North Dakota Department of Environmental Quality

NORTH DAKOTA RISK-BASED CORRECTIVE ACTION (NDRBCA) TECHNICAL GUIDANCE

January 2023

NORTH Dakota | Environmental Quality

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ABBREVIATIONS

AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
COC	Chemical of Concern
CI	Confidence Interval
CSM	Conceptual Site Model
DRO	Diesel Range Organics
ED	Exposure Domain
EM	Exposure Model
ET	Ecotox Thresholds
EP	Exposure Pathway
ERE	Ecological Risk Evaluation
GRO	Gasoline Range Organics
GWPP	Groundwater Protection Program
GWSDAT	Ground Water Spatio-Temporal Data Analysis Tool
HH&E	Human Health & Environment
HWP	Hazardous Waste & PCB Program
LUST	Leaking Underground Storage Tank
MCL	Maximum Contaminant Level
NAPL	Light Non-Aqueous Phase Liquid
NDAC	North Dakota Administrative Code
NDCC	North Dakota Century Code
NDDEQ	North Dakota Department of Environmental Quality
NDPTRCF	North Dakota Petroleum Tank Release Compensation Fund
NDRBCA	North Dakota Risk Based Corrective Action

NFA	No Further Action
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
ORO	Oil Range Organics
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethylene
PID	Photoionization Detector
POE	Point of Exposure
PVC	Polyvinyl chloride
RA	Risk Assessment
RAP	Remedial Action Plan
RBSL	Risk Based Screening Level
RBTLS	Risk Based Target Level
RC	Representative Concentration
RCRA	Resource Conservation Recovery Act
RM	Risk Management
RMP	Risk Management Plan
ROE	Route of Exposure
RP	Responsible Party
RL	Reporting Limit
RSL	Regional Screening Level
SC	Site Characterization
SSTL	Site Specific Target Level
TDS	Total Dissolved Solids
TCE	Trichloroethylene
TPH	Total Petroleum Hydrocarbons
TSDF	Treatment, Storage, and Disposal Facility
USEPA	United States Environmental Protection Agency
USDA	United States Dryland Agriculture
USGS	United States Geological Survey
UST	Underground Storage Tank
VRA	Voluntary Response Action
XRF	X-Ray Fluorescence

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1.1 INTRODUCTION

The intent of this guidance is to outline key procedures for implementing consistent and successful contaminant assessment and risk-based remediation strategies across applicable North Dakota Department of Environmental Quality (NDDEQ) programs. The NDDEQ has authority to use a risk-based decision-making process at contaminated sites and has previously applied a risk-based process. The process described in this document is termed North Dakota Risk Based Corrective Action (NDRBCA). It is consistent with the RBCA standard developed by the American Society for Testing and Materials (ASTM E1739-95(2015)).

This guidance applies to contaminated, or potentially contaminated, sites and will guide the user through the development of Risk-Based Target Levels (RBTLs) that are protective of current and future human health and environment (HH&E).

This guidance will be applicable to newly identified release sites, on-going projects as appropriate, newly discovered incidents/contamination at previously closed sites, and other projects, as required by the NDDEQ. The NDDEQ will not seek to re-open or reevaluate previously closed sites unless there has been a significant change in site conditions or planned site use that may impact HH&E. New requests, such as for the issuance of a certificate of completion as described in North Dakota Century Code (NDCC) 23.1-10-15, for sites previously granted letters of No Further Action may result in re-assessment through this process.

This guidance illustrates the type and format of information that should be collected and presented in a Remedial Action Plan (RAP) to demonstrate that a risk-based strategy is appropriate for the protection of human health and the environment. This guidance provides a technically defensible procedure for establishing RBTLs at impacted sites (Refer Section 2.3 and Appendix A).

This guidance is intended for use by environmental professionals with knowledge of environmental risk evaluation principles. Prior experience and/or training will be necessary for an individual to correctly implement the NDRBCA process.

1.2 NDDEQ AUTHORITY

The NDDEQ is established as the primary state environmental agency under NDCC Article 23.1. The duties of the NDDEQ include implementation of environmental rules and regulations, including oversight of environmental remediation or reclamation projects.

The following NDDEQ programs manage remediation projects:

1. Brownfields Program

2. Voluntary Response Action Program
3. Leaking & Underground Storage Tank Programs
4. Hazardous Waste and PCB Program
5. Groundwater Protection Program
6. Spill Investigation Program

All work conducted as part of the NDRBCA process must operate in accordance with all applicable rules and regulations. Nothing in this document overrules or supplants existing rules or regulations. This document is not intended to be used as an initial response to an active spill. To report an active spill or discovery of contamination, please call the North Dakota State Radio 24 Hour Hotline at 1.833.99SPILL (1.833.997.7455) or report online to the North Dakota Unified Spill Reporting System at https://www.spill.nd.gov/.

A brief description of each of the programs under which site characterization (SC), risk evaluation (RE) and risk management (RM) activities are conducted in North Dakota are discussed below.

1.3 SITE CLEANUP AND REMEDIATION PROGRAMS

1.3.1 Brownfields Program

The Brownfields Program is a non-regulatory program operated by the Hazardous Waste & PCB Program. The goal of the Brownfields Program is to return contaminated properties to an economically viable state by addressing contamination at the property. This means the Brownfields Program will use the NDRBCA process to make management decisions such as remedy selection, remediation targets, institutional control decisions, and others related to the direct management of a site.

1.3.2 Voluntary Response Action Program

The Voluntary Response Action (VRA) program provides a roadmap for developers, landowners, financial institutions, and technical experts to conduct contaminated site cleanups in a consistent manner. The goal of the VRA program is to manage sites where contamination has been fully delineated, risks have been assessed, and those risks have been mitigated and documented. VRA differs from the NDDEQ required responses (such as an environmental incident or spill) in that the NDDEQ has not required remediation or corrective action. Sites under an NDDEQ directive may not receive liability protection until the directive has been resolved. VRA projects must adhere to the requirements of NDCC §23.1-10-15: *Voluntary response actions – Liability protection – Procedures*.

The NDDEQ will utilize the procedures outlined in this document for VRA projects. All requirements outlined in NDCC §23.1-10-15 have been identified and are discussed in relation to this document in the *NDRBCA & Voluntary Response Actions* guidance document. Note that nothing in this document overrules or supersedes the requirements of NDCC §23.1-10-15. For more information about VRA and liability protection, please contact the NDDEQ directly.

1.3.3 Leaking & Underground Storage Tank Programs

The Underground Storage Tank (UST) Program works with owners and operators of underground storage tanks to ensure that compliance, leak detection, new installations, upgrades, and tank closures are completed in accordance with North Dakota's UST Rules.

The North Dakota UST Program is also in charge of ensuring that leaking underground storage tank (LUST) sites are reviewed and managed. The UST Program may require work to investigate, monitor or remediate the LUST sites. If the owner/operator is unable or unwilling to pay for these activities or if there is no responsible party (RP), the UST Program may write a contract that uses federal LUST Trust monies to fund this work. The funds used in LUST contracts are cost recoverable. If the RP performs the work and is eligible for funding, the North Dakota Petroleum Tank Release Compensation Fund (NDPTRCF) may be used as a funding source for the work.

1.3.4 Hazardous Waste and PCB Program

The Hazardous Waste and PCB Program (HWP) primarily oversees projects involving the release of hazardous wastes and/or hazardous constituents from regulated hazardous waste generators, or permitted transport, disposal, or treatment facilities (TSDFs). The NDRBCA process will be used in these cases for making regulatory decisions related to the release of contaminants regulated under the North Dakota Hazardous Waste Management Rules (NDAC §33.1-24). These decisions will include the selection of remediation targets, the need for institutional controls, and for determining if no further action is required at a site. Note that PCB releases are a joint management effort between the HWP and the United States Environmental Protection Agency (USEPA), with many of the remediation targets being defined in federal regulations, and the NDRBCA process will not likely be utilized for PCB sites.

1.3.5 Groundwater Protection Program

The Groundwater Protection Program provides general technical oversight for activities related to contaminant releases/discharges under the authority of NDCC §23.1-11, including data interpretation and evaluations of site-specific conditions, contaminant levels, and associated potential health risks, and appropriate remedial alternatives, and processing requests for site closure and releases of liability.

1.3.6 Spill Investigation Program

The Spill Investigation Program oversees multiple types of releases throughout North Dakota. Any spill or discharge of liquid or solid (not gaseous) waste which may cause pollution of waters of the state must be reported immediately under North Dakota Administrative Code 33-16-02.1. The Spills Investigation Program reviews incidences reported to the North Dakota Unified Reporting System and assigns cases to the appropriate oversight program.

The Spills Investigation Program has oversight for oil and gas releases that migrate off well pads, pipeline releases, and trucking accidents. This includes contaminates like natural gas condensates, production water, emulsion, crude oil, and formation water.

2.0
OVERVIEW OF NDRBCA PROCESS

2.1 INTRODUCTION

The NDRBCA process begins when a contaminated site is identified. The process includes all subsequent activities required to ensure that the site does not pose an unacceptable risk to HH&E due to residual chemicals at the site. The NDRBCA process consists of the following three primary activities:

- **Site characterization (SC)**: the collection of data to delineate the impacts in soil, groundwater, soil vapor, surface water, sediments, outdoor air, and indoor air, to protect HH&E. Additionally, information related to current and future land use; characteristics of the impacted media; and current and future receptors shall be collected. Information collected during SC is used to develop a conceptual site model (CSM) that includes an exposure model (EM).

- **Risk Assessment (RA)**: the calculation of risk-based target levels (RBTLs) as discussed in the Section 2.3 and Appendix A, under current and reasonable future land use scenarios. A RA requires identifying the impacted media, chemical of concern (COC), receptors, exposure pathways, and routes of exposure (ROE). An exposure pathway is the course chemicals travel from a source to the receptor and the route of exposure is the way the COC enters the receptor. A receptor is an entity that must be protected. The results of the RA are used to determine and implement the nature and scope of risk management activities.

- **Risk Management (RM):** the selection of cleanup levels for the various media and comparison with environmental media (media) specific representative concentrations (RCs), selection of risk management activities, and their implementation to ensure that the residual chemicals at the site are protective of HH&E under current and reasonably anticipated future conditions. RM activities include remediation activities and/or institutional controls.

Figure 2-1 illustrates these primary activities. The activities are fundamentally technical and rely on a variety of scientific disciplines such as geology, hydrology, engineering, chemistry, toxicology, ecology, and land use planning. Due to the inherent variability and uncertainty regarding several factors that affect SC, RA, and RM, multiple assumptions are necessary. These assumptions must be consistent with state and federal laws and regulations.

The implementation of the above activities involves numerous stakeholders. These include, but are not limited to, (i) the RP who is typically responsible to pay for and implement all the activities, (ii) service providers hired by the RP who implement the activities, and (iii) regulators who ensure that the activities are conducted in accordance with state and federal guidelines. Additional stakeholders include, but are not limited to, the public, proximate landowners, future landowners, insurance companies, and financial institutions.

2.2 RISK-BASED CORRECTIVE ACTION PROCESS

The NDRBCA decision-making process is illustrated in Figure 2-2 and discussed below.

2.2.1 Site Discovery

The stakeholders may learn about a contaminated site under a variety of circumstances that include but are not limited to:

- Citizen complaints,
- Investigations conducted as a part of real estate transactions,
- Investigations conducted in anticipation of land development,
- Environmental impacts observed in surface water bodies, and
- Accidents and spills that occur as a part of exploration, manufacturing, and transportation activities.

NDRBCA does not change any of the responsibilities or obligations for a RP, instead it provides a consistent streamlined process to manage the contaminated or potentially contaminated sites.

The process of site discovery and notification is further discussed in Section 3.0.

2.2.2 Determination and Abatement of Imminent Threat(s)

Upon discovery of contamination, the North Dakota Unified Spill Reporting System should be notified by calling 1-833-99SPILL (1.833.997.7455) or reported online at https://www.spill.nd.gov/.

If there is an imminent threat to HH&E, the RP will be required to take actions necessary to end the hazardous substance emergency, stop the release of chemicals to the environment and ensure the safety of HH&E. After the completion of such activities, a written report must be submitted to the NDDEQ to document the activities implemented and confirm that all imminent threats have been abated. The RP may also be requested to include recommendations for any additional work necessary for the continued protection of HH&E. Typically, these activities will include site characterization and the development of a conceptual site model (CSM).

Determination and abatement of imminent threat(s) are discussed in Section 3.0.

2.2.3 Initial Site Characterization and Development of Conceptual Site Model

Site characterization includes identification of the source, determination of the COCs, collection of data for all media affected by the release, current and reasonable future land use and utilities. This step focuses on fieldwork (drilling of soil borings; installation of soil vapor ports and groundwater monitoring wells; collection of soil, soil vapor, and groundwater samples; etc.) to identify the maximum concentrations of COCs in the affected media and the extent of impacts in each media. The level of effort (number of sampling points, location, and frequency of sampling) necessary for an adequate characterization is dependent upon site-specific conditions combined with professional judgement.

Impacts should be delineated to levels necessary to protect the receptors from a complete route of exposure. For example, at a commercial/industrial site with acceptable land use restrictions, the delineation criteria will be the commercial/industrial Tier 1 Risk-Based Screening Levels (RBSLs). Additionally, if an ecological threat exists, delineation must be to the levels protective of both the ecological and human receptors. To the extent possible, the laboratory reporting limits for all COCs must be lower than the corresponding delineation levels i.e., the applicable Risk-Based Screening Levels. Refer to Appendix E for discussion of reporting limits.

A CSM qualitatively and to a limited extent quantitatively describes all the relevant site-specific factors that determine the risk to HH&E and is the framework for management of risk at a site. The CSM should be documented using narrative descriptions, diagrams, and flow charts, as appropriate. It may include attachments such as boring logs, monitoring well construction details, and laboratory reports. The CSM should be updated as new site-specific information is collected and integrated into the understanding of the site.

Key elements of the CSM include:

1. The chemical release scenario, source(s), and COCs,
2. Spatial and temporal distribution of COCs in the various impacted media,
3. Current and future on-site/off-site land use, groundwater use, and characteristics of surface water bodies that may potentially be affected by site COCs,
4. Description of any known existing or proposed land or water use restrictions,
5. Description of media potentially impacted by the COCs (vadose zone soil, groundwater, surface water, indoor, etc.)
6. Remedial activities conducted to date, if any, and
7. An EM that identifies the receptors, exposure pathways, and routes of exposure under current and reasonable future land use conditions.

The extent of contamination and complete evaluation of routes of exposure, *not the property boundaries*, affect the extent of SC activities. The amount of data collected must allow the development and validation of the CSM.

Data required to develop a CSM and EM are discussed in Sections 4.0 and 5.0.

2.2.4 Tier 1 Evaluation

If the site concentrations exceed the relevant Tier 1 RBSLs (refer Section 2.6), the RP may choose to complete a Tier 2 risk evaluation or to select the Tier 1 RBSLs as the cleanup levels. Tier 1 RBSLs specific to the COC, media, exposure pathway, and receptor are tabulated in Table 6-1. If a COC is not listed on the Tier 1 RBSLs, refer to USEPA soil screening levels or USEPA maximum contaminant levels for groundwater or consult with the NDDEQ.

A Tier 1 risk evaluation involves:

1. Determination of site COCs,
2. Selection of the maximum concentrations (RCs) in each media,
3. Selection of relevant Tier 1 RBSLs from Table 6-1, and
4. Comparison of the selected Tier 1 RBSLs with the RCs.

Based on the comparison of RCs with Tier 1 RBSL, the RP can select one of the following options:

1. If the COC concentrations are less than the Tier 1 RBSLs, and other conditions discussed in Section 6.6 are satisfied, request NDDEQ to issue site closure,
2. If the representative COC concentrations exceed the RBSLs, then:

    - Adopt Tier 1 RBSLs as the cleanup levels and submit a Risk Management Plan (RMP) to meet the cleanup levels, or
    - Perform a Tier 2 evaluation.

Upon completion of the Tier 1 evaluation, the RP must provide a Tier 1 Report to the NDDEQ. If the RP chooses to immediately perform a Tier 2 evaluation, both evaluations may be combined into a single report and submitted to the NDDEQ.

The Tier 1 risk evaluation is further discussed in Section 6.0.

2.2.5 Tier 2 Evaluation

A Tier 2 evaluation allows for the use of site-specific exposure and fate and transport parameters to calculate Tier 2 site-specific target levels (SSTLs).

In preparation for a Tier 2 evaluation, additional data may have to be collected and the EM revised as needed. Tier 2 SSTLs are calculated concentrations, based on site-specific data, such as the physical characteristics of the impacted media.

After the Tier 2 SSTLs have been calculated, they must be compared with representative COC concentrations for each complete exposure pathway. Depending on the comparison, the RP can make one of the following options:

1. If the RCs for each complete route of exposure are below the respective Tier 2 SSTLs, and other conditions discussed in Section 7.6 are satisfied, request site closure from the NDDEQ,
2. If the RCs for each complete ROE exceed the respective Tier 2 SSTLs, then:

- Adopt the Tier 2 SSTLs as cleanup levels and develop a RMP to manage these levels, or
- Develop a work plan for a Tier 3 evaluation.

Upon completion of the Tier 2 evaluation, the RP must provide a Tier 2 evaluation report to the NDDEQ. Note Tier 1 and Tier 2 evaluation may be included in the same report.

The Tier 2 risk evaluation is further discussed in Section 7.0.

2.2.6 Tier 3 Evaluation

A Tier 3 evaluation allows considerable flexibility in managing risk at a contaminated site. Due to the many options available to the RP for the implementation of a Tier 3 evaluation, the NDDEQ requires that a work plan be submitted and approved prior to the implementation of a Tier 3 evaluation.

After the Tier 3 SSTLs are calculated, they must be compared to representative COC concentrations for each complete exposure pathway. Depending on the comparison, the RP can select either of the following two options:

1. If the RCs for each complete route of exposure are below the respective Tier 3 SSTLs, and other conditions discussed in Section 8.4 are satisfied, request site closure from the NDDEQ,
2. If the RCs for any complete ROE exceed the respective Tier 3 SSTLs, then adopt the Tier 3 SSTLs as cleanup levels and develop a RMP to meet these levels.

Upon completion of the Tier 3 evaluation, the RP must provide a Tier 3 risk evaluation report to the NDDEQ.

The Tier 3 risk evaluation is further discussed in Section 8.0.

2.2.7 Development and Implementation of Risk Management Plan (RMP)

The objective of all RMPs is to protect HH&E under current and reasonable future land use conditions. Typically, a RMP will be developed after the NDDEQ has approved media-specific cleanup levels under a Tier 1, Tier 2, or Tier 3 evaluation. The RMP must include details of the proposed remedial options, including environmental covenants, and the way the remedial options will be implemented and monitored. To the extent needed to protect HH&E, the plan may include:

1. Selection of remedial methods,
2. Proposed environmental covenants and justification for their use,
3. Estimate of the time needed to implement the RMP,
4. Monitoring plan to verify the effectiveness of the RMP,
5. Conditions that may require re-evaluation of the RMP, and
6. Steps that will be taken if the RMP is not effective.

The RMP must then be implemented as written and approved. The data collected and the evaluation must be submitted to the NDDEQ. If the RMP is not progressing as planned and changes are needed, a proposal for modifying the plan must be submitted to the NDDEQ for approval.

RMP activities must continue until the NDDEQ determines that, based on site-specific data, cleanup goals have been met, specified land use restrictions are in place, and the residual impacts are stable or decreasing. The RMP must include a commitment to maintain the environmental covenant for as long as is necessary to ensure protection of HH&E, i.e., until residual concentrations exceed unrestricted use levels (RBTLs). NDDEQ will issue a site closure, based on the information available to NDDEQ at the time, that conditions at the site are protective of HH&E.

In the future, additional information may become available that may lead to the conclusion that the site poses an unacceptable risk to HH&E or that the land use has changed and is no longer compatible with the RMP that was implemented. In either of these or similar cases, the NDDEQ may rescind the site closure and require further action at the site.

Risk Management Plan is further discussed in Section 9.0.

2.3 RISK-BASED TARGET LEVELS WITHIN THE NDRBCA PROCESS

Under the NDRBCA process, any of the following risk-based levels may be selected as the cleanup levels.

1. **Tier 1 RBSLs** are a combination of (i) the Regional Screening Levels presented in USEPA (2022b) and (ii) concentrations developed by NDDEQ using conservative default exposure and fate and transport parameters that depend on the receptor, media, pathway, route of exposure, and domestic use or likely use of impacted or threatened groundwater. Refer to Appendix A for further details of the RBSLs. The use of Tier 1 RBSLs as clean up levels may require environmental covenants be placed on the site.

2. **Tier 2 SSTLs** are concentrations calculated using site-specific exposure and fate and transport parameters and the guidelines in this document. Tier 2 SSTLs differ from Tier 1 RBSLs in that the Tier 2 SSTLs are based on site-specific values, whereas the Tier 1 RBSLs use default fate and transport parameters. Typically, but not always, Tier 2 SSTLs will be higher than the corresponding Tier 1 RBSLs. Use of Tier 2 SSTLs as clean up levels may also require environmental covenants.

3. **Tier 3 SSTLs** are concentrations that are calculated using data collected at the site (i.e., site-specific exposure factors and fate and transport parameters) and the guidelines in this document. However, compared with Tier 2 SSTLs, Tier 3 SSTLs may be based on the application of fate and transport models and exposure

scenarios other than those used to calculate the Tier 1 RBSLs and Tier 2 SSTLs. Use of Tier 3 SSTLs as cleanup levels may also require environmental covenants.

Table 2-1 compares the different tiers within the NDRBCA framework. However, as the analysis moves through the tiers, and if the target cleanup levels become lower, the RP does not have the option of using higher levels from the previous tier. The higher tier target levels are based on site-specific information and hence are expected to be more accurate representation of potential risks at the site. For large sites (several acres) different sections of the site may be managed using different cleanup levels and different land use restrictions.

2.4 RATIONALE AND CHARACTERISTICS OF TIERED APPROACH

Despite the differences among the three tiers, there is one very significant similarity: *each tier will result in cleanup target levels that provide an acceptable level of protection to HH&E.* Thus, the process provides considerable flexibility and a variety of options to manage site-specific risks. The RP working with the NDDEQ can thus select the optimal strategy.

As a site 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, and labor costs.
- In general, the calculated Tier 2 SSTLs will be higher than the Tier 1 RBSLs and Tier 3 SSTLs will be higher than 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 risk management activities at higher tiers should generally be lower.
- The need for, and the extent of, regulatory oversight and review will increase as the site moves from Tier 1 to Tier 2 and then to Tier 3.
- 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 NDRBCA PROCESS

To make decisions that protect HH&E, the NDRBCA process requires the collection and analysis of a considerable amount of data. In addition, a variety of stakeholders may be interested in the outcome of the NDRBCA process. Therefore, the process by which data is collected, analyzed, and documented and the way in which decisions are made must be as transparent and consistent across different sites as possible.

The method and format by which the RP reports data must be consistent across the state and unambiguous so that stakeholders can readily understand the:

- Data collected to quantify and analyze the problem,
- Nature and extent of the problem at a site,

- Process used to collect the necessary data,
- Chronology of relevant environmental activities, and
- Demonstration that the actions taken are protective of HH&E under current and reasonably anticipated future use conditions.

In general, reports that may be required as a part of the NDRBCA process are listed below:

- Determination and Abatement of Imminent Threats,
- Site Characterization Report,
- Tier 1 and 2 Risk Evaluation Report (Tier 1, 2, or both),
- Tier 3 Work Plan,
- Tier 3 Risk Evaluation Report,
- Risk Management Plan, and
- Completion of Risk Management Plan.

To facilitate the documentation of these activities and to ensure consistency across sites, the NDDEQ has developed forms and tables that must be used. These are included in Appendix B.

3.0
SITE DISCOVERY AND MANAGEMENT OF IMMINENT THREATS

3.1 SITE DISCOVERY

The NDRBCA process starts when a contaminated site is discovered and continues until the NDDEQ issues site closure. Several events may trigger site-specific activities that may ultimately lead to the discovery of a contaminated site. These include but are not limited to:

- Observation of a sheen on or near a site, e.g., in utilities, surface water bodies, observation wells, on ground surface, etc.
- Unusual industrial operating conditions, e.g., sudden loss of product in tanks, erratic behavior of product dispensing equipment, etc.,
- Monitoring results from a leak detection system that indicate a leak,
- Underground storage tank removals
- Phase I or phase II property investigations
- Accidental release, e.g., during loading and unloading of chemicals, and
- Citizen complaints

The RP of the facility must first abate any ongoing release of contaminants, abate any imminent threats to HH&E and report to the NDDEQ the suspicion and/or confirmation of release. Upon confirmation of the release, a site characterization will be necessary to collect relevant data to perform a risk-based evaluation (also refer to Section 4.0).

3.2 REPORTING A RELEASE

In accordance with state and federal law, the intentional or unintentional release of hazardous materials must be reported to the state within 24 hours of the incident through the Unified Spill Reporting System online at https://www.spill.nd.gov/ or by calling 1-833-99SPILL (1-833-997-7455).

Upon completion and documentation of the emergency response activities, additional data may have to be collected to perform a risk-based evaluation.
When a release is confirmed, the RP must take immediate steps to (i) prevent any additional release to the environment, and (ii) mitigate any fire, safety, or other immediate hazards to HH&E.

4.1 INTRODUCTION

This section discusses the types of data required to implement Tier 1, 2, and 3 evaluations to be consistent with the NDRBCA process. Typically, data at contaminated sites is collected over a long period of time (several years) and often by different individuals, and at times on behalf of different entities. Therefore, it is important to compile the data and document it in a consistent and easy to understand manner (See Appendix B). This section also discusses the documentation of the data. It is not the intent of this section to present the methods and techniques that can be used to collect the data. Such information is readily available in the public domain.

Within the NDRBCA process, the primary objective is to collect data to enable the estimation of RBTLs protective of HH&E and use management to achieve the calculated RBTLs. Specifically, this includes the following categories of data:

- Site information,
- Description of the source and the COCs,
- Adjacent land use, land use restrictions, and receptor information,
- Analysis of current and future groundwater use,
- Characteristics of various media that may potentially be impacted by the release (unsaturated zone, saturated zone, surface water bodies, sediments, buildings, and the indoor environment). Additionally, characteristics of aquatic and terrestrial organisms that may be potentially exposed to the COCs may be relevant,
- Delineation of impacts,
- Spatial and temporal distribution of COCs in each media impacted by the release,
- Remedial activities conducted at the site, and
- Other pertinent information (such as rainfall, infiltration rate, evapotranspiration, wind speed and direction)

The above data must be collected either using the current state of the practice or specific USEPA or NDDEQ guidance, if available.

The systematic compilation of above data (text, figures, and tables) is often referred to as the Conceptual Site Model (CSM). A CSM presents an overall understanding of the site. It is best developed at the start of a project and refined/updated as additional data is collected and knowledge of the site increases. A CSM is an important communication tool for regulators, RPs, and other stakeholders.

Inherent to the CSM is the Exposure Model (EM) that identifies all the receptors who maybe exposed to the COC's under current and reasonable future conditions, and the complete exposure pathways for each receptor. An exposure pathway describes how the COCs move from the source to the receptor, where contact between the COC and the receptor occurs, and types of exposure. Section 5.0 presents a discussion of the EM.

Environmental data used in the NDRBCA process must be scientifically valid, defensible, and of known and documented quality. This can be achieved by using adequate quality assurance and quality control procedures throughout the entire process, i.e., from initial study planning through data collection and use. To the extent possible, data must be collected using USEPA or NDDEQ procedures.

4.2 SITE INFORMATION

The term "site" refers to the property where the spill or release occurred. Areas beyond the property boundary that may be impacted by the site COCs, must be incorporated in the CSM are referred to as "off-site" areas.

The following information must be included in the CSM:

- A site location map,
- A site map,
- Ground surface conditions,
- Location of utilities on and adjacent to the site,
- Location and characteristics of surface water bodies,
- On-site and adjacent off-site groundwater use, and
- Local hydrogeology and aquifer characteristics.

A brief discussion of each of the above items is presented below.

4.2.1 Site Location Map

A site location map should be prepared using United States Geological Survey (USGS) 7½ minute topographic maps as a base. The site location should be centered and clearly marked on the topographic map. Contour lines on the topographic map must be legible and the map must include a scale bar and the north arrow.

4.2.2 Site Map

A detailed map(s) of the site should show:

- Site (property) boundaries,
- Layout of past and current relevant site features such as containment or storage systems; process areas; transportation and delivery distribution systems; waste handling and storage areas, piping runs; sumps; paved and unpaved areas; and buildings,
- Locations of area(s) of release (source area),
- Locations of on-site and off-site monitoring points (soil borings, confirmatory soil sampling locations, soil vapor points, groundwater monitoring wells, etc.),
- Locations of water wells (public and private) within a quarter mile of the source,
- Location of surface water features within at least 1,000 ft of the source,
- Ecological sensitive features within a 1,000 ft of the source,
- Location of soil excavation, if any, and

- Location of infrastructure associated with any other remedial system (e.g., soil vapor extraction, etc.)
- Source water protection areas

4.2.3 Ground Surface Conditions

The site map should identify the portion of the affected area (on-site and off-site) 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 (for example, swales, drainage, or detention ponds) should be noted.

4.2.4 Location of On and Adjacent Off-site Utilities

Knowledge of underground utilities are important because contaminated groundwater and vapors can flow preferentially into and through underground utility lines and conduits, utility workers are potential receptors, and COCs may affect the integrity of the utilities. Therefore, an assessment of potential and actual migration and impacts of COCs to underground utilities must be performed. Utilities include buried cables, electrical and telephone lines, sanitary and storm sewers, and water and natural gas lines. A combination of site observations, knowledge of buried utilities, and discussions with utility representatives (or use of a one-call system) and the site owner should be used to determine the location of site utilities. The following must be performed:

- Use field instrumentation to measure the vapor concentrations in underground manholes at sites where COCs are volatile. If explosive conditions are suspected or encountered, immediately inform the local fire department and the North Unified Spill Reporting System at 1.833.99SPILL (1.833.997.7455) or reported online at https://www.spill.nd.gov/.
- Locate all underground utility lines and conduits within the area of known or suspected soil and groundwater impact, both on- and off-site, where the release may have migrated or may migrate in the future.

The following information may be useful in the analysis:

- Direction of water flow in utility lines (potable water, storm water, and sewage).
- Location of the utility lines and conduits on a base map that shows the extent and thickness of contamination in soil and groundwater.
- Depth of the utility lines and conduits relative to the depth of groundwater. Seasonal fluctuations of groundwater levels must be considered. A cross-sectional diagram that illustrates the depth to groundwater, range of fluctuations, and the locations and depths of the various utility lines and conduits is recommended.
- Types of materials used for utility lines and conduits - for example, polyvinyl chloride (PVC), terra cotta, concrete, or steel - and the type of backfill around the utilities (sand, native soil).
- Any historical work completed on any of the utilities and if any contamination-

related issues were identified at the time the work was performed.

Refer to Appendix G for further information regarding utility line exposure to contaminants of concern.

4.2.5 On-site Groundwater Use

Current and former site owners and operators may be interviewed to determine whether any water use wells were located on site. Such wells maybe identified based on a search of local, state, and federal records and databases and/or windshield or door-to-door surveys, as appropriate.

To the extent that such information is available, well construction details for all wells is useful. Relevant construction details include the total depth of the well, casing depth, screened or open interval, static and/or pumping level, and the use of water from the well. If available, average well pumping rates and drawdown information also should be compiled.

If a water use well is currently not in use or not likely to be used in the future, it should be closed in accordance with well abandonment guidance.

4.2.6 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. This information can be found in published literature such as USGS resources, United States Department of Agriculture (USDA) soil surveys, North Dakota Department of Water Resources County Groundwater Studies, and reports for any investigations conducted at adjacent or nearby release sites.

The review discussed above should also identify surface water bodies (lakes, rivers streams, wetlands, and springs) located within 1,000 ft of the source that could be affected by a release at the site.

4.3 DESCRIPTION OF THE SOURCE AND COCs

Knowledge about the nature, location and magnitude of a release(s) is necessary to identify the:

- Soil and groundwater source(s) at the site,
- COCs,
- Methods used to analyze the samples,
- Horizontal and vertical extent of soil and groundwater contamination.

The RP must collect as much of the following information as is available for <u>each</u> release that has occurred at the site:

- History of site activities related to the release,
- Location(s) and date(s) of spill(s) or release(s),
- Quantity of the release(s),
- Product(s) or chemical(s) released, and
- Interim response or corrective action measure(s) taken with respect to each release.

Release-related information can be obtained from a variety of sources, including:

- Review of historical aerial photographs or Sanborn fire insurance maps,
- Review of waste inventory records and products manufactured,
- Interviews with past and current on-site employees,
- Review of the NDDEQ and USEPA files,
- Review of permits, and
- Review of site related administrative or consent orders, if any.

4.3.1 History of Activities at the Site

At many contaminated sites, site investigations, monitoring events, system (such as tanks, pipelines, or lagoons) removal activities, or remediation activities may have taken place over an extended period. Therefore, a key step is to develop a comprehensive chronology of historical events related to chemical impacts. A chronology will help create a complete picture of the site activities and identify COC and data gaps, if any. The chronology should include information such as the dates, descriptions, and results of:

- Installation, removal or upgrade of containment or waste systems,
- Remedial activities such as excavation and disposal of contaminated soil, removal of free product, groundwater, and soil vapor etc.,
- Drilling, sampling, and gauging of monitoring points,
- Collection of environmental media samples,
- Institutional controls, and
- Previous regulatory interactions

Remedial activities may have removed all or part of the COCs released at a site. Soil and groundwater data collected prior to the completion of these activities may not be representative of current conditions and should not be used in the calculation of current exposure and risk. At such sites, the RP must collect additional soil and groundwater concentration data representative of current conditions. However, data collected prior to the completion of interim action(s) may be used to guide decisions on additional data collection.

4.3.2 Location and Date of Spill or Release

The identification of the location of a release helps define the source area(s). Likely release locations include:

- Corroded or damaged containment or process system components,
- Piping, especially at pipe bends and joints and floor drains,
- Dispenser and delivery systems,
- Deposition near air discharge points,
- Accidental releases at areas for receiving, delivering, or handling chemicals and wastes,
- Wastewater lagoons and run-off basins,
- Waste storage and disposal areas, and
- Hazardous product materials storage areas.

A release may occur within the surficial soil. Surficial soil is the zone that a receptor could directly come in contact with and be exposed to COCs in the soil by ingestion, dermal contact, or inhalation of vapor and particulates. In the NDRBCA process, for both residential and commercial/industrial receptors, surficial soil is defined from 0 to 2 feet below ground surface (bgs). Subsurface soil is defined from 2 feet bgs to the water table.

Based on the site chronology and operational history, the RP may be able to determine the location and date of the release(s). However, often the exact location and date of the release(s) cannot be determined. In such cases, field screening, such as the use of a photoionization detector (PID), x-ray fluorescence (XRF) spectrophotometer, field bioassays, and/or collection of samples for laboratory analysis may be used to identify the likely location and extent (vertical and horizontal) of COCs in the soil and groundwater. Decisions regarding the use and application of field screening technologies and collection of samples must be based on site-specific conditions and chemicals. For example, PIDs may not be accurate for soils above a certain moisture content, and the PID does not detect all types of chemicals. Visual observations may be used to identify soil sample locations. This information is part of a sampling and analysis plan.

4.3.3 Quantity of Spill or Release

The NDRBCA process does not necessarily require knowledge of the exact quantity of the released chemicals or wastes. Often this information cannot be accurately determined, however, having a general idea of the amount released can assist in assessing the potential extent and severity of a chemical impact. Approximate amounts may also be used to provide the basis for any chemical mass balance calculations, if required.

4.3.4 Product(s) or Chemical(s) Released

The NDRBCA process primarily focuses on developing RBTLs for individual chemicals. However, at times spills occur for products or wastes that are mixtures of chemicals such as crude oil, gasoline, diesel, polychlorinated biphenyls (PCBs), and polychlorinated dioxin. The RP must identify the COCs comprising such products or wastes.

4.4 ADJACENT LAND USE AND RECEPTOR INFORMATION

Land use information is used to identify the location and type of potential receptors, exposure pathways by which the potential receptors may be exposed to the COCs, and presence of land use restrictions that may affect the completion of exposure pathways. This information is critical in developing EM. Specifically, the following information must be collected:

- Current land use and zoning,
- Potential future land use and zoning,
- Local ordinances, easements and restrictions that affect land or groundwater use,
- Quality and availability of potable water supplies,
- Off-site groundwater use, and
- Ecological receptor survey, if necessary.

At a minimum, the NDDEQ will require a land use and receptor survey covering the entire on-site and off-site area potentially impacted by the release.

4.4.1 Current Land Use

Knowledge of the current use of the site and nearby properties is necessary to define potential on-site and off-site receptors that may be exposed to the COCs. A visual, on-site land use reconnaissance survey must be conducted to avoid ambiguity about site uses. Alternatively, Google Earth mapping may be used to identify the current land use. The land use survey must clearly identify the following: schools, hospitals, residences (apartments, condominiums, townhouses, and single-family homes), buildings with basements, day care centers, churches, nursing homes, and types of businesses. The survey must also identify surface water bodies, parks, recreational areas, wildlife sanctuaries, wetlands, and agricultural areas. The results of the survey must be accurately documented on a land use map.

The land use map need not be drawn to an exact scale; in most cases, an approximate scale will suffice. However, a north arrow on the map is required.

4.4.2 Future Land Use

Future land use and receptors must be established, which are more difficult to determine than current land use and receptors. Unless future land use is known and can be documented (for example, by development plans or building permits), predictions of reasonably anticipated future use must be based on local zoning laws and surrounding land use patterns. As appropriate, zoning maps, aerial photographs, local planning offices, the U.S. Bureau of the Census, community master plans, changing land use patterns, and interviews with current property owners can provide information with which future land use can be reasonably estimated. Proximity to wetlands, critical habitat and other environmentally sensitive areas must also be considered in predicting future land uses.

4.4.3 Off-site Groundwater Use

A water well survey must be conducted to locate all public water supply wells and private water wells within a quarter-mile radius of the source. Information sources include the USGS, Department of Water Resources mapping service, water system operators, and interviews with local residents.

To the extent practicable the RP must provide well construction details for all wells identified. Relevant construction details include the total depth of the well, casing depth, screened or open interval, static and/or pumping level, and the use of water from the well. If available, average well pumping rates and drawdown information also should be provided.

4.4.4 Ecological Receptor Survey

Ecological receptors include both specific species and general populations of flora and fauna and their habitats, including wetlands, surface water bodies, sensitive habitats, and threatened and endangered species. The Ecological Risk Evaluation, Level 1, Checklist A (Appendix C), is a screening tool that must be completed for a Tier 1, Tier 2, or Tier 3 evaluation. Accurate information on the checklist may require that the area around the site be visually surveyed for the specific ecological receptor criteria. The NDDEQ will require that a visual survey be conducted if a checklist cannot be completed based on existing information.

4.5 ANALYSIS OF CURRENT AND FUTURE GROUNDWATER USE

A key determination in developing risk-based groundwater target levels is if the groundwater domestic use pathway is complete under current or future conditions. The process used to make this determination is discussed below. The analysis of current and future groundwater domestic use must include all groundwater zones beneath or in the vicinity of the site that could potentially be impacted by site-specific COCs or targeted in the future for the installation of water use wells. For the purposes of this analysis, groundwater-bearing zones must be evaluated in a three-dimensional context to determine groundwater flow direction.

