [(μg/m^3)$^{-1}$]
RfC	=	Chronic inhalation reference concentration [mg/m^3]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
24	=	Converts ET_{in} hours to days [hours/day]
10^3	=	Converts mg to μg [μg/mg]

Notes: the numerical values for exposure factors will vary for a child and adult residents, and non-resident adult.

Indoor Inhalation of Vapors (Age-Adjusted Resident)

Carcinogenic Effects

$$SSTL_{ininh} = \frac{TR \times AT_c \times 365 \times 24}{ET_i \times ED_{aa} \times EF \times IURF}$$

Non-carcinogenic Effects

$$SSTL_{ininh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 10^3 \times 24}{ET_i \times ED_{aa} \times EF}$$

where,

$$ED_{aa} = [ED_c + ED_a]$$

Mutagenic Effects

$$SSTL_{ininh} = \frac{TR \times AT_c \times 365 \times 24}{IURF \times 10^3 \times \begin{bmatrix} EF_{0-2} \times ED_{0-2} \times ET_{i0-2} \times 10 + \\ EF_{2-6} \times ED_{2-6} \times ET_{i2-6} \times 3 + \\ EF_{6-16} \times ED_{6-16} \times ET_{i6-16} \times 3 + \\ EF_{16-26} \times ED_{16-26} \times ET_{i16-26} \times 1 \end{bmatrix}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is included in Rule 299. Note Rule 299 does not include mutagenic effects.

where:

$SSTL_{ininh}$	=	Site-specific target level for indoor inhalation of vapors [µg/m^3]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ET_i	=	Exposure time for indoor inhalation [hours/day]
ET_{i0-2}	=	Exposure time for 0-2 years [hours/day]
ET_{i2-6}	=	Exposure time for 2-6 years [hours/day]
ET_{i6-16}	=	Exposure time for 6-16 years [hours/day]
ET_{i16-26}	=	Exposure time for 16-26 years [hours/day]
ED_{aa}	=	Age adjusted exposure duration [year]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
ED_{0-2}	=	Exposure duration for 0-2 years [year]
ED_{2-6}	=	Exposure duration for 2-6 years [year]
ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]
EF	=	Exposure frequency [days/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [days/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [days/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [days/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [days/year]
$IURF$	=	Inhalation unit risk factor [(µg/m^3)$^{-1}$]
RfC	=	Chronic inhalation reference concentration [mg/m^3]
10^3	=	Converts mg to µg [µg/mg]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
24	=	Converts ET_i hours to day [24 hours/day]
10	=	Age-dependent adjustment factor for 0-2 yr [unitless]
3	=	Age-dependent adjustment factor for 2-6 yr [unitless]
3	=	Age-dependent adjustment factor for 6-16 yr [unitless]
1	=	Age-dependent adjustment factor for 16-26 yr [unitless]

Carcinogenic Effects

$$SSTL_{oinh} = \frac{TR \times AT_c \times 365 \times 24}{ET_o \times ED \times EF \times IURF}$$

Non-carcinogenic Effects

$$SSTL_{oinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 10^3 \times 24}{ET_o \times ED \times EF}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where:

$SSTL_{oinh}$	=	Site-specific target level for outdoor inhalation of vapors [μg/m^3]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ET_o	=	Exposure time for outdoor inhalation [hours/day]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [days/year]
IURF	=	Inhalation unit risk factor [(μg/m^3)$^{-1}$]
RfC	=	Chronic inhalation reference concentration [mg/m^3]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
24	=	Converts ET_{in} hours to days [hours/day]
10^3	=	Converts mg to μg [μg/mg]

Notes: the numerical values for exposure factors will vary for a child and adult residents, and non-resident adult.

Carcinogenic Effects

$$SSTL_{oinh} = \frac{TR \times AT_c \times 365 \times 24}{ET_o \times ED_{aa} \times EF \times IURF}$$

Non-carcinogenic Effects

$$SSTL_{oinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 10^3 \times 24}{ET_o \times ED_{aa} \times EF}$$

where,

$$ED_{aa} = [ED_c + ED_a]$$

Mutagenic Effects

$$SSTL_{oinh} = \frac{TR \times AT_c \times 365 \times 24}{IURF \times 10^3 \times \begin{bmatrix} EF_{0-2} \times ED_{0-2} \times ET_{o0-2} \times 10 + \\ EF_{2-6} \times ED_{2-6} \times ET_{o2-6} \times 3 + \\ EF_{6-16} \times ED_{6-16} \times ET_{o6-16} \times 3 + \\ EF_{16-26} \times ED_{16-26} \times ET_{o16-26} \times 1 \end{bmatrix}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where:

$SSTL_{oinh}$	=	Site-specific target level for indoor inhalation of vapors [µg/m^3]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ET_o	=	Exposure time for indoor inhalation [hours/day]
ET_{o0-2}	=	Exposure time for 0-2 years [hours/day]
ET_{o2-6}	=	Exposure time for 2-6 years [hours/day]
ET_{o6-16}	=	Exposure time for 6-16 years [hours/day]
ET_{o16-26}	=	Exposure time for 16-26 years [hours/day]
ED_{aa}	=	Age adjusted exposure duration [year]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
ED_{0-2}	=	Exposure duration for 0-2 years [year]
ED_{2-6}	=	Exposure duration for 2-6 years [year]
ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]
EF	=	Exposure frequency [days/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [days/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [days/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [days/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [days/year]
$IURF$	=	Inhalation unit risk factor [(µg/m^3)$^{-1}$]
RfC	=	Chronic inhalation reference concentration [mg/m^3]
10^3	=	Converts mg to µg [µg/mg]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
24	=	Converts ET_i hours to day [24 hours/day]
10	=	Age-dependent adjustment factor for 0-2 yr [unitless]
3	=	Age-dependent adjustment factor for 2-6 yr [unitless]
3	=	Age-dependent adjustment factor for 6-16 yr [unitless]
1	=	Age-dependent adjustment factor for 16-26 yr [unitless]

Ingestion of Soil (Child and Adult Residents and Nonresidential Adult)

Carcinogenic Effects

$$SSTL_{sing} = \frac{TR \times BW \times AT_c \times 365 \times 10^3}{ED \times EF \times IR_s \times RBA \times SF_o \times 10^{-6}}$$

Non-carcinogenic Effects

$$SSTL_{sing} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_o \times 10^3}{ED \times EF \times IR_s \times RBA \times 10^{-6}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where:

$SSTL_{sing}$	=	Site-specific target level for ingestion of soil [µg/kg]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
BW	=	Body weight [kg]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [days/year]
IR_s	=	Soil ingestion rate [mg/day]
RBA	=	Relative bioavailability [unitless]
SF_o	=	Oral cancer slope factor [$(mg/kg\text{-}day)^{-1}$]
RfD_o	=	Oral reference dose [mg/kg-day]
365	=	Converts AT_c, AT_{nc} in years to days [day/year]
10^3	=	Converts mg to µg [µg/mg]
10^{-6}	=	Converts mg to kg [kg/mg]

Notes: the numerical values for exposure factors will vary for a child and adult residents, and non-resident adult.

Carcinogenic Effects

$$SSTL_{sd} = \frac{TR \times AT_c \times 365 \times BW \times GIABS \times 10^3}{EF \times ED \times SF_o \times SA \times AF \times ABS_d \times 10^{-6}}$$

Non-carcinogenic Effects

$$SSTL_{sd} = \frac{THQ \times AT_{nc} \times 365 \times BW \times RfD_o \times GIABS \times 10^3}{EF \times ED \times SA \times AF \times ABS_d \times 10^{-6}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where,

$SSTL_{sd}$	=	Site-specific target level for dermal contact with soil [μg/kg]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
BW	=	Body weight [kg]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [days/year]
SA	=	Skin surface area for dermal contact with soil [cm^2/day]
AF	=	Soil to skin adherence factor [mg/cm^2]
$GIABS$	=	Gastrointestinal absorption [unitless]
ABS_d	=	Dermal absorption fraction [unitless]
SF_o	=	Oral cancer slope factor [$(mg/kg\text{-}day)^{-1}$]
RfD_o	=	Oral reference dose [mg/kg-day]
365	=	Converts AT_c, AT_{nc} in years to days [day/year]
10^3	=	Converts mg to μg [μg/mg]
10^{-6}	=	Converts mg to kg [kg/mg]

Notes: the numerical values for exposure factors will vary for a child and adult residents, and non-resident adult.

Carcinogenic Effects

$$SSTL_{sing} = \frac{TR \times AT_c \times 365 \times 10^3}{IR_{saa} \times RBA \times SF_o \times 10^{-6}}$$

Non-carcinogenic Effects

$$SSTL_{sing} = \frac{THQ \times AT_{nc} \times 365 \times RfD_o \times 10^3}{IR_{saa} \times RBA \times 10^{-6}}$$

where,

$$IR_{saa} = \left[\frac{ED_c \times EF_c \times IR_{sc}}{BW_c} + \frac{ED_a \times EF_a \times IR_{sa}}{BW_a}\right]$$

Mutagenic Effects

$$SSTL_{sing} = \frac{TR \times AT_c \times 365 \times 10^3}{IR_{saam} \times RBA \times SF_o \times 10^{-6}}$$

where,

$$IR_{saam} = \left[\begin{array}{c} \frac{EF_{0-2} \times ED_{0-2} \times IR_{s0-2} \times 10}{BW_{0-2}} + \\ \frac{EF_{2-6} \times ED_{2-6} \times IR_{s2-6} \times 3}{BW_{2-6}} + \\ \frac{EF_{6-16} \times ED_{6-16} \times IR_{s6-16} \times 3}{BW_{6-16}} + \\ \frac{EF_{16-26} \times ED_{16-26} \times IR_{s16-26} \times 1}{BW_{16-26}} \end{array}\right]$$

where:

$SSTL_{sing}$	=	Site-specific target level for ingestion of soil [µg/kg]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
IR_{saa}	=	Age-adjusted soil ingestion rate for carcinogens and non-carcinogens [mg/kg]
IR_{saam}	=	Age-adjusted soil ingestion rate for mutagens [mg/kg]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
ED_{0-2}	=	Exposure duration for 0-2 years [year]
ED_{2-6}	=	Exposure duration for 2-6 years [year]
ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]
EF_c	=	Exposure frequency for child [days/year]
EF_a	=	Exposure frequency for adult [days/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [days/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [days/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [days/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [days/year]
IR_{sc}	=	Soil ingestion rate for child [mg/day]
IR_{sa}	=	Soil ingestion rate for adult [mg/day]
IR_{s0-2}	=	Soil ingestion rate for 0-2 years [mg/day]
IR_{s2-6}	=	Soil ingestion rate for 2-6 years [mg/day]
IR_{s6-16}	=	Soil ingestion rate for 6-16 years [mg/day]
IR_{s16-26}	=	Soil ingestion rate for 16-26 years [mg/day]
BW_c	=	Body weight for child [kg]
BW_a	=	Body weight for adult [kg]
BW_{0-2}	=	Body weight for 0-2 years [kg]
BW_{2-6}	=	Body weight for 2-6 years [kg]
BW_{6-16}	=	Body weight for 6-16 years [kg]
BW_{16-26}	=	Body weight for 16-26 years [kg]

Ingestion of Soil (Age-Adjusted Resident)
continued

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

A combined equation of ingestion of and dermal contact with soil for direct exposure for carcinogenic and non-carcinogenic effects is included in Rule 299. Note Rule 299 does not consider mutagenic effects.