As a part of this step, other groundwater uses (for example, cooling water, irrigation, livestock watering, and industrial process water) must also be identified and documented.

4.5.1 Current Groundwater Use

The current groundwater domestic consumption pathway is considered complete if water use wells are located on or near the site and the wells may potentially be impacted by site-specific chemical releases.

Whether a well may be impacted depends on the hydrogeological conditions, well construction and use of the well, including the following factors:

- Characteristics of soil and rock formations,
- Groundwater flow direction,
- Hydraulic conductivity,
- Distance to the well,
- The zone where the well is screened,
- Well casing,
- Zone(s) of influence and capture generated by well pumpage, and
- Biodegradability and other physical and chemical properties of the COCs.

If it is determined that no groundwater zone will be impacted, then justification for this determination should be provided in the development of the EM.

4.5.2 Future Groundwater Use

If an environmental covenant not to use groundwater for domestic purposes is in place and acceptable to the NDDEQ, the pathway will be considered incomplete. If such a covenant is not in place, then a site-specific analysis of reasonably anticipated future use of groundwater must be conducted for each groundwater zone that potentially could be impacted by site contaminants.

Sensitive Groundwater Area: If the groundwater zone being considered is a sensitive groundwater area, as defined by the NDDEQ, at or in the vicinity of the site, then the RP must assume that future domestic use is reasonable, and this zone must be evaluated if it is likely to be impacted by COCs from the site.

Reasonably Anticipated Future Use Determination: The probability that a groundwater zone could be used as a future source of water for domestic consumption must be evaluated based on consideration of the following factors:

- Current groundwater use patterns in the vicinity of the site under evaluation,
- Suitability of use,
- Well location and construction requirements/restrictions,
- Availability of alternative water supplies,
- Aquifer capacity limitations

In metropolitan urban areas, common human activities often impact the uppermost-saturated zone. Examples include the application of pesticides and fertilizers on household gardens, leakage of waste from sewer pipes and septic tanks, and infiltration of rain-dissolved chemicals that were present on the surface (oil from automobiles, etc.). Due to these anthropogenic impacts, it is reasonable to consider the uppermost saturated zone unsuitable for domestic water use supply.

Probability of Impact Determination: If a groundwater zone has a reasonably anticipated future use as a domestic water supply, the zone must be evaluated for the probability that the zone could be impacted by site COCs. The evaluation must consider the nature and extent of contamination at the site, site hydrogeology, contaminant fate and transport factors and mechanisms, and other pertinent variables. To evaluate potential site impacts to groundwater zones that could serve as future water supply sources, the potential impact must be evaluated at the nearest down-gradient location that could reasonably be considered for installation of a groundwater supply well. This point is referred to as the point of exposure for the groundwater protection pathway. In the absence of an environmental covenant restricting water use from wells the nearest location would be below the source.

4.6 VADOSE ZONE

4.6.1 Vadose Zone and Depth to Groundwater

Vadose zone soil is a medium through which COCs can migrate to groundwater and through which vapors can migrate upward to indoor and outdoor air. The thickness of the vadose zone can be determined based on information presented on boring logs and/or from measurements taken from monitoring wells or piezometers. It represents the distance from the ground surface to the depth at which the water table is encountered. For NDRBCA evaluation, the capillary fringe thickness is not considered part of the vadose zone. Depth to groundwater is used to estimate vapor emissions from groundwater and to determine the vadose zone dilution attenuation factor (DAF), 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 should be used in the development of the overall CSM and any related modeling efforts. 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, plans for well installation, 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.

4.6.2 Vadose Zone Characteristics

The following vadose zone parameters affect the movement of chemicals through vadose zone soil:

- Dry bulk density,
- Total porosity,
- Volumetric water content,
- Fractional organic carbon content,

- Thickness of vadose zone and depth to groundwater, and
- Thickness of capillary fringe.

The first four parameters are often collectively referred to as the soil geophysical or geotechnical parameters. For Tier 1 evaluations, the NDDEQ has assigned conservative default values to these parameters (See Appendix A, Table A-5). For Tier 2 and Tier 3 evaluations, site-specific values based on data collected from the site or justified default parameters must be used.

Generally, collection of soil samples will require more than one boring or probe, depending on site conditions and recovery volumes. Ultimately, the number of borings or probes necessary to obtain representative values of these parameters will be a site-specific decision of the environmental consultant based on professional experience and judgment. The objective is to collect enough samples so that the results are representative of site-specific conditions.

In situations where undisturbed samples cannot practically be collected for the purposes of measuring dry bulk density, literature values may be used for this parameter. However, disturbed samples may be used for fractional organic carbon, gravimetric water content, and particle density. (See Appendix D for details.)

4.7 SATURATED ZONES

COCs may reach the water table by travelling vertically through the vadose zone.

4.7.1 Characteristics of Saturation Zone

Saturated zone characteristics that determine the rate, magnitude, and direction of migration of COCs in groundwater include:

- Horizontal and vertical hydraulic conductivity,
- Hydraulic gradient (magnitude in both horizontal and vertical direction),
- Residual mass in capillary fringe,
- Saturated zone soil geotechnical characteristics (fractional organic carbon content, total and effective porosity, and bulk density),
- Occurrence and rate of biodegradation and retardation due to factors such as sorption due to soil mineral oxide content, and
- pH and redox potential especially at sites where the COCs include metals.

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

Early in the NDRBCA process, various groundwater zones and the hydraulic inter-connection among them should be identified. Qualitative and quantitative understanding of the above factors may be necessary for each of the zones.

When necessary, values of hydraulic conductivity, hydraulic gradient, effective porosity, and fractional organic carbon content must be used to estimate the theoretical advective migration velocity for the COCs in groundwater. The theoretical migration rate and extent of the groundwater plume should be compared with actual data to further validate the CSM.

4.7.1.1 Hydraulic Conductivity

Reliable estimates of site-specific hydraulic conductivity can be obtained by field methods such as pump tests or slug tests. Hydraulic conductivity may also be estimated based on the grain size distribution of the porous formation. 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 based on consideration of all predominant soil types comprising the saturated zone must be provided.

4.7.1.2 Hydraulic Gradient

The magnitude and direction of the hydraulic gradient is estimated by comparing 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 water level data corrected to elevations relative to, preferably, mean sea level, or other established datum. These contour maps can be used to estimate both the direction and magnitude of the horizontal hydraulic gradient. When drawing the contour maps, care should be taken to ensure that measurements from monitoring wells screened in the same interval or hydrologic 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 hydraulic gradient or predominant flow direction, estimates of the average hydraulic gradient for each season and each flow direction can be used in modeling efforts. For example, horizontal groundwater gradient can be calculated using the USEPA tool (EPA On-line Tools for Site Assessment Calculation) located at https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/gradient4plus-ns.html.

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

4.7.1.3 Saturated Zone Soil Geotechnical Parameters

The saturated zone soil characteristics include fractional organic carbon content, porosity, and dry bulk density. These parameters are required to estimate the extent of the contamination migration, 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 biodecay. (See Appendix D for details.)

4.7.2 Occurrence and Rate of Natural Attenuation

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

The occurrence of natural attenuation may be evaluated at a site. Monitoring appropriate indicators (such as chemical concentrations, geochemical indicators, electron acceptors, microorganisms, or carbon dioxide) may be required when natural attenuation is proposed as a principal element of the risk management plan. 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 is used to qualitatively evaluate the occurrence of natural attenuation/biodegradation.

The primary line of evidence is developed by demonstrating that reductions in chemical concentration or mass are occurring at a site. The primary line of evidence is best determined by:

- Plotting concentrations of COCs as a function of distance along the plume center line,
- Plotting concentrations of COCs 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 contaminant 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 such 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.

Within the secondary line of evidence, measuring the degradation or breakdown products of COCs is another approach that can be used to demonstrate the occurrence of biodegradation. For example, biodegradation breaks down tetrachloroethylene (PCE) to trichloroethylene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride. However, degradation products may be more toxic than the parent compound. Thus, the risk from degradation products also must be evaluated as part of any monitored natural attenuation proposal.

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 used in very rare cases.

The development of secondary and tertiary lines of evidence is not always 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. The NDDEQ will require that the groundwater plume be stable or decreasing prior to issuing a letter of closure.

4.8 SURFACE WATER BODY

It is unlawful for any person to cause or cause to be placed any wastes in a location where they are likely to cause pollution to enter waters of the state (NDCC 61-28).

"Waters of the State" means all waters within the jurisdiction of this state, including all streams, lakes ponds, impounding reservoirs, marshes, watercourses, waterways, and all other bodies or accumulations of water on or under the surface of the earth, natural or artificial, public or private, situated wholly or partly within or bordering upon the state, except those private waters that do not combine or effect a junction with natural surface or underground waters just defined (NDCC 61-28-02).

"Pollution" means such contamination, or other alteration of the physical chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor. Pollution includes discharge of any liquid, gaseous, soil, radioactive, or other substance into any waters of the state that will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to public health, safety, or welfare, domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or livestock, wild animals, birds, fish, or other aquatic biota (NDAC 33.1-16-02.1).

Reasonable discharge of pollutants may be permitted if they do not degrade water quality. Mechanisms available to support standards and still discharge include an antidegradation policy and mixing allowance. Discharge from a point source, defined as "any discernible, confined, and discrete conveyance, including any pipe, ditch, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel, or other floating craft, from which wastes are or may be discharged" (NDCC 61-28), may need a permit under the North Dakota Pollution Discharge Elimination System NDAC 33.1-16-01.

Mixing Zone and Dilution Policy NDAC 33.1-16-02.1 Appendix III

At a maximum, mixing zones for streams and rivers shall not exceed one-half the cross-sectional area or a length 10 times the stream width at critical low flow, whichever is more limiting. Mixing zones in lakes shall not exceed 5 percent of lake surface area or 200 feet in radius, whichever is more limiting. While exceedances of acute chemical specific numeric standards are not allowed within the entire mixing zone, a portion of the mixing zone (the zone of initial dilution) may exceed acute-chemical-specific numeric standards established for the protection of aquatic life. The zone of initial dilution shall be determined on a case-by-case basis by the NDDEQ with a rationale that the zone of initial dilution poses no unacceptable risks to aquatic life.

A dilution allowance may be provided in calculating chemical-specific acute and chronic and whole effluent toxicity discharge limitations as described in NDAC 33.1-16-02.1 Appendix III.

Antidegradation Policy NDAC 33.1-16-02.1 Appendix IV

Antidegradation implementation procedure is described in NDAC 33.1-16-02.1 Appendix IV. Antidegradation requirements are necessary whenever a regulated activity is proposed that may have some effect on water quality. The NDDEQ will complete an antidegradation review for all proposed regulated activities.

In addition, refer to Appendix A for information about developing soil and groundwater target levels that protect surface water beneficial uses.

4.9 DELINEATION OF IMPACTS

4.9.1 Delineation of Impacts in Soil and Groundwater

The RP must review the available data and determine if data of sufficient quality and quantity are available to delineate the extent of impacts in soil and groundwater. The horizontal and vertical extent of soil and groundwater contamination must be delineated to the extent necessary to assess potential exposures to receptors and impacts to surface water bodies.

The key issue related to the delineation of impacts is the concentration levels to which impacts are defined. Several alternatives are available. Examples include but are not limited to background levels, drinking water levels, or RBSLs. The NDRBCA guidance does not explicitly specify one-size-fits-all delineation concentrations for environmental media; instead, it uses "performance based" delineation criteria. Lateral and vertical impacts in soil and groundwater must be delineated to the extent required to determine:

- Potential exposure pathways to human and ecological receptors under current and reasonably anticipated future use conditions, <u>and</u>
- The extent of impacts above RBSLs for corresponding potential exposure pathways.

For example,

- For commercial properties, delineation is allowed to commercial/industrial levels. However, if the plume extends off-site and surrounding land uses are residential, then delineation would be to residential levels, or
- Delineate soil to the lower of levels protective of indoor inhalation or domestic use of groundwater target levels, depending on the complete exposure pathways

The above use of performance criteria presents a dilemma in that the contaminated media must be sufficiently delineated to perform the tiered evaluation; however, evaluation cannot be completed until the site has been delineated. If engineering controls are used as a component of the final remedy, delineation efforts will need to define areas over which these controls will be placed.

Thus, an iterative approach to delineation may be necessary unless the RP decides to delineate the site to conservative concentrations such as background or RBSLs protective of ingestion of groundwater. If these conservative delineation standards are not used, the following iterative approach is described for use. This approach may be more cost effective and requires additional professional judgment and up-front preparation. At sites where it is clear that active remediation is necessary, the RP may proceed with interim remedial measures and subsequently use confirmatory samples to delineate the extent of contamination. Thus, issues associated with contaminant delineation would not delay the implementation of remedial activities.

1. Prior to performing the site work, develop a preliminary CSM, including the EM. The EM must consider receptors on site and on adjacent properties that may be exposed to contamination. This will require a determination of whether the domestic use of groundwater is, or could be, a complete pathway.
2. Based on the complete exposure pathways for soil and groundwater, identify the applicable Tier 1 RBSLs from the tables in Section 6.0. At sites where it is clear that a Tier 2 risk evaluation will be necessary, it may be reasonable for the RP to initially develop preliminary Tier 2 target levels.
3. After the delineation level for each COC has been established, the following field activities should be conducted:

   - Groundwater data from a direct push investigation may be used to screen the extent of impact prior to the installation of monitoring wells. The number and location of direct push screening points and monitoring wells is a site-specific professional decision. Often, delineation will require multiple field mobilizations. For sites where sufficient groundwater data from monitoring wells indicates a shrinking plume, data from a direct push investigation could be used to delineate the downgradient extent of the plume. Direct push investigations should be conducted downgradient of the site source/release area until data indicates levels at or below the delineation level.
   - For sites where the available data indicates that the plume may be migrating, the RP must conduct sufficient investigations to determine the extent and rate

of migration. It may be more cost effective to conduct a direct push investigation followed by the installation of a permanent delineation monitoring well(s). Wells must be monitored at a frequency and for a period of time sufficient to clearly demonstrate plume trends (expanding, stable, or shrinking) and that COC concentrations in the downgradient wells are below the delineation levels.

- Upon preliminary completion of the site characterization, a check should be made to confirm that the assumptions used in the initial CSM were accurate and that the delineation levels are appropriate.
- For delineation of soil impacts, borings should be installed, and soils sampled at increasing horizontal and vertical distances from the source area until the delineation levels are reached.

Chemical fate and transport modeling may be used, as appropriate, to aid in the placement of monitoring wells.

4.9.2 Delineation of Impacts in Other Media

In addition to the delineation of soil and groundwater impacts, impacts to other media, (for example, surface water, sediments, and air) must be evaluated. The number of samples, sample locations, delineation levels, and sampling methodologies will be based on site-specific considerations; hence the RP must receive NDDEQ's approval for the work plan prior to conducting fieldwork. For surface water and sediment sampling, the work plan must contain a strategy to determine background levels, location, and concentration of site-related discharges to the surface water, and the extent of COC impacts. If air concentrations are to be measured, the work plan must contain a strategy to determine ambient background levels of the COCs.

Because the delineation process may be iterative, as part of the work plan report, the NDDEQ will require documentation supported by site-specific data to confirm that the impacts have been delineated to the RBSLs in all media.

4.10 ECOLOGICAL RISK EVALUATION

In the NDRBCA process, site remediation must be protective of both human health and ecological receptors before a letter of closure can be issued. Ecological protection includes all non-human organisms and their habitats (ecological receptors). Therefore, exposure to ecological receptors must be considered and evaluated.

Within the tiered NDRBCA process, Ecological Risk Evaluation (ERE) has three levels:

- Level 1 is a qualitative screening evaluation comprised of Checklists A and B,
- Level 2 requires comparison of site-specific levels with applicable ecological standards, readily available in literature, and
- Level 3 allows for a site-specific evaluation.

A Level 2 or Level 3 evaluation is necessary only if ecological concerns persist beyond the Level 1 evaluation.

4.10.1 Level 1 Ecological Risk Evaluation

A Level 1 ERE must be performed at every site to identify whether any ecological receptors or habitat exist at, adjacent to, or near the site. The evaluation, beginning with Ecological Risk Evaluation Level 1 Checklist A (Appendix C), consists of six questions. This checklist is a qualitative evaluation that can be completed by an experienced environmental professional who is not necessarily a trained biologist or ecologist. The checklist is designed such that, if the answer to all the questions is negative, no further ecological evaluation is necessary.

A positive answer to any one of the questions in Checklist A implies that a receptor or a habitat exists on or near the site and further evaluation is required. Therefore, a second checklist of seven questions, Ecological Risk Evaluation Level 1 Checklist B, must then be completed. The second checklist determines if any pathways are complete for any of the receptor(s) identified in Checklist A. If the answer to all questions is negative, the conclusion is that, even though a receptor exists on or near the site, a complete pathway to the receptor(s) does not exist and, therefore, there are no ecological concerns at the site. If the answer to one or more of the seven questions is positive, a Level 2 ecological risk evaluation may be necessary to determine whether contamination at the site poses an unacceptable risk to ecological receptors. A trained professional may be necessary to make these determinations.

4.10.2 Level 2 Ecological Risk Evaluation

In a Level 2 ERE, site-specific COC concentrations that may reach an environmental receptor are compared to literature values that may be obtained from the following:

- Ecotox Thresholds (ETs) as presented in ECO Update, US EPA, Office of Solid Waste and Emergency Response. Publication 9354.0-12FSI, EPA 540/F-95/038, PB95-963324. January 1996. Office of Emergency and Remedial Response Intermittent Bulletin Volume 3, Number 2,
- Oak Ridge National Laboratory Values as presented in Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/R/Tm-96/R2. Suter II and C.L. Tsao. June 1996
- EPA Water Quality Standards,
- TOXNET (National Institute of Health), and
- National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Table (SQuiRTS) U.S. EPA, 2003. Ecological Screening Levels. Region 5 RCRA Corrective Action Branch.

If the comparison of representative site-specific soil, groundwater, surface water or sediment concentrations indicates that applicable values are exceeded, the RP may perform a Level 3 ecological risk evaluation or use the applicable literature values as cleanup goals. If the latter option is chosen, then at least one element of the RMP must address remediation goals to protect ecological species.

4.10.3 Level 3 Ecological Risk Evaluation

A Level 3 ERE will include a detailed site-specific evaluation as per current USEPA guidance on performing risk evaluation (for instance, ***EPA's April 1998, Guidelines for Ecological Risk Assessment, EPA/630/R-95/002F***). A Level 3 ERE will require the development of a site-specific, detailed work plan and approval by NDDEQ prior to its implementation. As above, if a site-specific analysis determines that the risk to ecological species is still unacceptable, then at least one element of the RMP must address managing the risk to ecological species.

4.11 DISTRIBUTION OF CHEMICALS OF CONCERN IN SOIL

The objective of soil characterization is to delineate the vertical and horizontal extent of site-related COCs to identify the exposure domains for each combination of receptor-pathway-complete exposure pathway and estimate COC concentrations for each area of impact/exposure domain.

Data collected in areas that are clean (either because the samples were collected beyond the extent of impact, or the remedial activities eliminated the COCs) are not appropriate for use in the calculations. Use of such data may incorrectly underestimate the COC concentrations. Because of the significance of accurately estimating concentrations for each ED in the overall risk management decision, this concept is further discussed in Appendix E.

Because of the differences in exposure pathways for surface and subsurface soils, an adequate number of soil samples from each zone must be collected to meet the soil characterization objectives. Surficial soil (as well as subsurface soil) may include fill material - the distinction between surface and subsurface soil is one of depth rather than composition.

The number and locations of soil borings necessary to adequately delineate a site will vary from site to site depending on various factors; size of site, distribution of COCs, site hydrology and stratigraphy, exposure model, etc.

4.11.1 Logging of Soil and Groundwater Monitoring Well Boreholes

A qualified professional must log each soil boring to indicate depth correlating with changes in lithology, occurrence of groundwater, total depth, visual and olfactory observations, and other pertinent data such as a soil vapor screening. When a monitoring well is installed, as-built diagrams with depth to groundwater indicated must be submitted for each well. A continuous soil profile from soil borings should be developed with detailed lithologic descriptions. Particular emphasis should be placed on characteristics that may control chemical migration and distribution such as zones of higher or lower permeability, changes in lithology, correlation between soil vapor concentrations and different lithologic zones, obvious areas of soil discoloration, organic content, fractures, and other lithologic characteristics.

4.12 DISTRIBUTION OF CHEMICALS OF CONCERN IN GROUNDWATER

An adequate number of groundwater samples must be collected to:

1. Delineate the horizontal and vertical extent of dissolved groundwater COC plumes and non-aqueous phase liquids (NAPLs), and to identify the exposure domain for each receptor, pathway, and exposure pathway combination,
2. Allow calculation of representative COC concentrations for each exposure domain, and
3. Determine the status of the plume (increasing, stable or shrinking).

4.12.1 Delineation of Groundwater Impacts

The delineation criteria for groundwater depends on whether the current and potential future domestic use of groundwater is a complete or incomplete pathway.

Where the domestic use of groundwater pathway is complete, delineation criteria will be the lower of the following three criteria:

1. The Maximum Contaminant Levels (MCLs) (in the absence of MCLs, risk-based concentrations that assume ingestion of groundwater, dermal contact, and inhalation of vapors due to indoor water use),
2. Land use-dependent concentrations protective of indoor inhalation,
3. Concentrations for the protection of ecological receptors (when present)

Where the domestic use of groundwater pathway is determined to be incomplete, the delineation criteria will be based on other potentially complete pathways. Examples are protection of indoor air due to volatilization of contaminants from the groundwater, exposures that may be encountered by subsurface construction workers, or the discharge of contaminated groundwater to surface water.

- Table 6-1(a): MCLs or calculated risk-based groundwater concentrations protective of ingestion, dermal contact, and inhalation due to residential indoor water use
- Table 6-1(b): Risk-based groundwater concentrations protective of ingestion, dermal contact, and indoor air for commercial/industrial worker

4.12.2 Determination of Plume Stability

To assess plume stability, groundwater monitoring must be conducted for a period of time sufficient to show a reliably consistent trend in contaminant concentrations. Sampling and analysis of groundwater must be performed at a frequency and for parameters that are appropriate for site-specific conditions and are sufficient to enable assessment of contaminant trends, natural attenuation rates and seasonal or temporal variations in groundwater quality. Once cleanup levels are achieved, groundwater monitoring must continue for a period of time sufficient to ensure that residual subsurface contamination does not result in recontamination of groundwater above applicable MCLs or levels protective of other pathways, such as migration to surface water or indoor inhalation.

Groundwater monitoring for the purpose of evaluating plume stability must be conducted under a work plan approved by the NDDEQ. Depending on site-specific data, statistical, graphical (e.g., GWSDAT) or other techniques (e.g., Mann Kendall test) may be used to demonstrate plume stability.

4.12.3 Groundwater Sampling

If groundwater has been contaminated by COCs, direct push sampling methods or temporary sampling points may be used to screen for groundwater contamination and to assist in determining the optimal location of monitoring wells using following guidelines:

- An adequate number of monitoring wells must be installed to sufficiently delineate the horizontal and vertical extent of the dissolved and non-aqueous phase groundwater plume and the direction of groundwater flow.
- A sufficient number of monitoring wells must be installed to fully define the groundwater plume to levels protective of applicable exposure pathways.
- Well placement and design must consider the concentration of chemicals in the source area, the possible occurrence of both dense and light NAPLs at the site, presence of multiple water bearing zones, and groundwater flow direction.
- Well casing and screen materials must be compatible with the COCs to be monitored.
- Wells must be properly developed, and the water level must be measured after installation.
- A land surveyor is the best qualified to conduct a site survey to establish well elevations and, by that, groundwater elevations. Accuracy should generally be to within plus or minus 0.01 foot relative to an established national geodetic vertical datum (NGVD) or a local datum. Based on the groundwater elevations, groundwater flow direction and gradient must be determined and plotted on a site map.
- Appropriate geographic coordinates must be identified and documented.

Groundwater samples must be collected in accordance with the approved work plan.

4.13 DISTRIBUTION OF CHEMICALS OF CONCERN IN THE VAPOR MIGRATION TO INDOOR AIR PATHWAY

For sites where soil or groundwater concentrations result in the exceedance of Tier 1 RBSLs for the vapor migration to indoor air pathway, additional tools and methodologies may be considered on a site-specific basis and implemented as appropriate. Soil vapor sampling and foundation/indoor air sampling methodologies would be included in a data collection work plan. These methodologies include modeling, soil vapor monitoring, and/or foundation (crawlspace and subslab)/indoor air sampling. For further details, refer to relevant state and federal guidance, such as:

- ITRC, 2007: Vapor Intrusion Pathway: A Practical Guideline. January 2007.
- USEPA, 2015: Technical Guide For Addressing Petroleum Vapor Intrusion At Leaking Underground Storage Tank Sites. June 2015.
- USEPA, 2015: OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. June 2015.

4.14 DISTRIBUTION OF CHEMICALS OF CONCERN IN SEDIMENTS AND SURFACE WATER BODIES

When site investigation data or modeling indicates that COCs may have migrated to a surface water body, surface water samples should be collected. If surface drainage pathways are suspected of having been impacted by any site contaminants, sediment (and surface water, if present) from those pathways should also be sampled. Sediment analyses should include an analysis of sediment pore water to adequately characterize impacts in the hyporheic zone. Sampling must consider the representativeness of the samples with regard to the flow conditions. Water samples must be collected both upstream and downstream of each area where a discharge of contaminated groundwater is suspected.

If site investigation data shows or suggests that contaminated groundwater is discharging to surface water, sediment samples must be collected. The RP must compare the sediment sample data with sediment standards that are protective of human health and ecological receptors that can be obtained from literature or develop site-specific levels. The development of site-specific sediment standards would be considered a Tier 3 activity and would require a pre-approved work plan.

4.15 COLLECTION AND ANALYSES OF ENVIRONMENTAL SAMPLES

The RP must exercise extreme care in the collection of environmental samples. This guidance focuses on data necessary for the NDRBCA evaluation; it does not identify specific field sampling techniques and laboratory analytical methods to be used. The RP must collect all environmental samples using appropriate methods.

The RP must document the details of collecting and analyzing the samples in the work plan and obtain NDDEP's approval prior to collecting the data. Failure to do so may result in the collection of data not acceptable for NDRBCA evaluation and additional sampling may be required.

4.16 INFORMATION SOURCES FOR DATA COLLECTION

The above sections present an overview of the data needed to develop the CSM model and delineate releases for preparation of a risk-based evaluation. Whereas it is relatively easy to determine the categories of data required, it requires considerable judgment, knowledge, and experience to determine the location and number of samples to be collected and analyzed and the sampling and analytical methodologies to be used in data collection.

The following selected references can assist the user in developing a comprehensive work plan, identifying data gaps, and planning and implementing fieldwork.

- USEPA, 1998, EPA Requirements for QAPPs for Environmental Data Operations. EPA QA/R-5, USEPA, Quality Assurance Division, Washington, D.C.

- USEPA, 1998. Guidance for Data Quality Assessment: Practical Methods for Data Analysis, EPA QA/G-9, QA97 update, Office of Research and Development, EPA/600/R-96/084, Washington, D.C.

- USEPA, 1997. Expedited Site Assessment Tools for Underground Storage Tank Sites, EPA/510B-97-001, Office of Solid Waste and Emergency Response, Washington, D.C.

- ASTM, 1995. Standard Guide for Developing Conceptual Site Models for Contaminated Sites: E 1689-95.

- USEPA, 1994. Guidance for the Data Quality Objectives Process, EPA QA/G-4, Office of Research and Development, EPA/600/R-96/055, Washington, D.C.

- USEPA, 1993. Data Quality Objectives Process for Superfund, Interim Final Guidance, EPA/540-R-93-071, Office of Solid Waste and Emergency Response, Washington, D.C.

- USEPA, 1992. Guidance for Data Usability in Risk Assessment, Part A, Office of Solid Waste and Emergency Response, 92857-09A, Office of Emergency and Remedial Response, Washington, D.C.

- USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, OSWER-9335.3-01, Office of Solid Waste and Emergency Response, Washington, D.C.

- USEPA, 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document Draft, OSWER-9950.1, Office of Solid Waste and Emergency Response, Washington, D.C.

GENERAL CONSIDERATIONS FOR RISK EVALUATION

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

- Development of an exposure model,
- Calculation of risk-based target levels,
- Evaluation of groundwater use,
- Protection of surface water bodies,
- Estimation of representative chemical of concern concentrations,
- Evaluation of light non-aqueous phase liquids
- Ecological risk evaluation (Refer Section 4.10)

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

5.1 DEVELOPMENT OF AN EXPOSURE MODEL

An exposure model (EM) identifies the exposure pathways that are complete or may reasonably be expected to become complete under current or reasonably anticipated future conditions. An EM identifies the media of concern, receptors of concern, exposure pathways (EP) from the impacted media to the receptor, and routes of exposure (ROE). The EM presents a working hypothesis of how the COCs migrate from the source to the point of exposure (POE) where the COCs come in contact with the receptors and exposure occurs. For each complete EP, RBTLs must be developed for each COC. If migration of the COCs from the source to the receptors (i.e., the pathway) is not possible under current or reasonably anticipated future site use (e.g., due to engineering controls or land use restrictions), the COCs will not cause any exposure. Without exposure there can be no risk. Thus, for risk to be present at a site, at least one EP must be complete (or have a reasonable chance of becoming complete).

An EM is a qualitative evaluation based on information collected during site investigations. Typically, EMs for three time periods will be developed for each site: current land use, short-term future land use, such as a period of construction, and long-term future land use. Consideration of current and future land use ensures that site-specific decisions will be protective of both. At sites where the current and future land use is assumed the same, the EMs for current and future conditions would be identical.

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

5.1.1 Land Use

Within the NDRBCA process, under Tier 1 and 2, land use is categorized as residential or commercial/industrial. Other land uses such as recreational land use will be evaluated under Tier 3. Accurately identifying land use is important because RBTLs depend on the land use. Residential land use results in numerically lower RBTLs and cleanup to these levels generally allows for unrestricted land use. Prior to issuing a letter for closure, the NDDEQ will require that sites cleaned to commercial/industrial standards have an environmental covenant, as discussed further in Sections 6.0 and 7.0.

Examples of residential and commercial/industrial land use are presented below:

- **Residential –** Includes land uses where persons can be expected to reside for more than 8 hours a day, 7 days a week, such as homes, apartments, hospitals, nursing homes, residential schools, childcare centers, etc.

- **Commercial/industrial –** Includes land uses where persons can be expected to be on site less than 10 hours a day and absent on weekends and holidays. Examples include retail facilities, industrial and manufacturing operations, fleet operations, hotels and motels, offices, etc.

When a development includes a multi-story building, for mixed use, the presence of apartments on an upper floor does not necessarily mean that the applicable land use is "residential." Reasonable assumptions concerning exposures on the first floor of the building (and subsurface floors if such exist) should be used to develop RBTLs.

While it is not possible to identify every scenario in this document, the following guidelines are intended to assist in making land use determinations:

5.1.1.1 Determine Current Land Use

Current land use refers to land use as it exists today and can be readily determined by a site visit. Thus, there should be no ambiguity about current land use.

5.1.1.2 Determine Most Likely Future Land Use

Future land use is always uncertain, and its determination should be based on available information and good professional judgment. The following factors may be used to determine reasonably anticipated future use:

- Local zoning ordinance(s),
- City/County development plans,
- Current use of adjacent property,
- Development plans for the site and adjacent property,
- Type and size of streets/highways adjacent to the property,
- Existing land use restrictions affecting the site and/or adjacent properties,
- Building permits, and
- Community acceptance of proposed site development plans.

If an undeveloped parcel is in a predominantly commercial/industrial area, then consideration of the parcel's future use as commercial/industrial might be appropriate. However, if the setting is more rural or the land use is mixed, absent reliable evidence to the contrary, the undeveloped land should be considered residential.

5.1.2 Human Receptors

At a minimum, the following human receptors are considered:

- Residential – Child, adult, and age-adjusted individual
- Commercial/Industrial Worker – Adult
- Construction Worker – Adult

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) are applicable.

Other human receptors such as visitors or maintenance workers will generally have less exposure than those listed above (due to lower exposure frequency and duration) and, therefore, their exposure and risk need not be quantified.

NDRBCA evaluations must consider both on-site and off-site human receptors. A plume moving off-site might impact multiple land uses and multiple receptors. For example, a plume whose source is an industrial property, may have migrated off-site below a residential area. In this case, both land uses must be considered when developing the EM. For simplification, the following definitions should be used:

- **On-site**: The property located within the legal property boundaries within which the source of the release is located. This includes soil, groundwater, surface water, and air within those boundaries.

- **Off-site**: Property located outside the boundaries of the onsite property and on to which COCs associated with the release have or are likely to migrate. This includes soil, groundwater, surface water, and air located off-site.

5.1.3 Human Exposure Pathways and Routes of Exposure

A receptor comes in contact with COCs only if a complete EP exists under current or future land use conditions. For a pathway to be complete, there must be a chemical source, mechanism by which the chemical is released, medium through which the chemical travels from the point of release to the receptor location, and a route of exposure by which the chemical enters the receptor's body and potentially causes adverse health effects.

Commonly encountered EPs that must be considered are discussed below. For each complete pathway, the NDRBCA process requires collection of sufficient data to estimate the risk concentration of COCs for each pathway, and the comparison of risk concentrations's with RBTLs for the corresponding pathway.

5.1.3.1 Pathways for Inhalation

For the inhalation pathway, chemical intake may occur indoors and outdoors. Depending on the toxicity of the chemical, unacceptable exposures via the inhalation pathway might occur at concentrations below the odor threshold levels (i.e., receptors might be unaware of their exposure). If the source of these vapors is volatile chemicals in soil and/or groundwater, their migration through the capillary fringe, unsaturated zone, and cracks in the floor/foundation to indoor or outdoor air must be evaluated. Relative to outdoor inhalation, indoor inhalation is generally the "risk driver".

To quantitatively evaluate the indoor inhalation pathway, use the following approach:

- **Tier 1 evaluation:** Compare maximum soil vapor and groundwater concentrations to soil vapor and groundwater Tier 1 RBSLs tabulated in Tables 6-1(a) and 6-1(b).

- **Tier 2 evaluation:** Develop Tier 2 SSTLs for indoor air, soil vapor, and groundwater, as appropriate, and compare these concentrations with the corresponding risk concentrations.

- **Tier 3 evaluation**: Develop Tier 3 SSTLs for indoor air, soil vapor and groundwater, as appropriate, and compare these concentrations with the corresponding risk concentrations.

Mathematical models or empirical attenuation factor (AF) are used to estimate the soil vapor, and groundwater concentrations protective of indoor inhalation. Refer to Appendix A for the development of Tier 2 SSTLs.

5.1.3.2 Pathways for Surficial Soils (0 - 2 feet bgs)

Surficial soils are defined as soils extending from the surface to two feet below ground surface and include the following exposure pathways:

- Ingestion of soil, dermal contact with soil, and outdoor inhalation of vapors and particulates emitted by surficial soils.

5.1.3.3 Pathways for Subsurface Soils (>2 feet bgs to the water table)

Subsurface soils are defined as soils from two feet below ground surface to the water table or to bedrock, whichever occurs first and include the following exposure pathways:

- Indoor inhalation of vapor emissions,

It is important to note that no distinction is made between the surface and subsurface soil for the construction worker. Instead, dermal contact, accidental ingestion, and outdoor inhalation of soil vapors and particulates from soils are considered complete pathways up to the typical depth of construction.

5.1.3.4 Pathways for Groundwater

Potentially complete exposure pathways for impacted groundwater include:

- Indoor inhalation of vapors from groundwater
- Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)

Details of this pathway are discussed in Section 5.3.

5.1.3.5 Protection of Surface Water and Sediments

Depending on the use designation of the surface waters, potentially complete routes of exposure for surface water include:

- Ingestion of surface water,
- Contact with surface water during recreational activities (ingestion, inhalation of vapors, and dermal contact),
- Ingestion of fish, and
- Contact with (accidental ingestion and dermal contact with) sediments.

In addition, ecological effects must be considered if surface water impacts are likely to occur.

Each of the above routes of exposure for surface water and sediments must be considered as part of the EM. If all these ROEs are considered incomplete, no quantitative evaluation is necessary.

5.1.3.6 Other Pathways

At some sites, other ROEs might be significant. These include, but are not limited to, exposure due to ingestion of produce grown in impacted soils, exposures associated with use of groundwater for irrigation purposes, or use of groundwater for industrial purposes. These ROEs are likely to be significant only in rare cases and will be evaluated a part of Tier 3 evaluation.

5.1.4 Exposure Domain

A key part in the development of an EM is the determination of the size and location of the exposure domain (ED) for each pathway, route of exposure, and receptor. The ED is the portion of the total impacted area that contributes to the receptor's exposure via a specific pathway and route of exposure. The ED is specific to each complete EP. The following three examples may help clarify the concept of the exposure domain:

Example 1: For exposures within an existing building by indoor inhalation of vapors from subsurface soil, the exposure domain would be the volume of soil within the footprint of the building that contributes vapors to the indoor air.

Example 2: For direct contact with surficial soil, the exposure domain would be the area of impacted surficial soil that the receptor might come in contact with.

Example 3: For the protection of groundwater, the exposure domain would be the volume of soil that could contribute chemicals to the groundwater plume via leaching and infiltration.

For each complete exposure pathway, the exposure domain must be determined. Concentrations measured within each exposure domain must be used to estimate the risk concentrations for each complete pathway.

5.1.5 Documentation of the Exposure Model

A complete and accurate discussion of the exposure model is critical to NDRBCA evaluation. Therefore, the NDDEQ has developed forms that must be used to develop and document the exposure model.

5.2 CALCULATION OF RISK BASED TARGET LEVELS

Within the NDRBCA process there exist three RBTLs, that include, Tier 1 RBSLs, Tier 2 and Tier 3 SSTLs. The calculation of these is discussed in Appendix A. Note, the Tier 1 RBSLS for several exposure pathways were obtained from the USEPA RSL guidance (USEPA, 2022) for carcinogenic risk of 1E-05 and hazard quotient of 1.0.

5.3 EVALUATION OF GROUNDWATER USE

Within the NDRBCA process, all current and reasonably anticipated future use of groundwater must be protected. Groundwater uses include the domestic use of groundwater, industrial water use, water use for irrigation and livestock. A key consideration in developing RBTLs for groundwater is whether the groundwater use pathway is complete under current or future for all groundwater zones at and in the vicinity of a site.

5.3.1 Current Conditions

The current groundwater use pathway is considered complete if there are existing wells near the site, and the wells are reasonably likely to be impacted by site related COCs.

The existence of water supply wells near the site is determined based on a water well search. The level of effort to be expended in a well search would depend on site-specific considerations. For example, in urban areas having a municipal water supply, a door-to-door survey might not be necessary whereas in rural areas where groundwater is the primary source of water, a door-to-door survey might be necessary.

Whether the wells have a reasonable probability of impact depends on the hydrogeological conditions at the site including, but not limited to: groundwater flow direction, distance to well, the zone where the wells are screened, casing of the well, and biodegradability and other physical/chemical properties of the COCs. Depending on site-specific conditions, a fate and transport model may be used to evaluate the potential impacts (generally, such modeling would be a Tier 3 activity).

5.3.2 Future Conditions

All groundwater zones beneath and/or in the vicinity of the site that could potentially be targeted in the future for the installation of domestic water wells must be identified. For the purposes of this analysis, the saturated zone may consist of multiple "layers", but all layers within the saturated zone must be considered. For each zone, determining whether the future groundwater use pathway is complete or likely to be complete is based on consideration of the following factors:

Groundwater use restrictions: If there exists restrictions that essentially eliminates any reasonable probability that a groundwater zone will serve as a future source of domestic water, no further evaluation of the groundwater domestic use consumption pathway is required.

Suitability for Use Determination: Groundwater containing less than 10,000 mg/L total dissolved solids shall be considered as having sufficient natural quality to serve as a potential source of domestic water.

Probability of Future Use Determination: The probability that a groundwater zone could be used as a future source of water for domestic consumption shall be evaluated based on consideration of the following factors:

- Current groundwater use patterns in the vicinity of the site
- Suitability of use
- Availability of alternative water supplies
- Groundwater use restrictions
- Aquifer capacity limitations (ability to support a given density of production wells).

The above factors will be evaluated on a "weight of evidence" basis.

5.3.3 Evaluation of Complete Pathway

If the groundwater use pathway is deemed to be complete under current or future conditions, it must be quantitatively evaluated as follows:

Step 1: Identification of the critical POE. The POE shall be the nearest down-gradient three-dimensional location that could reasonably be considered for installation of a groundwater supply well. Note that the POE need not necessarily be an actual existing well; the POE could be a hypothetical future well.

Step 2: Determination of target levels at the POE. For chemicals that have maximum contaminant levels (MCLs), the target level at the POE will be the MCL. For chemicals that do not have MCLs, the target levels will be the risk-based calculated value that assumes groundwater ingestion, indoor inhalation of vapors based on indoor water use for volatile chemicals, and dermal contact with water.

Step 3: Identification of point of demonstration (POD) and calculation of target levels at the POD. PODs are located between the source and the POE where concentrations are measured to demonstrate that concentrations at the POE will not exceed the POE target level. Risk-based target concentrations will be developed for the PODs using appropriate fate and transport models and site-specific parameters, as discussed in Appendix A.

Step 4: Calculation of soil COC concentrations at the source. Risk-based target levels for soil should also be calculated at the source as indicated in Appendix A. Note, as sites where unsaturated dilution attenuation factor=1, the surficial and subsurface soil concentrations are identical.

Thus, the quantitative evaluation of this pathway requires the calculation of target levels at the POE, POD, and the source of release. These concentrations must be compared with risk concentration to make risk management decisions.

5.4 SURFACE WATER PROTECTION

Potential impacts to streams and other surface water bodies from a release must be evaluated and surface water quality protected. Sampling for COCs in surface water bodies will be necessary when COC migration is known or suspected to adversely affect a surface water body.

Per the NDAC 33.1-16-02.1-04, beneficial uses of a stream include one or more of the following:

- Municipal and domestic water,
- Fish and aquatic biota,
- Recreational (Primary: bathing and swimming; Secondary: boating, fishing, and wading)
- Agricultural uses, and
- Industrial water

A stream may have multiple beneficial use designations, in which case all beneficial uses must be identified. Protection of surface water requires the determination of surface water (streams, wetland, lakes, and reservoirs) classification, allowable COC concentrations in the stream, i.e., the stream water quality criteria point of discharge, and allowable source COC concentration in soil and groundwater. Each of these steps is described below.

Step 1: Determine surface water classification: Per the NDAC 33.1-16-02.1-09 and based on the beneficial use, surface water is classified as follows:

- Class I streams,
- Class IA streams,
- Class II streams,
- Class III streams,
- Wetlands, and
- Lakes and reservoirs.

Note, lakes and reservoirs are subcategorized as Class I to Class V based on the type of fishery (e.g., cold water, warm water, etc.) the lake or reservoir can support.

Appendix I and Appendix II of NDAC 33.1-16-02.1 presents the stream, and lakes and reservoir classification, respectively.

Step 2: Determine stream water quality criteria: Identify the stream water quality criteria depending on the classification of stream and lake/reservoir. Table 2 of NDAC 33.1-16-02.1 presents the water quality criteria for aquatic life (acute and chronic) and human health. Human health criteria are based on two categories: ingestion of aquatic organism and drinking water for Class I, IA, and II, and ingestion of aquatic organism for Class III. For COCs with both aquatic and human health criteria, select the most protective applicable criteria. If chemicals for which water quality criteria are not available are present at a site, contact the NDDEQ.

Step 4: Determine the location of POE (i.e., the location where the water quality criteria must be met): For Tier 1 evaluation this location, i.e., the POE, would be the surface where the groundwater seeps into the surface water body. For Tier 2 and Tier 3 evaluation this point may be located at the downstream edge of the mixing zone within the surface water. This would then require the estimation of groundwater discharge to the stream and the size of the mixing zone. Details on the mixing zone is presented in Appendix III (Mixing Zone and Dilution Policy and Implementation Procedure) of NDAC 33.1-16-02.1.

Step 5: Estimate groundwater and soil concentrations: Applicable COC concentrations for soil and groundwater can be back calculated using the concept of dilution attenuation factors. The specific equations, a combination of the Summer's Model and the Domenico's model, are presented in Appendix A.

5.5 ESTIMATION OF REPRESENTATIVE CONCENTRATIONS

Application of the NDRBCA process results in RBTLs for each complete EP identified in the EM and each associated COC. For direct EP, RBTLs are calculated for the POE whereas for the indirect EP, RBTLs are calculated for both the POE and PODs. For site-specific risk management decisions, the RBTLs must be compared with appropriate RCs.

Since there may be several complete EPs at a site, several RCs, one for each EP, must be calculated. If the maximum media-specific concentration of a COC does not exceed the RBTL, a RC need not be calculated for that pathway.

Calculation of RCs is further discussed at Appendix E.

5.6 EVALUATION OF LIGHT NON-AQUEOUS PHASE LIQUID (LNAPL)

The detection of LNAPL, at a site must trigger a response sufficient to achieve the following objectives:

1. LNAPL should not be present at levels that would cause explosive conditions to occur at or near the site,
2. The LNAPL plume shall be fully delineated,
3. Dissolution of and volatilization from LNAPL should not generate dissolved phase or vapor phase concentrations that result in unacceptable human or ecological risk,
4. Both the LNAPL and its associated dissolved phase plume shall be stable or shrinking, and
5. LNAPL shall be removed to the maximum extent practicable.

When data collected under the NDRBCA process shows that these goals have been achieved, no further evaluation or removal of LNAPL will be required. In some cases, provided all other site conditions are acceptable, the NDDEQ may grant site closure even though LNAPL remains.

A brief discussion of each of these objectives is presented below.

5.6.1 Protection Against Explosive Risk

In certain circumstances, the presence of LNAPL can pose a risk of explosion due to vapor migration and accumulation. At sites where LNAPL is present, vapor monitoring must be conducted in the area immediately above and within 50 feet of the known extent of LNAPL. Such monitoring must use monitoring equipment capable of detecting chemicals associated with the LNAPL at concentrations equal to or less than 25 percent of the lower explosive limit (LEL) of each volatile component of the LNAPL. Vapor concentrations must be monitored at all utilities, subsurface and surface structures, and any other enclosed spaces found immediately above and within 50 feet of the known extent of the LNAPL plume. The detection of vapors at concentrations equal to or greater than 25 percent of the LEL of any one of the volatile components of the LNAPL shall constitute a potential explosion hazard and shall require abatement. Refer to Table 5-1 for a listing of the LELs and 25% LELs of various volatile petroleum components.

5.6.2 LNAPL Plume Shall be Fully Delineated

The occurrence of LNAPL must be investigated to determine the extent of the LNAPL and whether it is migrating, either as LNAPL or via dissolution into groundwater. This determination will require the installation and periodic monitoring of monitoring wells sufficient to define the LNAPL and dissolved-phase plume. The resulting data must be sufficient to demonstrate spatial and temporal trends in LNAPL thickness and dissolved phase concentrations. Note that LNAPL thickness is critically affected by water table fluctuations. Therefore, the collection of sufficient data, especially at sites where there are strong seasonal and long-term water table fluctuations, is very important to ensuring accurate LNAPL delineation and characterization.

5.6.3 LNAPL Tiered Risk Evaluation

LNAPL can pose a direct risk to human health via, for instance, vapor migration and dissolution in groundwater contacting LNAPL. The risk LNAPL depends, in part, on the dissolved and vapor phase concentrations associated with the LNAPL. These concentrations, in turn, depend on the composition of the LNAPL. For a Tier 1 evaluation, the default LNAPL composition values shown in Table 5-2 for various types of products are used to estimate the dissolved and vapor phase concentrations associated with LNAPL at a site.

For Tier 2 and Tier 3 evaluation, it may be more appropriate to sample the LNAPL to determine the mole fraction of the various COCs comprising the LNAPL and use these site-specific values to evaluate the risk associated with the LNAPL. In the absence of such site-specific values, default values from Table 5-2 may be used. Additionally for a Tier 3 evaluation, alternate technically defensible methods and models to evaluate LNAPL, whether as to composition, fate and transport, or plume stability, may be proposed in the work plan and used upon approval by

5.6.4 LNAPL Plume Stability

Sufficient data shall be collected to delineate the extent of the LNAPL plume. In addition, the stability of the LNAPL plume and its associated dissolved-phase plume must be evaluated. The outcome of such an evaluation will, in part, dictate whether and to what extent continued LNAPL recovery is required.

5.6.5 Practicability of LNAPL Removal

LNAPL must be removed from the environment to the maximum extent practicable. The degree of removal constituting the "maximum extent practicable" is a site-specific determination and does not equate to a generic "LNAPL thickness in well" measurement that can be uniformly applied to all sites regardless of site and LNAPL characteristics.

5.7 CONSIDERATION OF TOTAL PETROLEUM HYDROCARBONS (TPH)

The development of RBTLs for petroleum products (gasoline, diesel, heating oils, aviation fuel, and others) is problematic for a number of reasons. These include but are not limited to:

1. These products contain a mixture of several hundred chemicals ranging from light, volatile, short chained organic compounds to heavy, long chained, branched compounds.
2. Analyzing the concentration of each of these compounds in the environmental media affected by a petroleum release is not practical.
3. The various constituent compounds exhibit a range of physical, chemical, and toxicological properties. The properties of several of these compounds are not known and, therefore, calculating RBTLs for them is not possible.
4. These products are mixtures of chemicals i.e., the composition of the fresh products vary.
5. Chemicals that constitute the mixtures, attenuate at different rates once the product is introduced to the environment, a process referred to as weathering. Thus, the composition of the fresh mixture is significantly different from the composition of the weathered mixture.

Thus, a variety of methods have been developed to identify key constituents of the products and to estimate media-specific target levels for these constituents for use in the management of petroleum contaminated sites. These methods include:

1. Development of target levels for total petroleum hydrocarbons (TPH),
2. Development of target levels for specified ranges of petroleum hydrocarbons, e.g., TPH-GRO (gasoline range organics), TPH-DRO (diesel range organics), and TPH-ORO (oil range organics),
3. Development of target levels for a few constituents (those considered most toxic and for which sufficient data is available), e.g., benzene, toluene, ethylbenzene, xylenes, naphthalene, and polynuclear aromatic hydrocarbons (PAHs). These are referred to as the indicator chemicals,
4. Development of target levels for a specified size range of aromatic and aliphatic fractions, e.g., aliphatics >C6-C8, aliphatics >C8-C10, aromatics >C10-C12, etc., Refer to Table 5-3 for fraction of TPH groups, and
5. A combination of the above approaches.

Each of the above methods results in RBTLs that can be used to manage contaminated sites. In each case, the field sampling and laboratory analysis method should be consistent with the method used to develop the RBTLs, or else the comparison of measured concentrations with the target levels may not be accurate. For example, if target levels are developed for specific aromatic and aliphatic fractions (method 4 above), soil and groundwater samples should be analyzed for the corresponding fractions. Note that the laboratory analysis costs for measuring TPH concentrations are significantly lower than for measuring individual petroleum fractions. Therefore, the selection of a particular method can have significant cost implications. If cost were not an issue, measurement of individual fractions (method 4) would perhaps be the most appropriate method for developing RBTLs.

Within the NDRBCA process, petroleum hydrocarbon impacts will be evaluated using the following approach:

1. Tier 1: Use the indicator chemicals or TPH screening levels in Tables 6-1(a) and (b) .
2. Tier 2: Use the indicator chemicals.
3. Tier 3: The RP may develop SSTLs for individual fractions and indicator chemicals in accordance with product released.

For Tier 3 evaluation, selected samples may be analyzed for specified petroleum fractions, in accordance with the Tier 3 workplan approved by the NDDEQ.

A Tier 1 evaluation requires the following steps:

Step 1: Compilation of data and identification of any data gaps,
Step 2: Development of a CSM that includes an EM,
Step 3: Collection of data to fill data gaps, if any,
Step 4: Calculation of exposure pathway-specific representative concentrations of COCs,
Step 5: Selection of Tier 1 RBSLs and comparison with appropriate representative concentrations,
Step 6: Recommendations for the next course of action, and
Step 7: Documentation of Tier 1 evaluation.

Details of each 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. The NDDEQ recommends that all data be compiled in the data tables developed as a part of the NDRBCA report forms included in Appendix B. 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 an updated/current land use map,
- Lack of soil or groundwater COC concentrations representative of current conditions (e.g., soil or groundwater COC data might be too old, or predate remedial activities at the site or may not be representative of recent releases),
- Lack of a water use well search in the proximity of the site,
- Insufficient delineation of impacts or absence of relevant data, (e.g., soil gas data), and
- Lack of soil and groundwater data for certain COCs.

After all the data gaps have been identified, the RP may have to develop a work plan to collect the necessary data. A Tier 1 evaluation can be performed with limited data, hence additional data may not be necessary at many sites that have been assessed and characterized.

6.2 STEP 2: DEVELOPMENT OF CONCEPTUAL SITE MODEL

This step is necessary to identify the receptors and exposure pathways that are currently complete or that are reasonably likely to become complete in the future. Note, if contamination has migrated off-site, the affected off-site property or properties must also be considered. Receptors and pathways should be considered for the entire area over which the impacts may have extended or may extend in the future. Thus, prior to determining exposure pathways, sufficient site evaluation will have to be conducted such that the horizontal and vertical extents 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.

For each complete exposure pathway, the following must be identified:

- The exposure domain (ED),
- The monitoring points located within the ED,
- Concentrations collected from the monitoring points included in the ED,
- Maximum concentration within the ED, and
- The point of exposure (POE).

To facilitate development of the EM, the NDDEQ has developed standardized report forms. These report forms list the routes of exposure typically considered at a site. On these forms, the evaluator indicates whether the pathway is complete or not complete, provides the rationale for the choice, and identifies monitoring points that are located within the ED from which data will be used to estimate maximum (representative) chemical concentrations for each pathway.

6.3 STEP 3: COLLECTION OF DATA TO FILL THE DATA GAPS, IF ANY

This step will be necessary only if data gaps are identified in Step 1. Depending on the specifics, this may require approval of a work plan by the NDDEQ. Upon completion of this step and with appropriate documentation of the fieldwork, the evaluator shall proceed with Step 4.

6.4 STEP 4: CALCULATION OF EXPOSURE PATHWAY-SPECIFIC REPRESENTATIVE CONCENTRATIONS

Using the data compiled in Steps 1 and 3, the evaluator shall select the representative chemical concentration within each domain for each media (soil, groundwater, soil vapor, etc.). Note, for Tier 1 evaluation the representative concentration (RC) is the maximum concentration. The need to identify the RC for each ED may be avoided by initially comparing the site-wide maximum media-specific concentrations with Tier 1 RBSLs. If the site-wide RCs do not exceed the RBSLs, selection of the maximum exposure pathway specific RC, is not necessary.

6.5 STEP 5: SELECTION OF TIER 1 RBSLs AND COMPARISON WITH REPRESNTATIVE CONCENTRATIONS

In this step, the Tier 1 RBSLs for the complete routes of exposure identified in Step 2 are compared with the maximum COC site-wide concentrations from Step 4. The Tier 1 RBSLs are presented in Tables 6-1(a) to 6-1(b).

For the protection of groundwater pathway, Tier 1 assumes the POE to be at the downgradient edge of the plume. Soil concentrations protective of groundwater will be selected from Table 6-1(a). Based on the results of this step, the RP shall recommend the path forward as discussed in Step 6.

6.6 STEP 6: RECOMMENDATIONS FOR THE NEXT COURSE OF ACTION

Depending on the result of the comparison, one of the following two alternatives is available.

Alternative 1: If the maximum concentrations do not exceed the Tier 1 RBSLs and the following three conditions are met, the RP may request that the NDDEQ to grant site closure for the release.

Condition 1: Confirmation that the plume is stable or decreasing (see definition at Section 4.12.2). If this condition is not satisfied, compliance monitoring must be continued until the plume is demonstrably stable and/or take actions to hasten plume stability.

Condition 2: Assurance that the land use assumptions used in the NDRBCA evaluation are not violated in the future. The NDDEQ may require an environmental covenant on the property

Condition 3: Absence of ecological concerns at the site. If this condition is not met, the RP shall provide recommendations to the NDDEQ to address the condition.

Alternative 2: If one or more concentrations exceed the RBSLs, the RP shall determine whether to conduct corrective action to achieve the Tier 1 RBSLs or perform a Tier 2 evaluation. Based on this determination, the RP shall recommend one of the following: selection of Tier 1 RBSLs as cleanup levels and remediation to these levels, environmental covenant to close the exposure pathway that resulted in the exceedance, or performance of a Tier 2 evaluation. Nationwide experience suggests that, unless the corrective action is very limited, the cost of a Tier 2 evaluation and subsequent remediation to Tier 2 SSTLs is typically less than the cost of remediation to Tier 1 RBSLs.

6.7 STEP 7: DOCUMENTATION OF TIER 1 EVALUATION

To facilitate documentation and review of the Tier 1 evaluation, the NDDEQ has developed standardized report forms (refer Appendix B). The Tier 1 evaluation shall be appropriately documented and submitted to NDDEQ. If a Tier 2 evaluation is conducted, both the Tier 1 and Tier 2 evaluations may be submitted simultaneously.

If any of representative concentrations exceed Tier 1 RBSLs or any other conditions for closure are not met, the RP may choose to complete a Tier 2 evaluation or use Tier I RBSLs as the cleanup levels. Thus, a Tier 2 evaluation would typically be conducted if the site does not close under Tier 1. At sites where a preliminary review of data indicates that the COCs will not meet the Tier 1 RBSL levels, a Tier 2 evaluation may be performed directly without performing and submitting a Tier 1 report.

As noted in Table 2-1, a Tier 2 evaluation uses a combination of site-specific and default fate and transport parameters and exposure factors. Specifically, a Tier 2 evaluation must include the following steps:

Step 1: Compilation of site-specific fate and transport parameters,
Step 2: Compilation of site-specific exposure factors,
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 Tier 2 evaluation and recommendations

Typically, the EM for Tier 1 and Tier 2 evaluation will be identical. Details of each of these steps are presented below.

7.1 STEP 1: COMPILATION OF SITE-SPECIFIC FATE AND TRANSPORT PARAMETERS

A Tier 2 evaluation allows for the application of site-specific fate and transport parameters. 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 are representative of the site and can be justified for a Tier 2 evaluation. Refer to Table A-5 in Appendix A for the Tier 1 fate and transport default values. The RP must review the site information and select values for each of these parameters and provide justification for the selection of each specific value. For some fate and transport parameters, literature values consistent with the site stratigraphy may be used in lieu of field measurements.

For a variety of reasons (such as soil heterogeneity, climatic changes, and measurement uncertainties), fate and transport parameters show considerable variability, hence it is recommended that the RP perform sensitivity analysis to understand the impact of the variability on the calculated SSTLs and present the results to the NDDEQ.

7.1.1 Soil Parameters

Depth Below Grade to Surface Soil Source (d_s)

This parameter is used to calculate the mass-limit volatilization factor (VF) which is used to calculate the RBTL for outdoor inhalation of vapors from surficial soil. Tier 2 requires the use of the actual measured depth to COCs in surficial soil. The default depth to surficial soil is 2 ft bgs.

Depth Below Grade to Subsurface Soil Source (d_{ts})

This parameter is used to calculate the attenuation factor (AF) from the subsurface soil source to indoor air. The AF is further used to calculate the RBTL for indoor inhalation of vapors from subsurface soil. Tier 2 requires the use of the actual measured depth to COCs in subsurface soil. The most conservative value of this parameter would be the shallowest levels at which the COC is detected or an average of the shallowest depths at which the COC was detected from multiple borings within the exposure domain for this pathway. Either way, the measurements should reflect the distance from the surface to the top of the first zone of impacted soil.

Depth Below Grade to Soil Vapor Measurement (d_{sv})

This parameter is used to calculate the AF from vapor measurement to indoor air. The AF is further used to calculate the RBTL for indoor inhalation of vapors from subsurface soil vapor if the Johnson and Ettinger (J&E) Model is used.

Thickness of Capillary Fringe (h_c)

This parameter is used to calculate the AF from groundwater source to indoor air if J&E Model is used. The AF is further used to calculate the RBTL for indoor inhalation of vapors from groundwater. The thickness of the capillary fringe must be representative of the site soils/sediments and is primarily dependent on soil grain size. Typically, the thickness of the capillary fringe is based on literature values because direct measurement is impractical. The sum of the thickness of the capillary fringe and the thickness of the vadose zone should equal the depth to groundwater (i.e., $h_c + h_v = L_{gw}$).

Thickness of Vadose Zone (h_v)

This parameter is used to calculate the AF from groundwater source to indoor air. At Tier 2, the thickness of the vadose zone is calculated by subtracting the capillary fringe thickness from the depth to groundwater ($L_{gw} – h_c = h_v$).

Vadose Zone Dry Soil Bulk Density (ρ_s)

This parameter is used for the calculation of RBTLs for all indirect exposure pathways that involve equilibrium calculations between various phases. Examples include leaching to groundwater, indoor inhalation from subsurface soil, and outdoor inhalation from surficial soil. If multiple measurements from the vadose zone are available, use the average value.

Fractional Organic Carbon Content in Vadose Zone (f_{ocv})

This parameter is used for the calculation of RBTLs for all indirect exposure pathways that involve equilibrium calculations between various phases. 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 4.6.2. 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 values are available, and if technically appropriate, the average value should be used. For example, assume that soil is impacted between 10 to15 feet below ground surface (bgs) and the water table is at 25 feet bgs. If three soil samples at 5, 12, and 20 feet 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. Hence, the average of the values from the samples at 5 and 12 feet may be used. Similarly, for soil leaching to the groundwater pathway, 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.

Porosity in the Vadose Zone (θ_T)

This parameter is used to calculate RBTLs for all indirect exposure pathways that involve equilibrium calculations between various phases. It is also used to calculate the effective diffusion coefficient of the COC in the vadose zone. Both Tier 1 and Tier 2 evaluations assume that the porosity of the vadose zone, capillary fringe, and soil that fills the foundation or wall cracks is identical. This assumption is necessary because measuring porosity in the capillary fringe and in foundation and wall cracks is generally not practical. See Appendix D 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.

Volumetric Water Content in Vadose Zone (θ_{ws})

This parameter is used to calculate the RBTLs for all indirect exposure pathways that involve equilibrium calculations between various phases and to calculate the effective diffusion coefficient of COCs in the vadose zone. Volumetric water content is typically measured as discussed in Appendix D and generally expressed on a weight basis (gravimetric: grams of water/grams of dry soil) and must be converted to a volumetric value (cm^3 of water/cm^3 of soil) as discussed in Appendix D 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. Moisture content values may be obtained from soil samples being analyzed for COCs. (The RP must direct their laboratories to report soil COCs concentration on a dry weight basis and the moisture content of each sample).

Volumetric Air Content in Vadose Zone (θ_{as})

This parameter is used for the calculation of risk from all indirect exposure pathways that involve equilibrium calculations between various phases as well as to calculate the effective 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 (i.e., $\theta_T - \theta_{ws} = \theta_{as}$).

Volumetric Water Content in Capillary Fringe (θ_{wcap})

This parameter is used to estimate the effective diffusion coefficient of COCs in the capillary fringe. Volumetric water content in the capillary fringe is typically estimated as 90 per cent of the total vadose zone soil porosity (i.e., $0.9\theta_T$). Total soil porosity in the capillary fringe is typically assumed to be equal to the total vadose zone porosity.

Volumetric Air Content in Capillary Fringe (θ_{acap})

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 ($\theta_{Tcap} - \theta_{wcap} = \theta_{acap}$).

Volumetric Water Content in Foundation or Wall Cracks (θ_{wcrack})

This parameter is used to calculate the effective diffusion coefficient of COCs in 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 ($\theta_{wcrack} = \theta_{ws}$).

Volumetric Air Content in Foundation or Wall Cracks (θ_{acrack})

This parameter is used to calculate the effective diffusion coefficient of COCs in the foundation or wall cracks. 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 ($\theta_{acrack} = \theta_{as}$). The latter is determined as described above.

7.1.2 Groundwater Parameters

Depth to Groundwater (L_{gw})

This parameter is used to estimate the risk due to indoor inhalation from groundwater and the dilution attenuation factor in the vadose zone.

Because the depth to groundwater fluctuates due to seasonal variations, the average depth to groundwater should be based on several years of 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 exposure domain, first the average depth should be calculated for each well. Second, (for modeling purposes) the average of the average depth 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 change, only recent data should be used.

Width of Groundwater Source Area Perpendicular to Groundwater Flow Direction (Y)

This parameter is used by Domenico's model to simulate migration in the saturated zone and estimate the saturated zone DAF. This parameter is necessary only in cases where horizontal migration of COCs in the groundwater is quantitatively evaluated. The Tier 2 risk evaluation assumes that COCs migrate vertically downward from the area of release to groundwater. By projecting the area of release to the water table, the dimension "Y" can be estimated. Figure 7-1 shows a schematic of the groundwater source that is considered by Domenico's groundwater model.

Length of Groundwater Source Area Parallel to Groundwater Flow Direction (W_{ga})

This parameter is necessary when the horizontal migration of COCs in groundwater is quantitatively evaluated. As mentioned above, a Tier 2 risk evaluation assumes that COCs migrate vertically downward from the area of release to groundwater. Figure 7-1 shows a schematic of the groundwater source that is considered by Domenic's groundwater model. By projecting the area of release to the water table, W_{ga} can be estimated.

Porosity in Saturated Zone (θ_{TS})

Porosity in the saturated zone is required when biodecay is considered in the horizontal migration of COCs. If the unsaturated and saturated zone stratigraphies are similar, the saturated zone porosity may be set equal to the vadose zone porosity. If multiple values are available, an average should be used. If the vadose and saturated zone soil stratigraphies 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 the 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 (ρ_{ss})

An accurate estimate of the dry soil bulk density in the saturated zone is essential only when biodecay is considered in the horizontal migration of COCs. 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 vadose and saturated zone stratigraphies 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 (f_{ocs})

An accurate estimate of the fractional organic carbon content in the saturated zone is essential only when biodecay is considered in the horizontal migration of COCs. 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 Mixing Zone Thickness (δ_{gw})

Mixing zone thickness is used by Summers and Domenico's model to estimate the dilution attenuation factors in the saturated zone. The groundwater mixing zone thickness is a measure of the thickness over which COCs mix within the saturated zone, primarily due to water table fluctuations. While difficult to estimate accurately, the mixing zone thickness may be approximated based either on photoionization detector (PID) readings, soil concentrations measured in borings extending below the water table or by measuring groundwater concentrations at depths below the water table. The 200 cm Tier 1 default value should be considered a minimum. The USEPA's Soil Screening Guidance (1996, page 31, Equation 12) contains an equation to calculate the groundwater mixing zone thickness that may be used for Tier 2 evaluation. Other procedures for determining the mixing zone thickness may be used with the prior approval of the NDDEQ. The mixing zone thickness should not exceed the thickness of the aquifer.

Groundwater Darcy Velocity (U_{gw})

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

$$U_{gw} = K \times i$$

Site-specific hydraulic conductivity can be estimated based on the results of site-specific pump tests or slug test, 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 and/or a range of velocities presented.

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 as 10 per cent of the average annual rainfall at the site. Average annual rainfall values are based on a 30-year average and may be obtained from literature.

Biodecay Rate (λ)

This parameter is an input to the Domenico's model that is used to estimate the migration of chemicals in the saturated zone. Specifically, it is used to estimate the DAF in the saturated zone.

In a Tier 1 risk evaluation, the biodecay rate is assumed to be zero. In a Tier 2 and Tier 3 evaluation a site-specific non-zero biodecay rate may be used. Prior to using the biodecay rate, the RP must provide evidence to the NDDEQ that supports the use of the proposed value. The RP is encouraged to consult the open literature to identify technical approaches to estimate site-specific biodecay rates. For additional details, also refer to Buscheck and Alcantar (1995).

7.2 STEP 2: COMPILATION OF SITE-SPECIFIC EXPOSURE FACTORS

The default exposure factors used for Tier 1 evaluations are presented in Table A-4 of Appendix A. For Tier 2 and Tier 3 evaluation site-specific factors with adequate justification may be used. Justification may include actual site-specific measurements or use of peer reviewed literature (e.g., USEAP (2011)). The Tier 1 default exposure frequency for a child exposed to surficial soil is assumed to be 350 days. As an example, based on the days when soil is covered with snow or days with heavy precipitation, the exposure frequency may be reduced with approval from the NDDEQ.

7.3 STEP 3: CALCULATION OF TIER 2 SSTLs

Using the site-specific data discussed above, Tier 2 SSTLs are calculated for each COC and each complete route of exposure. In calculating the Tier 2 SSTLs, fate and transport models, physical-chemical properties, and toxicological properties will be the same as used in the Tier 1 risk calculations and are presented in Appendix A.

As discussed in Section 4.10, Ecological Risk Evaluation, the RP must also identify appropriate levels protective of ecological receptors, if needed.

7.4 STEP 4: CALULATION OF REPRESENTATIVE CONCENTRATION

For the calculation of RC refer to Appendix E.

7.5 STEP 5: COMPARISION OF TIER 2 SSTLs WITH REPRESENTATIVE CONCENTRATIONS

In Step 3, Tier 2 SSTLs for each COC will be compared with their respective RCs. The comparison will result in the following two Alternatives:

Alternative 1: If the RCs do not exceed the Tier 2 SSTLs and the following three conditions are met, the RP may request the NDDEQ to issue a site the letter of closure for the release.

Condition 1: Confirmation that the plume is stable or decreasing (Refer to Section 4.12.2). If this condition is not satisfied, compliance monitoring must be continued until the plume is demonstrably stable and/or take actions to hasten plume stability.

Condition 2: Assurance that the land use assumptions used in the NDRBCA evaluation are not violated in the future. The NDDEQ may require an environmental covenant be placed on the site

Condition 3: Absence of ecological concerns at the site. If this condition is not met, the RP shall provide recommendations to the NDDEQ to address the condition.

Alternative 2: If one or more RCs exceed the Tier 2 SSTLs, the RP shall determine whether to conduct corrective action to achieve the Tier 2 SSTLs or perform a Tier 3 evaluation. Based on this determination, the RP shall recommend one of the following: selection of Tier 2 SSTLs as cleanup levels and remediation to these levels, environmental covenant to close the exposure pathway that resulted in the exceedance, or performance of a Tier 3 evaluation.

7.6 STEP 6: RECOMMENDATION FOR THE NEXT COURSE OF ACTION

Depending on the results of the comparison, one of the following options are available:

Option 1: The RP may request the NDDEQ to grant site closure if, in addition to Alternative 1 above, the following four conditions must be met.

Condition 1: The plume, if one exists, is stable or shrinking (Refer Section 4.12.2 for discussion of plume stability). If this condition is not satisfied, the RP must continue groundwater monitoring until the plume is demonstrably stable. This recommendation must include a sampling plan with specifics such as:

- Wells to be sampled,
- Frequency of sampling,
- Laboratory analysis methods,
- Method to be used to demonstrate that the plume is stable or shrinking, and
- The format and frequency of reporting requirements.

Condition 2: The maximum concentration of any COC in an ED is less than ten times the RC of that COC for any exposure pathway. This condition can be met if an exceedance can be justified by any of the following and/or appropriate actions taken:

- The maximum concentration is an outlier,
- The RC (average) was inaccurately calculated,
- The site is not adequately characterized,
- A hot spot may not have been adequately characterized, or
- Other explanation satisfactory to the department.

Any exceedance of this condition must be documented and the possible rationale, if any, submitted to the NDDEQ, who will determine what actions, if any, will be necessary to address the situation. For example, if a site is not adequately characterized, then further sampling and analysis may be needed.

Condition 3: Prior to issuance of a letter of closure, adequate assurance is provided that the land use assumptions used in the NDRBCA evaluation are not violated for current or future conditions. This condition may require an environmental covenant.

Condition 4: There are no ecological concerns at the site, as determined by confirmation that the maximum or RCs are below levels protective of ecological receptors or completion of the Ecological Risk Evaluation.. If this condition is not met, the RP must provide recommendations to the NDDEQ to manage the ecological risk.

Option 2: The RP must decide either to use the calculated Tier 2 SSTLs as the cleanup levels and conduct corrective action to meet these levels or to perform a Tier 3 risk evaluation.

Based on this decision, the RP must recommend one of the following:

1. Remediation to Tier 2 SSTLs (if the RP decides to remediate the site to Tier 2 SSTLs, the cleanup levels will be the lower of concentrations protective of human health and ecological receptors), or
2. Performance of a Tier 3 evaluation.

7.7 STEP 7: DOCUMENTATION OF TIER 2 EVALUATION AND RECOMMENDATIONS

To facilitate the review of a Tier 2 evaluation by various stakeholders the evaluation 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. At a minimum, the Tier 2 evaluation report must include the following:

- Conceptual Site Model
- Site background and chronology of events,
- Data used to perform the evaluation,
- Documentation of the EM,
- Documentation and justification of all fate and transport parameters and exposure factors,
- Calculated SSTL for each COC, each exposure pathway, and each receptor,
- Recommendations based on the Tier 2 evaluation, and
- If a site closure is requested, documentation that all four of the conditions in Section 7.6, Alternative 1, have been met.

8.0
TIER 3 EVALUATION

A Tier 3 evaluation is a detailed, site-specific evaluation that may be conducted when a site does not close based on a Tier 2 evaluation. This may occur if the RCs for one or more complete exposure pathways exceed the Tier 2 SSTLs and it is not cost-effective or feasible 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 the most recent toxicity factors, physical and chemical properties, site-specific exposure factors, and alternative fate and transport models may be used. A Tier 3 evaluation may include a Level 1, Level 2, or Level 3 ecological risk evaluation as described in Section 4.10.

The Tier 3 evaluation requires the following steps:

Step 1: Development of Tier 3 work plan,
Step 2: Collection of additional data, if necessary,
Step 3: Calculation of Tier 3 SSTLs and representative concentrations
Step 4: Development and implementation of a RMP, if necessary,
Step 5: Documentation of Tier 3 evaluation

8.1 STEP 1: DEVELOPMENT OF A TIER 3 WORK PLAN

Unlike Tier 1 and Tier 2 evaluations, Tier 3 evaluation provides considerable flexibility to the RP. Examples include:

- Evaluation of land uses other than residential and commercial/industrial e.g., recreational,
- Use of site-specific natural attenuation rates,
- Use of physical chemical and toxicity values from the open literature and different from those used for Tier 1 or Tier 2 evaluation,
- Use of alternative fate and transport models, and
- Alternative definition of surface soils based on site-specific considerations.

In each case, the specific choice must be technically justified. Because of this flexibility and the very site-specific nature of the Tier 3 evaluations, the NDDEQ requires the RP to prepare a detailed Tier 3 evaluation work plan for approval prior to the implementation of the work plan.

In Tier 3, the complete routes of exposure and COC's to be considered are those for which the Tier 2 SSTLs were less than the RCs, i.e., those that did not meet the Tier 2 levels. Receptors for whom the Tier 2 SSTLs did not exceed the RCs need not be evaluated. Thus, the COCs considered in Tier 3 evaluation will be the same or less than the COCs considered in Tier 2 evaluation, unless new data collected after the Tier 2 evaluation indicates otherwise. Typically, a Tier 3 evaluation follows a Tier 2 evaluation although, in a few cases it may be appropriate to proceed directly to Tier 3 after a Tier 1 evaluation.

The Tier 3 work plan must include the following:

- The receptors that will be evaluated,
- Complete and potentially complete exposure pathways for each receptor,
- The COCs
- The fate and transport models to be used to evaluate the indirect exposure pathways. If a model different than those included in Appendix A is proposed, it must be peer reviewed, publicly available or a copy provided to the NDDEQ at no cost, and have a history of use on similar projects.
- A tabulation of the input parameters required and the justification for each. These include:
  (i) Chemical-specific physical properties
  (ii) Chemical-specific toxicological properties,
  (iii) Exposure factors, and
  (iv) Media and fate and transport parameters required by the selected fate and transport models.
- A discussion of the data and the methodology that will be used to calculate the RCs.
- An explanation of data gaps, if any, that may require additional fieldwork. A scope of work for the collection of this data.
- A discussion of the variability and uncertainty in the input parameters and the way the impact of this variability will be evaluated. Uncertainty analysis techniques range from sensitivity analysis to detailed Monte Carlo simulations USEPA (1997).
- An evaluation of ecological risk. Ecological Risk Evaluations previously completed at any level are also acceptable in Tier 3 and do not need to be re-done.

After receiving approval of the Tier 3 work plan, the RP may start implementation of the approved work plan. Any changes to the methodology or input parameters made after the NDDEQ's approval must be communicated to the NDDEQ with a request for approval.

8.2 STEP 2: COLLECTION OF ADDITIONAL DATA, IF NECESSARY

Upon approval of the Tier 3 work plan, the RP must perform the necessary fieldwork to collect the data. Any changes in the data collection due to field conditions or logistics of fieldwork must be discussed with the NDDEQ prior to completion of the field effort. Depending on the nature and type of field work and data gaps, it may not be necessary to submit a separate report instead the data collection activities may be included as an appendix to the Tier 3 report.

8.3 STEP 3: CALCULATION OF TIER 3 SSTLs AND REPRESENTATIVE CONCENTRATIONS

This step requires the calculation of SSTLs for the complete exposure pathways and COCs per the approved work plan. Further, for each COC and complete exposure pathway the RC has to be calculated. If necessary, ecological risk should also be implemented as per the work plan.

8.4 STEP 4: DEVELOPMENT AND IMPLEMENTATION OF A RISK MANAGEMENT PLAN

The Tier 3 SSTLs must be compared with the RCs. After completion of the Tier 3 evaluation, one of the following two alternatives is available:

Alternative 1: The RP may request a letter of closure from the NDDEQ if the RC for each COC and each complete route of exposure is less than the corresponding Tier 3 SSTLs and the following conditions are satisfied:

Condition 1: The groundwater plume, if one exists, is stable or decreasing (refer to Section 4.12.2 for discussion of plume stability). If this condition is not satisfied, the RP must continue groundwater monitoring until the plume is demonstrably stable. In this situation, the monitoring plan must include a sampling plan with specifics such as:

- Wells to be monitored (gauged and sampled),
- Frequency of sampling,
- Laboratory analysis method,
- Method to be used to demonstrate that the plume is stable or shrinking, and
- The format and frequency of reporting requirements.