RBA = Relative bioavailability [unitless]
SF_o = Oral cancer slope factor [(mg/kg-day)$^{-1}$]
RfD_o = Oral reference dose [mg/kg-day]
365 = Converts AT_c, AT_{nc} in years to days [days/year]
10^3 = Converts mg to µg [µg/mg]
10^{-6} = Converts mg to kg [kg/mg]
10 = Age-dependent adjustment factor for 0-2 yr [unitless]
3 = Age-dependent adjustment factor for 2-6 yr [unitless]
3 = Age-dependent adjustment factor for 6-16 yr [unitless]
1 = Age-dependent adjustment factor for 16-26 yr [unitless]

Carcinogenic Effects

$$SSTL_{ds} = \frac{TR \times AT_c \times 365 \times GIABS \times 10^3}{DF_{saa} \times SF_o \times ABS_d \times 10^{-6}}$$

Non-carcinogenic Effects

$$SSTL_{ds} = \frac{THQ \times AT_{nc} \times 365 \times RfD_o \times GIABS \times 10^3}{DF_{saa} \times ABS_d \times 10^{-6}}$$

where,

$$DF_{saa} = \left[\frac{ED_c \times EF_c \times SA_c \times AF_c}{BW_c} + \frac{ED_a \times EF_a \times SA_a \times AF_a}{BW_a}\right]$$

Mutagenic Effects

$$SSTL_{ds} = \frac{TR \times AT_c \times 365 \times GIABS \times 10^3}{DF_{saam} \times SF_o \times ABS_d \times 10^{-6}}$$

$$DF_{saam} = \left[\begin{array}{c} \frac{EF_{0-2} \times ED_{0-2} \times SA_{0-2} \times AF_{0-2} \times 10}{BW_{0-2}} + \\ \frac{EF_{2-6} \times ED_{2-6} \times SA_{2-6} \times AF_{2-6} \times 3}{BW_{2-6}} + \\ \frac{EF_{6-16} \times ED_{6-16} \times SA_{6-16} \times AF_{6-16} \times 3}{BW_{6-16}} + \\ \frac{EF_{16-26} \times ED_{16-26} \times SA_{16-26} \times AF_{16-26} \times 1}{BW_{16-26}} \end{array}\right]$$

where,

$SSTL_{ds}$	=	Site-specific target level for dermal contact with soil [µg/kg]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
DF_{saa}	=	Age-adjusted soil dermal factor for carcinogens and non-carcinogens[mg/kg]
DF_{saam}	=	Age-adjusted soil dermal factor for mutagens [mg/kg]
BW_c	=	Body weight for child [kg]
BW_a	=	Body weight for adult [kg]
BW_{0-2}	=	Body weight for 0-2 years [kg]
BW_{2-6}	=	Body weight for 2-6 years [kg]
BW_{6-16}	=	Body weight for 6-16 years [kg]
BW_{16-26}	=	Body weight for 16-26 years [kg]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
ED_{0-2}	=	Exposure duration for 0-2 years [year]
ED_{2-6}	=	Exposure duration for 2-6 years [year]
ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]
EF_c	=	Exposure frequency for child [days/year]
EF_a	=	Exposure frequency for adult [days/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [days/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [day/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [days/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [days/year]
SA_c	=	Skin surface area for child [cm^2/day]
SA_a	=	Skin surface area for adult [cm^2/day]
SA_{0-2}	=	Skin surface area for 0-2 years [cm^2/day]

Dermal Contact with Soil (Age-Adjusted Resident)
continued

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

A combined equation of ingestion of and dermal contact with soil for direct exposure for carcinogenic and non-carcinogenic effects is included in Rule 299. Note Rule 299 does not consider mutagenic effects.

SA_{2-6}	=	Skin surface area for 2-6 years [cm²/day]
SA_{6-16}	=	Skin surface area for 6-16 years [cm²/day]
SA_{16-26}	=	Skin surface area for 16-26 years [cm²/day]
AF_c	=	Soil to skin adherence factor for child [mg/cm²]
AF_a	=	Soil to skin adherence factor for adult [mg/cm²]
AF_{0-2}	=	Soil to skin adherence factor for 0-2 years [mg/cm²]
AF_{2-6}	=	Soil to skin adherence factor for 2-6 years [mg/cm²]
AF_{6-16}	=	Soil to skin adherence factor for 6-16 years [mg/cm²]
AF_{16-26}	=	Soil to skin adherence factor for 16-26 years [mg/cm²]
$GIABS$	=	Gastrointestinal absorption [unitless]
ABS_d	=	Dermal absorption fraction [unitless]
SF_o	=	Oral cancer slope factor [(mg/kg-day)$^{-1}$]
RfD_o	=	Oral reference dose [mg/kg-day]
365	=	Converts AT_c, AT_{nc} in years to days [day/year]
10^3	=	Converts mg to µg [µg/mg]
10^{-6}	=	Converts mg to kg [kg/mg]
10	=	Age-dependent adjustment factor for 0-2 yr [unitless]
3	=	Age-dependent adjustment factor for 2-6 yr [unitless]
3	=	Age-dependent adjustment factor for 6-16 yr [unitless]
1	=	Age-dependent adjustment factor for 16-26 yr [unitless]

Indirect Routes of Exposure

Ambient Air Inhalation of Vapors and Particulates from Surficial Soil (Child and Adult Residents and Nonresidential Adult)

Carcinogenic Effects

$$SSTL_{sinh} = \frac{TR \times AT_c \times 365 \times 24 \times (VF + PEF)}{EF \times ED \times ET_o \times IURF}$$

Non-carcinogenic Effects

$$SSTL_{sinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 10^3 \times 24 \times (VF + PEF)}{EF \times ED \times ET_o}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where,

$SSTL_{sinh}$	=	Site-specific target level for inhalation of vapors and particulates from surficial soil [µg/kg]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [day/year]
ET_o	=	Exposure time for outdoor inhalation [hours/day]
IURF	=	Inhalation unit risk factor [$(\mu g/m^3)^{-1}$]
RfC	=	Chronic inhalation reference concentration [mg/m^3]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
24	=	Converts ET_o hours to days [24 hours/day]
10^3	=	Converts mg to µg [µg/mg]
VF	=	Volatilization factor from surficial soil to outdoor (ambient air) [m^3-air/kg-soil]
PEF	=	Wind particulate emission factor from surficial soil to outdoor (ambient air) [m^3-air/kg-soil]

Notes: the numerical values for exposure factors will vary for a child and adult residents, and non-resident adult.

Indirect Routes of Exposure

Direct Contact (Ingestion, Dermal Contact, and Ambient Air Inhalation of Vapors and Particulates) with Soil (Child and Adult Resident and Nonresidential Adult)

$$SSTL_s = \frac{1}{\frac{1}{SSTL_{sing}} + \frac{1}{SSTL_{sd}} + \frac{1}{SSTL_{sinh}}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where,

$SSTL_s$ = Site-specific target level for direct contact (ingestion, dermal contact, and ambient air inhalation of vapors and particulates) with soil [µg/kg]

$SSTL_{sing}$ = Site-specific target level for ingestion of soil [µg/kg]

$SSTL_{sd}$ = Site-specific target level for dermal contact with soil [µg/kg]

$SSTL_{sinh}$ = Site-specific target level for ambient air inhalation of vapors and particulates [µg/kg]

Ambient Air Inhalation of Vapors and Particulates from Surficial Soil (Age-Adjusted Resident)

Carcinogenic Effects

$$SSTL_{sinh} = \frac{TR \times AT_c \times 365 \times 24 \times (VF + PEF)}{EF \times ED_{aa} \times ET_o \times IURF}$$

Non-carcinogenic Effects

$$SSTL_{sinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 10^3 \times 24 \times (VF + PEF)}{EF \times ED_{aa} \times ET_o}$$

where,

$$ED_{aa} = ED_c + ED_a$$

Mutagenic Effects

$$SSTL_{sinh} = \frac{TR \times AT_c \times 365 \times 24 \times (VF + PEF)}{EF \times ED_{aa} \times ET_o \times IURF \times \left[\left(\frac{EF_{0-2} \times ED_{0-2} \times ET_{o0-2} \times 10}{BW_{0-2}}\right) + \left(\frac{EF_{2-6} \times ED_{2-6} \times ET_{o2-6} \times 3}{BW_{2-6}}\right) + \left(\frac{EF_{6-16} \times ED_{6-16} \times ET_{o6-16} \times 3}{BW_{6-16}}\right) + \left(\frac{EF_{16-26} \times ED_{16-26} \times ET_{o16-26} \times 1}{BW_{16-26}}\right) \right]}$$

where,

$SSTL_{inhs}$	=	Site-specific target level for inhalation of vapors and particulates from surficial soil [µg/kg]
TR	=	Target risk [unitless]
THQ	=	Target hazard quotient [unitless]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED_{aa}	=	Exposure duration for age-adjusted resident [year]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
EF	=	Exposure frequency [days/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [days/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [days/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [days/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [days/year]
ED_{0-2}	=	Exposure duration for 0-2 years [year]
ED_{2-6}	=	Exposure duration for 2-6 years [year]
ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]
ET_o	=	Exposure time for outdoor inhalation [hours/day]
ET_{0-2}	=	Exposure time for 0-2 years [hours/day]
ET_{2-6}	=	Exposure time for 2-6 years [hours/day]
ET_{6-16}	=	Exposure time for 6-16 years [hours/day]
ET_{16-26}	=	Exposure time for 16-26 years [hours/day]
10	=	Age-dependent adjustment factor for 0-2 yr [unitless]
3	=	Age-dependent adjustment factor for 2-6 yr [unitless]
3	=	Age-dependent adjustment factor for 6-16 yr [unitless]
1	=	Age-dependent adjustment factor for 16-26 yr [unitless]
IURF	=	Inhalation unit risk factor [$(\mu g/m^3)^{-1}$]

Ambient Air Inhalation of Vapors and Particulates from Surficial Soil (Age-Adjusted Resident)
continued

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

Equations for inhalation of vapors and particulates of resident (age-adjusted) for carcinogenic and non-carcinogenic effects are included in Rule 299. Note Rule 299 does not consider mutagenic effects.