Condition 2: The maximum concentration of any COC is more than ten times the RC of that COC for all exposure pathways. Note the maximum concentration here refers to the maximum concentration of a chemical in the exposure domain, not the site-wide maximum concentration. This condition can be met if an exceedance can be justified by any of the following and/or appropriate actions taken:

- The maximum concentration is an outlier,
- The RC was inaccurately calculated,
- The site is not adequately characterized,
- A hot spot may not have been adequately characterized, or
- Other explanation satisfactory to NDDEQ.

Any exceedance of this condition must be documented and the possible rationale, if any, submitted to the NDDEQ who will determine what actions, if any, will be necessary to address the situation.

Condition 3: Prior to issuance of a letter of closure, adequate assurance is provided that the land use assumptions used in the Tier 3 evaluation will remain valid for the foreseeable future. This condition may require the implementation of an environmental covenant.

Condition 4: There are no ecological concerns at the site. If this condition is not met, the RP must provide recommendations to manage the ecological risk. If the NDDEQ approves the recommendations, then this condition would be met.

Alternative 2: The RCs may exceed the Tier 3 SSTL, and the RP may propose remedial actions to achieve Tier 3 SSTLs. The methodologies used to achieve these levels must be included in the RMP.

8. 5 STEP 5: DOCUMENTATION OF TIER 3 EVALUATION

Because a Tier 3 evaluation is very site-specific, the RP must submit a report that clearly describes the data used, methodology used to calculate Tier 3 SSTLs, key assumptions, results, and recommendations. Any deviation from the approved scope of work, the rationale for the deviation, and the date when the deviation was approved by the NDDEQ must be clearly documented in the report. At a minimum the report must include:

- Site background and chronology of events,
- Data used to perform the evaluation,
- Documentation of the exposure model and its assumptions,
- Documentation and justification of all input parameters used,
- Estimated Tier 3 SSTLs for each COC, each complete or potentially complete exposure pathway,
- Recommendations based on the Tier 3 evaluation, and
- If a letter of closure is requested, documentation that all the conditions in Section 8.4, Alternative 1, have been met.

A RMP encompasses all activities necessary to ensure that the risk to human health and the environment due to residual COCs are protective of human health and the environment under current and reasonable future conditions.

9.1 NEED FOR A RISK MANAGEMENT PLAN

The RP is required to develop a site-specific RMP to be implemented upon approval by the NDDEQ, under any one of the following conditions:

- The selected cleanup levels (Tier 1 RBSLs or Tier 2 or Tier 3 SSTLs) exceed RCs for one or more COCs
- None of the RBTLs exceed the RCs but the groundwater plume is expanding, or
- Ecological risk does not meet the acceptable criteria.

The RMP ensures that:

- Site conditions are protective of human health and the environment based on meeting the RBTLs under any one of the three tiers,
- Acceptable ecological protection is based on issues identified in the Ecological Risk Evaluation (Section 4.10),
- Assumptions made in the estimation of RBTLs are not violated under current or future use, and
- The groundwater plume is stable or decreasing.

Successful implementation of the RMP will result in a site closure from the NDDEQ. The following sections provide general information on the preparation of the RMP.

9.2 RISK MANAGEMENT PLAN

After it is determined that a RMP is necessary for a site, the plan should include:

- Reasons why a RMP is being prepared and the specific objectives of the plan. An example of a specific objective would be "remediation of soil to achieve specific risk-based concentrations (selected as the cleanup level) for specific COCs."
- Dated reference to the approved Tiers 1,2 or 3 report,
- Application of technologies to reduce mass, concentration, and/or mobility of COCs to meet the RBTLs selected as the cleanup levels for the site or specific engineering activities. Examples of technologies or remediation activities include soil excavation and off-site disposal, pump and treat, vapor extraction, enhanced in-situ attenuation, and monitored natural attenuation,
- Data that will be collected during the implementation of the RMP. Examples of data that may be collected include confirmatory soil or groundwater sampling data to demonstrate the effectiveness of the remedial measures.

- Details of how and when data will be evaluated and presented to the NDDEQ. Examples include trend maps, concentration contours, concentration vs. distance plots, calculations related to mass removal rates, or application of specific statistical techniques.
- Application of environmental covenants to eliminate certain pathways of exposure and ensure that the pathways remain incomplete under current and reasonably anticipated future uses. Examples include conditions imposed on the property that prevent the installation of water use wells, thus eliminating the groundwater future use pathway, or prohibition of future residential land use.
- If needed, monitoring to demonstrate plume stability or the effectiveness of natural attenuation.
- A schedule for the implementation of the plan. If the duration of the planned activities exceeds a few months, a detailed project timeline must be developed. It must include all major milestones and all deliverables to the NDDEQ.
- Criteria that will be used to demonstrate that the RMP has been successfully completed.
- As appropriate, contingency plans if the selected remedy fails to meet the objectives of the RMP in a timely manner.

The NDDEQ will approve the RMP as submitted or provide comments. If comments are made, the NDDEQ will work with the RP to revise the RMP and to resubmit it for approval. Upon receipt of approval, the RP should begin implementing the plan.

9.3 COMPLETION OF RISK MANAGEMENT ACTIVITIES

Upon successful implementation of the approved RMP, the RP must submit a completion report for approval that includes:

- Documentation of completion of all risk management activities,
- Demonstration that all public notice requirements have been met, including response to public comments
- If applicable, a request to plug and abandon all nonessential monitoring points related to the environmental activities at the site.

9.4 PROCEDURE FOR SITE CLOSURE

After the RMP has been successfully implemented, the RP may request site closure**.** The NDDEQ will grant closure if the site satisfies all requirements of the approved RMP. The closure would state that, based on the information submitted, the concentrations of COCs on or adjacent to the site do not pose an unacceptable level of risk to HH&E for the current and reasonably anticipated future uses and provided that all environmental covenants remain in place.

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10.0 REFERENCES

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Table 2-1
Comparison of Risk Assessment Options for Various Tiers

Factors	Tier 1	Tier 2	Tier 3
Exposure Factors	Default	Site-specific	Site-specific
Toxicity Factors	Default	Default	Most current
Physical and Chemical Properties	Default	Default	Most current
Fate and Transport Parameters	Default	Site-specific	Site-specific
Unsaturated Zone Attenuation	Default=1	Depth to water table dependent	Site-specific model
Fate and Transport Models	Default	Default	Alternative
Representative Concentrations	Maximum Concentrations-See Appendix E	Maximum Concentrations-See Appendix E	Maximum Concentrations-See Appendix E
IELCR for Each Chemical & ROE	1×10^{-5}	1×10^{-5}	1×10^{-5}
Hazard Quotient for Each Chemical & ROE	1	1	1
Groundwater Protection	MCL or equivalent	MCL or equivalent	MCL or equivalent
Ecological Risk	Evaluate using	Evaluate	Evaluate
Outcome of Evaluation	Tier 2, RMP	Tier 3, RMP	RMP
Environmental Covenant	Yes	Yes	Yes

Notes:
IELCR: Individual Excess Lifetime Cancer Risk
MCL: Maximum Contaminant Level
ROE: Route of Exposure
RMP: Risk Management Plan

Table 5-1
Vapor Concentrations Protective of Explosive Hazards

Compound	LEL (%)	UEL (%)	Action Levels (%)*
Gasoline	1.2	7.6	0.12 (1,200 ppm)
JP-4	1.3	8	0.13 (1,300 ppm)
Diesel Fuel	1.3	7.5	0.13 (1,300 ppm)
Fuel Oils	0.6	7.5	0.06 (600 ppm)
Kerosene	0.7	5	0.07 (700 ppm)
Benzene	1.3	7.9	0.13 (1,300 ppm)
Ethylbenzene	1	6.7	0.10 (1,000 ppm)
Toluene	1.2	7.1	0.12 (1,200 ppm)
Xylenes	1	7	0.10 (1,000 ppm)

Notes:
*: Action levels are equal to 10 % of the LEL. ppm: parts per million

Table 5-2
Weight Percent for COCs in Different Products

	Weight Percent (%)									
	Gasoline		**Diesel**		**Jet Fuel (JP-4 & JP-5)**		**Kerosene**		**Fuel Oil No. 6**	
	Range	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**
VOLATILES										
Benzene	1.6-2.3	1.90	0.0026-0.1	0.029	0.47-0.5	0.47	---	---	---	---
Toluene	6.4-10	8.10	0.0069-0.7	0.180	1.3-1.6	1.6	---	---	---	---
Ethylbenzene	1.4-2	1.70	0.007-0.2	0.068	0.37-0.69	0.66	---	---	---	---
o-Xylene	2.1-3.1	2.50	0.0012-0.085	0.043	---	0.545	---	---	---	---
m-Xylene	3.9-5.4	4.60	0.009-0.255	0.110	---	0.545	---	---	---	---
p-Xylene	1.6-2.3	1.90	0.009-0.255	0.110	---	0.35	---	---	---	---
Xylenes (total)	---	---	---	0.5	---	---	---	---	---	---
1,2-Dibromoethane/Ethylene dibromide (EDB)	---	---	---	---	---	---	---	---	---	---
1,2-Dichloroethane/Ethylene dichloride (EDC)	---	---	---	---	---	---	---	---	---	---
PAHs										
Acenaphthene	---	---	---	---	---	---	---	0.0047		
Anthracene	---	---	3.0E6 -0.02	5.80E-03	---	---	---	0.00012		0.005
Benzo(a)anthracene	---	---	2.0E-6 - 6.7E-4	9.60E-05	---	---	---	---	0.0029-0.15	0.055
Benzo(a)pyrene			5.0E-6 - 8.4E-4	2.20E-04	---	---	---	---		0.0044
Benzo(b)fluoranthene	---	---	1.55E-07 - 9.5E-05	1.55E-04	---	---	---	---		0.022
Benzo(k)fluoranthene	---	---	1.55E-07 - 9.5E-06	1.55E-04	---	---	---	---		0.022
Chrysene	---	---		4.50E-05	---	---	---	---	0.0029-0.31	0.069
Dibenz(a,h)anthracene	---	---	---	---	---	---	---	---		
Fluoranthene	---	---	6.8E-7 - 0.02	0.0059	---	---	---	0.00086		0.024
Fluorene	---	---	0.034-0.15	0.086	---	---	---	---		
Naphthalene	0.15-0.36	0.25	0.01-0.8	0.26	0.25-0.5	0.41	0.15-0.46	0.31	0.00021-0.015	0.0042
Pyrene	---	---	0.000018-0.015	0.0046	---	---	---	0.00024		0.0023

Notes:

Data from Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG), May 1998. TPHCWG Series Volume 2: Composition of Petroleum Mixtures.

1. ---: Not available. For these COCs pure product solubilites and saturated vapor concentrations were used.
2. Jet Fuel: Average values of JP-4 and JP-5 are taken.
3. Diesel: Values were available for m+p-Xylene. Each was considered 50% composition.
4. Diesel and Fuel Oil No. 6: Values were available for Benzo(b+k)fluoranthene. Each was considered 50% composition.

Table 5-3
Constituent Fraction of TPH Groups

TPH Group	TPH Fractions
TPH-GRO	Aliphatics >C6-C8 >C8-C10 Aromatics >C7-C8 >C8-C10
TPH-DRO	Aliphatics >C10-C12 >C12-C16 >C16-C35 Aromatics >C10-C12 >C12-C16 >C16-C21
TPH-ORO	Aromatics >C21-C35

Table 6-1(a)
Tier 1 Risk Based Screening Levels for Resident

Chemical	CAS #	Air	Surface Soil	Subsurface Soil	Soil*	Soil Vapor	Groundwater	
		Indoor	Ingestion, dermal contact, and outdoor inhalation of vapors and particulates	Indoor Inhalation of Vapors	Protective of Groundwater	Indoor Inhalation of Vapors	Domestic Use (Ingestion, dermal contact, and inhalation of vapors)	Indoor Inhalation of Vapors
		[µg/m^3]	[mg/kg]	[mg/kg]	[mg/kg]	[µg/m^3]	[µg/L]	
VOCs								
Benzene	71-43-2	3.6	12	NA	0.0026	NA	**5**	NA
Ethylbenzene	100-41-4	11	58	NA	0.78	NA	**700**	NA
Isopropylbenzene (Cumene)	98-82-8	420	1900 c	NA	0.74	NA	450	NA
Methyl tert-Butyl Ether (MTBE)	1634-04-4	110	470	NA	0.032	NA	140	NA
Naphthalene	91-20-3	0.83	20	NA	0.0038	NA	1.2	NA
1,2,4-Trimethylbenzene	95-63-6	63	300 c	NA	0.081	NA	56	NA
1,3,5-Trimethylbenzene	108-67-8	63	270 c	NA	0.087	NA	60	NA
Toluene	108-88-3	5200	4900 c	NA	0.69	NA	**1000**	NA
Xylene, Total	1330-20-7	100	580 c	NA	9.9	NA	**10000**	NA
PAHs								
Acenaphthene	83-32-9	NA	3600	NA	5.5	NA	530	NA
Anthracene	120-12-7	NA	18000	NA	58	NA	1800 s	NA
Benzo(a)anthracene	56-55-3	0.17	11	NA	0.11	NA	0.3	NA
Benzo (a) Pyrene	50-32-8	0.017	1.1	NA	0.24	NA	**0.2**	NA
Benzo(b)fluoranthene	205-99-2	0.17	11	NA	3	NA	2.5 s	NA
Benzo(k)fluoranthene	207-08-9	1.7	110	NA	29	NA	25 s	NA
Chrysene	218-01-9	17	1100	NA	90	NA	250 s	NA
Ethylene dibromide	106-93-4	0.047	0.36	NA	0.000014	NA	**0.05**	NA
Fluoranthene	206-44-0	NA	2400	NA	89	NA	800 s	NA
Fluorene	86-73-7	NA	2400	NA	5.4	NA	290	NA
Indeno (1,2,3-cd) Pyrene	193-39-5	0.17	11	NA	9.8	NA	2.5 s	NA
1-Methylnapthalene	90-12-0	NA	180	NA	0.06	NA	11	NA
2-Methylnapthalene	91-57-6	NA	240	NA	0.19	NA	36	NA
Naphthalene	91-20-3	0.83	20	NA	0.0038	NA	1.2	NA
Pyrene	129-00-0	NA	1800	NA	13	NA	120	NA
Metals								
Arsenic	7440-38-2	0.0065	6.8	NA	0.29	NA	**10**	NA
Barium	7440-39-3	0.52	15000	NA	82	NA	**2000**	NA

Beryllium	7440-41-7	0.012	160	NA	3.2	NA	**4**	NA
Cadmium (diet)	7440-43-9	0.016	7.1	NA	NA	NA	NA	NA
Cadmium (water)		0.016	NA	NA	0.38	NA	**5**	NA
Chromium (III)	16065-83-1	NA	120000	NA	40000000	NA	22000	NA
Chromium (VI)	18540-29-9	0.00012	3	NA	0.0067	NA	0.35	NA
Chromium (total)	7440-47-3	NA	NA	NA	180000	NA	**100**	NA
Lead	7439-92-1	0.15	400	NA	14	NA	**15**	NA
Manganese (non-diet)	7439-96-5	0.052	1800	NA	28	NA	430	NA
Mercury (elemental)	7439-97-6	0.31	11 c	NA	0.1	NA	**2**	NA
Selenium	7782-49-2	21	390	NA	0.26	NA	**50**	NA
Silver	7440-22-4	NA	390	NA	0.8	NA	94	NA
Chlorinated Solvents								
Hexachloroethane	67-72-1	2.6	18	NA	0.002	NA	3.3	NA
Pentachloroethane	76-01-7	NA	77	NA	0.0031	NA	6.5	NA
1,1,1,2-Tetrachloroethane	630-20-6	3.8	20	NA	0.0022	NA	5.7	NA
1,1,2,2-Tetrachloroethane	79-34-5	0.48	6	NA	0.0003	NA	0.76	NA
1,1,2-Trichloroethane	79-00-5	1.8	11	NA	0.0016	NA	**5**	NA
1,1,1-Trichloroethane	71-55-6	5200	8100 c	NA	0.07	NA	**200**	NA
1,2-Dichloroethane	107-06-2	1.1	4.6	NA	0.0014	NA	**5**	NA
1,1-Dichloroethane	75-34-3	18	36	NA	0.0078	NA	28	NA
Chloroethane	75-00-3	4200	5400 c	NA	2.4	NA	8300	NA
Perchloroethene (PCE)	127-18-4	110	240 c	NA	0.0023	NA	**5**	NA
Trichloroethene (TCE)	79-01-6	4.8	9.4	NA	0.0018	NA	**5**	NA
1,1-Dichloroethene	75-35-4	210	230	NA	0.0025	NA	**7**	NA
cis-1,2-Dichloroethene	156-59-2	NA	160	NA	0.021	NA	**70**	NA
trans-1,2-Dichloroethene	156-60-5	42	70	NA	0.031	NA	**100**	NA
Vinyl chloride (VC)	75-01-4	1.7	0.59	NA	0.00069	NA	**2**	NA
NDDEQ Specific					**[mg/kg]**	**[mg/L]**		
Ammonia	7664-41-7	NA	NA	NA	NA	NA	5	NA
Bromide	7726-95-6	NA	NA	NA	NA	NA	NA	NA
Chloride	16887-00-6	NA	NA	NA	NA	NA	250 s	NA
Nitrate as total nitrogen	14797-55-8	NA	130000	NA	500	NA	**10**	NA
Strontium	7440-24-6	NA	47000	NA	420	NA	12	NA
Total Kjeldahl Nitrogen (TKN)		NA	NA	NA	500	NA	10000	NA
Total Petroleum Hydrocarbons (TPH)		NA	NA	NA	100	NA	500	NA

Notes:

*: Surface and subsurface soil NA: Not available **Domestic water use RBSL in bold font represents maximum contaminant level (MCL)**

c: calculated RBSL shown in the table exceeded the saturated soil concentration

p: calculated soil vapor RBTL shown in the table exceeded the chemical vapor pressure

s: calculated RBSL shown in the table exceeded the chemical solubility

The above values were obtained from Regional Screening Level (RSL) Summary Tables (USEPA, May 2022)

Table 6-1(b)
Tier 1 Risk Based Screening Levels for Commercial/Industrial Worker

Chemical	CAS #	Air	Surface Soil		Subsurface Soil	Soil Vapor	Groundwater	
		Indoor	Ingestion, dermal contact, and outdoor inhalation of vapors and particulates		Indoor Inhalation of Vapors	Indoor Inhalation of Vapors	Domestic Use (Ingestion, dermal contact, and inhalation of vapors)	Indoor Inhalation of Vapors
		[µg/m^3]	[mg/kg]		[mg/kg]	[µg/m^3]	[µg/L]	
VOCs								
Benzene	71-43-2	16	51		NA	NA	**5**	NA
Ethylbenzene	100-41-4	49	250		NA	NA	**700**	NA
Isopropylbenzene (Cumene)	98-82-8	1800	9900	c	NA	NA	450	NA
Methyl tert-Butyl Ether (MTBE)	1634-04-4	470	2100		NA	NA	140	NA
Naphthalene	91-20-3	3.6	86		NA	NA	1.2	NA
1,2,4-Trimethylbenzene	95-63-6	260	1800	c	NA	NA	56	NA
1,3,5-Trimethylbenzene	108-67-8	260	1500	c	NA	NA	60	NA
Toluene	108-88-3	22000	47000	c	NA	NA	**1000**	NA
Xylene, Total	1330-20-7	440	2500	c	NA	NA	**10000**	NA
PAHs								
Acenaphthene	83-32-9	NA	45000		NA	NA	530	NA
Anthracene	120-12-7	NA	230000		NA	NA	1800	NA
Benzo(a)anthracene	56-55-3	2	210		NA	NA	0.3	NA
Benzo (a) Pyrene	50-32-8	0.0088	21		NA	NA	**0.2**	NA
Benzo(b)fluoranthene	205-99-2	2	210		NA	NA	2.5	NA
Benzo(k)fluoranthene	207-08-9	20	2100		NA	NA	25	NA
Chrysene	218-01-9	200	21000		NA	NA	250	NA
Ethylene dibromide	106-93-4	0.2	1.6		NA	NA	**0.05**	NA
Fluoranthene	206-44-0	NA	30000		NA	NA	800	NA
Fluorene	86-73-7	NA	30000		NA	NA	290	NA
Indeno (1,2,3-cd) Pyrene	193-39-5	2	210		NA	NA	2.5	NA
1-Methylnapthalene	90-12-0	NA	730	c	NA	NA	11	NA
2-Methylnapthalene	91-57-6	NA	3000		NA	NA	36	NA
Naphthalene	91-20-3	3.6	86		NA	NA	1.2	NA
Pyrene	129-00-0	NA	23000		NA	NA	120	NA
Metals								
Arsenic	7440-38-2	0.029	30		NA	NA	**10**	NA
Barium	7440-39-3	2.2	220000		NA	NA	**2000**	NA
Beryllium	7440-41-7	0.051	2300		NA	NA	**4**	NA

Cadmium (diet)	7440-43-9	0.068	100	NA	NA	NA	NA
Cadmium (water)		0.068	NA	NA	NA	**5**	NA
Chromium (III)	16065-83-1	NA	1800000	NA	NA	22000	NA
Chromium (VI)	18540-29-9	0.0015	63	NA	NA	0.35	NA
Chromium (total)	7440-47-3	NA	NA	NA	NA	**100**	NA
Lead	7439-92-1	NA	800	NA	NA	**15**	NA
Manganese (non-diet)	7439-96-5	0.22	26000	NA	NA	430	NA
Mercury (elemental)	7439-97-6	1.3	46 c	NA	NA	**2**	NA
Selenium	7782-49-2	88	5800	NA	NA	**50**	NA
Silver	7440-22-4	NA	5800	NA	NA	94	NA
Chlorinated Solvents							
Hexachloroethane	67-72-1	11	80	NA	NA	3.3	NA
Pentachloroethane	76-01-7	NA	360	NA	NA	6.5	NA
1,1,1,2-Tetrachloroethane	630-20-6	17	88	NA	NA	5.7	NA
1,1,2,2-Tetrachloroethane	79-34-5	2.1	27	NA	NA	0.76	NA
1,1,2-Trichloroethane	79-00-5	7.7	50	NA	NA	**5**	NA
1,1,1-Trichloroethane	71-55-6	22000	36000 c	NA	NA	**200**	NA
1,2-Dichloroethane	107-06-2	4.7	20	NA	NA	**5**	NA
1,1-Dichloroethane	75-34-3	77	160	NA	NA	28	NA
Chloroethane	75-00-3	18000	23000 c	NA	NA	8300	NA
Perchloroethene (PCE)	127-18-4	470	1000 c	NA	NA	**5**	NA
Trichloroethene (TCE)	79-01-6	30	60	NA	NA	**5**	NA
1,1-Dichloroethene	75-35-4	880	1000	NA	NA	**7**	NA
cis-1,2-Dichloroethene	156-59-2	NA	2300	NA	NA	**70**	NA
trans-1,2-Dichloroethene	156-60-5	180	300	NA	NA	**100**	NA
Vinyl chloride (VC)	75-01-4	28	17	NA	NA	**2**	NA
NDDEQ Specific						**[mg/L]**	
Ammonia	7664-41-7	NA	NA	NA	NA	5	NA
Bromide	7726-95-6	NA	NA	NA	NA	NA	NA
Chloride	16887-00-6	NA	NA	NA	NA	250	NA
Nitrate as total nitrogen	14797-55-8	NA	1900000	NA	NA	**10**	NA
Strontium	7440-24-6	NA	700000	NA	NA	12	NA
Total Kjeldahl Nitrogen (TKN)		NA	NA	NA	NA	10000	NA
Total Petroleum Hydrocarbons (TPH)		NA	NA	NA	NA	500	NA

Notes: NA: Not available

c: calculated RBSL shown in the table exceeded the saturated soil concentration

p: calculated soil vapor RBTL exceeded the chemical vapor pressure

Domestic water use RBSL in bold font represents maximum contaminant level (MCL)

s: calculated RBSL shown in the table exceeded the chemical solubility

Values obtained from Regional Screening Level (RSL) Summary Tables (USEPA, May 2022)

Table A-1
List of Chemicals of Concern (COCs)

Chemical	CAS #
VOCs	
Benzene	71-43-2
Ethylbenzene	100-41-4
Isopropylbenzene (Cumene)	98-82-8
Methyl tert-Butyl Ether (MTBE)	1634-04-4
Naphthalene	91-20-3
1,2,4-Trimethylbenzene	95-63-6
1,3,5-Trimethylbenzene	108-67-8
Toluene	108-88-3
Xylene, Total	1330-20-7
PAHs	
Acenaphthene	83-32-9
Anthracene	120-12-7
Benzo(a)anthracene	56-55-3
Benzo (a) Pyrene	50-32-8
Benzo(b)fluoranthene	205-99-2
Benzo(k)fluoranthene	207-08-9
Chrysene	218-01-9
Ethylene dibromide	106-93-4
Fluoranthene	206-44-0
Fluorene	86-73-7
Indeno (1,2,3-cd) Pyrene	193-39-5
1-Methylnapthalene	90-12-0
2-Methylnapthalene	91-57-6
Naphthalene	91-20-3
Pyrene	129-00-0
Metals	
Arsenic	7440-38-2
Barium	7440-39-3
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium (III)	16065-83-1
Chromium (VI)	18540-29-9
Chromium (total)	7440-47-3
Lead	7439-92-1
Manganese	7439-96-5
Mercury (elemental)	7439-97-6
Selenium	7782-49-2
Silver	7440-22-4

Table A-1
List of Chemicals of Concern (COCs)

Chemical	CAS #
Chlorinated Solvents	
Hexachloroethane	67-72-1
Pentachloroethane	76-01-7
1,1,1,2-Tetrachloroethane	630-20-6
1,1,2,2-Tetrachloroethane	79-34-5
1,1,2-Trichloroethane	79-00-5
1,1,1-Trichloroethane	71-55-6
1,2-Dichloroethane	107-06-2
1,1-Dichloroethane	75-34-3
Chloroethane	75-00-3
Perchloroethene (PCE)	127-18-4
Trichloroethene (TCE)	79-01-6
1,1-Dichloroethene	75-35-4
cis-1,2-Dichloroethene	156-59-2
trans-1,2-Dichloroethene	156-60-5
Vinyl chloride (VC)	75-01-4
Others	
Bromide	7726-95-6
Chloride	16887-00-6
Nitrate as total nitrogen	14797-55-8
Strontium	7440-24-6
Total Petroleum Hydrocarbon (TPH)[#]	
TPH-GRO	
Aliphatic - > C6-C8	NA
Aliphatic - > C8-C10	NA
Aromatic - >C8-C10	NA
TPH-DRO	
Aliphatic - >C10-C12	NA
Aliphatic - >C12-C16	NA
Aliphatic - >C16-C21	NA
Aromatic - >C10-C12	NA
Aromatic - >C12-C16	NA
Aromatic - >C16-C21	NA
TPH-ORO	
Aliphatic - >C21-C35	NA
Aromatic - >C21-C35	NA

Notes:
NA: Not available

Table A-2
Physical and Chemical Properties

Chemical	CAS #	Is Chemical Volatile?*	Molecular Weight, MW	Water Solubility, S	Henry's Law Constant, HLC	Henry's Law Constant, H'	Organic Carbon Adsorption Coefficient, K_{oc}	Soil-Water Partition Coefficient, K_d	Diffusivity in Air, D_a	Diffusivity in Water, D_w	Vapor Pressure, VP	Relative Contribution of Permeability Coefficient, B	Lag Time, τ_{event}	Duration of Event, t*	Permeability Constant, K_p	Fraction Absorbed Water, FA[#]
			(g/mol)	(mg/L)	(atm-m³/mole)	(unitless)	(L/kg)	(L/kg)	(cm²/s)	(cm²/s)	(mmHg)	(unitless)	(hr/event)	(hr)	(cm/hr)	(unitless)
VOCs																
Benzene	71-43-2	Yes	78	1.79E+03	5.55E-03	2.27E-01	1.46E+02	NA	8.95E-02	1.03E-05	9.48E+01	5.07E-02	2.88E-01	6.91E-01	1.49E-02	1.0
Ethylbenzene	100-41-4	Yes	106	1.69E+02	7.88E-03	3.22E-01	4.46E+02	NA	6.85E-02	8.46E-06	9.60E+00	1.95E-01	4.13E-01	9.92E-01	4.93E-02	1.0
Isopropylbenzene (Cumene)	98-82-8	Yes	120	6.13E+01	1.15E-02	4.70E-01	6.98E+02	NA	6.03E-02	7.86E-06	4.50E+00	3.78E-01	4.95E-01	1.19E+00	8.97E-02	NA
Methyl tert-Butyl Ether (MTBE)	1634-04-4	Yes	88	5.10E+04	5.87E-04	2.40E-02	1.16E+01	NA	7.53E-02	8.59E-06	2.50E+02	7.62E-03	3.28E-01	7.87E-01	2.11E-03	NA
Naphthalene	91-20-3	Yes	128	3.10E+01	4.40E-04	1.80E-02	1.54E+03	NA	6.05E-02	8.38E-06	8.50E-02	2.03E-01	5.49E-01	1.32E+00	4.66E-02	1.0
1,2,4-Trimethylbenzene	95-63-6	Yes	120	5.70E+01	6.16E-03	2.52E-01	6.14E+02	NA	6.07E-02	7.92E-06	2.10E+00	3.61E-01	4.95E-01	1.19E+00	8.57E-02	NA
1,3,5-Trimethylbenzene	108-67-8	Yes	120	4.82E+01	8.77E-03	3.59E-01	6.02E+02	NA	6.02E-02	7.84E-06	2.48E+00	2.62E-01	4.95E-01	1.19E+00	6.21E-02	NA
Toluene	108-88-3	Yes	92	5.26E+02	6.64E-03	2.71E-01	2.34E+02	NA	7.78E-02	9.20E-06	2.84E+01	1.15E-01	3.45E-01	8.28E-01	3.11E-02	1.0
Xylene, Total	1330-20-7	Yes	106	1.06E+02	6.63E-03	2.71E-01	3.83E+02	NA	6.85E-02	8.46E-06	7.99E+00	1.98E-01	4.13E-01	9.92E-01	5.00E-02	NA
PAHs																
Acenaphthene	83-32-9	Yes	154	3.90E+00	1.84E-04	7.52E-03	5.03E+03	NA	5.06E-02	8.33E-06	2.15E-03	4.11E-01	7.68E-01	1.84E+00	8.60E-02	NA
Anthracene	120-12-7	Yes	178	4.34E-02	5.56E-05	2.27E-03	1.64E+04	NA	3.90E-02	7.85E-06	6.53E-06	7.29E-01	1.05E+00	4.05E+00	1.42E-01	NA
Benzo(a)anthracene	56-55-3	Yes	228	9.40E-03	1.20E-05	4.91E-04	1.77E+05	NA	2.61E-02	6.75E-06	2.10E-07	3.21E+00	2.00E+00	8.48E+00	5.52E-01	1.0
Benzo (a) Pyrene	50-32-8	No	252	1.62E-03	4.57E-07	1.87E-05	5.87E+05	NA	2.55E-02	6.58E-06	5.49E-09	4.36E+00	2.72E+00	1.18E+01	7.13E-01	1.0
Benzo(b)fluoranthene	205-99-2	No	252	1.50E-03	6.57E-07	2.69E-05	5.99E+05	NA	2.50E-02	6.43E-06	5.00E-07	2.55E+00	2.72E+00	1.13E+01	4.17E-01	1.0
Benzo(k)fluoranthene	207-08-9	No	252	8.00E-04	5.84E-07	2.39E-05	5.87E+05	NA	2.50E-02	6.43E-06	9.65E-10	4.22E+00	2.72E+00	1.18E+01	6.91E-01	NA
Chrysene	218-01-9	No	228	2.00E-03	5.23E-06	2.14E-04	1.81E+05	NA	2.61E-02	6.75E-06	6.23E-09	3.46E+00	2.00E+00	8.53E+00	5.96E-01	1.0
Ethylene dibromide	106-93-4	Yes	188	3.91E+03	6.50E-04	2.66E-02	3.96E+01	NA	4.30E-02	1.04E-05	1.12E+01	1.47E-02	1.19E+00	2.84E+00	2.78E-03	1.0
Fluoranthene	206-44-0	No	202	2.60E-01	8.86E-06	3.62E-04	5.55E+04	NA	2.76E-02	7.18E-06	9.22E-06	1.68E+00	1.43E+00	5.73E+00	3.08E-01	1.0
Fluorene	86-73-7	Yes	166	1.69E+00	9.62E-05	3.93E-03	9.16E+03	NA	4.40E-02	7.89E-06	6.00E-04	5.45E-01	8.97E-01	2.15E+00	1.10E-01	NA
Indeno (1,2,3-cd) Pyrene	193-39-5	No	276	1.90E-04	3.48E-07	1.42E-05	1.95E+06	NA	2.47E-02	6.37E-06	1.25E-10	7.93E+00	3.71E+00	1.67E+01	1.24E+00	0.6
1-Methylnapthalene	90-12-0	Yes	142	2.58E+01	5.14E-04	2.10E-02	2.53E+03	NA	5.28E-02	7.85E-06	6.70E-02	4.27E-01	6.58E-01	1.58E+00	9.31E-02	NA
2-Methylnapthalene	91-57-6	Yes	142	2.46E+01	5.18E-04	2.12E-02	2.48E+03	NA	5.24E-02	7.78E-06	5.50E-02	4.21E-01	6.58E-01	1.58E+00	9.17E-02	NA
Naphthalene	91-20-3	Yes	128	3.10E+01	4.40E-04	1.80E-02	1.54E+03	NA	6.05E-02	8.38E-06	8.50E-02	2.03E-01	5.49E-01	1.32E+00	4.66E-02	1.0
Pyrene	129-00-0	Yes	202	1.35E-01	1.19E-05	4.87E-04	5.43E+04	NA	2.78E-02	7.25E-06	4.50E-06	1.10E+00	1.43E+00	5.54E+00	2.01E-01	NA
Metals																
Arsenic	7440-38-2	No	75	NA	NA	NA	NA	2.90E+01	NA	NA	NA	3.33E-03	2.76E-01	6.63E-01	1.00E-03	NA
Barium	7440-39-3	No	137	NA	NA	NA	NA	4.10E+01	NA	NA	NA	4.51E-03	6.18E-01	1.48E+00	1.00E-03	NA
Beryllium	7440-41-7	No	9	NA	NA	NA	NA	7.90E+02	NA	NA	NA	1.15E-03	1.18E-01	2.83E-01	1.00E-03	NA
Cadmium (diet)	7440-43-9	No	112	NA	NA	NA	NA	7.50E+01	NA	NA	NA	4.08E-03	4.48E-01	1.08E+00	1.00E-03	NA
Cadmium (water	7440-43-9	No	112	NA	NA	NA	NA	7.50E+01	NA	NA	NA	4.08E-03	4.48E-01	1.08E+00	1.00E-03	NA
Chromium (III)	16065-83-1	No	52	NA	NA	NA	NA	1.80E+06	NA	NA	NA	2.77E-03	2.06E-01	4.93E-01	1.00E-03	NA
Chromium (VI)	18540-29-9	No	52	1.69E+06	NA	NA	NA	1.90E+01	NA	NA	NA	5.55E-03	2.06E-01	4.93E-01	2.00E-03	NA
Chromium (total)	7440-47-3	No	52	NA	NA	NA	NA	1.80E+06	NA	NA	NA	2.77E-03	2.06E-01	4.93E-01	1.00E-03	NA
Lead	7439-92-1	No	207	NA	NA	NA	NA	9.00E+02	NA	NA	NA	5.54E-04	1.52E+00	3.65E+00	1.00E-04	NA
Manganese (non-diet)	7439-96-5	No	55	NA	NA	NA	NA	6.50E+01	NA	NA	NA	2.85E-03	2.14E-01	5.13E-01	1.00E-03	NA
Mercury (elemental)	7439-97-6	Yes	201	6.00E-02	8.62E-03	3.52E-01	NA	5.20E+01	3.07E-02	6.30E-06	1.96E-03	5.45E-03	1.40E+00	3.35E+00	1.00E-03	NA
Selenium	7782-49-2	No	79	NA	NA	NA	NA	5.00E+00	NA	NA	1.42E-10	3.42E-03	2.91E-01	6.99E-01	1.00E-03	NA
Silver	7440-22-4	No	108	NA	NA	NA	NA	8.30E+00	NA	NA	NA	2.40E-03	4.23E-01	1.01E+00	6.00E-04	NA
Chlorinated Solvents																
Hexachloroethane	67-72-1	Yes	237	5.00E+01	3.89E-03	1.59E-01	1.97E+02	NA	3.21E-02	8.89E-06	2.10E-01	2.46E-01	2.23E+00	5.34E+00	4.15E-02	1.0
Pentachloroethane	76-01-7	Yes	202	4.90E+02	1.94E-03	7.93E-02	1.36E+02	NA	3.15E-02	8.57E-06	3.50E+00	8.64E-02	1.43E+00	3.43E+00	1.58E-02	NA
1,1,1,2-Tetrachloroethane	630-20-6	Yes	168	1.07E+03	2.50E-03	1.02E-01	8.60E+01	NA	4.82E-02	9.10E-06	1.20E+01	7.92E-02	9.16E-01	2.20E+00	1.59E-02	NA
1,1,2,2-Tetrachloroethane	79-34-5	Yes	168	2.83E+03	3.67E-04	1.50E-02	9.49E+01	NA	4.89E-02	9.29E-06	4.62E+00	3.46E-02	9.16E-01	2.20E+00	6.94E-03	1.0
1,1,2-Trichloroethane	79-00-5	Yes	133	4.59E+03	8.24E-04	3.37E-02	6.07E+01	NA	6.69E-02	1.00E-05	2.30E+01	2.24E-02	5.87E-01	1.41E+00	5.04E-03	1.0
1,1,1-Trichloroethane	71-55-6	Yes	133	1.29E+03	1.72E-02	7.03E-01	4.39E+01	NA	6.48E-02	9.60E-06	1.24E+02	5.60E-02	5.87E-01	1.41E+00	1.26E-02	1.0
1,2-Dichloroethane	107-06-2	Yes	99	8.60E+03	1.18E-03	4.82E-02	3.96E+01	NA	8.57E-02	1.10E-05	7.89E+01	1.61E-02	3.77E-01	9.04E-01	4.20E-03	1.0
1,1-Dichloroethane	75-34-3	Yes	99	5.04E+03	5.62E-03	2.30E-01	3.18E+01	NA	8.36E-02	1.06E-05	2.27E+02	2.58E-02	3.77E-01	9.04E-01	6.75E-03	1.0
Chloroethane	75-00-3	Yes	65	6.71E+03	1.11E-02	4.54E-01	2.17E+01	NA	1.04E-01	1.16E-05	1.01E+03	1.88E-02	2.42E-01	5.80E-01	6.07E-03	1.0
Perchloroethene (PCE)	127-18-4	Yes	166	2.06E+02	1.77E-02	7.24E-01	9.49E+01	NA	5.05E-02	9.46E-06	1.85E+01	1.65E-01	8.92E-01	2.14E+00	3.34E-02	1.0
Trichloroethene (TCE)	79-01-6	Yes	131	1.28E+03	9.85E-03	4.03E-01	6.07E+01	NA	6.87E-02	1.02E-05	6.90E+01	5.11E-02	5.72E-01	1.37E+00	1.16E-02	1.0
1,1-Dichloroethene	75-35-4	Yes	97	2.42E+03	2.61E-02	1.07E+00	3.18E+01	NA	8.63E-02	1.10E-05	6.00E+02	4.43E-02	3.67E-01	8.81E-01	1.17E-02	1.0
cis-1,2-Dichloroethene	156-59-2	Yes	97	6.41E+03	4.08E-03	1.67E-01	3.96E+01	NA	8.84E-02	1.13E-05	2.00E+02	4.17E-02	3.67E-01	8.81E-01	1.10E-02	NA
trans-1,2-Dichloroethene	156-60-5	Yes	97	4.52E+03	9.38E-03	3.83E-01	3.96E+01	NA	8.76E-02	1.12E-05	3.31E+02	4.17E-02	3.67E-01	8.81E-01	1.10E-02	NA
Vinyl chloride (VC)	75-01-4	Yes	62	8.80E+03	2.78E-02	1.14E+00	2.17E+01	NA	1.07E-01	1.20E-05	2.98E+03	2.55E-02	2.35E-01	5.65E-01	8.38E-03	1.0
Others																
Bromide	7726-95-6	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloride	16887-00-6	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate as total nitrogen	14797-55-8	No	62	NA	NA	NA	NA	NA	NA	NA	NA	3.03E-03	2.34E-01	5.61E-01	1.00E-03	NA
Strontium	7440-24-6	No	88	NA	NA	NA	NA	3.50E+01	NA	NA	NA	3.60E-03	3.25E-01	7.81E-01	1.00E-03	NA