RfC	=	Chronic inhalation reference concentration [mg/m^3]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
24	=	Converts ET_o hours to day [24 hours/day]
10^3	=	Converts mg to µg [µg/mg]
VF	=	Volatilization factor from surficial soil to outdoor (ambient air) [m^3-air/kg-soil]
PEF	=	Wind particulate emission factor from surficial soil to outdoor (ambient air) [m^3-air/kg-soil]

Direct Contact (Ingestion, Dermal Contact, and Ambient Air Inhalation of Vapors and Particulates) with Soil (Age-Adjusted Resident)

$$SSTL_s = \frac{1}{\frac{1}{SSTL_{sing}} + \frac{1}{SSTL_{sd}} + \frac{1}{SSTL_{sinh}}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

This equation was not included in Rule 299.

where,

$SSTL_s$	=	Site-specific target level for direct contact (ingestion, dermal contact, and ambient air inhalation of vapors and particulates) with soil [µg/kg]
$SSTL_{sing}$	=	Site-specific target level for ingestion of soil [µg/kg]
$SSTL_{sd}$	=	Site-specific target level for dermal contact with soil [µg/kg]
$SSTL_{sinh}$	=	Site-specific target level for ambient air inhalation of vapors and particulates [µg/kg]

Volatilization to Indoor Air from Soil Gas (Residential and Nonresidential Receptors)

$$SSTL_{svi} = \frac{SSTL_{ininh}}{\alpha_{sv}}$$

where:

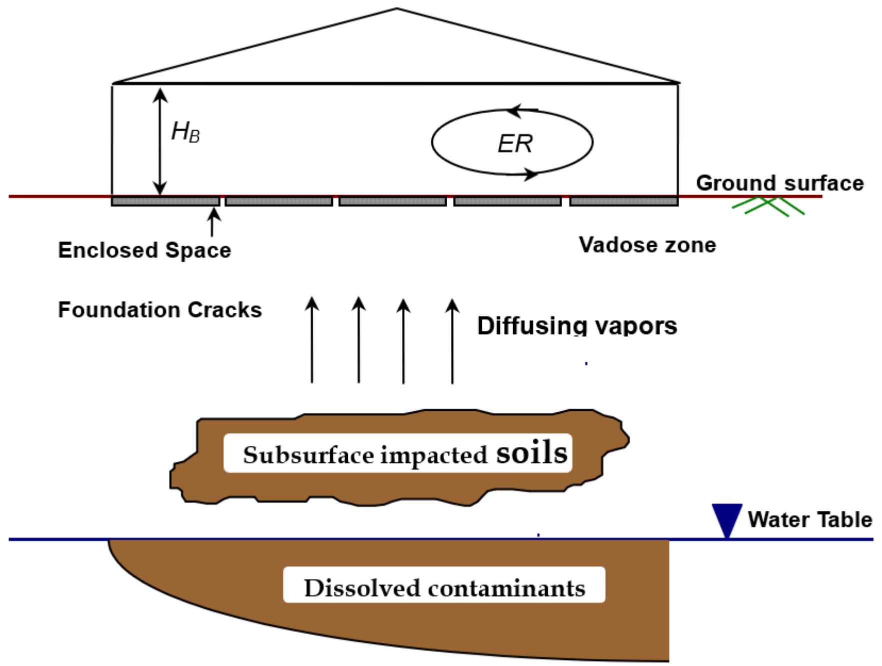
$SSTL_{svi}$ = Site-specific target level for indoor inhalation of vapors from soil gas [µg/m^3-air]

$SSTL_{ininh}$ = Site-specific target level for indoor inhalation of air [µg/m^3-air] (calculated in Tier 2 using Equations 3 and 4)

α_{sv} = Attenuation factor from subsurface soil gas to indoor (enclosed space) air [unitless]

Source: ASTM E1739-95

This equation is not included in Rule 299.



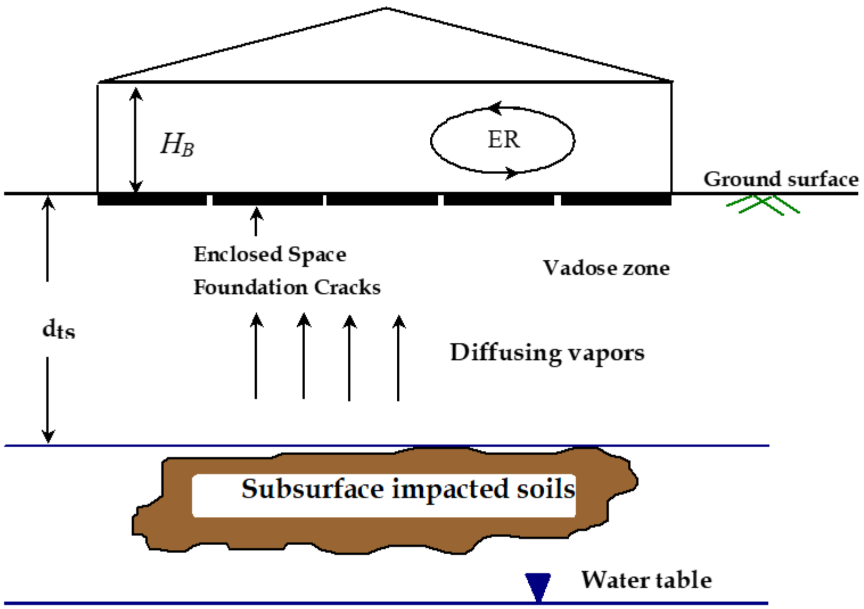
Volatilization to Indoor Air from Vadose Zone Soil (Residential and Nonresidential Receptors)

$$SSTL_{si} = \frac{SSTL_{ininh}}{VF_{sesp}}$$

where:

- $SSTL_{si}$ = Site-specific target level for indoor inhalation of vapors from subsurface soil [µg/kg-soil]
- $SSTL_{ininh}$ = Site-specific target level for indoor inhalation of air [µg/m^3-air] (calculated in Tier 2 using Equations 3 and 4)
- VF_{sesp} = Volatilization factor from subsurface soil to indoor (enclosed space) air [(mg/m^3-air)/(mg/kg-soil)]

Source: ASTM E1739-95
This equation is included in Rule 299.



Volatilization to Indoor Air from Groundwater (Residential and Nonresidential Receptors)

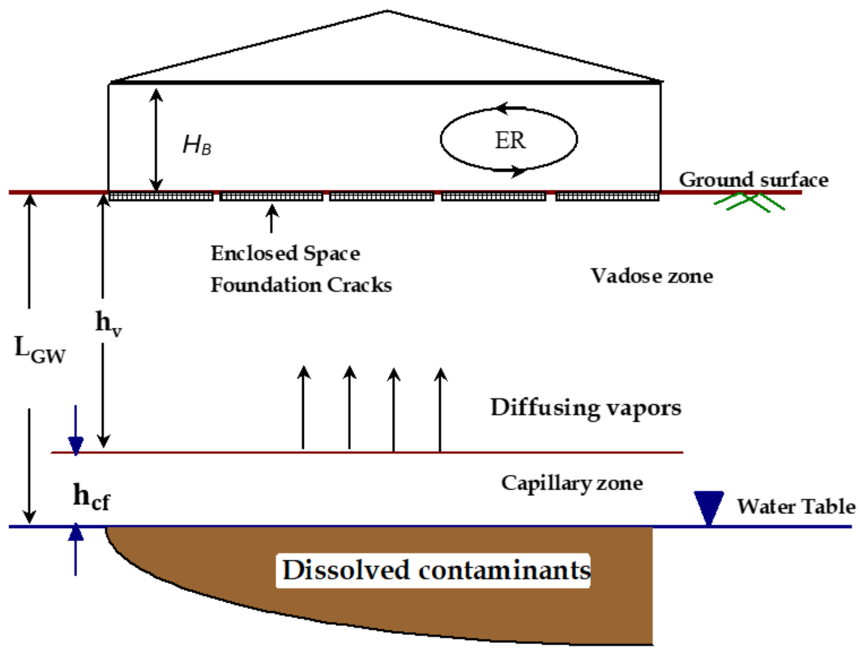
$$SSTL_{wi} = \frac{SSTL_{ininh}}{VF_{wesp}}$$

where:

$SSTL_{wi}$	=	Site-specific target level protective of indoor inhalation of vapors from groundwater [µg/L]
$SSTL_{ininh}$	=	Site-specific target level for indoor inhalation of air [µg/m^3-air] (calculated in Tier 2 using Equations 3 and 4)
VF_{wesp}	=	Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-water)]

Source: ASTM E1739-95

This equation is included in Rule 299.



Volatilization Factors

For Infinite Source

$$VF = \frac{Q/C \times (3.14 \times D_A \times t)^{1/2} \times 10^{-4}}{2 \times \rho_{bv} \times D_A}$$

where:

$$D_A = \frac{\left(\theta_{av}^{10/3} \times D_a \times H'_{TS} + \theta_{wv}^{10/3} \times D_w\right)/\theta_T^2}{(\rho_{bv} \times K_d) + \theta_{wv} + (\theta_{av} \times H'_{TS})}$$

where:

$$H'_{TS} = \frac{exp\left[-\frac{\Delta H_{v,TS}}{R_C}\left(\frac{1}{T_S} - \frac{1}{T_R}\right)\right] H_R}{RT_S}$$

$$\Delta H_{v,TS} = \Delta H_{v,b}\left[\frac{(1 - T_S/T_C)}{(1 - T_B/T_C)}\right]^n$$

If $T_B/T_C < 0.57$, n = 0.3
If $T_B/T_C > 0.71$, n = 0.41
If T_B/T_C 0.57 – 0.71, n = 0.74 (T_B/T_C) – 0.116

For Mass Limit Source

$$VF = \frac{Q/C \times t \times 3.15 \times 10^{-4}}{\rho_{bv} \times d_s}$$

Use higher of the two *VF*.

Source: Regional Screening Level (RSL) User's Guide, USEPA, November 2024.

These equations are included in Rule 299. However, the infinite source equation includes a temperature adjustment factor (TAF) of 0.5 for Henry's law constant.