Table A-2
Physical and Chemical Properties

Chemical	CAS #	Is Chemical Volatile?*	Molecular Weight, MW	Water Solubility, S	Henry's Law Constant, HLC	Henry's Law Constant, H'	Organic Carbon Adsorption Coefficient, K_{oc}	Soil-Water Partition Coefficient, K_d	Diffusivity in Air, D_a	Diffusivity in Water, D_w	Vapor Pressure, VP	Relative Contribution of Permeability Coefficient, B	Lag Time, τ_{event}	Duration of Event, t*	Permeability Constant, K_p	Fraction Absorbed Water, FA#
			(g/mol)	(mg/L)	(atm-m^3/mole)	(unitless)	(L/kg)	(L/kg)	(cm^2/s)	(cm^2/s)	(mmHg)	(unitless)	(hr/event)	(hr)	(cm/hr)	(unitless)
Total Petroleum Hydrocarbon (TPH)#																
TPH-GRO																
Aliphatic - > C6-C8	NA	Yes	100	5.40E+00	1.22E+00	5.00E+01	3.98E+03	NA	1.00E-01	1.00E-05	4.79E+01	NA	NA	NA	NA	NA
Aliphatic - > C8-C10	NA	Yes	130	4.30E-01	1.96E+00	8.00E+01	3.16E+04	NA	1.00E-01	1.00E-05	4.79E+00	NA	NA	NA	NA	NA
Aromatic - >C8-C10	NA	Yes	120	6.50E+01	1.17E-02	4.80E-01	1.58E+03	NA	1.00E-01	1.00E-05	4.79E+00	NA	NA	NA	NA	NA
TPH-DRO																
Aliphatic - >C10-C12	NA	Yes	160	3.40E-02	2.94E+00	1.20E+02	2.51E+05	NA	1.00E-01	1.00E-05	4.79E-01	NA	NA	NA	NA	NA
Aliphatic - >C12-C16	NA	Yes	200	7.60E-04	1.27E+01	5.20E+02	5.01E+06	NA	1.00E-01	1.00E-05	3.65E-02	NA	NA	NA	NA	NA
Aliphatic - >C16-C21	NA	Yes	270	2.50E-06	1.20E+02	4.90E+03	6.31E+08	NA	1.00E-01	1.00E-05	8.40E-04	NA	NA	NA	NA	NA
Aromatic - >C10-C12	NA	Yes	130	2.50E+01	3.42E-03	1.40E-01	2.51E+03	NA	1.00E-01	1.00E-05	4.79E-01	NA	NA	NA	NA	NA
Aromatic - >C12-C16	NA	Yes	150	5.80E+00	1.30E-03	5.30E-02	5.01E+03	NA	1.00E-01	1.00E-05	3.65E-02	NA	NA	NA	NA	NA
Aromatic - >C16-C21	NA	Yes	190	6.50E-01	3.18E-04	1.30E-02	1.58E+04	NA	1.00E-01	1.00E-05	8.36E-04	NA	NA	NA	NA	NA
TPH-ORO																
Aliphatic - >C21-C35	NA	Yes	270	2.50E-06	1.20E+02	4.90E+03	6.31E+08	NA	1.00E-01	1.00E-05	8.40E-04	NA	NA	NA	NA	NA
Aromatic - >C21-C35	NA	Yes	240	6.60E-03	1.64E-05	6.70E-04	1.26E+05	NA	1.00E-01	1.00E-05	3.34E-07	NA	NA	NA	NA	NA

Notes:

NA: Not available

*: Chemicals that have a Henry's law constant greater than 0.00001 atm-m^3/mole at 25°C or a vapor pressure greater than 1 mm Hg are considered volatile

Source: Regional Screening Level Generic Table, USEPA, May 2022

#: Source: Exhibit B-3 in RAGS Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (USPEA, 2004)

Table A-3
Toxicity Values

Chemical	CAS #	Slope Factor			Reference Dose			Absorption Factor		Relative Bioavailability Factor (RBA)
		Oral, SF_o	Inhalation, IUR	Dermal, SF_d $	Oral, RfD_o	Inhalation, RfCi	Dermal, RfD_d $	GIABS	ABS_d	
		$(mg/kg\text{-}day)^{-1}$	$(ug/m^3)^{-1}$	$(mg/kg\text{-}day)^{-1}$	(mg/kg-day)	(mg/m^3)	(mg/kg-day)	(unitless)	(unitless)	(unitless)
VOCs										
Benzene	71-43-2	5.5E-02	7.8E-06	5.5E-02	4.0E-03	3.0E-02	4.0E-03	1	NA	1
Ethylbenzene	100-41-4	1.1E-02	2.5E-06	1.1E-02	5.0E-02	1.0E+00	5.0E-02	1	NA	1
Isopropylbenzene (Cumene)	98-82-8	NA	NA	N/A	1.0E-01	4.0E-01	1.0E-01	1	NA	1
Methyl tert-Butyl Ether (MTBE)	1634-04-4	1.8E-03	2.6E-07	1.8E-03	NA	3.0E+00	N/A	1	NA	1
Naphthalene	91-20-3	1.2E-01	3.4E-05	1.2E-01	2.0E-02	3.0E-03	2.0E-02	1	0.13	1
1,2,4-Trimethylbenzene	95-63-6	NA	NA	N/A	1.0E-02	6.0E-02	1.0E-02	1	NA	1
1,3,5-Trimethylbenzene	108-67-8	NA	NA	N/A	1.0E-02	6.0E-02	1.0E-02	1	NA	1
Toluene	108-88-3	NA	NA	N/A	8.0E-02	5.0E+00	8.0E-02	1	NA	1
Xylene, Total	1330-20-7	NA	NA	N/A	2.0E-01	1.0E-01	2.0E-01	1	NA	1
PAHs										
Acenaphthene	83-32-9	NA	NA	N/A	6.0E-02	NA	6.0E-02	1	0.13	1
Anthracene	120-12-7	NA	NA	N/A	3.0E-01	NA	3.0E-01	1	0.13	1
Benzo(a)anthracene	56-55-3	1.0E-01	6.0E-05	1.0E-01	NA	NA	N/A	1	0.13	1
Benzo (a) Pyrene	50-32-8	1.0E+00	6.0E-04	1.0E+00	3.0E-04	2.0E-06	3.0E-04	1	0.13	1
Benzo(b)fluoranthene	205-99-2	1.0E-01	6.0E-05	1.0E-01	NA	NA	N/A	1	0.13	1
Benzo(k)fluoranthene	207-08-9	1.0E-02	6.0E-06	1.0E-02	NA	NA	N/A	1	0.13	1
Chrysene	218-01-9	1.0E-03	6.0E-07	1.0E-03	NA	NA	N/A	1	0.13	1
Ethylene dibromide	106-93-4	2.0E+00	6.0E-04	2.0E+00	9.0E-03	9.0E-03	9.0E-03	1	NA	1
Fluoranthene	206-44-0	NA	NA	N/A	4.0E-02	NA	4.0E-02	1	0.13	1
Fluorene	86-73-7	NA	NA	N/A	4.0E-02	NA	4.0E-02	1	0.13	1
Indeno (1,2,3-cd) Pyrene	193-39-5	1.0E-01	6.0E-05	1.0E-01	NA	NA	N/A	1	0.13	1
1-Methylnapthalene	90-12-0	2.9E-02	NA	2.9E-02	7.0E-02	NA	7.0E-02	1	0.13	1
2-Methylnapthalene	91-57-6	NA	NA	N/A	4.0E-03	NA	4.0E-03	1	0.13	1
Naphthalene	91-20-3	1.2E-01	3.4E-05	1.2E-01	2.0E-02	3.0E-03	2.0E-02	1	0.13	1
Pyrene	129-00-0	NA	NA	N/A	3.0E-02	NA	3.0E-02	1	0.13	1
Metals										
Arsenic	7440-38-2	1.5E+00	4.3E-03	1.5E+00	3.0E-04	1.5E-05	3.0E-04	1	0.03	0.6
Barium	7440-39-3	NA	NA	N/A	2.0E-01	5.0E-04	1.4E-02	0.07	NA	1
Beryllium	7440-41-7	NA	2.4E-03	N/A	2.0E-03	2.0E-05	1.4E-05	0.007	NA	1
Cadmium (diet)	7440-43-9	NA	1.8E-03	N/A	1.0E-04	1.0E-05	2.5E-06	0.025	0.001	1
Cadmium (water	7440-43-9	NA	1.8E-03	N/A	1.0E-04	1.0E-05	5.0E-06	0.05	0.001	1
Chromium (III)	16065-83-1	NA	NA	N/A	1.5E+00	NA	2.0E-02	0.013	NA	1
Chromium (VI)	18540-29-9	5.0E-01	8.4E-02	2.0E+01	3.0E-03	1.0E-04	7.5E-05	0.025	NA	1
Chromium (total)	7440-47-3	NA	NA	N/A	NA	NA	N/A	0.013	NA	1
Lead	7439-92-1	NA	NA	N/A	NA	NA	N/A	1	NA	NA
Manganese (non-diet)	7439-96-5	NA	NA	N/A	2.4E-02	5.0E-05	9.6E-04	0.04	NA	1
Mercury (elemental)	7439-97-6	NA	NA	N/A	NA	3.0E-04	N/A	1	NA	1
Selenium	7782-49-2	NA	NA	N/A	5.0E-03	2.0E-02	5.0E-03	1	NA	1
Silver	7440-22-4	NA	NA	N/A	5.0E-03	NA	2.0E-04	0.04	NA	1

Table A-3
Toxicity Values

Chemical	CAS #	Slope Factor			Reference Dose			Absorption Factor		Relative Bioavailability Factor (RBA)
		Oral, SF_o	Inhalation, IUR	Dermal, SF_d [$]	Oral, RfD_o	Inhalation, RfCi	Dermal, RfD_d [$]	GIABS	ABS_d	
		$(mg/kg\text{-}day)^{-1}$	$(ug/m^3)^{-1}$	$(mg/kg\text{-}day)^{-1}$	(mg/kg-day)	(mg/m^3)	(mg/kg-day)	(unitless)	(unitless)	(unitless)
Chlorinated Solvents										
Hexachloroethane	67-72-1	4.0E-02	1.1E-05	4.0E-02	7.0E-04	3.0E-02	7.0E-04	1	NA	1
Pentachloroethane	76-01-7	9.0E-02	NA	9.0E-02	NA	NA	N/A	1	NA	1
1,1,1,2-Tetrachloroethane	630-20-6	2.6E-02	7.4E-06	2.6E-02	3.0E-02	NA	3.0E-02	1	NA	1
1,1,2,2-Tetrachloroethane	79-34-5	2.0E-01	5.8E-05	2.0E-01	2.0E-02	NA	2.0E-02	1	NA	1
1,1,2-Trichloroethane	79-00-5	5.7E-02	1.6E-05	5.7E-02	4.0E-03	2.0E-04	4.0E-03	1	NA	1
1,1,1-Trichloroethane	71-55-6	NA	NA	N/A	2.0E+00	5.0E+00	2.0E+00	1	NA	1
1,2-Dichloroethane	107-06-2	9.1E-02	2.6E-05	9.1E-02	6.0E-03	7.0E-03	6.0E-03	1	NA	1
1,1-Dichloroethane	75-34-3	5.7E-03	1.6E-06	5.7E-03	2.0E-01	NA	2.0E-01	1	NA	1
Chloroethane	75-00-3	NA	NA	N/A	NA	4.0E+00	N/A	1	NA	1
Perchloroethene (PCE)	127-18-4	2.1E-03	2.6E-07	2.1E-03	6.0E-03	4.0E-02	6.0E-03	1	NA	1
Trichloroethene (TCE)	79-01-6	4.6E-02	4.1E-06	4.6E-02	5.0E-04	2.0E-03	5.0E-04	1	NA	1
1,1-Dichloroethene	75-35-4	NA	NA	N/A	5.0E-02	2.0E-01	5.0E-02	1	NA	1
cis-1,2-Dichloroethene	156-59-2	NA	NA	N/A	2.0E-03	NA	2.0E-03	1	NA	1
trans-1,2-Dichloroethene	156-60-5	NA	NA	N/A	2.0E-02	4.0E-02	2.0E-02	1	NA	1
Vinyl chloride (VC)	75-01-4	7.2E-01	4.4E-06	7.2E-01	3.0E-03	8.0E-02	3.0E-03	1	NA	1
Others										
Bromide	7726-95-6	NA	NA	NA	NA	NA	N/A	NA	NA	1
Chloride	16887-00-6	NA	NA	NA	NA	NA	N/A	NA	NA	1
Nitrate as total nitrogen	14797-55-8	NA	NA	NA	1.6E+00	NA	1.6E+00	1	0.001	1
Strontium	7440-24-6	NA	NA	NA	6.0E-01	NA	6.0E-01	1	0.001	1
Total Petroleum Hydrocarbon (TPH) [#]										
TPH-GRO										
Aliphatic - > C6-C8	NA	NA	NA	N/A	5.0E+00	1.9E+01	5.0E+00	1	NA	1
Aliphatic - > C8-C10	NA	NA	NA	N/A	1.0E-01	1.0E+00	1.0E-01	1	NA	1
Aromatic - >C8-C10	NA	NA	NA	N/A	4.0E-02	2.0E-01	4.0E-02	1	NA	1
TPH-DRO										
Aliphatic - >C10-C12	NA	NA	NA	N/A	1.0E-01	1.0E+00	1.0E-01	1	0.1	1
Aliphatic - >C12-C16	NA	NA	NA	N/A	1.0E-01	1.0E+00	1.0E-01	1	0.1	1
Aliphatic - >C16-C21	NA	NA	NA	N/A	2.0E+00	NA	2.0E+00	1	0.1	1
Aromatic - >C10-C12	NA	NA	NA	N/A	4.0E-02	2.0E-01	4.0E-02	1	0.1	1
Aromatic - >C12-C16	NA	NA	NA	N/A	4.0E-02	2.0E-01	4.0E-02	1	0.1	1
Aromatic - >C16-C21	NA	NA	NA	N/A	3.0E-02	NA	3.0E-02	1	0.1	1
TPH-ORO										
Aliphatic - >C21-C35	NA	NA	NA	N/A	2.0E+00	NA	2.0E+00	1	0.1	1
Aromatic - >C21-C35	NA	NA	NA	N/A	3.0E-02	NA	3.0E-02	1	0.1	1

Notes:
NA: Not available; N/A: Not applicable; GIABS: Gastrointestinal absorption; Abs: Dermal absorption
SF: Slope factor; RfD: Reference dose; IUR: Inhalation unit risk; RfC: Reference concentration
Source: Regional Screening Level Generic Table, USEPA, May 2022
#: Source: Missouri Risk Based Corrective Action Guidance, MDNR, June 2006.

$:Dermal Toxicity Calculation

$$SF_d = \frac{SF_o}{GIABS} \qquad RfD_d = RfD_o \times GIABS$$

Table A-4
Exposure Factors

Parameter	Symbol	Unit	Default
Averaging Time for Carcinogen	AT_c	year	70
Averaging Time for Non-Carcinogen	AT_{nc}	year	=ED
Body Weight:			
Resident Child	BW	kg	15
Resident Adult	BW	kg	80
Resident Age Segment 0-2	BW	kg	15
Resident Age Segment 2-6	BW	kg	15
Resident Age Segment 6-16	BW	kg	80
Resident Age Segment 16-26	BW	kg	80
Commercial/Industrial Worker	BW	kg	80
Exposure Duration:			
Resident Child	ED	year	6
Resident Adult (non-carcinogenic)	ED	year	26
Resident Adult (carcinogenic)	ED	year	20
Resident Age Segment 0-2	ED	year	2
Resident Age Segment 2-6	ED	year	4
Resident Age Segment 6-16	ED	year	10
Resident Age Segment 16-26	ED	year	10
Commercial/Industrial Worker	ED	year	25
Exposure Frequency:			
Resident Child	EF	day/year	350
Resident Adult	EF	day/year	350
Resident Age Segment 0-2	EF	day/year	350
Resident Age Segment 2-6	EF	day/year	350
Resident Age Segment 6-16	EF	day/year	350
Resident Age Segment 16-26	EF	day/year	350
Commercial/Industrial Worker	EF	day/year	250
Soil Ingestion Rate:			
Resident Child	IR_{soil}	mg/day	200
Resident Adult	IR_{soil}	mg/day	100
Resident Age Segment 0-2	IR_{soil}	mg/day	200
Resident Age Segment 2-6	IR_{soil}	mg/day	200
Resident Age Segment 6-16	IR_{soil}	mg/day	100
Resident Age Segment 16-26	IR_{soil}	mg/day	100
Commercial/Industrial Worker	IR_{soil}	mg/day	100
Groundwater Ingestion Rate:			
Resident Child	IR_w	L/day	0.78
Resident Adult	IR_w	L/day	2.5
Resident Age Segment 0-2	IR_w	L/day	0.78
Resident Age Segment 2-6	IR_w	L/day	0.78
Resident Age Segment 6-16	IR_w	L/day	2.5
Resident Age Segment 16-26	IR_w	L/day	2.5
Fish Ingestion Rate:			
Resident Adult	IR_f	mg/day	site-specific
Exposure Time for Indoor Inhalation:			
Resident Child	ET_{in}	hr/day	24
Resident Adult	ET_{in}	hr/day	24
Resident Age Segment 0-2	ET_{in}	hr/day	24
Resident Age Segment 2-6	ET_{in}	hr/day	24
Resident Age Segment 6-16	ET_{in}	hr/day	24
Resident Age Segment 16-26	ET_{in}	hr/day	24
Commercial/Industrial Worker	ET_{in}	hr/day	8

Table A-4
Exposure Factors

Parameter	Symbol	Unit	Default
Exposure Time for Outdoor Inhalation:			
Resident Child	ET_{out}	hr/day	24
Resident Adult	ET_{out}	hr/day	24
Resident Age Segment 0-2	ET_{out}	hr/day	24
Resident Age Segment 2-6	ET_{out}	hr/day	24
Resident Age Segment 6-16	ET_{out}	hr/day	24
Resident Age Segment 16-26	ET_{out}	hr/day	24
Commercial/Industrial Worker	ET_{out}	hr/day	8
Exposure Time for Dermal Contact with Water:			
Resident Child	ET_w	hours/event	0.54
Resident Adult	ET_w	hours/event	0.71
Resident Age Segment 0-2	ET_w	hours/event	0.54
Resident Age Segment 2-6	ET_w	hours/event	0.54
Resident Age Segment 6-16	ET_w	hours/event	0.71
Resident Age Segment 16-26	ET_w	hours/event	0.71
Skin Surface Area for Dermal Contact with Soil:			
Resident Child	SA_{soil}	cm^2/day	2,373
Resident Adult	SA_{soil}	cm^2/day	6,032
Resident Age Segment 0-2	SA_{soil}	cm^2/day	2,373
Resident Age Segment 2-6	SA_{soil}	cm^2/day	2,373
Resident Age Segment 6-16	SA_{soil}	cm^2/day	6,032
Resident Age Segment 16-26	SA_{soil}	cm^2/day	6,032
Commercial/Industrial Worker	SA_{soil}	cm^2/day	3,527
Skin Surface Area for Dermal During Domestic Water Use:			
Resident Child	SA_{gw}	cm^2	6,365
Resident Adult	SA_{gw}	cm^2	19,652
Resident Age Segment 0-2	SA_{gw}	cm^2	6,365
Resident Age Segment 2-6	SA_{gw}	cm^2	6,365
Resident Age Segment 6-16	SA_{gw}	cm^2	19,652
Resident Age Segment 16-26	SA_{gw}	cm^2	19,652
Soil to Skin Adherence Factor:			
Resident Child	AF	mg/cm^2	0.2
Resident Adult	AF	mg/cm^2	0.07
Resident Age Segment 0-2	AF	mg/cm^2	0.2
Resident Age Segment 2-6	AF	mg/cm^2	0.2
Resident Age Segment 6-16	AF	mg/cm^2	0.07
Resident Age Segment 16-26	AF	mg/cm^2	0.07
Commercial/Industrial Worker	AF	mg/cm^2	0.12
Event Frequency for Dermal Contact During Domestic Water Use:			
Resident Child	EV_{gw}	event/day	1
Resident Adult	EV_{gw}	event/day	1
Resident Age Segment 0-2	EV_{gw}	event/day	1
Resident Age Segment 2-6	EV_{gw}	event/day	1
Resident Age Segment 6-16	EV_{gw}	event/day	1
Resident Age Segment 16-26	EV_{gw}	event/day	1

Notes:

The above values were obtained from Regional Screening Level (RSL) User Guide (USEPA, May 2022)

Table A-5
Fate and Transport Parameters

Parameter	Symbol	Unit	Default Value
SOIL PARAMETERS:			
Depth Below Grade to Surficial Soil Source	d_s	cm	100
Depth to Below Grade to Subsurface Soil Source	d_{ts}	cm	100
Depth to Below Grade to Soil Vapor Measurement	d_{sv}	cm	100
VADOSE ZONE:			
Total Soil Porosity	θ_T	cm^3/cm^3-soil	0.43
Volumetric Water Content	θ_{ws}	cm^3/cm^3	0.15
Volumetric Air Content *	θ_{as}	cm^3/cm^3	0.28
Thickness	h_v	cm	295
Dry Soil Bulk Density	ρ_s	g/cm^3	1.5
Fractional Organic Carbon Content	f_{ocv}	g-C/g-soil	0.002
SOIL IN CRACKS:			
Total Soil Porosity	θ_{Tcrack}	cm^3/cm^3-soil	0.43
Volumetric Water Content	θ_{wcrack}	cm^3/cm^3	0.15
Volumetric Air Content *	θ_{acrack}	cm^3/cm^3	0.28
CAPILLARY FRINGE:			
Total Soil Porosity	θ_{Tcap}	cm^3/cm^3-soil	0.43
Volumetric Water Content	θ_{wcap}	cm^3/cm^3	0.39
Volumetric Air Content*	θ_{acap}	cm^3/cm^3	0.04
Thickness	h_c	cm	5
GROUNDWATER PARAMETERS:			
Depth to Groundwater	L_{gw}	cm	300
Length of Groundwater Source Area Parallel to Groundwater Flow Direction	W_{ga}	cm	3,000
Width of Groundwater Source Area Perpendicular to Groundwater Flow Direction	Y	cm	3,000
Total Porosity in the Saturated Zone	θ_{TS}	cm^3/cm^3	0.43
Dry Soil Bulk Density in the Saturated Zone	ρ_{ss}	g/cm^3	1.5
Fractional Organic Carbon Content in the Saturated Zone	f_{ocs}	g-C/g-soil	0.002
Groundwater Mixing Zone Thickness	δ_{gw}	cm	200
Hydraulic Conductivity in the Saturated Zone	K	cm/year	730,000
Hydraulic Gradient in the Saturated Zone	i	cm/cm	0.001
Groundwater Darcy Velocity	U_{gw}	cm/year	730
Infiltration Rate of Water Through Vadose Zone	I	cm/year	21
DOMESTIC WATER USE PARAMETERS:			
Andelman volatilization factor	K	L/m^3	0.5
AMBIENT AIR PARAMETERS:			
Inverse of Mean Concentration at Center of a 0.5 Acre-Square Source	Q/C	$(g/m^2\text{-}s)/(kg/m^3)$	83.39
Fraction of Vegetative Cover	V	m^2/m^2	0.5 (50%)
Mean Annual Wind Speed	U_m	m/s	4.69
Equivalent Threshold Value of Windspeed	U_t	m/s	11.32
Windspeed Distribution Function from Cowherd et. al, 1985	F(x)	unitless	0.194
Dispersion correction factor	F_D	unitless	0.185
Exposure Interval	T	seconds	=ED

*: Calculated value. *Volumetric Air Content = Total Soil Porosity - Volumetric Water Content*

Table A-6
Building Parameters

Parameter	Symbol	Units	Default Value
Volumetric Flow Rate of Soil Gas into the Enclosed Space:			
Residential	Q_{soil}	cm^3/s	136.1
Non-residential	Q_{soil}	cm^3/s	5,626
Building Foundation/Slab Thickness:			
Residential	L_{crack}	cm	10
Non-residential	L_{crack}	cm	20
Air Exchange Rate:			
Residential	ER	l/24 hr	10.8
Non-residential	ER	l/24 hr	36.0
Building Height:			
Residential	H_B	cm	244
Non-residential	H_B	cm	300
Building Area:			
Residential	A_B	cm^2	1,500,000
Non-residential	A_B	cm^2	15,000,000
Depth below Grade to Bottom of Enclosed Space Floor:			
Residential	L_F	cm	10
Non-residential	L_F	cm	20
Floor-Wall Seam Gap:			
Residential	w	cm	0.1
Non-residential	w	cm	0.1

Notes:

If a default value of Q_{soil} is used, the two parameters (ΔP and k_v) used to estimate Q_{soil} are not required. The software provides two options, i.e., either enter Q_{soil} or the values of the two parameters.

The above values were obtained from Johnson and Ettinger Model Spreadsheet Tool, Version 6.0 (USEPA, 2017)

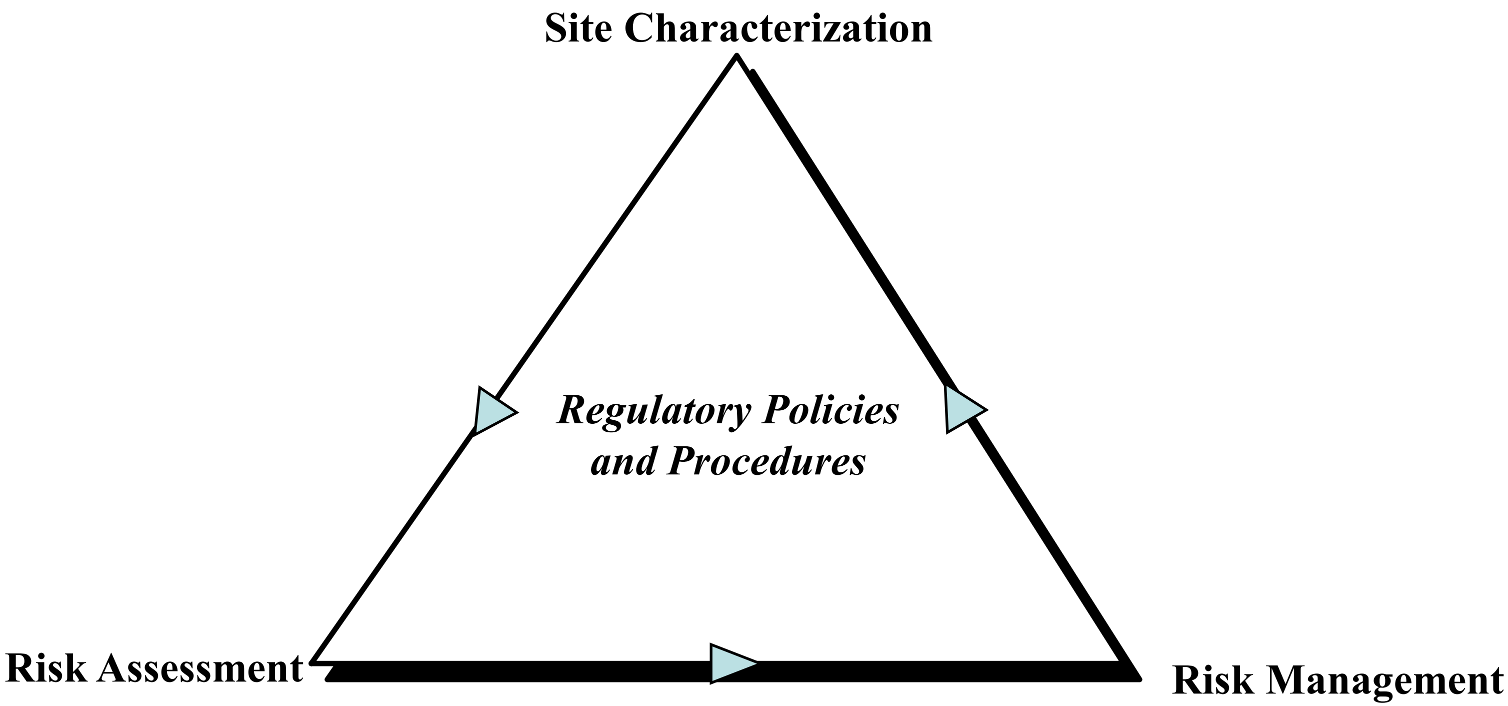

Figure 2-1. Primary Activities Conducted under the NDRBCA Process

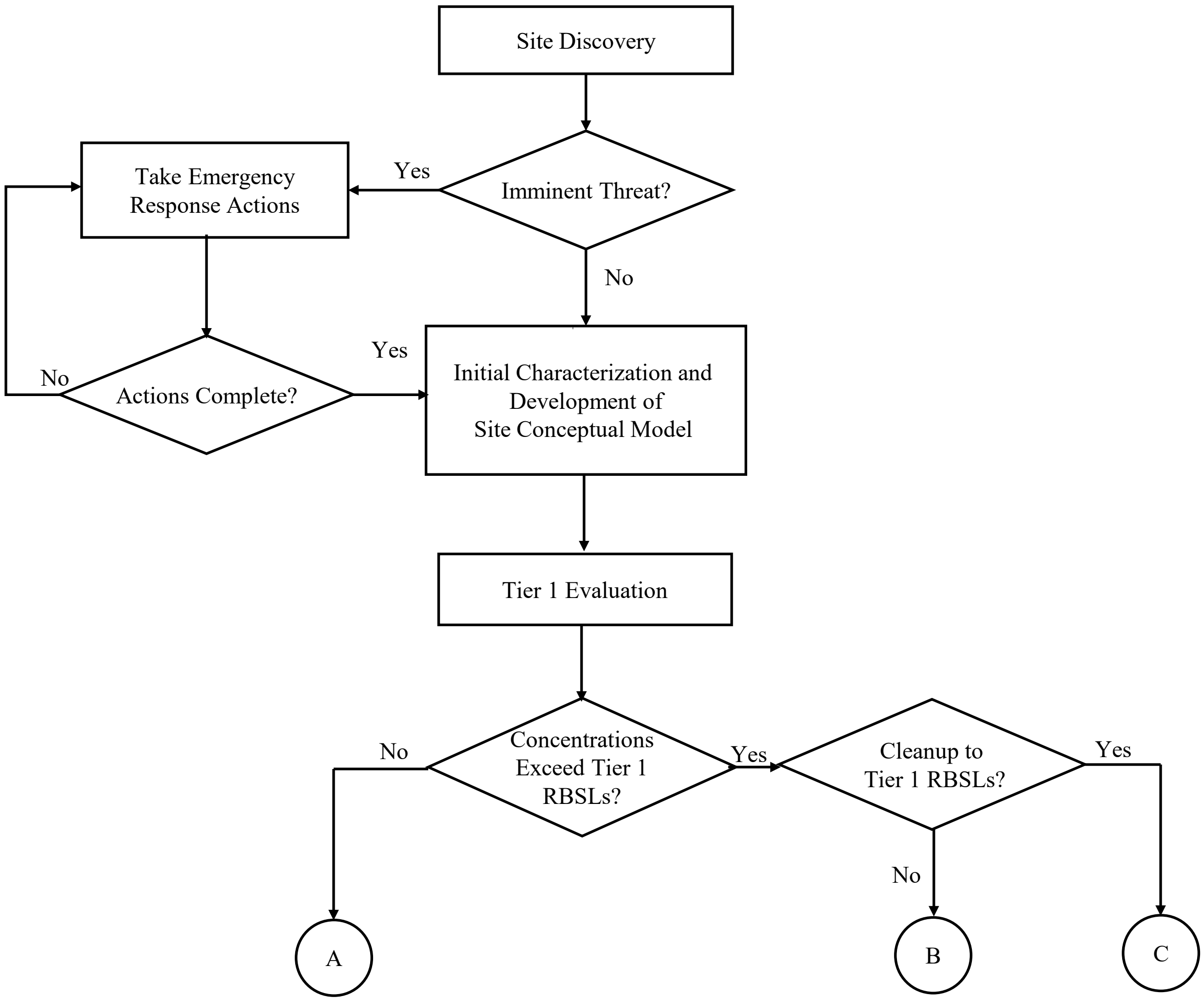

Figure 2-2: NDRBCA Process Flowchart (*page 1 of 2*)

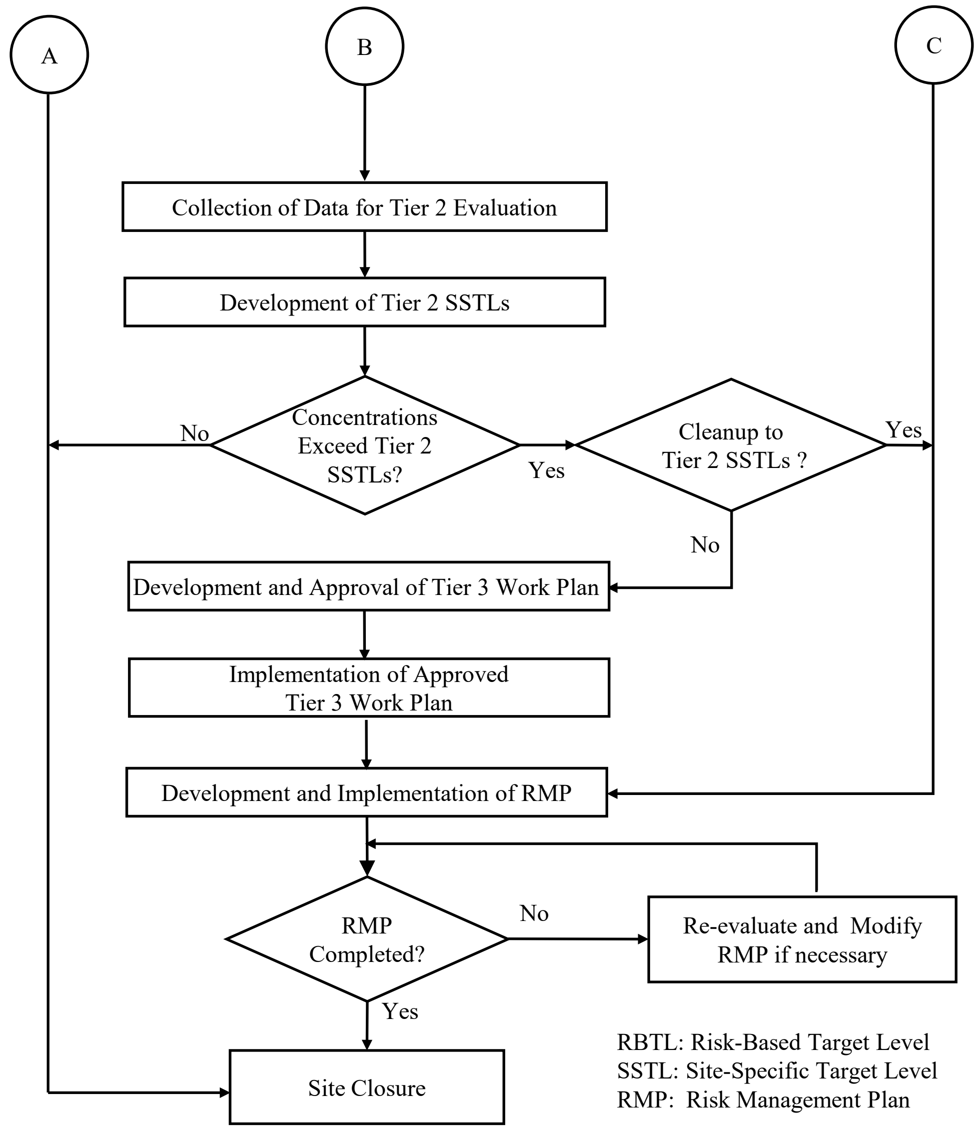

Figure 2-2: NDRBCA Process Flowchart (*page 2 of 2*)

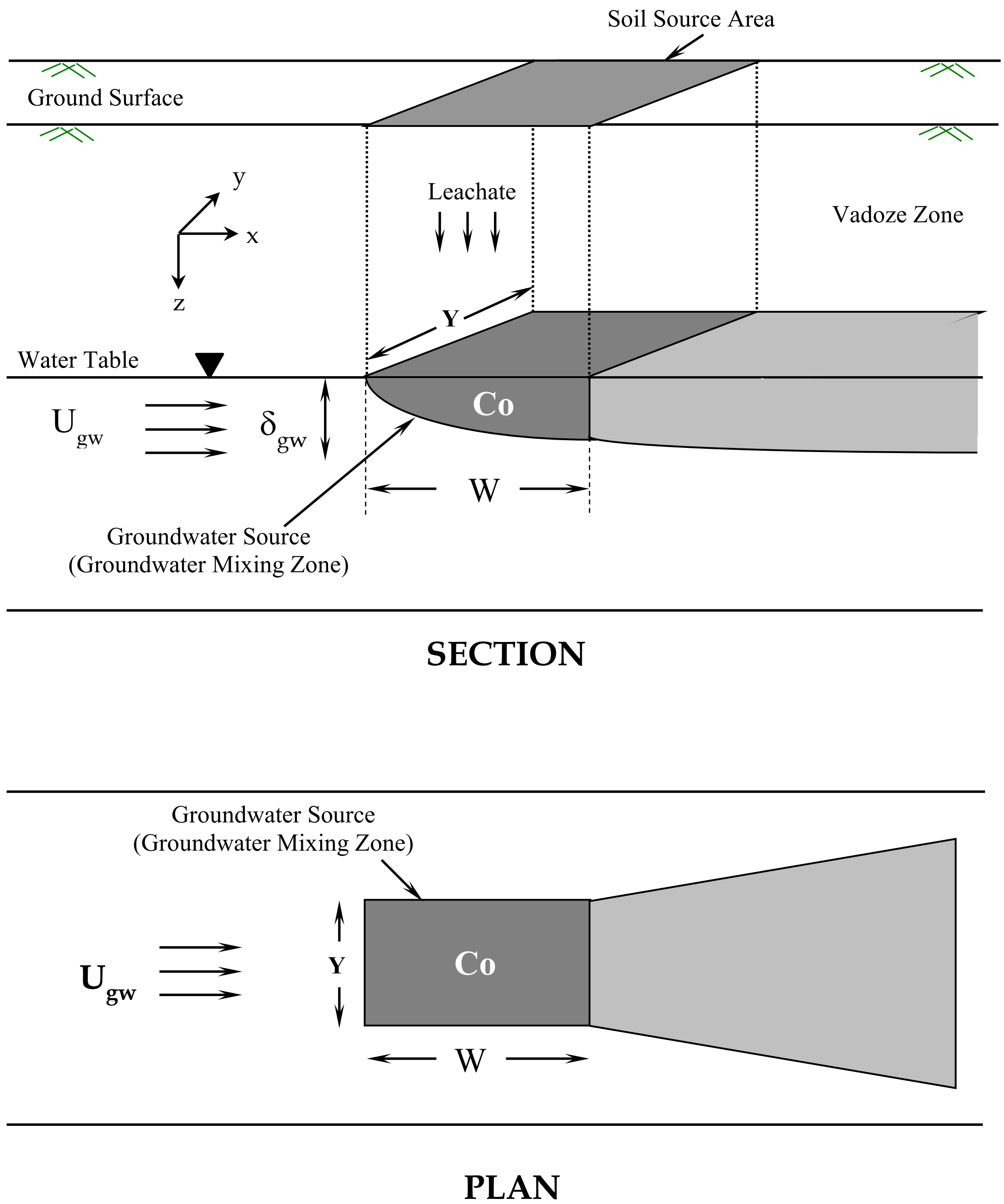

Figure 7-1. Schematic Description of Domenico's Model

LIST OF APPENDICES

APPENDIX A
CALCULATION OF RISK BASED TARGET LEVELS (RBTLs)

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A.1 BACKGROUND

The methodology used to calculate RBTLs is presented in this appendix. RBTLs include Tier 1 RBSLs, Tier 2 and Tier 3 SSTLs. Whereas the methodology to develop these levels is identical, they differ in numerical values because of changes in some or all the exposure factors, media-specific parameters, and fate and transport models. To facilitate the calculation of Tier 2 and Tier 3 SSTLs, the NDDEQ provides a calculator referred to as the NDRBCA Computational Spreadsheet. This calculator can be obtained from https://deq.nd.gov/NDRBCA/.