Volatilization Factors for Emissions from Surficial Soil to Ambient Air

VF	=	Volatilization factor [m^3-air/kg-soil]
Q/C	=	Dispersion factor for 0.5-acre source [(g/m^2-s)/(kg/m^3)]
D_A	=	Apparent diffusivity [cm^2/s]
t	=	Exposure interval [s]
ρ_{bv}	=	Dry soil bulk density in vadose zone soil [g/cm^3]
K_d	=	Soil-water partition coefficient for inorganics [L/kg]; $K_d = K_{oc} \times f_{oc}$ for organics
K_{oc}	=	Soil organic carbon partition coefficient [L/kg]
f_{ocv}	=	Fraction of organic carbon content in vadose zone soil [g/g]
D_a	=	Chemical-specific diffusion coefficient in air [cm^2/s]
D_w	=	Chemical-specific diffusion coefficient in water [cm^2/s]
θ_{Tv}	=	Total porosity in vadose zone soil [cm^3/cm^3]
θ_{av}	=	Volumetric air content in vadose zone soil [cm^3/cm^3]
θ_{wv}	=	Volumetric water content in vadose zone soil [cm^3/cm^3]
H'_{TS}	=	Dimensionless Henry's law constant at the average system temperature [unitless]. System is either soil or groundwater.
10^{-4}	=	Conversion factor [m^2/cm^2]
d_s	=	Depth to base of surficial soil zone [cm]
$\Delta H_{v,TS}$	=	Enthalpy of vaporization at the average system temperature [cal/mol]
T_S	=	Average system temperature [°K], (°K = °C + 273.15)
T_R	=	Henry's law constant reference temperature [°K]
T_C	=	Critical temperature [°K]
T_B	=	Normal boiling point [°K]
H_R	=	Henry's law constant at the reference temperature [atm-m^3/mol]
R_C	=	Gas constant, 1.9872 [cal/mol-°K]
R	=	Gas constant, 8.205×10^{-5} [atm-m^3/mol-°K]
$\Delta H_{v,b}$	=	Enthalpy of vaporization at the normal boiling point [cal/mol]
n	=	Exponent [unitless]

Wind Particulate Emission Factor for Ambient Air Inhalation from Surficial Soil

$$PEF = \frac{Q/C \times 3{,}600}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)}$$

Source: Regional Screening Level (RSL) User Guide, USEPA, November 2024.

This equation is not included in Rule 299.

where:

PEF	=	Wind particulate emission factor (ambient) air [m^3-air /kg-soil]
Q/C	=	Inverse of mean concentration at the center of a 0.5-acre square source [$(g/m^2\text{-}s)/(kg/m^3)$]
V	=	Fraction of vegetative cover [unitless]
U_m	=	Mean annual wind speed [m/s]
U_t	=	Equivalent threshold value of wind speed at 7 m [m/s]
F(x)	=	Function dependent on U_m/U_t derived using Cowherd *et al.* 1985 [unitless]
0.036	=	Empirical constant [g/m^2-hr]
3,600	=	Converts hour to seconds [s/h]

Attenuation Factor for Volatilization to Indoor Air from Soil Gas

For advective and diffusive transport,

$$\alpha_{sv} = \frac{\left[\left(\frac{D_T^{eff} \times A_B}{Q_{bldg} \times L_T}\right) \times \exp\left(\frac{Q_{soil} \times L_{crack}}{D_{crack}^{eff} \times A_{crack}}\right)\right]}{\left[\exp\left(\frac{Q_{soil} \times L_{crack}}{D_{crack}^{eff} \times A_{crack}}\right) + \left(\frac{D_T^{eff} \times A_B}{Q_{bldg} \times L_T}\right) + \left(\frac{D_T^{eff} \times A_B}{Q_{soil} \times L_T}\right)\left[\exp\left(\frac{Q_{soil} \times L_{crack}}{D_{crack}^{eff} \times A_{crack}}\right) - 1\right]\right]}$$

where,

$$L_T = D_{POC} - L_F$$

$$A_B = L_B \times W_B$$

$$Q_{bldg} = \left(\frac{L_B \times W_B \times H_B \times ER}{3600}\right)$$

$$A_{crack} = L_B \times W_B \times \frac{\eta_c}{100}$$

$$Q_{soil} = \frac{2\pi \times \Delta P \times k_v \times X_{crack}}{\mu \times ln\left(\frac{2L_F}{r_{crack}}\right)}$$

$$X_{crack} = 2 \times (L_B + W_B)$$

$$w = \frac{A_{crack}}{X_{crack}}$$

$$r_{crack} = \frac{w}{2}$$

Source: USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.

This equation is not included in Rule 299.

where,

α_{sv} = Attenuation factor for soil gas to indoor air [unitless]
D_T^{eff} = Total overall effective diffusion coefficient [cm^2/s]
A_B = Area of building floor [cm^2]
Q_{bldg} = Building ventilation rate [cm^3/s]
L_T = Distance between bottom of floor slab and point of compliance (POC) [cm]
Q_{soil} = Volumetric flow rate of soil gas entering the building [cm^3/s]
L_{crack} = Building floor thickness [cm]
D_{crack}^{eff} = Effective diffusion coefficient through the cracks in the floor [cm^2/s]
A_{crack} = Area of total cracks in the floor [cm^2]
D_{POC} = Depth below ground to POC [cm]
  d_{ts} = depth to vadose zone soil POC
  d_v = depth to soil gas POC
  L_{GW} = depth to groundwater POC
L_F = Depth below ground to bottom of building floor [cm]
L_B = Length of building [cm]
W_B = Width of building [cm]
H_B = Height of building [cm]
ER = Air exchange rate [l/hr]
$3,600$ = Conversion factor [sec/hr]
ΔP = Soil-building pressure differential [g/cm-s^2]
k_v = Soil gas permeability[cm^2]
X_{crack} = Length of crack assumed equal to the perimeter of the floor [cm]
μ = Viscosity of air at soil temperature [g/cm-s]
r_{crack} = Equivalent crack radius [cm]
w = Average width of the crack [cm]
η_c = Percent of the building floor area that is cracked [%]
100 = Conversion factor [unitless]

Notes:

1. r_{crack} is not a user-specified input.
2. w is not a user-specified input.
3. d_{ts} must be greater than L_F
4. d_v must be greater than L_F
5. L_{GW} must be greater than $L_F + h_{cf}$ (thickness of capillary fringe)

Volatilization Factor for Volatilization to Indoor Air from Vadose Zone Soil

$$VF_{sesp} = \frac{H'_{ST} \times \rho_{bv}}{[\theta_{wv} + (K_d \times \rho_{bv}) + (H'_{ST} \times \theta_{av})]} \times \alpha_s \times 10^3$$

For organics:

$$K_d = K_{oc} \times f_{ocv}$$

Note: α_s is calculated using equation for α_{sv} with depth to subsurface soil source from ground surface (d_{ts}).

Source: USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.

This equation is included in Rule 299. However, the equation includes a TAF for Henry's law constant.

where,

VF_{sesp}	=	Volatilization factor from subsurface soil to indoor (enclosed space) air [kg/m^3]
H'_{ST}	=	Dimension less Henry's law constant at the average system temperature [unitless]
ρ_{bv}	=	Dry soil bulk density in vadose zone soil [g/cm^3]
θ_{wv}	=	Volumetric water content in vadose zone soil [cm^3/cm^3]
θ_{av}	=	Volumetric air content in vadose zone soil [cm^3/cm^3]
K_d	=	Soil-water sorption coefficient for inorganics [L/kg]
K_{oc}	=	Soil-organic carbon partition coefficient [L/kg]
f_{ocv}	=	Fraction of organic carbon content in vadose zone soil [g/g]
α_s	=	Attenuation factor from subsurface soil to indoor
10^3	=	Conversion factor [L/m^3]

Dilution Attenuation Factor for the Groundwater Mixing Zone (Summers Model)

$$VF_{wesp} = H'_{ST} \times \alpha_{gw} \times 10^3$$

Note: α_{gw} is calculated using equation for α_{sv} with depth to groundwater (L_{GW}).

Source: USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.

This equation is included in Rule 299. However, the equation includes a TAF for Henry's law constant.

where,

VF_{wesp}	=	Volatilization factor from groundwater to indoor (enclosed space) air [L/m^3]
H'_{ST}	=	Dimension less Henry's law constant at the average system temperature [unitless]
α_{gw}	=	Attenuation factor from groundwater to indoor [unitless]
10^3	=	Conversion factor [L/m^3]

Total effective diffusion coefficient:

$$D_T^{eff} = \frac{L_T}{\left(h_v/D_v^{eff}\right) + \left(h_{cf}/D_{cf}^{eff}\right)} \quad \text{when: } D_{POC} = L_{GW}$$

$$D_T^{eff} = D_v^{eff} \quad \text{when: } D_{POC} = d_{ts} \text{ or } d_v$$

where:

D_T^{eff}	=	Total effective diffusion coefficient [cm²/s]
L_T	=	Distance between bottom of floor and point of compliance (POC) [cm]
h_v	=	Thickness of vadose zone below enclosed space floor [cm]
L_{crack}	=	Building foundation thickness [cm]
D_v^{eff}	=	Effective diffusion coefficient through vadose zone [cm²/s]
h_{cf}	=	Thickness capillary fringe [cm]
D_{cf}^{eff}	=	Effective diffusion coefficient through capillary fringe [cm²/s]

Effective diffusion coefficient through vadose zone:

$$D_v^{eff} = \left[D_a\left(\theta_{av}^{3.33}/\theta_{TV}^2\right)\right] + \left[\frac{D_w}{H'_{ST}}\left(\theta_{wv}^{3.33}/\theta_{TV}^2\right)\right]$$

where:

D_v^{eff}	=	Effective diffusion coefficient through vadose zone [cm²/s]
D_a	=	Diffusivity in air [cm²/s]
θ_{av}	=	Volumetric air content in vadose zone soil [cm³/cm³]
θ_{TV}	=	Total porosity in vadose zone soil [cm³/cm³]
D_w	=	Diffusivity in water [cm²/s]
H'_{ST}	=	Dimensionless Henry's law constant at the average system temperature [unitless]
θ_{wv}	=	Volumetric water content in vadose zone soil [cm³/cm³]

Effective diffusion coefficient through capillary fringe:

$$D_{cf}^{eff} = \left[D_a\left(\theta_{acap}^{3.33}/\theta_{TS}^2\right)\right] + \left[\frac{D_w}{H'_{ST}}\left(\theta_{wcap}^{3.33}/\theta_{TS}^2\right)\right]$$

where:

D_v^{eff}	=	Effective diffusion coefficient through capillary fringe [cm²/s]
D_a	=	Diffusivity in air [cm²/s]
θ_{acap}	=	Volumetric air content in saturated zone-capillary fringe [cm³/cm³]
θ_{TS}	=	Total porosity in saturated zone [cm³/cm³]
D_w	=	Diffusivity in water [cm²/s]
H'_{ST}	=	Dimensionless Henry's law constant at the average system temperature [unitless]
θ_{wcap}	=	Volumetric water content in saturated zone-capillary fringe [cm³/cm³]

Effective diffusion coefficient through building foundation cracks:

$$D_v^{eff} = \left[D_a\left(\theta_{ac}^{3.33}/\theta_{TC}^2\right)\right] + \left[\frac{D_w}{H'_{ST}}\left(\theta_{wc}^{3.33}/\theta_{TC}^2\right)\right]$$

where:

D_v^{eff}	=	Effective diffusion coefficient through vadose zone [cm²/s]
D_a	=	Diffusivity in air [cm²/s]
θ_{ac}	=	Volumetric air content in foundation crack soil [cm³/cm³]
θ_{TC}	=	Total porosity in foundation crack soil [cm³/cm³]
D_w	=	Diffusivity in water [cm²/s]
H'_{ST}	=	Dimensionless Henry's law constant at the average system temperature [unitless]
θ_{wc}	=	Volumetric water content in foundation crack soil [cm³/cm³]

Source: Modified from Michigan Rule 299.