The calculation of RBTLs, whether Tier 1 RBSLs, Tier 2, or 3 SSTLs requires the following inputs:

1. Direct route of exposure (ROE) and indirect exposure pathways
2. Chemicals of concern
3. Carcinogenic and non-carcinogenic target risk level
4. Chemical specific toxicity values
5. Receptor specific exposure factors
6. Fate and transport models for indirect routes of exposure
7. Chemical specific physical and chemical properties
8. Media specific fate and transport parameters
9. Building parameters for indoor vapor intrusion
10. Risk equations for direct and indirect routes of exposure

For several pathways, NDRBCA program uses the Regional Screening Levels (RSLs) guidance (USEPA, 2022) as the Tier 1 RBSLs. Each of the above inputs is discussed below.

A.2 INPUTS FOR CALCULATION OF RISK BASED LEVELS

A.2.1 Direct Routes of Exposure and Indirect Exposure Pathways

The NDRBCA process includes the following direct ROE and indirect exposure pathways:

Direct Routes of Exposure

- Drinking water (residential receptors)
- Incidental ingestion of soil (residential and commercial/industrial receptors)
- Dermal contact with soil (residential and commercial/industrial receptors)
- Ingestion of fish

Indirect Exposure Pathways

- Volatilization from groundwater to indoor air inhalation (residential and commercial/industrial receptors)
- Volatilization from subsurface soil to indoor air inhalation (residential and commercial/industrial receptors)
- Volatilization from soil vapor to indoor air inhalation (residential and

commercial/industrial receptors)

- Volatilization from surface soil to outdoor inhalation (residential and commercial/industrial receptors)
- Emissions of particulates from surface soil to outdoor inhalation (residential and commercial/industrial receptors)
- Leaching from contaminated soil to groundwater
- Leaching from contaminated soil to groundwater and migration to surface water

A.2.2 Chemicals of Concern

Contaminated sites may include many classes of chemicals such as metals, chlorinated solvents, petroleum hydrocarbons, pesticides, etc. Table A-1 presents a list of COCs that are commonly found at contaminated sites in North Dakota and regulated by the NDDEQ. The calculation of risk-based target levels (Tier 1, 2 or 3) for the indirect routes of exposure requires physical chemical properties that are presented in Table A-2. These values were obtained from USEPA Regional Screening Level (RSL) chemical-specific parameters supporting table (May 2022). Chemicals that have a Henry's law constant greater than 0.00001 atm-m^3/mole at 25^{o}C or a vapor pressure greater than 1 mm Hg are considered volatile. For these chemicals, the inhalation of vapors is a potentially complete route of exposure. The volatile chemicals are identified in Table A-2.

A.2.3 Carcinogenic and Non-carcinogenic Target Risks

NDRBCA Tier 1 RBTLs are based on carcinogenic risk of 1.0×10^{-5} and a non-carcinogenic hazard quotient of 1.0 for each chemical and each complete exposure pathway. Additivity of risk to account for the presence of multiple chemicals or multiple complete routes of exposure is not considered. This is so because the NDDEQ believes that the overall NDRBCA process is conservative and typically a few chemicals account for most of the risk to receptors and their adverse health effects may not be additive.

A.2.4 Chemical-Specific Toxicity Values

Table A-3 presents the toxicity values for the various chemicals included in NDRBCA that are required to calculate the RBTLs for direct routes of exposure. These values were obtained from the USEPA RSL summary tables (May 2022). Specifically, carcinogenic toxicity is quantified as slope factor for the oral and dermal routes of exposure and inhalation unit risk for the inhalation route of exposure. Non carcinogenic toxicity is quantified using a reference dose for the oral and dermal routes of exposure and reference concentration for the inhalation route of exposure.

A.2.5 Receptor Specific Exposure Factors

Tier 1 RBTLs are calculated using the exposure factors presented in Table A-4. These values were obtained from USEPA RSL Guidance Document (May 2022) and are required for the direct routes of exposure. For the calculation of Tier 2 and Tier 3 SSTLs, these exposure values may be modified to account for site specific conditions. An excellent source for these factors is the Exposure Factors Handbook (USEPA, 2011).

A.2.6 Fate and Transport Models for Indirect Routes of Exposure

Fate and transport models are required for the calculation of RBTLs for each of the indirect exposure pathways. The models included in the USEPA RSL calculations were used. It is necessary to use these models for Tier 1 and Tier 2 evaluations. Alternative models maybe used for Tier 3 evaluation with prior approval of the NDDEQ.

Following are the models used for the indirect exposure pathways included in Section 2.1:

Indirect Exposure Pathway	Model
Indoor inhalation of vapors from sub-surface soil, soil vapor, and groundwater	Johnson & Ettinger model or the use of an attenuation factor
Outdoor inhalation of vapors from surficial soil	Jury and dispersion model and Mass balance model
Outdoor inhalation of particulates from surficial soil	Wind and vehicle driven particulate emission rate and dispersion model
Soil concentration protective of groundwater	Summer's model for mixing below the source and Domenico's model for horizontal migration of plume
Groundwater concentration protective of surface water	Mixing zone model based on mass balance

A.2.7 Chemical Specific Physical and Chemical Properties

The calculation of risk-based target levels for the indirect routes of exposure requires physical chemical properties that are presented in Table A-2. These values were obtained from USEPA Regional Screening Level (RSL) chemical-specific parameters supporting table (May 2022).

A.2.8 Media-Specific Fate and Transport Parameters

To implement the fate and transport models presented in Section A.2.6, required for the indirect exposure pathways, media-specific parameters are required. These parameters quantify certain aspects of the media. For the indirect exposure pathways listed in Section A.2.1 the media of concern include:

- Surface soil,
- Subsurface soil,
- Soil vapor,
- Indoor air,
- Ambient air, and
- Groundwater.

These are the media through which COC's travel from the source to the point of exposure where exposure occurs by direct route of exposure.

Tier 1 RBSLs are based on default media specific parameters presented in Table A-5. For the calculation of Tier 2 and Tier 3 SSTLs, these fate and transport parameters may be modified to account for site specific conditions.

A.2.9 Risk Equations for Direct Routes of Exposure and Indirect Exposure Pathways

Equations and fate and transport models used to calculate the generic (Tier 1) RBTLs and Tier 2 and Tier 3 SSTLs are presented in Appendix C to this document. The source of each model is also presented in Appendix C.

A.2.10 Building Parameters for Indoor Vapor Inhalation

If the soil vapor and groundwater concentration protective of indoor inhalation is calculated using a model, the following parameters would be required:

- Building dimensions (length, width, height of first floor),
- Building foundation/slab thickness,
- Building pressure difference,
- Air exchange rate,
- Depth below grade to bottom of enclosed space floor, and
- Floor-wall seam gap width?

These above parameters are presented in Table A-6. However, if the soil vapor and groundwater concentrations are calculated using an attenuation factor, the above parameters are not required.

A.2.11 Computational Tool to Calculate Risk Based Target levels

The calculation of RBTLs requires several equations, models and inputs parameters discussed above. The NDDEQ developed a customized, easy to use computational tool to perform the calculations. The tool is available from https://deq.nd.gov/NDRBCA/.

A.3 TIER 1 RISK BASED SCREENING LEVELs

The Tier 1 RBSLs for residential and commercial/industrial receptors are presented in Tables 6-1(a) and 6-1(b) in Section 6.0, respectively.

A.4 TIER 2 AND TIER 3 SITE-SPECIFIC TARGET LEVELS

The calculation of Tier 2 and Tier 3 SSTLs will require compilation of the input parameters and models discussed above. Documentation of these inputs and justification of the values used must be included in the Tier 2 and Tier 3 evaluation reports.

APPENDIX B
TIER 1 AND TIER 2 REPORT FORMS

NORTH DAKOTA RISK-BASED CORRECTIVE ACTION (NDRBCA)
TIER 1 REPORT FORMS

Considerable care was exercised in developing these Excel based forms. However, the North Dakota Department of Environmental Quality (NDDEQ) or EDGE makes no warranty regarding the accuracy of these forms and shall not be held liable for any

CONTINUE *Version 1.0, December 2022* **EXIT**

Developed for:

North Dakota Department of Environmental Quality (NDDEQ)

Developed by:

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vpsambana@edge-es.com
amsalhotra@edge-es.com

TITLE | **NDRBCA** | PRINT

COVER PAGE | TABLE OF CONTENTS

CONCEPTUAL SITE MODEL

12 EXPOSURE MODEL

ON-SITE RECEPTORS	OFF-SITE RECEPTORS
RESIDENT	RESIDENT
COMMERCIAL/INDUSTRIAL WORKER	COMMERCIAL/INDUSTRIAL WORKER
CONSTRUCTION WORKER	CONSTRUCTION WORKER

SUMMARY OF EXPOSURE MODEL

13 GROUNDWATER PROTECTION | 14 SURFACE WATER PROTECTION

15 TIER 1 EVALUATION (CURRENT AND ALLOWABLE FUTURE CONDITIONS)

ON-SITE RECEPTORS	OFF-SITE RECEPTORS
CURRENT RESIDENT	CURRENT RESIDENT
CURRENT COMMERCIAL/INDUSTRIAL WORKER	CURRENT COMMERCIAL/INDUSTRIAL WORKER
CURRENT CONSTRUCTION WORKER	CURRENT CONSTRUCTION WORKER
FUTURE RESIDENT	FUTURE RESIDENT
FUTURE COMMERCIAL/INDUSTRIAL WORKER	FUTURE COMMERCIAL/INDUSTRIAL WORKER
FUTURE CONSTRUCTION WORKER	FUTURE CONSTRUCTION WORKER

SUMMARY OF EXCEEDANCES

16 GROUNDWATER PROTECTON | 17 SURFACE WATER PROTECTION

18 CONCLUSION AND RECOMMENDATION FOR TIER 1 EVALUATION

ON-SITE RECEPTORS | OFF-SITE RECEPTORS

19 CORRECTIVE ACTIONS

SOIL EXCAVATION	LNAPL REMOVAL
PUMP AND TREAT ACTIVITY	ENHANCED MONITORED NATURAL ATTENUATION
AIR SPARGE SOIL VAPOR EXTRACTION	DUAL/MULTI PHASE EXTRACTION
SOIL VAPOR EXTRACTION BY VACUUM TRUCK	INSTITUTIONAL CONTROLS, NOTICES, AND RESTRICTIONS

20 REFERENCES

REFERENCES

North Dakota Risk-Based Corrective Action (NDRBCA) Tier 1 Report Forms

(NDRBCA Draft Tier 1 Report Forms, January 2023)

Site name:	
Facility ID number (if any):	
Site address:	
Date site discovered:	
Responsible Party Information:	
Business name:	
Contact person name:	
Contact person address:	
Contact person Phone No.:	
Contact person Email ID:	
Qualified consultant information:	
Name:	
Company name:	
Address:	
Phone No. & Email ID:	
Date form completed:	
Form completed by:	

NDRBCA REPORT

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SITE INFORMATION AND TIER 1 FORMS (Continued)

RBCA REPORT

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SITE INFORMATION AND TIER 1 FORMS (Continued)

LIST OF TABLES

Additional Tables

		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐

NDRBCA REPORT

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SITE INFORMATION AND TIER 1 FORMS (Continued)

All maps/figures submitted to the EGLE must include a bar scale, legend, north arrow. Include maps showing all sampling points (soil, groundwater, soil vapor, and subslab vapor, and ambient air) and date prepared.

No.	Description			In report?

LIST OF FIGURES

Additional Figures

	Figure No.		☐
	Figure No.		☐
	Figure No.		☐
	Figure No.		☐
	Figure No.		☐
	Figure No.		☐

NDRBCA REPORT

TABLE OF CONTENTS

SITE INFORMATION AND TIER 1 FORMS (Continued)

No.	Description	No. of Pages	In report?
	ATTACHMENTS		
1.	Documentation of LNAPL Disposal Manifests		☐
2.	Soil Boring Logs		☐
3.	Monitoring Well Construction Logs		☐
4.	Documentation for Calculation of Vertical Gradients		☐
5.	Documentation of Soil and Water Disposal Manifests		☐
6.	Operation and Maintenance Plan for Each Corrective Action Technology (as appropriate)		☐
7.	Monitoring Plan for Each Corrective Action Technology (as appropriate)		☐
8.	Documentation for Calculation of Representative Concentrations		☐
9.	Laboratory Analytical Report		☐
10.	Documentation of Environmental Covenants		☐
11.	Output Tables from the NDRBCA Computational Coftware		☐

Additional Attachments

Description	No. of Pages	In report?
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐
		☐

NDRBCA REPORT	FORM NO. 1
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

EXECUTIVE SUMMARY

Site address				
Status of facility	☐ Active	☐ Inactive		
Is off-site soil impacted?	☐ Yes	☐ No		
Is off-site soil data available?	☐ Yes	☐ No		
Is groundwater impacted?	☐ On-site	☐ Off-site		
Groundwater flow direction				
Shallowest historical depth to groundwater	ft bgs;	Period	to	
Average historical depth to groundwater	ft bgs;	Period	to	
Has the source of release been identified?				
Was LNAPL ever detected in a well/excavation?				
Was LNAPL removed?				
When was LNAPL last detected?	Date			
Has surface water been impacted?				
Has a water supply well been impacted?				
Is there a public water supply well within 1,000 ft?	Distance	ft;	Direction	
Is there a private water supply well within 1,000 ft?	Distance	ft;	Direction	

RECOMMENDATIONS

TIER 1 Evaluation	**TIER 2 Evaluation**
☐ Closure under Tier 1	☐ Closure under Tier 2
☐ Remediate to Tier 1	☐ Remediate to Tier 2
☐ Perform monitoring	☐ Perform monit
☐ Go to Tier 2	☐ Go to Tier 3

BASIS OF RECOMMENDATION AND ADDITIONAL NOTES

REPORT PREPARED BY

I attest that the information upon which this report is based is complete and true to the best of my knowledge.

Signature of Owner or Representative	*Print Owner or Representative Name*	*Date*
Name of Company	*Address*	
Email Address	*Phone Number*	

NDRBCA REPORT	FORM NO. 2
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

SITE INFORMATION

Site name:
Facility ID number (if any):
Site address:
Date site discovered:
Responsible Party Information:
Business name:
Contact person name:
Contact person address:
Contact person Phone No.:
Contact person Email ID:

SITE TYPE	OPERATING?
☐ Petroleum UST site	☐
☐ Petroleum AST site	☐
☐ Oil and gas facility/site	☐
☐ Manufacturing facility	☐
☐ Pesticide facility	☐
☐ Dry cleaning facility	☐
☐ Land fill	☐
☐ Other	☐

For facility type identified as "other", discuss specific details below:

Subsurface Utilities

Have the on-site subsurface utilities been identified? ☐ YES ☐ NO
Range of depth to utilities (ft bgs)
Type of utilities
Have the utilities been screened for vapor levels? ☐ YES ☐ NO
If YES, attach documentation of vapor monitoring results.
If drinking water lines potentially impacted, has drinking water been tested for VOCs? ☐ YES ☐ NO
If YES, attach documentation of drinking water monitoring results.

ADDITIONAL NOTES FOR FACILITY AND UTILITIES

Attachments: (1) Figure 1 Site location map; (2) Figure 2 Site map showing property boundaries, past and current site features (e.g., storage systems, process areas, distribution areas, location of release, location of on and off-site monitoring points, location of public and private water wells within 1,000 ft, location of surface water features within 1,000 ft, ecological receptors within 1,000 ft, location of excavation, and location of remedial system, if any); (3) Figure 3 Site map showing locations and depths of on-site subsurface utilities

NDRBCA REPORT	FORM NO. 3
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

SITE DISCOVERY

Instructions: *Describe (i) site operations, (ii) how the site was discovered (e.g., sheen in utilities and observation wells, sudden loss of product in tanks, Phase I or II investigations as part of real estate transactions, accidental release, citizen compliant of odors) (iii) when was the release occurred, (iv) location of release, (v) chemicals stored, used, and released at the facility, (vi) quantity released (if known) etc.*

Attachments: None.

NDRBCA REPORT	FORM NO. 4
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

UNDERGROUND STORAGE TANK TYPES

New Tank ID Number(s)	Product	Capacity	In Use Yes	In Use No	Installation Date	Removal Date	Closure in Place Date	Temporarily closed
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				
			☐	☐				

*Tank number(s) identified with " * " are associated with the confirmed release(s).*

ADDITIONAL NOTES

Attachment: Figure 2 Site Map Showing Site Boundaries and Past and Present Site Features

NDRBCA REPORT	FORM NO. 5

Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

LAND USE (ON-SITE AND OFF-SITE)

Current On-site Land Use		Allowable Future On-site Land Use	
Residential	☐	Residential	☐
Non-residential	☐	Non-residential	☐
Other (please explain below)	☐	Other (please explain below)	☐
Is site located in wellhead protection area?	☐ ☐	Is site located in wellhead protection area?	☐ ☐

- Describe the current and potential future use of the on-site land and surrounding land, groundwater, surface water, and sensitive habitats within 1,000 ft of the site boundary and in all directions (N, S, E, and W).

Attachments: (1) Figure 4 Land use map (Radius of 1,000 feet); (2) Figure 5 Site map showing buildings within 1,000 ft of source

NDRBCA REPORT	FORM NO. 6
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CHRONOLOGY OF EVENTS

Date	***Instructions:*** *Describe site characterization, sampling, and remediation activities including installation of soil borings, monitoring wells, soil vapor monitoring points, subslab vapor points, slug tests, institutional controls, LNAPL removal, etc.*

Include completed Form 20 for list of references.

NDRBCA REPORT	FORM NO. 6

Facility ID number (if any):	Site address:
Date form completed:	**Form completed by:**

CHRONOLOGY OF EVENTS	
Date	***Instructions:*** *Describe site characterization, sampling, and remediation activities including installation of soil borings, monitoring wells, soil vapor monitoring points, subslab vapor points, slug tests, institutional controls, LNAPL removal, etc.*

Include completed Form 20 for list of references.

NDRBCA REPORT	FORM NO. 7
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPREHENSIVE SUMMARY OF DATA

No. of soil borings advanced	
Range of depth of soil borings	ft bgs to ft bgs
No. of soil samples collected from soil borings and analyzed	
No. of permanent groundwater monitoring wells installed	
No. of permanent active groundwater monitoring wells	
No. of abandoned permanent groundwater monitoring wells	
No. of nested permanent groundwater monitoring well pairs	
No. of temporary groundwater monitoring wells installed	
No. of temporary groundwater monitoring wells still active	
Range of depth of permanent groundwater monitoring wells	ft bgs to ft bgs
No. of piezometers installed	
No. of piezometers still active	
No. of LNAPL recovery wells	
No. of soil vapor extraction wells	
No. of soil vapor monitoring ports installed	
No. of soil vapor samples analyzed (and no. of events)	
No. of subslab vapor monitoring points installed	
No. of subslab vapor samples analyzed (and no. of events)	
No. of ambient air samples analyzed by laboratory (not PIDs)	
No. of soil samples analyzed for geotechnical parameters	
No. of tanks removed	
No. of soil samples collected during tank removal	
No. of soil samples collected post excavation, if any	

Please confirm that the above information is consistent with the chronology, figures, and tables. For example, if the number of monitoring wells installed is 10, Table 2 must list 10 wells, Figure 6 must show 10 wells, Attachment 3 must show 10 well construction details, and the chronology must match the dates of well installation shown on Table 2. Any inconsistencies must be explained in the space provided below. The total number of samples must include the duplicates and also the number of duplicates.

ADDITIONAL NOTES COMPREHENSIVE SUMMARY OF DATA

Attachments: Tables 1 to 8 (see table of contents for specifics)

NDRBCA REPORT	FORM NO. 8
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

LIGHT NON-AQUEOUS PHASE LIQUID (LNAPL)

Has LNAPL been encountered in any monitoring well? ☐ Yes ☐ No

(Note if No, proceed to the next report form)

Type of product released

Estimated quantity of product released

List the monitoring wells that have contained measurable LNAPL

Date when LNAPL was last measured in a monitoring well

List the monitoring wells currently containing measurable LNAPL

Maximum thickness ______ feet Well ID ______ Date ______

Include attachments to provide relevant supporting information, as appropriate.

SUMMARY OF LNAPL REMOVAL

Has LNAPL removal been conducted? ☐ Yes ☐ No

Method of removal (bailer, pump, etc.)?

Frequency of removal (weekly, monthly, etc.)

Total number of recovery events

Total volume of water recovered with LNAPL

Total volume of LNAPL recovered

Date of most recent LNAPL removal activity

Describe how the recovered LNAPL was disposed

If LNAPL removal was conducted complete Form 19(e).

ADDITIONAL NOTES FOR LNAPL

Attachments: (1) Table 3: Gauging data for monitoring wells; (2) Table 4: LNAPL recovery; (3) Figure 7: Site map showing suspected source(s) of LNAPL and (4) Attachment 1: Completed LNAPL disposal manifests

NDRBCA REPORT	FORM NO. 9
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

SITE STRATIGRAPHY AND HYDROGEOLOGY

STRATIGRAPHY

Depth [feet]	**Type of Soil**
Predominant soil type in vadose zone	
Predominant soil type in saturated zone	

HYDROGEOLOGY

	Zone 1	Zone 2	Zone 3
Range of measured groundwater level [ft bgs]			
Average depth to stabilized water level [ft bgs]			
Estimated depth to top of zone (ft bgs)			
Estimated depth to bottom of zone (ft bgs)			
Estimated thickness of water bearing zone (ft)			
Aquifer type (confined/unconfined/perched, etc.)			
Predominant flow direction			
Hydraulic gradient (i) [--]			
Hydraulic conductivity (K) [cm/year]			
Hydraulic conductivity test method			
Darcy velocity (K × i) [cm/year - calculated]			
Predominant vertical gradient (Zone 1 to Zone 2) [--]			
Predominant vertical gradient (Zone 2 to Zone 3) [--]			

Show details of vertical gradient calculations in Attachment 4, if available.

ADDITIONAL NOTES FOR SITE STRATIGRAPHY AND HYDROGEOLOGY

Attachments: (1) Table 3: Gauging data for monitoring wells; (2) Figure 8: site stratigraphy and cross sections; ; (3) Figure 9: groundwater gradients or water level contour map; (4) Attachment 2: Soil boring logs; (5) Attachment 3: Monitoring well construction logs; (6) Attachment 4: Documentation for calculation of vertical gradients

NDRBCA REPORT	FORM NO. 10

Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

GEOTECHNICAL PARAMETERS

VADOSE ZONE

	Mean/Range			Method
Dry bulk density (ρ_b) [g/cm^3]		☐Estimated	☐ Measured	
Estimated porosity (θ_T) [cm^3/cm^3]		☐Estimated	☐ Measured	
Water content (θ_w)[cm^3/cm^3]		☐Estimated	☐ Measured	
Fractional organic carbon content (f_{oc}) [g-C/g-soil]		☐Estimated	☐ Measured	

Provide details of measured values below.

SATURATED ZONE

	Values/Range			Method
Dry bulk density (ρ_b) [g/cm^3]		☐Estimated	☐ Measured	
Estimated porosity (θ_T) [cm^3/cm^3]		☐Estimated	☐ Measured	
Water content (θ_w)[cm^3/cm^3]		☐Estimated	☐ Measured	
Fractional organic carbon content (f_{oc}) [g-C/g-soil]		☐Estimated	☐ Measured	

Provide details of measured values below.

ADDITIONAL NOTES GEOTECHNICAL PARAMETERS

Attachments: (1) Attachment 2: Soil boring logs; (2) Attachment 3: Monitoring well construction log

NDRBCA REPORT	FORM NO. 11

Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

GROUNDWATER TO SURFACE WATER PATHWAY

Has the plume impacted the surface water body? ☐ Yes ☐ No

Are surface waters of the state located within 1,000 ft downgradient of the source area? ☐ Yes ☐ No

(If No, proceed to the next Form)

Please describe the surface water body

Approximate elevation of bottom of surface water body (ft msl)

Is the approximate bottom of surface water body above the groundwater table? ☐ Yes ☐ No

(If Yes, groundwater to surface water pathway is not complete)

Is groundwater to surface water pathway complete? ☐ Yes ☐ No

Provide justification for your choice:

ADDITIONAL NOTES FOR GROUNDWATER TO SURFACE WATER

Attachments: (1) Figure 18: Site map showing the surface water feature including storm water sewer; (2) Figure 19: Cross-section showing the groundwater table and bottom of surface water feature

NDRBCA REPORT		FORM NO. 12 - ON-SITE RESIDENT

Facility ID number (if any):	Site address:
Date form completed:	**Form completed by:**

EXPOSURE MODEL - ON-SITE RESIDENT

MEDIA AND ROUTE OF EXPOSURE	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*
SURFACE SOIL (0 to 2 ft bgs)						
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates	☐ C ☐ NC			☐ C ☐ NC		
SUBSURFACE SOIL (>2 ft bgs to water table) (Recommendation is to Use Soil Vapor RBTLs)						
Indoor inhalation of vapors	☐ C ☐ NC			☐ C ☐ NC		
GROUNDWATER						
Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)	☐ C ☐ NC			☐ C ☐ NC		
Indoor inhalation of vapors from groundwater	☐ C ☐ NC			☐ C ☐ NC		

Notes:

C : Complete Pathway; **NC** : Not Complete **RC**: Representative concentration

*: If space is not sufficient to list the monitoring points within the exposure domain, then please include the list of monitoring points in an attachment/table showing each exposure domain and monitoring points within the domain.

Attachments: (1) Figure 6: Site map showing soil boring and monitoring well locations (including drinking water wells onsite)**;** (2) Figure 10: Soil Concentrations or Contour Map**;** (3) Figure 11: Groundwater Concentrations or Contour Map

NDRBCA REPORT	FORM NO. 12 - EXPOSURE MODEL - ON-SITE COMMERCIAL/INDUSTRIAL WORKER
Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

EXPOSURE MODEL - ON-SITE COMMERCIAL/INDUSTRIAL WORKER

MEDIA AND ROUTE OF EXPOSURE	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*
SURFACE SOIL (0 to 2 ft bgs)						
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates	☐ C ☐ NC			☐ C ☐ NC		
SUBSURFACE SOIL (>2 ft bgs to water table) (Recommendation is to Use Soil Vapor RBTLs)						
Indoor inhalation of vapors	☐ C ☐ NC			☐ C ☐ NC		
GROUNDWATER						
Indoor inhalation of vapors from groundwater	☐ C ☐ NC			☐ C ☐ NC		

Notes:
C : Complete Pathway; **NC** : Not Complete **RC**: Representative concentration

*: If space is not sufficient to list the monitoring points within the exposure domain, then please include the list of monitoring points in an attachment/table showing each exposure domain and monitoring points within the domain.

Attachments: (1) Figure 6: Site map showing soil boring and monitoring well locations (including drinking water wells onsite); (2) Figure 10: Soil Concentrations or Contour Map; (3) Figure 11: Groundwater Concentrations or Contour Map

NDRBCA REPORT	FORM NO. 12 - ON-SITE CONSTRUCTION WORKER
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

EXPOSURE MODEL - ON-SITE CONSTRUCTION WORKER

MEDIA AND ROUTE OF EXPOSURE	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*
SOIL UP TO DEPTH OF CONSTRUCTION						
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates	☐ C ☐ NC			☐ C ☐ NC		

Notes:

C : Complete Pathway; **NC** : Not Complete **RC**: Representative concentration

*: If space is not sufficient to list the monitoring points within the exposure domain, then please include the list of monitoring points in an attachment/table showing each exposure domain and monitoring points within the domain.

Attachments: (1) Figure 6: Site map showing soil boring and monitoring well locations (including drinking water wells onsite); (2) Figure 10: Soil Concentrations or Contour Map;

NDRBCA REPORT	FORM NO. 12 - OFF-SITE RESIDENT
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

EXPOSURE MODEL - OFF-SITE RESIDENT

MEDIA AND ROUTE OF EXPOSURE	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*
SURFACE SOIL (0 to 2 ft bgs)						
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates	☐ C ☐ NC			☐ C ☐ NC		
SUBSURFACE SOIL (>2 ft bgs to water table) (Recommendation is to Use Soil Vapor RBTLs)						
Indoor inhalation of vapors	☐ C ☐ NC			☐ C ☐ NC		
GROUNDWATER						
Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)	☐ C ☐ NC			☐ C ☐ NC		
Indoor inhalation of vapors from groundwater	☐ C ☐ NC			☐ C ☐ NC		

Notes:

C : Complete Pathway; **NC** : Not Complete **RC**: Representative concentration

*: If space is not sufficient to list the monitoring points within the exposure domain, then please include the list of monitoring points in an attachment/table showing each exposure domain and monitoring points within the domain.

Attachments: (1) Figure 6: Site map showing soil boring and monitoring well locations (including drinking water wells onsite)**;** (2) Figure 10: Soil Concentrations or Contour Map**;** (3) Figure 11: Groundwater Concentrations or Contour Map

NDRBCA REPORT	FORM NO. 12 - EXPOSURE MODEL - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

EXPOSURE MODEL - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER

MEDIA AND ROUTE OF EXPOSURE	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*
SURFACE SOIL (0 to 2 ft bgs)						
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates	☐ C ☐ NC			☐ C ☐ NC		
SUBSURFACE SOIL (>2 ft bgs to water table) (Recommendation is to Use Soil Vapor RBTLs)						
Indoor inhalation of vapors	☐ C ☐ NC			☐ C ☐ NC		
GROUNDWATER						
Indoor inhalation of vapors from groundwater	☐ C ☐ NC			☐ C ☐ NC		

Notes:

C : Complete Pathway; **NC** : Not Complete **RC**: Representative concentration

*: If space is not sufficient to list the monitoring points within the exposure domain, then please include the list of monitoring points in an attachment/table showing each exposure domain and monitoring points within the domain.

Attachments: (1) Figure 6: Site map showing soil boring and monitoring well locations (including drinking water wells onsite)**;** (2) Figure 10: Soil Concentrations or Contour Map**;** (3) Figure 11: Groundwater Concentrations or Contour Map

NDRBCA REPORT						FORM NO. 12 - OFF-SITE CONSTRUCTION WORKER
Facility ID number (if any):			Site address:			
Date form completed:			Form completed by:			

EXPOSURE MODEL - OFF-SITE CONSTRUCTION WORKER

MEDIA AND ROUTE OF EXPOSURE	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*	C/NC	Justification for Route of Exposure	Monitoring Points Exposure Domain for Calculating RC*
SOIL UP TO DEPTH OF CONSTRUCTION						
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates	☐ C ☐ NC			☐ C ☐ NC		

Notes:

C : Complete Pathway; **NC** : Not Complete **RC**: Representative concentration

*: If space is not sufficient to list the monitoring points within the exposure domain, then please include the list of monitoring points in an attachment/table showing each exposure domain and monitoring points within the domain.

Attachments: (1) Figure 6: Site map showing soil boring and monitoring well locations (including drinking water wells onsite); (2) Figure 10: Soil Concentrations or Contour Map;

NDRBCA REPORT	FORM NO. 12 - SUMMARY OF EM
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

SUMMARY OF EXPOSURE MODEL (COMPLETE ROUTES OF EXPOSURE HIGHLIGHTED)

MEDIA AND ROUTE OF EXPOSURE	ON-SITE RECEPTOR						OFF-SITE RECEPTOR					
	CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS			CURRENT CONDITIONS			ALLOWABLE FUTURE CONDITIONS		
	Resident	Commercial /Industrial Worker	Construction Worker	Resident	Commercial/ Industrial Worker	Construction Worker	Resident	Commercial /Industrial Worker	Construction Worker	Resident	Commercial /Industrial Worker	Construction Worker
SURFICIAL SOIL FOR RESIDENT AND COMMERCIAL/INDUSTRIAL WORKER AND SOIL UPTO DETPH OF CONSTRUCTION FOR CONSTRUCTION WORKER												
Ingestion of and dermal contact with, and inhalation of vapors and particulates	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
SUBSURFACE SOIL (>2 ft bgs to water table) (Recommendation is to Use Soil Vapor RBTLs)												
Indoor inhalation of vapors	NC	NC	NA	NC	NC	NA	NC	NC	NA	NC	NC	NA
GROUNDWATER												
Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)	NC	NA	NA	NC	NA	NA	NC	NA	NA	NC	NA	NA
Indoor inhalation of vapors	NC	NC	NA	NC	NC	NA	NC	NC	NA	NC	NC	NA

Notes

C: Complete Pathway **NC**: Not Complete NA: Not applicable

NDRBCA REPORT	FORM NO. 13
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CONSIDERATION OF GROUNDWATER PORTECTION PATHWAY

Per Section 5.3.3 of NDRBCA Guidance document this pathway requires the (i) location of point of exposure (POE), (ii) acceptable concentration at POE, and (iii) location of point of demonstration (POD). Based on these RBTLs are developed for (i) groundwater POD, (ii) subsurface soil, and (iii) surface soil.

For this pathway provide the following:

Location of POE: ________ feet (ft) from downgradient edge of source

Concentration at POE: ☐ MCL ☐ Tapwater RBTL ☐ Other ________

Location of POD (include well ID and location): ________

Note, there may be multiple PODs.

ADDITIONAL NOTES FOR CONSIDERATION OF GROUNDWATER PROTECTION PATHWAY

Attachments: (1)**:** Figure 20: Figure showing the location(s) of the soil source(s), location of POE, and location(s) of POD for Groundwater Protection

NDRBCA REPORT	FORM NO. 14
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CONSIDERATION OF SURFACE WATER PROTECTION PATHWAY

Per Section 5.4 of NDRBCA Guidance document this pathway requires the (i) surface water classification, (ii) surface water quality criteria, and (iii) location of point of exposure (POE). Based on these acceptable RBTLs are developed for (i) groundwater POD, (ii) subsurface soil, and (iii) surface soil.

For this pathway provide the following:

SURFACE WATER CLASSIFICATION

- ☐ Class I streams
- ☐ Class IA streams
- ☐ Class II streams
- ☐ Class III streams
- ☐ Wetlands
- ☐ Lakes and reservoirs (Class 1 to 5)*

STREAM WATER QUALITY CRITERIA

- ☐ Aquatic life
  - ☐ Acute
  - ☐ Chronic
- ☐ Human health
  - ☐ Ingestion of aquatic organisms & drinking water for Class I, IA, and II
  - ☐ Ingestion of aquatic organisms for Class III

Location of POE for Tier 1: ________ ft
(The distance from source to the point where groundwater seeps into the surface water)

Location of POE for Tier 2: ________ ft
(The distance from source to the downstream edge of the mixing zone within the surface water)

Location of POD for Tier 2: ________ *ft*
(The distance from source to the POD well)

**: Note, lakes and reservoirs are subcategorized as Class 1 to Class 5 based on the type of fishery (e.g., cold water, warm water, etc.) the lake or reservoir can support (refer to Appendix I and Appendix II of NDAC 33.1-16-02.1).*

Note, there may be multiple PODs.