Groundwater Protection and Surface Water Protection

Soil Source Concentration Protective of Surface Water and Groundwater

$$C_{sl} = DAF_{unsat} \times DAF_{mix} \times DAF_{sat} \times C_{POE}$$

$$C_s = C_{sl} \times ECF$$

This equation is not included in Rule 299.

where:

C_s	=	Soil source concentration [µg/kg]
C_{sl}	=	Soil leachate concentration at the bottom of the soil source [µg/L]
DAF_{unsat}	=	Dilution attenuation factor in the unsaturated (vadose) zone [unitless]
DAF_{mix}	=	Dilution attenuation factor in the mixing zone [unitless]
DAF_{sat}	=	Dilution attenuation factor in the saturated zone [unitless]
C_{POE}	=	Concentration at the point of exposure (POE) [µg/L]
		The location of groundwater surface water interface (GSI) [µg/L] or
		The location of POE for the groundwater protection pathway [µg/L]
ECF	=	Equilibrium conversion factor to convert soil leachate concentration to soil concentration [L/kg]

The unsaturated zone DAF (DAF_{UNSAT}) is often assumed 1 (no attenuation) if the depth to groundwater less than about 15 ft. For depths greater than 15 ft, an unsaturated transport model may be used.

Domenico model for multi-dimensional transport with decay and continuous source

$$\frac{C(x,y,z,t)}{C_o} = (1/8)\ exp\left[\frac{x}{2\,\alpha_x}\left[1 - \sqrt{1+\frac{4\,\lambda\,\alpha_x}{v}}\right]\right] \times erfc\left[\frac{\left[(x-vt)\sqrt{1+\frac{4\,\lambda\,\alpha_x}{v}}\right]}{2\sqrt{\alpha_x \times v \times t}}\right] \times$$

$$\left[erf\left[\frac{(y+Y/2)}{2\sqrt{\alpha_y\,x}}\right] - erf\left[\frac{(y-Y/2)}{2\sqrt{\alpha_y\,x}}\right]\right] \times \left[erf\left[\frac{(z+\delta_{gw})}{2\sqrt{\alpha_z\,x}}\right] - erf\left[\frac{(z-\delta_{gw})}{2\sqrt{\alpha_z\,x}}\right]\right]$$

where,

C	=	Dissolved-phase concentration [mg/L]
C_o	=	Dissolved-phase concentration at the source (at x-y, ≤ z ≤δ_{gw}) [mg/L]
v	=	Retarded seepage velocity [cm/year]
λ	=	First order decay rate [1/year]
α_x	=	Longitudinal dispersivity [cm]
α_y	=	Lateral dispersivity [cm]
α_z	=	Vertical dispersivity [cm]
x, y, z	=	Spatial coordinates [cm]
t	=	Time [year]
x	=	Distance along the centerline from the downgradient edge of dissolved-plume source zone or source well [cm]
Y	=	Width of soil source perpendicular to the groundwater flow direction [cm]
δ_{gw}	=	Groundwater mixing zone thickness [cm]
DAF	=	$C_0/C(x)$

Source: Domenico, P.A. and F.W. Schwartz, 1990, *Physical and Chemical Hydrogeology.* John Wiley and Sons, NY, 824 p. (Eqn. 17.21)
This equation is not included in Rule 299.

At the centerline, for steady-state (after a long time) the DAF can be obtained by setting $y = 0$, $z = 0$, and $x << v \times t$ as:

$$\frac{C(x)}{C_o} = exp\left[\frac{x}{2\,\alpha_x}\left[1 - \sqrt{1+\frac{4\,\lambda\,\alpha_x}{v}}\right]\right] \times erf\left[\frac{Y}{4\sqrt{\alpha_y\,x}}\right] \times erf\left[\frac{\delta_{gw}}{2\sqrt{\alpha_z\,x}}\right] \quad (1)$$

At the centerline, for steady-state, the DAF without decay can be obtained by setting $y = 0$, $z = 0$, and $x << vt$, and $\lambda = 0$ as:

$$\frac{1}{DAF} = \frac{C(x)}{C_o} = erf\left[\frac{Y}{4\sqrt{\alpha_y\,x}}\right] \times erf\left[\frac{\delta_{gw}}{2\sqrt{\alpha_z\,x}}\right] \quad (2)$$

Note: Comparing to ASTM E1739-95, p. 31, where $Y = S_w$, $\delta_{gw} = S_d$, $v = u$, and $C_o = C_{source}$

At the centerline, for steady-state, the DAF with decay can be calculated using Equation (1). In Equation (1), the retarded seepage velocity (v) is calculated as:

$$V = (K\,i)/R_s\,\theta_{TS}$$

where,

K	=	Hydraulic conductivity [cm/year]
i	=	Hydraulic gradient [cm/cm]
θ_{TS}	=	Total porosity in the saturated zone [cm^3/cm^3-soil]
R_s	=	Retardation factor in the saturated zone [--]

Retardation Factor for Saturated Zone and Half-Life

Retardation factor in the saturated zone:

$$R_s = 1 + \frac{\rho_{bs} K_d}{\theta_{TS}}$$

For organics:

$$K_d = K_{oc} \times f_{ocs}$$

Source: ASTM E1739-95

Half-Life:

$$t_{1/2} = \frac{0.693}{\lambda}$$

This equation is not included in Rule 299.

where,

R_S	=	Retardation factor in the saturated zone [unitless]
ρ_{bs}	=	Dry soil bulk density of saturated zone [g/cm^3] or [kg/L]*
K_d	=	Soil-water partition coefficient for inorganics [L/kg]
K_{oc}	=	Soil organic carbon partition coefficient [L/kg]
f_{ocs}	=	Fraction of organic carbon content in saturated zone soil [g/g]
θ_{TS}	=	Total soil porosity in saturated zone [cm^3/cm^3]
λ	=	Biodegradation rate [1/year]
$t_{1/2}$	=	Half-life for biodegradation [years]

*: For consistency the units of dry soil bulk density are in g/cm^3 or kg/L. The numerical value is the same for both the units.

Concentration at the Point of Compliance (POC) Groundwater Well

$$C_{POC} = C_{POE} \times \frac{DAF_{POE}}{DAF_{POC}}$$

Source: ASTM E1739-95

This equation is not included in Rule 299.

where,

C_{POC}	=	Concentration at the point of compliance groundwater well [µg/L]
C_{POE}	=	Concentration at the groundwater surface water interface (GSI) or the concentration in POE well [µg/L]
DAF_{POE}	=	Dilution attenuation factor from groundwater source to the point of exposure (POE) [unitless]
DAF_{POC}	=	Dilution attenuation factor from groundwater source to the point of compliance (POC) [unitless]

Dilution Attenuation Factor for the Groundwater Mixing Zone

$$DAF_{mix} = \frac{C_{st}}{C_{gwm}} = 1 + \frac{U_{gw}\delta_{gw}}{IW}$$

$$U_{gw} = i \times \frac{K}{365}$$

Source: ASTM E1739-95

This equation is not included in Rule 299.

where,

DAF_{mix}	=	Dilution attenuation factor (DAF) in the groundwater mixing zone [unitless]
C_{st}	=	Leachate concentration at the water table [µg/L]
C_{gwm}	=	Groundwater concentration at the edge of groundwater mixing zone [µg/L]
U_{gw}	=	Groundwater Darcy velocity [cm/day]
δ_{gw}	=	Groundwater mixing zone thickness [cm]
I	=	Infiltration rate of water through unsaturated zone [cm/day]
W	=	Groundwater source dimension parallel to groundwater flow direction [cm]
i	=	Hydraulic gradient [cm/cm]
K	=	Hydraulic conductivity [cm/year]
365	=	Converts year to days [days/year]

Groundwater Mixing Zone Thickness

$$\delta_{gw} = (0.0112 \times W^2)^{0.5} + d_a\left\{1 - exp\left[\frac{-WI}{Kid_a} \times 365\right]\right\}$$

Source: USEPA, July 1996. Soil Screening Guidance: User's Guide.

This equation is not included in Rule 299.

where,

δ_{gw}	=	Groundwater mixing zone thickness [cm]
W	=	Groundwater source dimension parallel to groundwater flow direction [cm]
d_a	=	Aquifer thickness [cm]
I	=	Infiltration rate of water through unsaturated zone [cm/day]
K	=	Hydraulic conductivity [cm/year]
i	=	Hydraulic gradient [cm/cm]
365	=	Converts year to days [days/year]

δ_{gw} is either a user-input or calculated if aquifer thickness (d_a) is available.

Equilibrium Conversion Factor to Convert Soil Leachate Concentration to Soil Concentration

$$ECF = \frac{[\theta_{wv} + (K_d \times \rho_{bv}) + (H'_{ST} \times \theta_{av})]}{\rho_{bv}}$$

For organics:

$$K_d = K_{oc} \times f_{ocv}$$

Source: ASTM E1739-95

This equation is not included in Rule 299.

where,

ECF	=	Equilibrium conversion factor [L/kg]
ρ_{bv}	=	Dry soil bulk density in vadose zone soil [g/cm^3]
θ_{wv}	=	Volumetric water content in vadose zone soil [cm^3/cm^3]
θ_{av}	=	Volumetric air content in vadose zone soil [cm^3/cm^3]
K_d	=	Soil-water partition coefficient for inorganics [L/kg]
K_{oc}	=	Soil-organic carbon partition coefficient for organics [L/kg]
f_{ocv}	=	Fraction of organic carbon content in vadose zone soil [g/g]
H'_{ST}	=	Dimensionless Henry's law constant at the average system temperature [unitless]

Saturation Concentrations

Soil Saturation Concentration

Single component:

$$C_s^{SAT} = \frac{S}{\rho_{bv}} \times 10^3 \times [(H'_{ST} \times \theta_{av}) + \theta_{wv} + (K_d \times \rho_{bv})]$$

Multiple components:

$$C_s^{SAT} = \frac{S_{ei}}{\rho_{bv}} \times [(H'_{ST} \times \theta_{av}) + \theta_{wv} + (K_d \times \rho_{bv})]$$

For organics:

$$K_d = K_{oc} \times f_{oc}$$

Source: ASTM E1739-95.

This equation is not included in Rule 299.

where:

C_s^{SAT}	=	Soil saturation concentration [µg/kg]
S	=	Pure component solubility in water [mg/L]
S_{ei}	=	Effective solubility of component *i* in water [µg/L]
x_i	=	Mole fraction of component [unitless]
w_i	=	Weight fraction of component *i* [unitless]
MW_{avg}	=	Average molecular weight of mixture [g/mole]
MW_i	=	Molecular weight of component *i* [g/mole]
ρ_{bv}	=	Dry soil bulk density in vadose zone soil [g/cm^3]
H'_{TS}	=	Dimension less Henry's law constant at the average system temperature [unitless]
θ_{av}	=	Volumetric air content in vadose zone soil [cm^3/cm^3]
θ_{wv}	=	Volumetric water content in vadose zone soil [cm^3/cm^3]
K_d	=	Soil-organic carbon partition coefficient for inorganics [L/kg]
K_{oc}	=	Soil-organic carbon partition coefficient for organics [L/kg]
f_{ocv}	=	Fraction of organic carbon content in vadose zone soil [g/g]
10^3	=	Conversion factor [µg/mg]

Soil Gas Saturation Concentration and Effective Solubility (Single Component)

$$C_v^{SAT} = \frac{P \times MW_i}{760 \times R \times T} \times 10^9$$

$$S_{ei} = S \times 10^3$$

Soil Gas Saturation Concentration and Effective Solubility (Multiple Components)

$$C_v^{SAT} = \frac{P_i \times MW_i}{760 \times R \times T} \times 10^9$$

$$P_i = x_i \times P$$

$$S_{ei} = x_i \times S \times 10^3$$

$$x_i = \frac{w_i \times MW_{avg}}{MW_i}$$

Source: Modified from ASTM E1739-95

This equation is not included in Rule 299.

where,

C_v^{SAT}	=	Soil gas saturation concentration [µg/m^3]
P	=	Saturated vapor pressure of pure component [mgHg]
MW_i	=	Molecular weight of component i [g/mole]
P_i	=	Effective vapor pressure of component i in water [mmHg]
S_{ei}	=	Effective solubility of component i in water [µg/L]
S	=	Pure chemical solubility in water [mg/L]
x_i	=	Mole fraction of component i [unitless]
w_i	=	Weight fraction of component i [unitless]
MW_{avg}	=	Average molecular weight of mixture [g/mole]
R	=	Gas constant, 8.205 × 10^{-2} [atm-L/mol-^{o}K]
T	=	Temperature [^{o}K]
760	=	Conversion factor mmHg to atm [unitless]
10^9	=	Conversion factor (g/L) to (µg/m^3) [unitless]
10^3	=	Conversion factor (mg/L) to (µg/L) [unitless]

Sump Model

Volatilization to Indoor Inhalation from Sump Water (Residential and Nonresidential Receptors)

$$SSTL_{swi} = \frac{SSTL_{ininh} \times Q_{bldg}}{K_L \times A_t \times 10^9}$$

$$Q_{bldg} = \frac{L_B \times W_B \times H_B \times ER}{3{,}600}$$

$$K_L = \frac{k_l \times \left(H'_{TS} \times k_g\right)}{k_l + \left(H'_{TS} \times k_g\right)}$$

$$k_l = 6.5 \times 10^{-6} \times \left[\frac{D_w}{(1.488 \times 10^{-9}) \times 10^4}\right]^{0.67}$$

$$k_g = 0.003 \times \left[\frac{D_a}{(2.6 \times 10^{-5}) \times 10^4}\right]^{0.67}$$

$$A_t = A_{sump} + \left(0.25 \times A_{fd}\right)$$

$$A_{fd} = \frac{2(L_B + W_B)}{100} \times \frac{d_d}{39.37}$$

Source: Vicenc Marti et al., June 11, 2014. Water-Air Volatilization Factors to Determine Volatile Organic Compound Reference Levels in Water. *Toxics* ISSN 2305-6304.

This equation is not included in Rule 299.

where,

$SSTL_{swi}$	=	Site-specific target level for indoor inhalation of vapors from sump water [μg/L]
$SSTL_{ininh}$	=	Site-specific target level for indoor inhalation of vapors [μg/m³] (calculated in Tier 2 using Equations 3 and 4)
Q_{bldg}	=	Building ventilation rate [cm³/s]
L_B	=	Length of building [cm]
W_B	=	Width of building [cm]
H_B	=	Height of building [cm]
ER	=	Air exchange rate [l/hr]
K_L	=	Overall mass transfer coefficient [m/s]
k_l	=	Liquid-phase mass transfer coefficient [m/s]
k_g	=	Gas-phase mass transfer coefficient [m/s]
H'_{TS}	=	Dimensionless Henry's law constant at system (the interface) temperature [unitless]
D_w	=	Diffusivity in water [cm²/s]
D_a	=	Diffusivity in air [cm²/s]
A_t	=	Total surface area for volatilization [m²]
A_{sump}	=	Surface area of sump [m²]
A_{fd}	=	Total area of the perimeter foundation drain [m²]
d_d	=	Diameter of the foundation drain [inches]
100	=	Converts centimeters to meters [unitless]
39.37	=	Converts inches to meters [unitless]
3,600	=	Converts hours to seconds [unitless]
10^3	=	Converts cubic meter to liters [unitless]

Appendix B – Determining if the Groundwater Protection Exposure Pathway is Incomplete for Future Use

B.1 Background

Impacts to groundwater and potential exposures via groundwater ingestion are of significant concern in Michigan since many areas of the state obtain their drinking water from groundwater sources. The groundwater protection pathway must be evaluated if this exposure pathway is complete. For the pathway to be complete there must be a (i) source of COCs, (ii) mechanism by which COCs are released, (iii) medium through which the COCs travel from the point of release to the receptor location, (iv) point of exposure, and (v) route of exposure by which the COCs enter the receptor's body and potentially cause adverse health effects (Figure B-1).

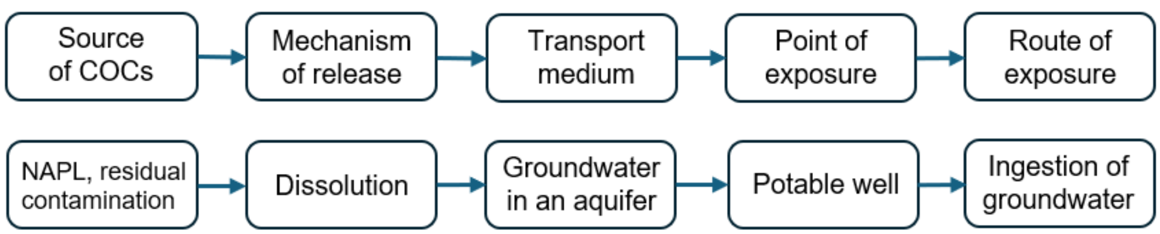


Figure B-1. Elements of a complete groundwater protection exposure pathway

If any one of these items is missing, the exposure pathway is incomplete and does not require evaluation. The pathway is complete for current use if there is a water supply well that is potentially impacted by the release. If there are no water supply wells potentially impacted by the release, the exposure pathway is not complete for current use. This section focuses on the information needed to demonstrate that the groundwater protection exposure pathway is incomplete for future use because either item (iii) or (iv) is not present at the site or surrounding area.

B.2 Transport Medium

In order for the groundwater protection exposure pathway to be complete there must be a medium through which the COCs can travel from the point of release to the receptor location. COCs are transported through groundwater in an aquifer. If groundwater is not in an aquifer (lack of groundwater quantity) or the formation or saturated zone being evaluated cannot reasonably be expected to transport the COCs to an aquifer (lack of hydraulic communication), the groundwater protection exposure pathway is incomplete for future use (Figure B-2). This determination is defined by Section 21302(l) of Part 213 as groundwater not in an aquifer (GWNIAA) and is described in detail in the EGLE-RRD Resource Materials, *Groundwater Not In An Aquifer*.

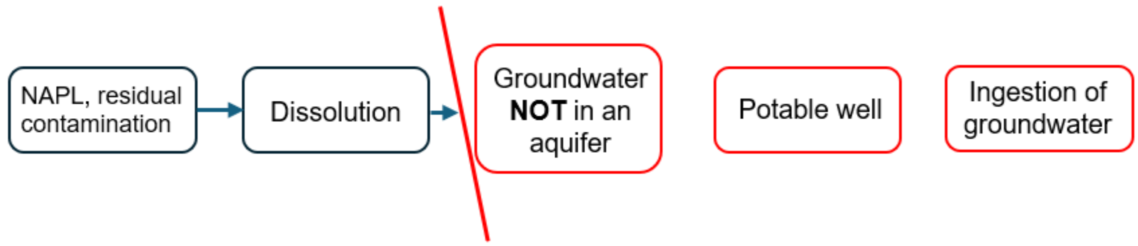


Figure B-2. Groundwater protection exposure pathway is incomplete for future use

To provide an acceptable GWNIAA demonstration, one of the listed Condition 1 options regarding groundwater quantity ***and*** one of the listed Condition 2 options regarding hydraulic communication must be met. These conditions are discussed in the next section. Information from sites in the immediate vicinity of the site being evaluated may be used to support maximum sustainable yields if validated by an analysis of the areawide conditions. State of Michigan and EGLE online resources GeoWebFace, GIS Open Data, MGS publications, and Quaternary and other geologic maps can aid in this determination.

A GWNIAA determination can also be made by demonstrating that groundwater at the site consists of water that is trapped or isolated in fill material in an underground storage tank or equivalent basin in lieu of demonstrating the two conditions below.