ADDITIONAL NOTES FOR CONSIDERATION OF SURFACE WATER PROTECTION PATHWAY

Attachments: (1)**:** Figure 21: Figure showing the location(s) of the soil source(s), location of POE, and location(s) of POD for Surface Water Protection

NDRBCA REPORT	FORM NO. 15 - ON-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Benzene		1E+01			NA			5E+00			NA	
Ethylbenzene		6E+01			NA			7E+02			NA	
Isopropylbenzene (Cumene)		2E+03			NA			5E+02			NA	
Methyl tert-Butyl Ether (MTBE)		5E+02			NA			1E+02			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
1,2,4-Trimethylbenzene		3.0E+02			NA			5.6E+01			NA	
1,3,5-Trimethylbenzene		2.7E+02			NA			6.0E+01			NA	
Toluene		4.9E+03			NA			1.0E+03			NA	
Xylene (total)		5.8E+02			NA			1.0E+04			NA	
Acenaphthene		3.6E+03			NA			5.3E+02			NA	
Anthracene		1.8E+04			NA			1.8E+03			NA	
Benzo(a)anthracene		1.1E+01			NA			3.0E-01			NA	
Benzo (a) Pyrene		1.1E+00			NA			2.0E-01			NA	
Benzo(b)fluoranthene		1.1E+01			NA			2.5E+00			NA	
Benzo(k)fluoranthene		1.1E+02			NA			2.5E+01			NA	
Chrysene		1.1E+03			NA			2.5E+02			NA	
Ethylene dibromide		3.6E-01			NA			5.0E-02			NA	
Fluoranthene		2.4E+03			NA			8.0E+02			NA	
Fluorene		2.4E+03			NA			2.9E+02			NA	
Indeno (1,2,3-cd) Pyrene		1.1E+01			NA			2.5E+00			NA	
1-Methylnapthalene		1.8E+02			NA			1.1E+01			NA	
2-Methylnapthalene		2.4E+02			NA			3.6E+01			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
Pyrene		1.8E+03			NA			1.2E+02			NA	
Arsenic		6.8E+00			NA			1.0E+01			NA	
Barium		1.5E+04			NA			2.0E+03			NA	
Beryllium		1.6E+02			NA			4.0E+00			NA	
Cadmium (diet)		7.1E+00			NA			NA			NA	
Cadmium (water)		NA			NA			5.0E+00			NA	
Chromium (III)		1.2E+05			NA			2.2E+04			NA	
Chromium (VI)		3.0E+00			NA			3.5E-01			NA	
Chromium (total)		NA			NA			1.0E+02			NA	
Lead		4.0E+02			NA			1.5E+01			NA	
Manganese (non-diet)		1.8E+03			NA			4.3E+02			NA	
Mercury (elemental)		1.1E+01			NA			2.0E+00			NA	
Selenium		3.9E+02			NA			5.0E+01			NA	
Silver		3.9E+02			NA			9.4E+01			NA	

NDRBCA REPORT	FORM NO. 15 - ON-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [μg/L]	SLs [μg/L]	E/NE	Rep. Conc. [μg/L]	SLs [μg/L]	E/NE
Hexachloroethane		1.8E+01			NA			3.3E+00			NA	
Pentachloroethane		7.7E+01			NA			6.5E+00			NA	
1,1,1,2-Tetrachloroethane		2.0E+01			NA			5.7E+00			NA	
1,1,2,2-Tetrachloroethane		6.0E+00			NA			7.6E-01			NA	
1,1,2-Trichloroethane		1.1E+01			NA			5.0E+00			NA	
1,1,1-Trichloroethane		8.1E+03			NA			2.0E+02			NA	
1,2-Dichloroethane		4.6E+00			NA			5.0E+00			NA	
1,1-Dichloroethane		3.6E+01			NA			2.8E+01			NA	
Chloroethane		5.4E+03			NA			8.3E+03			NA	
Perchloroethene (PCE)		2.4E+02			NA			5.0E+00			NA	
Trichloroethene (TCE)		9.4E+00			NA			5.0E+00			NA	
1,1-Dichloroethene		2.3E+02			NA			7.0E+00			NA	
cis-1,2-Dichloroethene		1.6E+02			NA			7.0E+01			NA	
trans-1,2-Dichloroethene		7.0E+01			NA			1.0E+02			NA	
VinyL chloride (VC)		5.9E-01			NA			2.0E+00			NA	
Bromide		NA			NA			NA			NA	
Chloride		NA			NA			NA			NA	
Nitrate as total nitrogen		1.3E+05			NA			1.0E+04			NA	
Strontium		4.7E+04			NA			1.2E+04			NA	

Notes:
E Representative concentration exceeds screening level (SL).
NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

Page 1 of ____

NDRBCA REPORT	FORM NO. 15 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Benzene		5E+01			NA			NA	
Ethylbenzene		3E+02			NA			NA	
Isopropylbenzene (Cumene)		1E+04			NA			NA	
Methyl tert-Butyl Ether (MTBE)		2E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
1,2,4-Trimethylbenzene		1.8E+03			NA			NA	
1,3,5-Trimethylbenzene		1.5E+03			NA			NA	
Toluene		4.7E+04			NA			NA	
Xylene (total)		2.5E+03			NA			NA	
Acenaphthene		4.5E+04			NA			NA	
Anthracene		2.3E+05			NA			NA	
Benzo(a)anthracene		2.1E+02			NA			NA	
Benzo (a) Pyrene		2.1E+01			NA			NA	
Benzo(b)fluoranthene		2.1E+02			NA			NA	
Benzo(k)fluoranthene		2.1E+03			NA			NA	
Chrysene		2.1E+04			NA			NA	
Ethylene dibromide		1.6E+00			NA			NA	
Fluoranthene		3.0E+04			NA			NA	
Fluorene		3.0E+04			NA			NA	
Indeno (1,2,3-cd) Pyrene		2.1E+02			NA			NA	
1-Methylnapthalene		7.3E+02			NA			NA	
2-Methylnapthalene		3.0E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
Pyrene		2.3E+04			NA			NA	
Arsenic		3.0E+01			NA			NA	
Barium		2.2E+05			NA			NA	
Beryllium		2.3E+03			NA			NA	
Cadmium (diet)		1.0E+02			NA			NA	
Cadmium (water)		NA			NA			NA	
Chromium (III)		1.8E+06			NA			NA	
Chromium (VI)		6.3E+01			NA			NA	
Chromium (total)		NA			NA			NA	
Lead		8.0E+02			NA			NA	
Manganese (non-diet)		2.6E+04			NA			NA	
Mercury (elemental)		4.6E+01			NA			NA	
Selenium		5.8E+03			NA			NA	
Silver		5.8E+03			NA			NA	

NDRBCA REPORT	FORM NO. 15 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		8.0E+01			NA			NA	
Pentachloroethane		3.6E+02			NA			NA	
1,1,1,2-Tetrachloroethane		8.8E+01			NA			NA	
1,1,2,2-Tetrachloroethane		2.7E+01			NA			NA	
1,1,2-Trichloroethane		5.0E+01			NA			NA	
1,1,1-Trichloroethane		3.6E+04			NA			NA	
1,2-Dichloroethane		2.0E+01			NA			NA	
1,1-Dichloroethane		1.6E+02			NA			NA	
Chloroethane		2.3E+04			NA			NA	
Perchloroethene (PCE)		1.0E+03			NA			NA	
Trichloroethene (TCE)		6.0E+01			NA			NA	
1,1-Dichloroethene		1.0E+03			NA			NA	
cis-1,2-Dichloroethene		2.3E+03			NA			NA	
trans-1,2-Dichloroethene		3.0E+02			NA			NA	
VinyL chloride (VC)		1.7E+01			NA			NA	
Bromide		NA			NA			NA	
Chloride		NA			NA			NA	
Nitrate as total nitrogen		1.9E+06			NA			NA	
Strontium		7.0E+05			NA			NA	

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

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Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)		
Facility ID number (if any):			
Date form completed:			
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)			
CHEMICALS OF CONCERN	**SURFACE SOIL**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**
	Rep. Conc. [mg/kg]	SLs [mg/kg]	**E/NE**
Benzene			
Ethylbenzene			
Isopropylbenzene (Cumene)			
Methyl tert-Butyl Ether (MTBE)			
Naphthalene			
1,2,4-Trimethylbenzene			
1,3,5-Trimethylbenzene			
Toluene			
Xylene (total)			
Acenaphthene			
Anthracene			
Benzo(a)anthracene			
Benzo (a) Pyrene			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Chrysene			
Ethylene dibromide			
Fluoranthene			
Fluorene			
Indeno (1,2,3-cd) Pyrene			
1-Methylnapthalene			
2-Methylnapthalene			
Naphthalene			
Pyrene			
Arsenic			
Barium			
Beryllium			
Cadmium (diet)			
Cadmium (water)			
Chromium (III)			
Chromium (VI)			
Chromium (total)			
Lead			
Manganese (non-diet)			
Mercury (elemental)			
Selenium			
Silver			

NDRBCA REPORT	FORM NO. 15 - ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

Facility ID number (if any):

Date form completed:

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE
Hexachloroethane			
Pentachloroethane			
1,1,1,2-Tetrachloroethane			
1,1,2,2-Tetrachloroethane			
1,1,2-Trichloroethane			
1,1,1-Trichloroethane			
1,2-Dichloroethane			
1,1-Dichloroethane			
Chloroethane			
Perchloroethene (PCE)			
Trichloroethene (TCE)			
1,1-Dichloroethene			
cis-1,2-Dichloroethene			
trans-1,2-Dichloroethene			
VinyL chloride (VC)			
Bromide			
Chloride			
Nitrate as total nitrogen			
Strontium			

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - ON-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Domestic use of water (ingestion, dermal contact, inhalation of vapors due to indoor water use)		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SLs [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SLs [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SLs [µg/L]	**E/NE**	Rep. Conc. [µg/L]	SLs [µg/L]	**E/NE**
Benzene		1E+01			NA			5E+00			NA	
Ethylbenzene		6E+01			NA			7E+02			NA	
Isopropylbenzene (Cumene)		2E+03			NA			5E+02			NA	
Methyl tert-Butyl Ether (MTBE)		5E+02			NA			1E+02			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
1,2,4-Trimethylbenzene		3.0E+02			NA			5.6E+01			NA	
1,3,5-Trimethylbenzene		2.7E+02			NA			6.0E+01			NA	
Toluene		4.9E+03			NA			1.0E+03			NA	
Xylene (total)		5.8E+02			NA			1.0E+04			NA	
Acenaphthene		3.6E+03			NA			5.3E+02			NA	
Anthracene		1.8E+04			NA			1.8E+03			NA	
Benzo(a)anthracene		1.1E+01			NA			3.0E-01			NA	
Benzo (a) Pyrene		1.1E+00			NA			2.0E-01			NA	
Benzo(b)fluoranthene		1.1E+01			NA			2.5E+00			NA	
Benzo(k)fluoranthene		1.1E+02			NA			2.5E+01			NA	
Chrysene		1.1E+03			NA			2.5E+02			NA	
Ethylene dibromide		3.6E-01			NA			5.0E-02			NA	
Fluoranthene		2.4E+03			NA			8.0E+02			NA	
Fluorene		2.4E+03			NA			2.9E+02			NA	
Indeno (1,2,3-cd) Pyrene		1.1E+01			NA			2.5E+00			NA	
1-Methylnapthalene		1.8E+02			NA			1.1E+01			NA	
2-Methylnapthalene		2.4E+02			NA			3.6E+01			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
Pyrene		1.8E+03			NA			1.2E+02			NA	
Arsenic		6.8E+00			NA			1.0E+01			NA	
Barium		1.5E+04			NA			2.0E+03			NA	
Beryllium		1.6E+02			NA			4.0E+00			NA	
Cadmium (diet)		7.1E+00			NA			NA			NA	
Cadmium (water)		NA			NA			5.0E+00			NA	
Chromium (III)		1.2E+05			NA			2.2E+04			NA	
Chromium (VI)		3.0E+00			NA			3.5E-01			NA	
Chromium (total)		NA			NA			1.0E+02			NA	
Lead		4.0E+02			NA			1.5E+01			NA	
Manganese (non-diet)		1.8E+03			NA			4.3E+02			NA	
Mercury (elemental)		1.1E+01			NA			2.0E+00			NA	
Selenium		3.9E+02			NA			5.0E+01			NA	
Silver		3.9E+02			NA			9.4E+01			NA	

NDRBCA REPORT	FORM NO. 15 - ON-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion, dermal contact, inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		1.8E+01			NA			3.3E+00			NA	
Pentachloroethane		7.7E+01			NA			6.5E+00			NA	
1,1,1,2-Tetrachloroethane		2.0E+01			NA			5.7E+00			NA	
1,1,2,2-Tetrachloroethane		6.0E+00			NA			7.6E-01			NA	
1,1,2-Trichloroethane		1.1E+01			NA			5.0E+00			NA	
1,1,1-Trichloroethane		8.1E+03			NA			2.0E+02			NA	
1,2-Dichloroethane		4.6E+00			NA			5.0E+00			NA	
1,1-Dichloroethane		3.6E+01			NA			2.8E+01			NA	
Chloroethane		5.4E+03			NA			8.3E+03			NA	
Perchloroethene (PCE)		2.4E+02			NA			5.0E+00			NA	
Trichloroethene (TCE)		9.4E+00			NA			5.0E+00			NA	
1,1-Dichloroethene		2.3E+02			NA			7.0E+00			NA	
cis-1,2-Dichloroethene		1.6E+02			NA			7.0E+01			NA	
trans-1,2-Dichloroethene		7.0E+01			NA			1.0E+02			NA	
VinyL chloride (VC)		5.9E-01			NA			2.0E+00			NA	
Bromide		NA			NA			NA			NA	
Chloride		NA			NA			NA			NA	
Nitrate as total nitrogen		1.3E+05			NA			1.0E+04			NA	
Strontium		4.7E+04			NA			1.2E+04			NA	

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

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NDRBCA REPORT	FORM NO. 15 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [μg/L]	SLs [μg/L]	E/NE
Benzene		5E+01			NA			NA	
Ethylbenzene		3E+02			NA			NA	
Isopropylbenzene (Cumene)		1E+04			NA			NA	
Methyl tert-Butyl Ether (MTBE)		2E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
1,2,4-Trimethylbenzene		1.8E+03			NA			NA	
1,3,5-Trimethylbenzene		1.5E+03			NA			NA	
Toluene		4.7E+04			NA			NA	
Xylene (total)		2.5E+03			NA			NA	
Acenaphthene		4.5E+04			NA			NA	
Anthracene		2.3E+05			NA			NA	
Benzo(a)anthracene		2.1E+02			NA			NA	
Benzo (a) Pyrene		2.1E+01			NA			NA	
Benzo(b)fluoranthene		2.1E+02			NA			NA	
Benzo(k)fluoranthene		2.1E+03			NA			NA	
Chrysene		2.1E+04			NA			NA	
Ethylene dibromide		1.6E+00			NA			NA	
Fluoranthene		3.0E+04			NA			NA	
Fluorene		3.0E+04			NA			NA	
Indeno (1,2,3-cd) Pyrene		2.1E+02			NA			NA	
1-Methylnapthalene		7.3E+02			NA			NA	
2-Methylnapthalene		3.0E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
Pyrene		2.3E+04			NA			NA	
Arsenic		3.0E+01			NA			NA	
Barium		2.2E+05			NA			NA	
Beryllium		2.3E+03			NA			NA	
Cadmium (diet)		1.0E+02			NA			NA	
Cadmium (water)		NA			NA			NA	
Chromium (III)		1.8E+06			NA			NA	
Chromium (VI)		6.3E+01			NA			NA	
Chromium (total)		NA			NA			NA	
Lead		8.0E+02			NA			NA	
Manganese (non-diet)		2.6E+04			NA			NA	
Mercury (elemental)		4.6E+01			NA			NA	
Selenium		5.8E+03			NA			NA	
Silver		5.8E+03			NA			NA	

NDRBCA REPORT	FORM NO. 15 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		8.0E+01			NA			NA	
Pentachloroethane		3.6E+02			NA			NA	
1,1,1,2-Tetrachloroethane		8.8E+01			NA			NA	
1,1,2,2-Tetrachloroethane		2.7E+01			NA			NA	
1,1,2-Trichloroethane		5.0E+01			NA			NA	
1,1,1-Trichloroethane		3.6E+04			NA			NA	
1,2-Dichloroethane		2.0E+01			NA			NA	
1,1-Dichloroethane		1.6E+02			NA			NA	
Chloroethane		2.3E+04			NA			NA	
Perchloroethene (PCE)		1.0E+03			NA			NA	
Trichloroethene (TCE)		6.0E+01			NA			NA	
1,1-Dichloroethene		1.0E+03			NA			NA	
cis-1,2-Dichloroethene		2.3E+03			NA			NA	
trans-1,2-Dichloroethene		3.0E+02			NA			NA	
VinyL chloride (VC)		1.7E+01			NA			NA	
Bromide		NA			NA			NA	
Chloride		NA			NA			NA	
Nitrate as total nitrogen		1.9E+06			NA			NA	
Strontium		7.0E+05			NA			NA	

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

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Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - ON-SITE CONSTRUCTION WORKER (FUTURE CONDITIONS)		
Facility ID number (if any):			
Date form completed:			
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)			
CHEMICALS OF CONCERN	**SURFACE SOIL**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**
	Rep. Conc. [mg/kg]	SLs [mg/kg]	**E/NE**
Benzene			
Ethylbenzene			
Isopropylbenzene (Cumene)			
Methyl tert-Butyl Ether (MTBE)			
Naphthalene			
1,2,4-Trimethylbenzene			
1,3,5-Trimethylbenzene			
Toluene			
Xylene (total)			
Acenaphthene			
Anthracene			
Benzo(a)anthracene			
Benzo (a) Pyrene			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Chrysene			
Ethylene dibromide			
Fluoranthene			
Fluorene			
Indeno (1,2,3-cd) Pyrene			
1-Methylnapthalene			
2-Methylnapthalene			
Naphthalene			
Pyrene			
Arsenic			
Barium			
Beryllium			
Cadmium (diet)			
Cadmium (water)			
Chromium (III)			
Chromium (VI)			
Chromium (total)			
Lead			
Manganese (non-diet)			
Mercury (elemental)			
Selenium			
Silver			

NDRBCA REPORT	FORM NO. 15 - ON-SITE CONSTRUCTION WORKER (FUTURE CONDITIONS)		
Facility ID number (if any):			
Date form completed:			

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- ON-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE
Hexachloroethane			
Pentachloroethane			
1,1,1,2-Tetrachloroethane			
1,1,2,2-Tetrachloroethane			
1,1,2-Trichloroethane			
1,1,1-Trichloroethane			
1,2-Dichloroethane			
1,1-Dichloroethane			
Chloroethane			
Perchloroethene (PCE)			
Trichloroethene (TCE)			
1,1-Dichloroethene			
cis-1,2-Dichloroethene			
trans-1,2-Dichloroethene			
VinyL chloride (VC)			
Bromide			
Chloride			
Nitrate as total nitrogen			
Strontium			

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - OFF-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion, dermal contact, inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Benzene		1E+01			NA			5E+00			NA	
Ethylbenzene		6E+01			NA			7E+02			NA	
Isopropylbenzene (Cumene)		2E+03			NA			5E+02			NA	
Methyl tert-Butyl Ether (MTBE)		5E+02			NA			1E+02			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
1,2,4-Trimethylbenzene		3.0E+02			NA			5.6E+01			NA	
1,3,5-Trimethylbenzene		2.7E+02			NA			6.0E+01			NA	
Toluene		4.9E+03			NA			1.0E+03			NA	
Xylene (total)		5.8E+02			NA			1.0E+04			NA	
Acenaphthene		3.6E+03			NA			5.3E+02			NA	
Anthracene		1.8E+04			NA			1.8E+03			NA	
Benzo(a)anthracene		1.1E+01			NA			3.0E-01			NA	
Benzo (a) Pyrene		1.1E+00			NA			2.0E-01			NA	
Benzo(b)fluoranthene		1.1E+01			NA			2.5E+00			NA	
Benzo(k)fluoranthene		1.1E+02			NA			2.5E+01			NA	
Chrysene		1.1E+03			NA			2.5E+02			NA	
Ethylene dibromide		3.6E-01			NA			5.0E-02			NA	
Fluoranthene		2.4E+03			NA			8.0E+02			NA	
Fluorene		2.4E+03			NA			2.9E+02			NA	
Indeno (1,2,3-cd) Pyrene		1.1E+01			NA			2.5E+00			NA	
1-Methylnapthalene		1.8E+02			NA			1.1E+01			NA	
2-Methylnapthalene		2.4E+02			NA			3.6E+01			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
Pyrene		1.8E+03			NA			1.2E+02			NA	
Arsenic		6.8E+00			NA			1.0E+01			NA	
Barium		1.5E+04			NA			2.0E+03			NA	
Beryllium		1.6E+02			NA			4.0E+00			NA	
Cadmium (diet)		7.1E+00			NA			NA			NA	
Cadmium (water)		NA			NA			5.0E+00			NA	
Chromium (III)		1.2E+05			NA			2.2E+04			NA	
Chromium (VI)		3.0E+00			NA			3.5E-01			NA	
Chromium (total)		NA			NA			1.0E+02			NA	
Lead		4.0E+02			NA			1.5E+01			NA	
Manganese (non-diet)		1.8E+03			NA			4.3E+02			NA	
Mercury (elemental)		1.1E+01			NA			2.0E+00			NA	
Selenium		3.9E+02			NA			5.0E+01			NA	
Silver		3.9E+02			NA			9.4E+01			NA	

NDRBCA REPORT	FORM NO. 15 - OFF-SITE RESIDENT (CURRENT CONDITIONS)

Facility ID number (if any): **Site address:**

Date form completed: **Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion, dermal contact, inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		1.8E+01			NA			3.3E+00			NA	
Pentachloroethane		7.7E+01			NA			6.5E+00			NA	
1,1,1,2-Tetrachloroethane		2.0E+01			NA			5.7E+00			NA	
1,1,2,2-Tetrachloroethane		6.0E+00			NA			7.6E-01			NA	
1,1,2-Trichloroethane		1.1E+01			NA			5.0E+00			NA	
1,1,1-Trichloroethane		8.1E+03			NA			2.0E+02			NA	
1,2-Dichloroethane		4.6E+00			NA			5.0E+00			NA	
1,1-Dichloroethane		3.6E+01			NA			2.8E+01			NA	
Chloroethane		5.4E+03			NA			8.3E+03			NA	
Perchloroethene (PCE)		2.4E+02			NA			5.0E+00			NA	
Trichloroethene (TCE)		9.4E+00			NA			5.0E+00			NA	
1,1-Dichloroethene		2.3E+02			NA			7.0E+00			NA	
cis-1,2-Dichloroethene		1.6E+02			NA			7.0E+01			NA	
trans-1,2-Dichloroethene		7.0E+01			NA			1.0E+02			NA	
VinyL chloride (VC)		5.9E-01			NA			2.0E+00			NA	
Bromide		NA			NA			NA			NA	
Chloride		NA			NA			NA			NA	
Nitrate as total nitrogen		1.3E+05			NA			1.0E+04			NA	
Strontium		4.7E+04			NA			1.2E+04			NA	

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Page 5 of ______

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [μg/L]	SLs [μg/L]	E/NE
Benzene		5E+01			NA			NA	
Ethylbenzene		3E+02			NA			NA	
Isopropylbenzene (Cumene)		1E+04			NA			NA	
Methyl tert-Butyl Ether (MTBE)		2E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
1,2,4-Trimethylbenzene		1.8E+03			NA			NA	
1,3,5-Trimethylbenzene		1.5E+03			NA			NA	
Toluene		4.7E+04			NA			NA	
Xylene (total)		2.5E+03			NA			NA	
Acenaphthene		4.5E+04			NA			NA	
Anthracene		2.3E+05			NA			NA	
Benzo(a)anthracene		2.1E+02			NA			NA	
Benzo (a) Pyrene		2.1E+01			NA			NA	
Benzo(b)fluoranthene		2.1E+02			NA			NA	
Benzo(k)fluoranthene		2.1E+03			NA			NA	
Chrysene		2.1E+04			NA			NA	
Ethylene dibromide		1.6E+00			NA			NA	
Fluoranthene		3.0E+04			NA			NA	
Fluorene		3.0E+04			NA			NA	
Indeno (1,2,3-cd) Pyrene		2.1E+02			NA			NA	
1-Methylnapthalene		7.3E+02			NA			NA	
2-Methylnapthalene		3.0E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
Pyrene		2.3E+04			NA			NA	
Arsenic		3.0E+01			NA			NA	
Barium		2.2E+05			NA			NA	
Beryllium		2.3E+03			NA			NA	
Cadmium (diet)		1.0E+02			NA			NA	
Cadmium (water)		NA			NA			NA	
Chromium (III)		1.8E+06			NA			NA	
Chromium (VI)		6.3E+01			NA			NA	
Chromium (total)		NA			NA			NA	
Lead		8.0E+02			NA			NA	
Manganese (non-diet)		2.6E+04			NA			NA	
Mercury (elemental)		4.6E+01			NA			NA	
Selenium		5.8E+03			NA			NA	
Silver		5.8E+03			NA			NA	

NDRBCA REPORT	FORM NO. 15 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		8.0E+01			NA			NA	
Pentachloroethane		3.6E+02			NA			NA	
1,1,1,2-Tetrachloroethane		8.8E+01			NA			NA	
1,1,2,2-Tetrachloroethane		2.7E+01			NA			NA	
1,1,2-Trichloroethane		5.0E+01			NA			NA	
1,1,1-Trichloroethane		3.6E+04			NA			NA	
1,2-Dichloroethane		2.0E+01			NA			NA	
1,1-Dichloroethane		1.6E+02			NA			NA	
Chloroethane		2.3E+04			NA			NA	
Perchloroethene (PCE)		1.0E+03			NA			NA	
Trichloroethene (TCE)		6.0E+01			NA			NA	
1,1-Dichloroethene		1.0E+03			NA			NA	
cis-1,2-Dichloroethene		2.3E+03			NA			NA	
trans-1,2-Dichloroethene		3.0E+02			NA			NA	
VinyL chloride (VC)		1.7E+01			NA			NA	
Bromide		NA			NA			NA	
Chloride		NA			NA			NA	
Nitrate as total nitrogen		1.9E+06			NA			NA	
Strontium		7.0E+05			NA			NA	

Notes:
E Representative concentration exceeds screening level (SL).
NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)		
Facility ID number (if any):			
Date form completed:			

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE
Benzene			
Ethylbenzene			
Isopropylbenzene (Cumene)			
Methyl tert-Butyl Ether (MTBE)			
Naphthalene			
1,2,4-Trimethylbenzene			
1,3,5-Trimethylbenzene			
Toluene			
Xylene (total)			
Acenaphthene			
Anthracene			
Benzo(a)anthracene			
Benzo (a) Pyrene			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Chrysene			
Ethylene dibromide			
Fluoranthene			
Fluorene			
Indeno (1,2,3-cd) Pyrene			
1-Methylnapthalene			
2-Methylnapthalene			
Naphthalene			
Pyrene			
Arsenic			
Barium			
Beryllium			
Cadmium (diet)			
Cadmium (water)			
Chromium (III)			
Chromium (VI)			
Chromium (total)			
Lead			
Manganese (non-diet)			
Mercury (elemental)			
Selenium			
Silver			

NDRBCA REPORT	FORM NO. 15 - OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)		
Facility ID number (if any):			
Date form completed:			
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)			
CHEMICALS OF CONCERN	**SURFACE SOIL**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**
	Rep. Conc. [mg/kg]	SLs [mg/kg]	**E/NE**
Hexachloroethane			
Pentachloroethane			
1,1,1,2-Tetrachloroethane			
1,1,2,2-Tetrachloroethane			
1,1,2-Trichloroethane			
1,1,1-Trichloroethane			
1,2-Dichloroethane			
1,1-Dichloroethane			
Chloroethane			
Perchloroethene (PCE)			
Trichloroethene (TCE)			
1,1-Dichloroethene			
cis-1,2-Dichloroethene			
trans-1,2-Dichloroethene			
VinyL chloride (VC)			
Bromide			
Chloride			
Nitrate as total nitrogen			
Strontium			

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - OFF-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any): **Site address:**	
Date form completed: **Form completed by:**	

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion, dermal contact, inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Benzene		1E+01			NA			5E+00			NA	
Ethylbenzene		6E+01			NA			7E+02			NA	
Isopropylbenzene (Cumene)		2E+03			NA			5E+02			NA	
Methyl tert-Butyl Ether (MTBE)		5E+02			NA			1E+02			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
1,2,4-Trimethylbenzene		3.0E+02			NA			5.6E+01			NA	
1,3,5-Trimethylbenzene		2.7E+02			NA			6.0E+01			NA	
Toluene		4.9E+03			NA			1.0E+03			NA	
Xylene (total)		5.8E+02			NA			1.0E+04			NA	
Acenaphthene		3.6E+03			NA			5.3E+02			NA	
Anthracene		1.8E+04			NA			1.8E+03			NA	
Benzo(a)anthracene		1.1E+01			NA			3.0E-01			NA	
Benzo (a) Pyrene		1.1E+00			NA			2.0E-01			NA	
Benzo(b)fluoranthene		1.1E+01			NA			2.5E+00			NA	
Benzo(k)fluoranthene		1.1E+02			NA			2.5E+01			NA	
Chrysene		1.1E+03			NA			2.5E+02			NA	
Ethylene dibromide		3.6E-01			NA			5.0E-02			NA	
Fluoranthene		2.4E+03			NA			8.0E+02			NA	
Fluorene		2.4E+03			NA			2.9E+02			NA	
Indeno (1,2,3-cd) Pyrene		1.1E+01			NA			2.5E+00			NA	
1-Methylnapthalene		1.8E+02			NA			1.1E+01			NA	
2-Methylnapthalene		2.4E+02			NA			3.6E+01			NA	
Naphthalene		2.0E+01			NA			1.2E+00			NA	
Pyrene		1.8E+03			NA			1.2E+02			NA	
Arsenic		6.8E+00			NA			1.0E+01			NA	
Barium		1.5E+04			NA			2.0E+03			NA	
Beryllium		1.6E+02			NA			4.0E+00			NA	
Cadmium (diet)		7.1E+00			NA			NA			NA	
Cadmium (water)		NA			NA			5.0E+00			NA	
Chromium (III)		1.2E+05			NA			2.2E+04			NA	
Chromium (VI)		3.0E+00			NA			3.5E-01			NA	
Chromium (total)		NA			NA			1.0E+02			NA	
Lead		4.0E+02			NA			1.5E+01			NA	
Manganese (non-diet)		1.8E+03			NA			4.3E+02			NA	
Mercury (elemental)		1.1E+01			NA			2.0E+00			NA	
Selenium		3.9E+02			NA			5.0E+01			NA	
Silver		3.9E+02			NA			9.4E+01			NA	

NDRBCA REPORT	FORM NO. 15 - OFF-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion, dermal contact, outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion, dermal contact, inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		1.8E+01			NA			3.3E+00			NA	
Pentachloroethane		7.7E+01			NA			6.5E+00			NA	
1,1,1,2-Tetrachloroethane		2.0E+01			NA			5.7E+00			NA	
1,1,2,2-Tetrachloroethane		6.0E+00			NA			7.6E-01			NA	
1,1,2-Trichloroethane		1.1E+01			NA			5.0E+00			NA	
1,1,1-Trichloroethane		8.1E+03			NA			2.0E+02			NA	
1,2-Dichloroethane		4.6E+00			NA			5.0E+00			NA	
1,1-Dichloroethane		3.6E+01			NA			2.8E+01			NA	
Chloroethane		5.4E+03			NA			8.3E+03			NA	
Perchloroethene (PCE)		2.4E+02			NA			5.0E+00			NA	
Trichloroethene (TCE)		9.4E+00			NA			5.0E+00			NA	
1,1-Dichloroethene		2.3E+02			NA			7.0E+00			NA	
cis-1,2-Dichloroethene		1.6E+02			NA			7.0E+01			NA	
trans-1,2-Dichloroethene		7.0E+01			NA			1.0E+02			NA	
VinyL chloride (VC)		5.9E-01			NA			2.0E+00			NA	
Bromide		NA			NA			NA			NA	
Chloride		NA			NA			NA			NA	
Nitrate as total nitrogen		1.3E+05			NA			1.0E+04			NA	
Strontium		4.7E+04			NA			1.2E+04			NA	

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

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Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Benzene		5E+01			NA			NA	
Ethylbenzene		3E+02			NA			NA	
Isopropylbenzene (Cumene)		1E+04			NA			NA	
Methyl tert-Butyl Ether (MTBE)		2E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
1,2,4-Trimethylbenzene		1.8E+03			NA			NA	
1,3,5-Trimethylbenzene		1.5E+03			NA			NA	
Toluene		4.7E+04			NA			NA	
Xylene (total)		2.5E+03			NA			NA	
Acenaphthene		4.5E+04			NA			NA	
Anthracene		2.3E+05			NA			NA	
Benzo(a)anthracene		2.1E+02			NA			NA	
Benzo (a) Pyrene		2.1E+01			NA			NA	
Benzo(b)fluoranthene		2.1E+02			NA			NA	
Benzo(k)fluoranthene		2.1E+03			NA			NA	
Chrysene		2.1E+04			NA			NA	
Ethylene dibromide		1.6E+00			NA			NA	
Fluoranthene		3.0E+04			NA			NA	
Fluorene		3.0E+04			NA			NA	
Indeno (1,2,3-cd) Pyrene		2.1E+02			NA			NA	
1-Methylnapthalene		7.3E+02			NA			NA	
2-Methylnapthalene		3.0E+03			NA			NA	
Naphthalene		8.6E+01			NA			NA	
Pyrene		2.3E+04			NA			NA	
Arsenic		3.0E+01			NA			NA	
Barium		2.2E+05			NA			NA	
Beryllium		2.3E+03			NA			NA	
Cadmium (diet)		1.0E+02			NA			NA	
Cadmium (water)		NA			NA			NA	
Chromium (III)		1.8E+06			NA			NA	
Chromium (VI)		6.3E+01			NA			NA	
Chromium (total)		NA			NA			NA	
Lead		8.0E+02			NA			NA	
Manganese (non-diet)		2.6E+04			NA			NA	
Mercury (elemental)		4.6E+01			NA			NA	
Selenium		5.8E+03			NA			NA	
Silver		5.8E+03			NA			NA	

NDRBCA REPORT	FORM NO. 15 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE	Rep. Conc. [µg/L]	SLs [µg/L]	E/NE
Hexachloroethane		8.0E+01			NA			NA	
Pentachloroethane		3.6E+02			NA			NA	
1,1,1,2-Tetrachloroethane		8.8E+01			NA			NA	
1,1,2,2-Tetrachloroethane		2.7E+01			NA			NA	
1,1,2-Trichloroethane		5.0E+01			NA			NA	
1,1,1-Trichloroethane		3.6E+04			NA			NA	
1,2-Dichloroethane		2.0E+01			NA			NA	
1,1-Dichloroethane		1.6E+02			NA			NA	
Chloroethane		2.3E+04			NA			NA	
Perchloroethene (PCE)		1.0E+03			NA			NA	
Trichloroethene (TCE)		6.0E+01			NA			NA	
1,1-Dichloroethene		1.0E+03			NA			NA	
cis-1,2-Dichloroethene		2.3E+03			NA			NA	
trans-1,2-Dichloroethene		3.0E+02			NA			NA	
VinyL chloride (VC)		1.7E+01			NA			NA	
Bromide		NA			NA			NA	
Chloride		NA			NA			NA	
Nitrate as total nitrogen		1.9E+06			NA			NA	
Strontium		7.0E+05			NA			NA	

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Page 8 of ____

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT	FORM NO. 15 - OFF-SITE CONSTRUCTION WORKER (FUTURE CONDITIONS)		
Facility ID number (if any):			
Date form completed:			
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)			
CHEMICALS OF CONCERN	**SURFACE SOIL**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**
	Rep. Conc. [mg/kg]	SLs [mg/kg]	**E/NE**
Benzene			
Ethylbenzene			
Isopropylbenzene (Cumene)			
Methyl tert-Butyl Ether (MTBE)			
Naphthalene			
1,2,4-Trimethylbenzene			
1,3,5-Trimethylbenzene			
Toluene			
Xylene (total)			
Acenaphthene			
Anthracene			
Benzo(a)anthracene			
Benzo (a) Pyrene			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Chrysene			
Ethylene dibromide			
Fluoranthene			
Fluorene			
Indeno (1,2,3-cd) Pyrene			
1-Methylnapthalene			
2-Methylnapthalene			
Naphthalene			
Pyrene			
Arsenic			
Barium			
Beryllium			
Cadmium (diet)			
Cadmium (water)			
Chromium (III)			
Chromium (VI)			
Chromium (total)			
Lead			
Manganese (non-diet)			
Mercury (elemental)			
Selenium			
Silver			

NDRBCA REPORT	FORM NO. 15 - OFF-SITE CONSTRUCTION WORKER (FUTURE CONDITIONS)

Facility ID number (if any):

Date form completed:

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 RBSLs- OFF-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC
	Rep. Conc. [mg/kg]	SLs [mg/kg]	E/NE
Hexachloroethane			
Pentachloroethane			
1,1,1,2-Tetrachloroethane			
1,1,2,2-Tetrachloroethane			
1,1,2-Trichloroethane			
1,1,1-Trichloroethane			
1,2-Dichloroethane			
1,1-Dichloroethane			
Chloroethane			
Perchloroethene (PCE)			
Trichloroethene (TCE)			
1,1-Dichloroethene			
cis-1,2-Dichloroethene			
trans-1,2-Dichloroethene			
VinyL chloride (VC)			
Bromide			
Chloride			
Nitrate as total nitrogen			
Strontium			

Notes:

E Representative concentration exceeds screening level (SL).

NE Representative concentration does not exceed SL.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report

NDRBCA REPORT												
											FORM NO. 15 - SUMMARY OF EXCEEDANCES	
Facility ID number (if any):						**Site address:**						
Date form completed:						**Form completed by:**						
SUMMARY OF EXCEEDANCES												
ROUTES OF EXPOSURE	**ON-SITE RECEPTOR**						**OFF-SITE RECEPTOR**					
	CURRENT CONDITIONS			**REASONABLY ANTICIPATED FUTURE CONDITIONS**			**CURRENT CONDITIONS**			**REASONABLY ANTICIPATED FUTURE CONDITIONS**		
	Resident	**Commercial/ Industrial Worker**	**Construction Worker**	**Resident**	**Commercial/ Industrial Worker**	**Construction Worker**	**Resident**	**Commercial/ Industrial Worker**	**Construction Worker**	**Resident**	**Commercial/ Industrial Worker**	**Construction Worker**
SURFACE SOIL/ SOIL UP TO DEPTH OF CONSTRUCTION FOR CONSTRUCTION WORKER												
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates												
SUBSURFACE SOIL (SOIL VAPOR)												
Indoor inhalation of vapors			NA			NA			NA			NA
GROUNDWATER												
Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)			NA			NA			NA			NA
Indoor inhalation of vapors			NA			NA			NA			NA

Notes

E: exceeded **NE**: Not exceeded **NA**: Not applicable

NDRBCA REPORT **FORM NO. 16**

Facility ID number (if any): **Site address:**

Date form completed: **Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 GROUNDWATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOIL SOURCE			COMPARISON FOR GROUNDWATER SOURCE			COMPARISON FOR POINT OF DEMONSTRATION (POD) WELLS								
	Soil Source Rep. Conc. [1]	Allowable Soil Conc. [2]	NC	GW Source Rep. Conc. [3]	Allowable GW Conc. at the Source [4]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC
	[mg/kg]	[mg/kg]	E/NE	[µg/L]	[µg/L]	E/NE	[µg/L]	[µg/L]	E/NE	[µg/L]	[µg/L]	E/NE	[µg/L]	[µg/L]	E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Benzene															
Ethylbenzene															
Isopropylbenzene (Cumene)															
Methyl tert-Butyl Ether (MTBE)															
Naphthalene															
1,2,4-Trimethylbenzene															
1,3,5-Trimethylbenzene															
Toluene															
Xylene (total)															
Acenaphthene															
Anthracene															
Benzo(a)anthracene															
Benzo (a) Pyrene															
Benzo(b)fluoranthene															
Benzo(k)fluoranthene															
Chrysene															
Ethylene dibromide															
Fluoranthene															
Fluorene															
Indeno (1,2,3-cd) Pyrene															
1-Methylnapthalene															
2-Methylnapthalene															
Naphthalene															
Pyrene															
Arsenic															
Barium															
Beryllium															
Cadmium (diet)															
Cadmium (water)															
Chromium (III)															
Chromium (VI)															
Chromium (total)															
Lead															
Manganese (non-diet)															
Mercury (elemental)															
Selenium															

NDRBCA REPORT	FORM NO. 16
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 1 GROUNDWATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOIL SOURCE			COMPARISON FOR GROUNDWATER SOURCE			COMPARISON FOR POINT OF DEMONSTRATION (POD) WELLS								
	Soil Source Rep. Conc. [1] [mg/kg]	Allowable Soil Conc. [2] [mg/kg]	NC E/NE	GW Source Rep. Conc. [3] [µg/L]	Allowable GW Conc. at the Source [4] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Silver															
Hexachloroethane															
Pentachloroethane															
1,1,1,2-Tetrachloroethane															
1,1,2,2-Tetrachloroethane															
1,1,2-Trichloroethane															
1,1,1-Trichloroethane															
1,2-Dichloroethane															
1,1-Dichloroethane															
Chloroethane															
Perchloroethene (PCE)															
Trichloroethene (TCE)															
1,1-Dichloroethene															
cis-1,2-Dichloroethene															
trans-1,2-Dichloroethene															
VinyL chloride (VC)															
Bromide															
Chloride															
Nitrate as total nitrogen															
Strontium															

NOTE: Use the ***NDRBCA Computational Software*** to calculate the (i) soil source conc., (ii) GW source conc., and (iii) the point of demonstration (POD) well conc.