Condition 1 – Groundwater Quantity

The formation does not yield a significant amount of groundwater considering the local and regional hydrogeology. This condition can be met by satisfying ***any*** of the following options:

1. All monitoring wells in the formation being evaluated bail or pump dry when pumped at a maximum pumping rate of 0.1 gallons per minute (gpm). Well locations must be spaced to accurately characterize the formation being evaluated throughout the site. Monitoring wells must be properly installed and in good condition, be a minimum of two inches in diameter, and have at least 5 feet of screen length.
2. In-situ hydraulic conductivity of the formation being evaluated determined by rising and/or falling head slug tests at a minimum of three (3) separate locations per ¼ acre and can be adjusted and scaled based on plume size. Results from the testing locations can be averaged if it is demonstrated that the average is representative of site conditions. Well locations and construction must be appropriate for the testing and locations must be representative of the formation being evaluated. The exact number of tests will depend on the size and complexity of the site. Hydraulic conductivity results at or below 1.0×10^{-5} cm/s are assumed to be not in an aquifer. For more information about how to conduct slug tests or pump tests, refer to USEPA published Ground Water Issue papers or USGS publications.

3. Other testing or documentation may be submitted to the EGLE district office for approval on a site-specific or regional-specific basis. This may include but is not limited to aquifer pump tests, well yield tests, or specific capacity tests. Note: pump tests have a low likelihood for success in low permeability formations; however, if successful, pump tests results may also provide data to evaluation Condition 2.

4. In parts of the State with mapped areas of clay, diamicton, or other low permeable lithology (e.g., lacustrine clay and silt) on the Quaternary Geology Maps contained on EGLE's GeoWebFace or areas known by the EGLE district office with low permeabilities, one of the following:

    a. One monitoring well installed in the formation being evaluated that will bail or pump dry at a rate of 0.1 gallons per minute.

    b. In-situ hydraulic conductivity of the formation being evaluated determined by rising and/or falling head slug test or pump tests at 1 monitoring well location. Hydraulic conductivity results at or below 1.0×10^{-5} centimeters per second (cm/s) will be assumed to not be in an aquifer.

Condition 2 – Hydraulic Communication

The formation is not likely to transport COCs to an aquifer. This condition can be met by satisfying any of the following options:

1. Documentation of the regional geology supplemented with site-specific information that supports that the saturated zone is not in communication with any aquifers either vertically or horizontally in the subsurface. Site-specific information may include:

    a. Pumping test results that demonstrate all water-bearing units being evaluated are isolated and discrete, do not provide a means for sufficient contaminant mass migration, and/or are not in communication with an aquifer via any subsurface hydrogeologic route. See USEPA Ground Water Issue papers and USGS publications for more information on pumping tests.

    b. Boring and/or monitoring well logs, geophysical information, geologic cross-sections, field notes that indicate groundwater is perched and discontinuous across the site or isolated from an aquifer with a sufficient thickness of an aquitard. The aquitard type and competency will generally aid in the determination of the thickness required.

2. A demonstration that all of the formation groundwater is directly discharging to a surface water body. This option may support a GWNIAA determination and that the groundwater protection pathway is incomplete, but the surface water protection pathway must be evaluated as a complete pathway.
3. A fate and transport assessment that includes modeling results supported by site-specific information and field data that indicate that COCs will not reach an aquifer. For additional information on modeling, refer to the February 14 resource, *Groundwater Modeling*.

B.3 POINT OF EXPOSURE

In order for the groundwater protection exposure pathway to be complete there must be a point of exposure at which a receptor comes into contact with the COCs. The point of exposure is a water supply well such as a potable well. This is an existing well for current use and a reasonable potential for a well in the impacted aquifer for future use.

Groundwater is used as a source of drinking water in most of Michigan. Rural areas often rely on groundwater supplied by private potable wells. Many cities extract and distribute groundwater in their municipal water supply systems. The wells used in both situations represent current POEs, and the future use of groundwater must be protected when a supply well could reasonably be installed in the future. At many sites, therefore, the groundwater protection exposure pathway is considered complete.

If a water supply well does not exist or current supply wells are not potentially impacted by the release, the pathway is not complete for current use. The groundwater protection exposure pathway is assumed to be complete for future use unless it can be eliminated by an evaluation under Section B.2 or B.3.

It should be noted that the presence of municipal water does not make the groundwater protection exposure pathway incomplete for future use. Private potable wells could be present, even in areas supplied by municipal water. A well survey based on a database search is also likely to be inconclusive because many undocumented private wells exist. Further, even if a thorough well survey does not reveal any potable wells within the survey area, water supply wells could be present within the affected aquifer outside of this area or could be installed in the future, and therefore the groundwater protection pathway would be complete for future use. The future use assessment of the groundwater protection pathway, either under Tier 1, 2, or 3, is necessary to assure the delineation of the dissolved plume, to evaluate and document the stability of the plume, and to assure that there will be no unacceptable future exposure to COCs.

The groundwater protection exposure pathway is incomplete if the aquifer is not able to be used as a drinking water source and there is no reasonable likelihood of transporting COCs to a useable aquifer. The exposure pathway is therefore eliminated because there is no current or likely future POE and the COCs cannot be transported to an aquifer that has a POE (Figure B-3). This demonstration can be made by meeting **all** the following conditions:

1. The bottom of the impacted aquifer is less than approximately 15 feet from the ground surface,
2. The aquifer is not hydraulically connected laterally or vertically to another aquifer that could be used as a drinking water source, and
3. There are no water supply wells in **any** aquifer within 300 feet of the site property boundary.

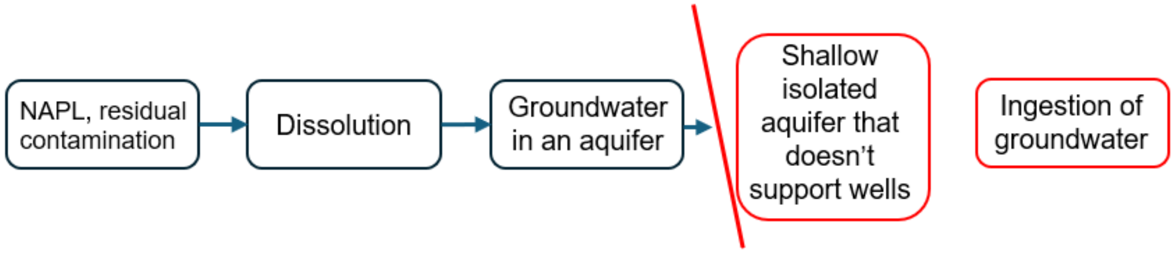


Figure B-3. Groundwater protection exposure pathway is incomplete for future use

The above conditions describe a shallow, isolated aquifer (refer to Section 5.1) that does not have a POE and is not likely to transport COCs to another aquifer. The Michigan Groundwater Quality Control Rules, R 325.1601 et seq., require casing for potable wells to extend to at least 25 feet below the ground surface, and therefore an aquifer that extends no deeper than approximately 15 feet would not be able to have a potable well installed.

To ensure that COCs in the impacted shallow aquifer are not transmitted to another aquifer that could support supply wells, the shallow aquifer cannot be hydraulically connected to another aquifer. A hydraulic connection can exist due to natural hydrogeologic conditions (e.g., a discontinuous aquitard) or anthropogenic conditions (a water supply well that penetrates the aquitard). This condition is critical in the area of impacted groundwater. The three conditions listed above can generally be demonstrated with (i) soil boring logs and cross sections and (ii) a well survey that documents no supply wells are present within 300 feet of the site property boundary. If the dissolved contaminant plume extends longer than 300 feet, conditions within the entire impacted area must be evaluated.

Appendix C – Development of a Site-Specific Biodegradation Rate

C.1 Background

The application of the MIRBCA process at petroleum-impacted LUST sites in Michigan ultimately results in corrective action and/or risk management decisions based on the SSTLs developed for all the complete routes of exposure. At all sites, the MIRBCA process requires the development of soil and groundwater target levels protective of groundwater use and surface water. These target levels may be developed using site-specific biodegradation rates provided that there is sufficient site-specific evidence to confirm that biodegradation is occurring, and that sufficient data are available to estimate a site-specific biodegradation rate. This appendix provides the methodology for determining site-specific biodegradation rates.

This appendix contains guidance on the development of a site-specific biodegradation rate for use in estimating soil and groundwater SSTLs protective of groundwater use and surface water. This appendix should be used in conjunction with the latest version of the *Michigan Leaking Underground Storage Tanks Risk-Based Corrective Action Guidance Manual*. The estimation of site-specific biodegradation rates is an evolving science, and the user is encouraged to review publicly available literature for current approaches to estimate site-specific biodegradation rates.

The soil and groundwater concentrations protective of groundwater use and surface water can be estimated using the MIRBCA computational software. This software includes two options to calculate these concentrations. One option is calculated without biodegradation, and one is calculated with biodegradation. The former uses a DAF in the saturated zone that does not consider biodegradation of COCs whereas the latter allows for the use of a DAF that incorporates a user-specified biodegradation rate.

The choice to utilize biodegradation in calculating groundwater protection and surface water protection SSTLs must be justified. At a site with little to no evidence of biodegradation, the O/O should not use this option to calculate the concentrations protective of the groundwater resource. When properly justified, a site-specific biodegradation rate is an appropriate choice.

EGLE will accept MIRBCA evaluations using the biodegradation rate only if (i) adequate evidence is presented that indicates that biodegradation is occurring at the site, and (ii) the calculated biodegradation rate is technically correct. Even at sites where the O/O proposes the application of the biodegradation rate, an evaluation without the application of the biodegradation rate should be presented in the event the evaluation utilizing the biodegradation rate is not acceptable.

The following two sections contain information and procedures for applying a site-specific biodegradation rate. The first section contains information on how the site data itself must be evaluated to determine if biodegradation is a significant process at the site. The second section contains a procedure to calculate the site-specific biodegradation rate.

- Section C.2 presents a discussion of the type of information that should be evaluated to demonstrate that biodegradation is occurring at the site.
- Section C.3 discusses the method used to calculate a site-specific biodegradation rate for use in the MIRBCA computational software.

C.2 Demonstration of Natural Attenuation and Biodegradation

Several parameters (hydrocarbons, electron acceptors, microorganisms, nutrients, and carbon dioxide) may be measured to demonstrate the occurrence of biodegradation.

These measurements are typically divided into three tiers, or lines of evidence, to demonstrate natural attenuation. These include (i) primary, (ii) secondary, and (iii) tertiary lines of evidence. Data collected under each line of evidence can be evaluated qualitatively or quantitatively as discussed in the following sections. A discussion of the interpretation of the most common primary and secondary lines of evidence for the occurrence of natural attenuation is given in the ASTM standard on the topic (1999).

C.2.1 Primary Lines of Evidence

The primary lines of evidence for the occurrence of natural attenuation, not specifically biodegradation, include data demonstrating the loss of chemical mass through evaluation of measured petroleum hydrocarbon concentrations. Of all the methods available to demonstrate the occurrence of natural attenuation, this is perhaps the simplest and most useful to demonstrate reduction in site-specific groundwater concentrations and risks. Site-specific application of the primary lines of evidence requires: (i) an adequate number of correctly installed sampling points (monitoring wells), (ii) adequate duration and frequency of chemical data collected from these points, and (iii) proper evaluation of these data.

Although the primary line of evidence can show whether a contaminant plume is attenuating based on chemical concentrations, it does not demonstrate whether the decrease in concentrations, or attenuation, is due to destructive mechanisms, e.g., biodegradation or dilution. A secondary line of evidence is necessary to determine whether the decrease is due to biodegradation.

Statistical tests may be used to establish and characterize the trend in concentrations over time. These tests can be used to test a null hypothesis vs. an alternative hypothesis. An example of a null hypothesis is that there is no trend in the concentrations vs. distance. The alternate hypothesis is that there is a downward or upward trend. Application of a statistical test would then result in the acceptance or rejection of the null hypothesis at a specified level of significance.

If the concentration vs. time or concentration vs. distance data indicate a decreasing or increasing trend, a regression analysis may be used to estimate the slope of the best-fit line and determine whether or not the trend is significant. The slope of the best-fit line for the data can be used to estimate the natural attenuation or the biodegradation rate. For additional information on regression analysis, refer to any statistics textbook.

C.2.2 Secondary Lines of Evidence

Secondary lines of evidence of the occurrence of biodegradation refer to the measurements of electron acceptors and products of metabolism and their comparison with concentrations in the unimpacted area of the aquifer, where no biodegradation activity would be expected to occur. These parameters are also referred to as geochemical indicators or intrinsic indicators of biodegradation. Parameters that are typically measured in the field include: (i) dissolved oxygen, (ii) carbon dioxide, (iii) dissolved nitrates, (iv) manganese, (v) ferrous iron, (vi) sulfate, and (vii) methane. These parameters should be measured at upgradient locations, inside the plume near the source, and in the downgradient locations. The distribution and occurrence of these parameters that is indicative of biodegradation is discussed in the ASTM standard on the topic (1999).

As chemicals are consumed by microorganisms, there is a corresponding decrease of the compounds that serve as electron acceptors. Thus, the concentration of these compounds decreases in the portion of the plume where biodegradation is occurring. For example, under aerobic biodegradation, the concentration of oxygen would decrease, assuming oxygen is not being added to the plume. Similarly, under anaerobic conditions, a depletion of nitrate, ferric (III) iron, and sulfate. The byproducts of biodegradation are carbon dioxide, methane, and water. Thus, an increase in the concentrations of methane and carbon dioxide in portions of a plume may indicate biodegradation.

It should be noted that the secondary lines of evidence demonstrate the occurrence of biodegradation only. It does not provide any data on the occurrence of other natural attenuation processes.

C.2.3 Tertiary or Optional Lines of Evidence

Tertiary or optional lines of evidence involve the performance of microbiological studies such as the identification and counting of the microorganisms present in the formation. Thus, the objective of the measurement of secondary and tertiary lines of evidence is similar. Although petroleum-degrading microbes are ubiquitous in soil and groundwater, microbes at a site may not be able to degrade certain compounds, for example MTBE. In the portion of the plume where biodegradation is occurring, the ratio of petroleum-degrading bacteria to the total number of bacteria is expected to be higher. Tertiary lines of evidence may be beneficial at very complex sites but may not be warranted at most petroleum LUST sites, hence, they are not discussed further here.

C.2.4 Documentation of Biodegradation in the MIRBCA Report

If the secondary or tertiary (rarely measured) lines of evidence indicate that biodegradation is occurring, at a minimum, the following information should be submitted as justification:

- Tables of historical intrinsic indicators of biodegradation
- Graphs of historical values of intrinsic indicators of biodegradation plotted as time vs. concentration per well
- A series of contour maps illustrating trends of pertinent indicators of biodegradation over time
- Include comparison of site concentrations with SSTLs with and without biodegradation in the Tier 2 MIRBCA report forms
- Table of decay rate input/output values
- Table of calculated attenuation and biodegradation rates including ranges and averages
- Copy of the relevant input and output tables from the MIRBCA computational software

C.3 Estimation of Site-Specific Chemical Half-Lives

The following step-by-step procedure may be used to develop a site-specific biodegradation rate or half-life for use in the groundwater protection and surface water protection evaluation. Note, the procedure should be repeated for each chemical of concern.

Step 1: Determine the groundwater flow direction(s) based on the water level measurements for each monitoring event.

Step 2: For each monitoring event, identify the wells located along the directions of flow, i.e., along the plume centerline(s). Note, since the flow direction may vary, different wells may be used for different monitoring events.

Step 3: Tabulate the concentrations of the chemicals of concern and calculate the natural log of the concentrations.

Step 4: For each monitoring event, plot the natural log of the concentrations on the Y-axis and the distance along the X-axis. A separate plot should be made for each event.

Step 5: For each plot, calculate the slope of the best-fit line and test whether or not the null hypothesis can be rejected at the 0.05 level of significance. The null hypothesis in this case is that the slope of the regression line is zero, indicating no relationship between the natural log of concentration and distance.

Step 6: Estimate the groundwater seepage velocity and the longitudinal dispersivity.

Step 7: Multiply the slope of the best-fit line calculated in Step 5 by the seepage velocity to estimate k (see Buscheck and Alcantar, 1995).

The result would represent the overall natural attenuation rate. This natural attenuation rate represents the reduction in concentration due to the combined influence of the various natural attenuation processes mentioned in Section C.2. Note that this overall natural attenuation rate (*k*) should not be confused with the biodegradation rate (λ) that is an input to the model used to calculate groundwater protection and surface water protection SSTLs in MIRBCA (see Equation 25 in Appendix A).

Step 8: Estimate the biodegradation rate (λ) using Equation C-1 derived by Buscheck and Alcantar (1995, equation 9) based on the solution of the one-dimensional transport equation with biodegradation.

$$\lambda = \frac{v}{4\alpha_x}\left\{\left[1 + 2\alpha_x\left(\frac{k}{v}\right)\right]^2 - 1\right\} \qquad \text{(C-1)}$$

where,

λ	=	Biodegradation rate (1/year)
α_x	=	Longitudinal dispersivity (x/10) (ft)
x	=	Distance from the source to the POE (ft)
k	=	Attenuation rate (1/year)
v	=	Seepage velocity (ft/day)

Steps one through eight should be completed for each relevant groundwater monitoring event, for example, all those within the period over which representative concentrations have been calculated. The results should be presented as a range of natural attenuation and biodegradation rates, *k* and λ, respectively. The latter is used as an input to the Domenico model to estimate the saturated zone dilution attenuation factor. Due to confounding factors such as seasonal variations in groundwater velocity, water level fluctuations, errors in sampling and analysis methods, natural attenuation and biodegradation rates may vary significantly between events. Therefore, it is best to present the range as well as the average rates.

Professional judgment must be used to determine the most representative λ for use in the calculation of the chemical half-lives.

Step 9: Calculate a half-life for each chemical using Equation C-2:

$$\lambda = 0.693 / t_{1/2} \qquad \text{(C-2)}$$

where,

λ	=	biodegradation rate (1/year)
$t_{1/2}$	=	half-life (years)

Utilize the site-specific half-lives in the calculation of the groundwater protection and surface water protection with biodegradation SSTLs (soil and groundwater). In the computational software, the half-lives for each chemical of concern should be entered on the worksheet entitled “Chemicals of Concern, Half Life and Unsaturated Zone DAF.” In lieu of calculating a site-specific half-life, a default half-life of 5 years for benzene may be used if supported by site data. For other COCs, a site-specific half-life must be calculated.

C.4 References

- ASTM International, 1999, Designation E 1943-98 Standard Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites, in: *ASTM Standards on Assessment and Remediation of Petroleum Release Sites*, ASTM Committee E-50 on Environmental Assessment, ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, 19428-2959, pages 82-123.

- Buscheck, T.E., and Alcantar, C.M., 1995. “Regression techniques and analytical solutions to demonstrate intrinsic bioremediation.” In: R.E. Hinchee, J.T. Wilson, and D.C. Downey (eds.), Intrinsic Bioremediation, pp.109-116. Battelle Press, Columbus, OH.

Appendix D – Model Water Well Survey Form and Letter

[DATE]

[Property Owner Name]
[Property Owner Address]
[City, State]

Re: Water Well Survey for Investigation of Petroleum Release

Release Location (Site): **[LUST Site Name]**
[LUST Site Address]
[City, State]
Facility Id#: **[Facility Id#]**

Dear **[Property Owner]**:

[Consultant] is conducting an environmental investigation on behalf of **[Owner/Operator]** for the above referenced site as required by the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Remediation and Redevelopment Division (RRD), to protect public health and the environment. EGLE requires a survey to be conducted for all properties within 300 feet of the site referenced above to determine if drinking water wells are or have been present. This investigation is being performed in an effort to protect drinking water resources and evaluate potential exposure to contaminated groundwater.

This letter was sent to you because your property is located within 300 feet of the site referenced above. Please answer the questions on the enclosed survey form and return the survey within ten days to assist us in evaluating drinking water usage within the surrounding area of the site. By returning this survey, you are helping us make an informed, environmentally responsible decision in your community. If you have any questions, please contact me at **[PHONE NUMBER]**.

Sincerely,

[Name of Person Who Prepared Form]
[Title]
[Consulting Company Name]

Enclosures: Water Well Survey Form
Self-Addressed Stamped Envelope

Water Well Survey Form

[Property Owner Name]
[Property Address]
[City, State]

Thank you for your help with this survey. Please complete the form to the best of your knowledge about the property and return it in the envelope provided within ten days.

1. Is a water well installed on your property for drinking, irrigation, or other purposes? *(circle one)*

   YES **NO** **Unsure**

2. If **YES** to #1, is the water well still in use (if no, please explain below)?

   YES **NO**

3. If **Unsure** to #1, would you like an inspector to look for a well on the property?

   YES **NO**

4. Are you obtaining your drinking water from a municipal source (city, township, etc.)?

   YES **NO**

5. Are you aware of any water wells in the area (if yes, please explain)?

   YES **NO**

Comments:

____

____

____

____

Signature of Property Owner/Manager:________________________ Date:__________

Appendix E – MIRBCA Forms

The MIRBCA forms are provided in a downloadable zip file. Individuals with disabilities may request these materials in an alternative format by emailing EGLE-Accessibility@Michigan.gov or calling 800-662-9278.

Appendix F – User's Guide for the MIRBCA Forms