1: The soil source representative concentrations have to be calculated and entered here.

2: Allowable soil concentrations at the source protective of groundwater at the POE.

3: The groundwater source representative concentrations have to be calculated and entered here.

4: Allowable groundwater concentrations at the source protective of groundwater at the POE.

5: Represents the representative concentrations in the POD well

6: Represents the allowable groundwater concentrations at a POD protective of a POE.

For representative concentrations, refer **Attachment 8**:

E: Representative on-site concentration exceeds calculated POD well concentration.

NE: Representative on-site concentration does not exceed calculated POD well concentration.

Attachments: (i) Figure 20: Showing the location(s) of the soil source(s), location of POE, and location(s) of POD. (ii) Attachment 8: Documentation for Calculation of Representative Concentrations

NDRBCA REPORT **FORM NO. 17**

Facility ID number (if any): **Site address:**

Date form completed: **Form completed by:**

TIER 1 SURFACE WATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOIL SOURCE			COMPARISON FOR GROUNDWATER SOURCE			COMPARISON FOR POD WELL AT THE STREAM BANK			COMPARISON FOR POD WELLS BETWEEN THE SOURCE AND THE STREAM BANK					
	Soil Source Rep. Conc. [1] [mg/kg]	Allowable Soil Conc. [2] [mg/kg]	NC E/NE	GW Source Rep. Conc. [3] [µg/L]	Allowable GW Conc. at the Source [4] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Benzene															
Ethylbenzene															
Isopropylbenzene (Cumene)															
Methyl tert-Butyl Ether (MTBE)															
Naphthalene															
1,2,4-Trimethylbenzene															
1,3,5-Trimethylbenzene															
Toluene															
Xylene (total)															
Acenaphthene															
Anthracene															
Benzo(a)anthracene															
Benzo (a) Pyrene															
Benzo(b)fluoranthene															
Benzo(k)fluoranthene															
Chrysene															
Ethylene dibromide															
Fluoranthene															
Fluorene															
Indeno (1,2,3-cd) Pyrene															
1-Methylnapthalene															
2-Methylnapthalene															
Naphthalene															
Pyrene															
Arsenic															
Barium															
Beryllium															
Cadmium (diet)															
Cadmium (water)															
Chromium (III)															
Chromium (VI)															
Chromium (total)															
Lead															
Manganese (non-diet)															
Mercury (elemental)															
Selenium															

NDRBCA REPORT	FORM NO. 17

Facility ID number (if any):	Site address:
Date form completed:	**Form completed by:**

TIER 1 SURFACE WATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOIL SOURCE			COMPARISON FOR GROUNDWATER SOURCE			COMPARISON FOR POD WELL AT THE STREAM BANK			COMPARISON FOR POD WELLS BETWEEN THE SOURCE AND THE STREAM BANK					
	Soil Source Rep. Conc. [1]	Allowable Soil Conc. [2]	NC	GW Source Rep. Conc. [3]	Allowable GW Conc. at the Source [4]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC
	[mg/kg]	[mg/kg]	E/NE	[μg/L]	[μg/L]	E/NE	[μg/L]	[μg/L]	E/NE	[μg/L]	[μg/L]	E/NE	[μg/L]	[μg/L]	E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Silver															
Hexachloroethane															
Pentachloroethane															
1,1,1,2-Tetrachloroethane															
1,1,2,2-Tetrachloroethane															
1,1,2-Trichloroethane															
1,1,1-Trichloroethane															
1,2-Dichloroethane															
1,1-Dichloroethane															
Chloroethane															
Perchloroethene (PCE)															
Trichloroethene (TCE)															
1,1-Dichloroethene															
cis-1,2-Dichloroethene															
trans-1,2-Dichloroethene															
VinyL chloride (VC)															
Bromide															
Chloride															
Nitrate as total nitrogen															
Strontium															

NOTE: Use the ***NDRBCA Computational Software*** to calculate the (i) soil source conc., (ii) GW source conc., and (iii) the point of demonstration (POD) well conc.

1: The soil source representative concentrations have to be calculated and entered here.

2: Allowable soil concentrations at the source protective of surface water at the POE.

3: The groundwater source representative concentrations have to be calculated and entered here.

4: Allowable groundwater concentrations at the source protective of surface water at the POE.

5: Represents the representative concentrations in the POD well

6: Represents the allowable groundwater concentrations at a POD protective of surface water at the POE.

For representative concentrations, refer **Attachment 8**:

E: Representative on-site concentration exceeds calculated POD well concentration.

NE: Representative on-site concentration does not exceed calculated POD well concentration.

Attachments: (i) Figure 21: Showing the location(s) of the soil source(s), location of POE, and location(s) of POD. (ii) Attachment 8: Documentation for Calculation of Representative Concentrations

NDRBCA REPORT	FORM NO. 18(a)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CONCLUSION AND RECOMMENDATION (ON-SITE RECEPTORS)

Instructions: *Based on the results of Tier 1 Evaluation, (refer Form 15(9)), discuss each media, pathway and receptor combination that exceeds the Tier 1 screening levels. For each exceedance, propose actions to manage the risk. Actions can include (i) Tier 2 evaluation, (ii) environmental covenant to eliminate the pathway, (iii) an active remediation or a combination of these.*

Media	Receptor	Complete Exposure Pathway for Which Representative Conc. Exceeds Screening Level	Proposed Management Strategy
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other

ADDITIONAL NOTES FOR CONCLUSION AND RECOMMENDATION

NDRBCA REPORT	FORM NO. 18(a)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CONCLUSION AND RECOMMENDATION (OFF-SITE RECEPTORS)

Instructions: *Based on the results of Tier 1 Evaluation, (refer Form 15(9)), discuss each media, pathway and receptor combination that exceeds the Tier 1 screening levels. For each exceedance, propose actions to manage the risk. Actions can include (i) Tier 2 evaluation, (ii) environmental covenant to eliminate the pathway, (iii) an active remediation or a combination of these.*

Media	Receptor	Complete Exposure Pathway for Which Representative Conc. Exceeds Screening Level	Proposed Management Strategy
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other
			☐ Tier 2 Evaluation ☐ Environmental covenant ☐ Active remediation ☐ Other

ADDITIONAL NOTES FOR CONCLUSION AND RECOMMENDATION

NDRBCA REPORT	FORM NO. 19(a)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CORRECTIVE ACTION (SOIL EXCAVATION)

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ **I** ☐ **P**	☐ **I** ☐ **P**	☐ **I** ☐ **P**	☐ **I** ☐ **P**
Date of soil excavation				
Area excavated (sq ft)				
Depth of soil excavated (ft)				
Amount of soil excavated (ton(s)/yd(s)^3)				
Soil disposed off-site/on-site				
Volume of liquid removed (gallon(s))				
Material used to fill the excavation				
No. of post excavation floor soil samples				
No. of post excavation sidewall soil samples				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR SOIL EXCAVATION

Attachments: (1) Figure 12: Figure showing areas of excavation; (2) Figure 13: Figure showing location of post excavation soil samples; (3) Attachment 5: Documentation of completed soil disposal manifests

NDRBCA REPORT				FORM NO. 19(b)
Facility ID number (if any):		**Site address:**		
Date form completed:		**Form completed by:**		

CORRECTIVE ACTION (PUMP AND TREAT ACTIVITY)

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P
System start date or planned start date				
Date system temporarily stopped				
Date system restarted				
Date pump and treat system permanently stopped				
Number of extraction wells				
Volume of liquid removed				
Mass of chemicals removed (if applicable)				
Details for treatment of extracted liquids				
Details of disposal of treated liquid				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR PUMP AND TREAT ACTIVITY

Attachments: (1) Figure 14: Figure showing location of pumping wells; (2) Attachment 6: Operation and maintenance plan as appropriate; (3) Attachment 7: Monitoring plan as appropriate.

NDRBCA REPORT	FORM NO. 19(c)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CORRECTIVE ACTION (AIR SPARGE SOIL VAPOR EXTRACTION)

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P
System start date or planned start date				
Date system temporarily stopped				
Date system restarted				
Date system permanently stopped				
Number of extraction wells				
Volume of liquid removed				
Mass of chemicals removed (if applicable)				
Details for treatment of extracted liquids				
Details of disposal of treated liquid				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR AIR SPARGE SOIL VAPOR EXTRACTION

Attachments: (1) Figure 15: Figure showing location of vapor excavation points. (2) Attachment 6: Operation and maintenance plan as appropriate; (3) Attachment 7: Monitoring plan as appropriate.

NDRBCA REPORT		FORM NO. 19(d)
Facility ID number (if any):	**Site address:**	
Date form completed:	**Form completed by:**	

CORRECTIVE ACTION (SOIL VAPOR EXTRACTION BY VACUUM TRUCK)

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P
Date of soil vapor extraction				
No. of vapor extraction wells				
Vapor extraction well ID(s)				
Volume of vapor removed				
Mass of chemicals removed (if available)				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR SOIL VAPOR EXTRACTION BY VACUUM TRUCK

Attachments: (1) Figure 15: Figure showing location of vapor excavation points; (2) Attachment 6: Operation and maintenance plan as appropriate; (3) Attachment 7: Monitoring plan as appropriate.

NDRBCA REPORT		FORM NO. 19(e)
Facility ID number (if any):	**Site address:**	
Date form completed:	**Form completed by:**	

CORRECTIVE ACTION (LNAPL REMOVAL)

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ **I** ☐ **P**	☐ **I** ☐ **P**	☐ **I** ☐ **P**	☐ **I** ☐ **P**
Date or period of LNAPL removal				
Method of removal (bailer, vac truck etc.)				
No. of LNAPL removal wells				
LNAPL removal well ID(s)				
Total volume of water recovered with LNAPL				
Total volume of LNAPL recovered				
Describe how the recovered LNAPL was disposed				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR LNAPL REMOVAL

Attachments: (1) Table 8: LNAPL removal data; (2) Figure 7: Figure showing suspected source(s) of LNAPL; (3) Attachment 1: Completed LNAPL disposal manifests

NDRBCA REPORT	FORM NO. 19(f)

Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CORRECTIVE ACTION (ENHANCED MONITORED NATURAL ATTENUATION (EMNA))

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P
Date of pilot test, if any				
Date of full scale injection event				
No. of injection points				
Injection point ID(s)				
Chemical injected (oxygen, ozone, hydrogen peroxide, sulfate, other specify)				
Quantity of chemical injected				
Wells used to monitor progress of remediation				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR ENHANCED MONITORED NATURAL ATTENUATION

Attachments: (1) Figure 16: Figure showing location of injection of injection points for EMNA; (2) Attachment 6: Operation and maintenance plan as appropriate; (3) Attachment 7: Monitoring plan as appropriate.

NDRBCA REPORT	FORM NO. 19(g)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CORRECTIVE ACTION (DUAL/MULTI PHASE EXTRACTION)

Item	Event 1	Event 2	Event 3	Event 4
Implemented (I) or Proposed (P)	☐ **I** ☐ **P**	☐ **I** ☐ **P**	☐ **I** ☐ **P**	☐ **I** ☐ **P**
Date of pilot test, if any				
Date of full scale extraction event				
No. of well(s)				
Well ID(s)				
Date extraction started				
Date extraction stopped				
Details for treatment of extracted liquid/vapor				
Details of disposal of treated liquid/vapor				
Qualified consultant contact details:				
Name				
Telephone No.				

ADDITIONAL NOTES FOR DUAL/MULTI PHASE EXTRACTION

Attachments: (1) Figure 17: Location of dual phase extraction wells

NDRBCA REPORT	FORM NO. 19(h)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CORRECTIVE ACTION (ENVIRONMENTAL COVENANT (EC))

Item	IC1	IC2	IC3	IC4	IC5
Implemented (I) or Proposed (P)	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P	☐ I ☐ P
Date implemented					
Type of EC					
Parcel number(s)					
Parcel address(es)					
Area covered by EC					
Exposure pathway prevented or controlled by EC, notice or restriction					
Qualified consultant contact details:					
Name					
Telephone No.					

ADDITIONAL NOTES FOR EC

Attachments: (1) Attachment 10: Documentation of institutional controls, notices, and restrictions (copy of recorded instrument, copy of notice, and proof of providing the notice to the public directly impacted by the release)

NDRBCA REPORT	FORM NO. 20
Facility ID number (if any):	**Form completed by:**
Date form completed:	**Form completed by:**

REFERENCES

NORTH DAKOTA RISK-BASED CORRECTIVE ACTION (NDRBCA)
TIER 2 REPORT FORMS

Considerable care was exercised in developing these Excel based forms. However, the North Dakota Department of Environmental Quality (NDDEQ) or EDGE makes no warranty regarding the accuracy of these forms and shall not be held liable for any damages resulting from its use.

CONTINUE *Version 1.0, December 2022* **EXIT**

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North Dakota Department of Environmental Quality (NDDEQ)

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TITLE

NDRBCA

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COVER PAGE

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24 JUSTIFICATION FOR EXPOSURE FACTORS

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CURRENT COMMERCIAL/INDUSTRIAL WORKER

CURRENT CONSTRUCTION WORKER

FUTURE RESIDENT

FUTURE COMMERCIAL/INDUSTRIAL WORKER

FUTURE CONSTRUCTION WORKER

OFF-SITE RECEPTORS

CURRENT RESIDENT

CURRENT COMMERCIAL/INDUSTRIAL WORKER

CURRENT CONSTRUCTION WORKER

FUTURE RESIDENT

FUTURE COMMERCIAL/INDUSTRIAL WORKER

FUTURE CONSTRUCTION WORKER

SUMMARY OF EXCEEDANCES

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ON-SITE RECEPTORS

OFF-SITE RECEPTORS

North Dakota Risk-Based Corrective Action (NDRBCA) Tier 2 Report Forms

(NDRBCA Draft Tier 2 Forms, September 2022)

Site name:	
Facility ID number (if any):	
Site address:	
Date site discovered:	
Repsonsible Party Information:	
Business name:	
Contact person name:	
Contact person address:	
Contact person Phone No:	
Contact person Email ID:	
Qualified consultant information:	
Name:	
Company name:	
Address:	
Phone No. & Email ID:	
Date form completed:	
Form completed by:	

NDRBCA REPORT					FORM NO. 21
Facility ID number (if any):	**Site address:**				
Date form completed:	**Form completed by:**				
TIER 2 FATE AND TRANSPORT PARAMETERS					
Parameter	**Symbol**	**Unit**	**Tier 1 Default Value**	**Tier 2 Value**	**Comment**
SOIL					
Depth Below Grade to Surficial Soil Source	d_s	cm	60.96		
Depth to Below Grade to Subsurface Soil Source	d_{ts}	cm	100		
Depth to Below Grade to Soil Vapor Measurement	d_{sv}	cm	100		
Total Soil Porosity in Vadose Zone	q_T	cm^3/cm^3-soil	0.40		
Volumetric Water Content in Vadose Zone	q_{ws}	cm^3/cm^3	0.10		
Volumetric Air Content Vadose Zone	q_{as}	cm^3/cm^3	0.30		
Thickness of Vadose Zone	h_v	cm	295		
Dry Soil Bulk Density in Vadose Zone	r_s	g/cm^3	1.64		
Fractional Organic Carbon Content in Vadose Zone	f_{ocv}	g-C/g-soil	0.001		
Total Soil Porosity in Soil in Building Foundation Cracks	q_{Tcrack}	cm^3/cm^3-soil	0.4		
Volumetric Water Content in Soil in Building Foundation Cracks	q_{wcrack}	cm^3/cm^3	0.1		
Volumetric Air Content in Soil in Building Foundation Cracks	q_{acrack}	cm^3/cm^3	0.30		
Total Soil Porosity in Capillary Fringe	q_{Tcap}	cm^3/cm^3-soil	0.40		
Volumetric Water Content in Capillary Fringe	q_{wcap}	cm^3/cm^3	0.36		
Volumetric Air Content in Capillary Fringe	q_{acap}	cm^3/cm^3	0.04		
Thickness of Capillary Fringe	h_c	cm	5		
GROUNDWATER					
Depth to Groundwater	L_{gw}	cm	300		
Length of Groundwater Source Area Parallel to Groundwater Flow Direction	W_{ga}	cm	3,000		
Width of Groundwater Source Area Perpendicular to Groundwater Flow Direction	Y	cm	3,000		
Total Porosity in the Saturated Zone	q_{TS}	cm^3/cm^3	0.4		
Dry Soil Bulk Density in the Saturated Zone	r_{ss}	g/cm^3	1.64		
Fractional Organic Carbon Content in the Saturated Zone	f_{ocs}	g-C/g-soil	0.001		
Groundwater Mixing Zone Thickness	d_{gw}	cm	200		
Hydraulic Conductivity in the Saturated Zone	K	cm/year	730,000		
Hydraulic Gradient in the Saturated Zone	i	cm/cm	0.001		
Groundwater Darcy Velocity	U_{gw}	cm/year	730		
Infiltration Rate of Water Through Vadose Zone	K_f	L/m^3	21		
DOMESTIC WATER USE					
Andelman Volatilization Factor	I	cm/year	0.5		
AMBIENT AIR					
Inverse of Mean Concentration at Center of a 0.5 Acre-Square Source	Q/C	$(g/m^2\text{-}s)/(kg/m^3)$	83.39		
Fraction of Vegetative Cover	V	m^2/m^2	0.5 (50%)		
Mean Annual Wind Speed	U_m	m/s	4.69		
Equivalent Threshold Value of Windspeed	U_t	m/s	11.32		
Windspeed Distribution Function from Cowherd et. al, 1985	F(x)	unitless	0.194		
Exposure Interval	T	seconds	819,936,000		

Note for site-specific values, justification has been provided in Forms 22(1) to 22(3)

NDRBCA REPORT					FORM NO. 21
Facility ID number (if any):		Site address:			
Date form completed:		Form completed by:			

TIER 2 BUILDING PARAMETERS

Parameter	Symbol	Unit	Tier 1 Default Value	Tier 2 Value	Comment
Volumetric Flow Rate of Soil Gas into the Enclosed Space:					
Residential	Q_{soil}	cm^3/s	136.1		
Non-residential	Q_{soil}	cm^3/s	5,626		
Building Foundation/Slab Thickness:					
Residential	L_{crack}	cm	10		
Non-residential	L_{crack}	cm	20		
Air Exchange Rate:					
Residential	ER	l/24 hr	10.8		
Non-residential	ER	l/24 hr	36		
Building Height:					
Residential	H_B	cm	244		
Non-residential	H_B	cm	300		
Building Area:					
Residential	W_B	cm	1,500,000		
Non-residential	W_B	cm	15,000,000		
Depth below Grade to Bottom of Enclosed Space Floor:					
Residential	L_F	cm	10		
Non-residential	L_F	cm	20		
Floor-Wall Seam Gap:					
Residential	w	cm	0.1		
Non-residential	w	cm	0.1		

Note for site-specific values, justification has been provided in Forms 22(1) to 22(3)

NDRBCA REPORT	FORM NO. 22
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

JUSTIFICATION FOR TIER 2 FATE & TRANSPORT (F&T) AND BUILDING PARAMETERS

Parameter	Justification

NDRBCA REPORT	FORM NO. 22

Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

JUSTIFICATION FOR TIER 2 FATE & TRANSPORT (F&T) AND BUILDING PARAMETERS

Parameter	Justification

NDRBCA REPORT	FORM NO. 22
Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

JUSTIFICATION FOR TIER 2 FATE & TRANSPORT (F&T) AND BUILDING PARAMETERS

Parameter	Justification

NDRBCA REPORT				FORM NO. 23	
Facility ID number (if any):		Site address:			
Date form completed:		Form completed by:			

TIER 2 EXPOSURE FACTORS

Exposure Factor	Symbol	Unit	Tier 1 Default Value	Tier 2 Value	Comment
Averaging Time for Carcinogen	AT_c	year	70		
Averaging Time for Non-Carcinogen	AT_{nc}	year	=ED	=ED	NA
Body Weight:					
Resident Child	BW	kg	15		
Resident Adult	BW	kg	80		
Resident Age Segment 0-2	BW	kg	15		
Resident Age Segment 2-6	BW	kg	15		
Resident Age Segment 6-16	BW	kg	80		
Resident Age Segment 16-26	BW	kg	80		
Commercial/Industrial Worker	BW	kg	80		
Construction Worker	BW	kg	NA		
Exposure Duration:					
Resident Child	ED	year	6		
Resident Adult (non-carcinogenic)	ED	year	26		
Resident Adult (carcinogenic)	ED	year	20		
Resident Age Segment 0-2	ED	year	2		
Resident Age Segment 2-6	ED	year	4		
Resident Age Segment 6-16	ED	year	10		
Resident Age Segment 16-26	ED	year	10		
Commercial/Industrial Worker	ED	year	25		
Construction Worker	ED	year	NA		
Exposure Frequency:					
Resident Child	EF	day/year	350		
Resident Adult	EF	day/year	350		
Resident Age Segment 0-2	EF	day/year	350		
Resident Age Segment 2-6	EF	day/year	350		
Resident Age Segment 6-16	EF	day/year	350		
Resident Age Segment 16-26	EF	day/year	350		
Commercial/Industrial Worker	EF	day/year	250		
Construction Worker	EF	day/year	NA		
Soil Ingestion Rate:					
Resident Child	IR_{soil}	mg/day	200		
Resident Adult	IR_{soil}	mg/day	100		
Resident Age Segment 0-2	IR_{soil}	mg/day	200		
Resident Age Segment 2-6	IR_{soil}	mg/day	200		
Resident Age Segment 6-16	IR_{soil}	mg/day	100		
Resident Age Segment 16-26	IR_{soil}	mg/day	100		
Commercial/Industrial Worker	IR_{soil}	mg/day	100		
Construction Worker	IR_{soil}	mg/day	NA		
Groundwater Ingestion Rate:					
Resident Child	IR_w	L/day	0.78		
Resident Adult	IR_w	L/day	2.5		
Resident Age Segment 0-2	IR_w	L/day	0.78		
Resident Age Segment 2-6	IR_w	L/day	0.78		
Resident Age Segment 6-16	IR_w	L/day	2.5		
Resident Age Segment 16-26	IR_w	L/day	2.5		
Fish Ingestion Rate:					
Resident Child	IR_f	mg/day	site-specific		
Resident Adult	IR_f	mg/day	site-specific		
Exposure Time for Indoor Inhalation:					
Resident Child	ET_{in}	hr/day	24		
Resident Adult	ET_{in}	hr/day	24		

Note for site-specific values, justification has been provided in Forms 24(1) to 24(2) NA: Not applicable

NDRBCA REPORT					FORM NO. 23
Facility ID number (if any):		Site address:			
Date form completed:		Form completed by:			

TIER 2 EXPOSURE FACTORS

Exposure Factor	Symbol	Unit	Tier 1 Default	Tier 2 Value	Comment
Exposure Time for Indoor Inhalation:					
Resident Age Segment 0-2	ET_{in}	hr/day	24		
Resident Age Segment 2-6	ET_{in}	hr/day	24		
Resident Age Segment 6-16	ET_{in}	hr/day	24		
Resident Age Segment 16-26	ET_{in}	hr/day	24		
Commercial/Industrial Worker	ET_{in}	hr/day	8		
Exposure Time for Outdoor Inhalation:					
Resident Child	ET_{out}	hr/day	24		
Resident Adult	ET_{out}	hr/day	24		
Resident Age Segment 0-2	ET_{out}	hr/day	24		
Resident Age Segment 2-6	ET_{out}	hr/day	24		
Resident Age Segment 6-16	ET_{out}	hr/day	24		
Resident Age Segment 16-26	ET_{out}	hr/day	24		
Commercial/Industrial Worker	ET_{out}	hr/day	8		
Construction Worker	ET_{out}	hr/day	NA		
Exposure Time for Dermal Contact with Water:					
Resident Child	ET_w	hours/event	0.54		
Resident Adult	ET_w	hours/event	0.71		
Resident Age Segment 0-2	ET_w	hours/event	0.54		
Resident Age Segment 2-6	ET_w	hours/event	0.54		
Resident Age Segment 6-16	ET_w	hours/event	0.71		
Resident Age Segment 16-26	ET_w	hours/event	0.71		
Construction Worker	ET_w	hours/event	NA		
Skin Surface Area for Dermal Contact with Soil:					
Resident Child	SA_{soil}	cm^2/day	2,373		
Resident Adult	SA_{soil}	cm^2/day	6,032		
Resident Age Segment 0-2	SA_{soil}	cm^2/day	2,373		
Resident Age Segment 2-6	SA_{soil}	cm^2/day	2,373		
Resident Age Segment 6-16	SA_{soil}	cm^2/day	6,032		
Resident Age Segment 16-26	SA_{soil}	cm^2/day	6,032		
Commercial/Industrial Worker	SA_{soil}	cm^2/day	3,527		
Construction Worker	SA_{soil}	cm^2/day	NA		
Skin Surface Area for Dermal Contact with Water:					
Resident Child	SA_{gw}	cm^2	6,365		
Resident Adult	SA_{gw}	cm^2	19,652		
Resident Age Segment 0-2	SA_{gw}	cm^2	6,365		
Resident Age Segment 2-6	SA_{gw}	cm^2	6,365		
Resident Age Segment 6-16	SA_{gw}	cm^2	19,652		
Resident Age Segment 16-26	SA_{gw}	cm^2	19,652		
Construction Worker	SA_{gw}	cm^2	NA		
Soil to Skin Adherence Factor:					
Resident Child	AF	mg/cm^2	0.2		
Resident Adult	AF	mg/cm^2	0.07		
Resident Age Segment 0-2	AF	mg/cm^2	0.2		
Resident Age Segment 2-6	AF	mg/cm^2	0.2		
Resident Age Segment 6-16	AF	mg/cm^2	0.07		
Resident Age Segment 16-26	AF	mg/cm^2	0.07		
Commercial/Industrial Worker	AF	mg/cm^2	0.12		
Construction Worker	AF	mg/cm^2	NA		
Event Frequency for Dermal Contact with Water					
Resident Child	EV_{gw}	event/day	1		
Resident Adult	EV_{gw}	event/day	1		
Resident Age Segment 0-2	EV_{gw}	event/day	1		
Resident Age Segment 2-6	EV_{gw}	event/day	1		
Resident Age Segment 6-16	EV_{gw}	event/day	1		
Resident Age Segment 16-26	EV_{gw}	event/day	1		
Construction Worker	EV_{gw}	event/day	NA		

Note for site-specific values, justification has been provided in Forms 24(1) to 24(2)   NA: Not applicable

NDRBCA REPORT	FORM NO. 24
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

JUSTIFICATION FOR TIER 2 EXPOSURE FACTORS

Exposure Factor	Justification

NDRBCA REPORT	FORM NO. 24
Facility ID number (if any):	Site address:
Date form completed:	Form completed by:

JUSTIFICATION FOR TIER 2 EXPOSURE FACTORS

Exposure Factor	Justification

NDRBCA REPORT	FORM NO. 25 - ON-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Benzene												
Ethylbenzene												
Isopropylbenzene (Cumene)												
Methyl tert-Butyl Ether (MTBE)												
Naphthalene												
1,2,4-Trimethylbenzene												
1,3,5-Trimethylbenzene												
Toluene												
Xylene (total)												
Acenaphthene												
Anthracene												
Benzo(a)anthracene												
Benzo (a) Pyrene												
Benzo(b)fluoranthene												
Benzo(k)fluoranthene												
Chrysene												
Ethylene dibromide												
Fluoranthene												
Fluorene												
Indeno (1,2,3-cd) Pyrene												
1-Methylnapthalene												
2-Methylnapthalene												
Naphthalene												
Pyrene												
Arsenic												
Barium												
Beryllium												
Cadmium (diet)												
Cadmium (water)												
Chromium (III)												
Chromium (VI)												
Chromium (total)												
Lead												
Manganese (non-diet)												
Mercury (elemental)												
Selenium												
Silver												

NDRBCA REPORT	FORM NO. 25 - ON-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Hexachloroethane												
Pentachloroethane												
1,1,1,2-Tetrachloroethane												
1,1,2,2-Tetrachloroethane												
1,1,2-Trichloroethane												
1,1,1-Trichloroethane												
1,2-Dichloroethane												
1,1-Dichloroethane												
Chloroethane												
Perchloroethene (PCE)												
Trichloroethene (TCE)												
1,1-Dichloroethene												
cis-1,2-Dichloroethene												
trans-1,2-Dichloroethene												
VinyL chloride (VC)												
Bromide												
Chloride												
Nitrate as total nitrogen												
Strontium												

Notes: **Page 1 of**

Enter the representative concentration (Rep. Conc.) and indicate (Select One):
- Maximum
- Arithmetic Average
- Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report**;** (3) Attachment 11: Output tables from the NDRBCA Computational Software

NDRBCA REPORT	FORM NO. 25 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [μg/L]	SSTL [μg/L]	**E/NE**
Benzene									
Ethylbenzene									
Isopropylbenzene (Cumene)									
Methyl tert-Butyl Ether (MTBE)									
Naphthalene									
1,2,4-Trimethylbenzene									
1,3,5-Trimethylbenzene									
Toluene									
Xylene (total)									
Acenaphthene									
Anthracene									
Benzo(a)anthracene									
Benzo (a) Pyrene									
Benzo(b)fluoranthene									
Benzo(k)fluoranthene									
Chrysene									
Ethylene dibromide									
Fluoranthene									
Fluorene									
Indeno (1,2,3-cd) Pyrene									
1-Methylnapthalene									
2-Methylnapthalene									
Naphthalene									
Pyrene									
Arsenic									
Barium									
Beryllium									
Cadmium (diet)									
Cadmium (water)									
Chromium (III)									
Chromium (VI)									
Chromium (total)									
Lead									
Manganese (non-diet)									
Mercury (elemental)									
Selenium									
Silver									

NDRBCA REPORT	FORM NO. 25 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane									
Pentachloroethane									
1,1,1,2-Tetrachloroethane									
1,1,2,2-Tetrachloroethane									
1,1,2-Trichloroethane									
1,1,1-Trichloroethane									
1,2-Dichloroethane									
1,1-Dichloroethane									
Chloroethane									
Perchloroethene (PCE)									
Trichloroethene (TCE)									
1,1-Dichloroethene									
cis-1,2-Dichloroethene									
trans-1,2-Dichloroethene									
VinyL chloride (VC)									
Bromide									
Chloride									
Nitrate as total nitrogen									
Strontium									

Notes: **Page 2 of**

Enter the representative concentration (Rep. Conc.) and indicate (Select One):
Maximum
Arithmetic Average
Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	FORM NO. 25 - ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	**SOIL UP TO DEPTH OF CONSTRUCTION**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene						
Ethylbenzene						
Isopropylbenzene (Cumene)						
Methyl tert-Butyl Ether (MTBE)						
Naphthalene						
1,2,4-Trimethylbenzene						
1,3,5-Trimethylbenzene						
Toluene						
Xylene (total)						
Acenaphthene						
Anthracene						
Benzo(a)anthracene						
Benzo (a) Pyrene						
Benzo(b)fluoranthene						
Benzo(k)fluoranthene						
Chrysene						
Ethylene dibromide						
Fluoranthene						
Fluorene						
Indeno (1,2,3-cd) Pyrene						
1-Methylnapthalene						
2-Methylnapthalene						
Naphthalene						
Pyrene						
Arsenic						
Barium						
Beryllium						
Cadmium (diet)						
Cadmium (water)						
Chromium (III)						
Chromium (VI)						
Chromium (total)						
Lead						
Manganese (non-diet)						
Mercury (elemental)						
Selenium						
Silver						

NDRBCA REPORT	FORM NO. 25 - ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	**SOIL UP TO DEPTH OF CONSTRUCTION**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Hexachloroethane						
Pentachloroethane						
1,1,1,2-Tetrachloroethane						
1,1,2,2-Tetrachloroethane						
1,1,2-Trichloroethane						
1,1,1-Trichloroethane						
1,2-Dichloroethane						
1,1-Dichloroethane						
Chloroethane						
Perchloroethene (PCE)						
Trichloroethene (TCE)						
1,1-Dichloroethene						
cis-1,2-Dichloroethene						
trans-1,2-Dichloroethene						
VinyL chloride (VC)						
Bromide						
Chloride						
Nitrate as total nitrogen						
Strontium						

Notes:

Enter the representative concentration (Rep. Conc.) and indicate (Select One):

Maximum

Arithmetic Average

Other

E: Representative concentration exceeds Tier 2 SSTL

NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete

NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	**FORM NO. 25 - ON-SITE RESIDENT (FUTURE CONDITIONS)**
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene												
Ethylbenzene												
Isopropylbenzene (Cumene)												
Methyl tert-Butyl Ether (MTBE)												
Naphthalene												
1,2,4-Trimethylbenzene												
1,3,5-Trimethylbenzene												
Toluene												
Xylene (total)												
Acenaphthene												
Anthracene												
Benzo(a)anthracene												
Benzo (a) Pyrene												
Benzo(b)fluoranthene												
Benzo(k)fluoranthene												
Chrysene												
Ethylene dibromide												
Fluoranthene												
Fluorene												
Indeno (1,2,3-cd) Pyrene												
1-Methylnapthalene												
2-Methylnapthalene												
Naphthalene												
Pyrene												
Arsenic												
Barium												
Beryllium												
Cadmium (diet)												
Cadmium (water)												
Chromium (III)												
Chromium (VI)												
Chromium (total)												
Lead												
Manganese (non-diet)												
Mercury (elemental)												
Selenium												
Silver												

NDRBCA REPORT	FORM NO. 25 - ON-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane												
Pentachloroethane												
1,1,1,2-Tetrachloroethane												
1,1,2,2-Tetrachloroethane												
1,1,2-Trichloroethane												
1,1,1-Trichloroethane												
1,2-Dichloroethane												
1,1-Dichloroethane												
Chloroethane												
Perchloroethene (PCE)												
Trichloroethene (TCE)												
1,1-Dichloroethene												
cis-1,2-Dichloroethene												
trans-1,2-Dichloroethene												
VinyL chloride (VC)												
Bromide												
Chloride												
Nitrate as total nitrogen												
Strontium												

Notes: Page 4 of

Enter the representative concentration (Rep. Conc.) and indicate (Select One):

- Maximum
- Arithmetic Average
- Other

E: Representative concentration exceeds Tier 2 SSTL

NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete

NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	FORM NO. 25 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene									
Ethylbenzene									
Isopropylbenzene (Cumene)									
Methyl tert-Butyl Ether (MTBE)									
Naphthalene									
1,2,4-Trimethylbenzene									
1,3,5-Trimethylbenzene									
Toluene									
Xylene (total)									
Acenaphthene									
Anthracene									
Benzo(a)anthracene									
Benzo (a) Pyrene									
Benzo(b)fluoranthene									
Benzo(k)fluoranthene									
Chrysene									
Ethylene dibromide									
Fluoranthene									
Fluorene									
Indeno (1,2,3-cd) Pyrene									
1-Methylnapthalene									
2-Methylnapthalene									
Naphthalene									
Pyrene									
Arsenic									
Barium									
Beryllium									
Cadmium (diet)									
Cadmium (water)									
Chromium (III)									
Chromium (VI)									
Chromium (total)									
Lead									
Manganese (non-diet)									
Mercury (elemental)									
Selenium									
Silver									

NDRBCA REPORT	FORM NO. 25 - ON-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [μg/L]	SSTL [μg/L]	E/NE
Hexachloroethane									
Pentachloroethane									
1,1,1,2-Tetrachloroethane									
1,1,2,2-Tetrachloroethane									
1,1,2-Trichloroethane									
1,1,1-Trichloroethane									
1,2-Dichloroethane									
1,1-Dichloroethane									
Chloroethane									
Perchloroethene (PCE)									
Trichloroethene (TCE)									
1,1-Dichloroethene									
cis-1,2-Dichloroethene									
trans-1,2-Dichloroethene									
VinyL chloride (VC)									
Bromide									
Chloride									
Nitrate as total nitrogen									
Strontium									

Notes:

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Enter the representative concentration (Rep. Conc.) and indicate (Select One):

☐ Maximum
☐ Arithmetic Average
☐ Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT						FORM NO. 25 - ON-SITE CONSTRUCTION WORKER (FUTURE CONDITIONS)
Facility ID number (if any):			**Site address:**			
Date form completed:			**Form completed by:**			
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)						
CHEMICALS OF CONCERN	**SOIL UP TO DEPTH OF CONSTRUCTION**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene						
Ethylbenzene						
Isopropylbenzene (Cumene)						
Methyl tert-Butyl Ether (MTBE)						
Naphthalene						
1,2,4-Trimethylbenzene						
1,3,5-Trimethylbenzene						
Toluene						
Xylene (total)						
Acenaphthene						
Anthracene						
Benzo(a)anthracene						
Benzo (a) Pyrene						
Benzo(b)fluoranthene						
Benzo(k)fluoranthene						
Chrysene						
Ethylene dibromide						
Fluoranthene						
Fluorene						
Indeno (1,2,3-cd) Pyrene						
1-Methylnapthalene						
2-Methylnapthalene						
Naphthalene						
Pyrene						
Arsenic						
Barium						
Beryllium						
Cadmium (diet)						
Cadmium (water)						
Chromium (III)						
Chromium (VI)						
Chromium (total)						
Lead						
Manganese (non-diet)						
Mercury (elemental)						
Selenium						
Silver						

NDRBCA REPORT	FORM NO. 25 - ON-SITE CONSTRUCTION WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- ON-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SOIL UP TO DEPTH OF CONSTRUCTION			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane						
Pentachloroethane						
1,1,1,2-Tetrachloroethane						
1,1,2,2-Tetrachloroethane						
1,1,2-Trichloroethane						
1,1,1-Trichloroethane						
1,2-Dichloroethane						
1,1-Dichloroethane						
Chloroethane						
Perchloroethene (PCE)						
Trichloroethene (TCE)						
1,1-Dichloroethene						
cis-1,2-Dichloroethene						
trans-1,2-Dichloroethene						
VinyL chloride (VC)						
Bromide						
Chloride						
Nitrate as total nitrogen						
Strontium						

Notes:

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Enter the representative concentration (Rep. Conc.) and indicate (Select One):

Maximum

Arithmetic Average

Other

E: Representative concentration exceeds Tier 2 SSTL

NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete

NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	FORM NO. 25 - OFF-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Benzene												
Ethylbenzene												
Isopropylbenzene (Cumene)												
Methyl tert-Butyl Ether (MTBE)												
Naphthalene												
1,2,4-Trimethylbenzene												
1,3,5-Trimethylbenzene												
Toluene												
Xylene (total)												
Acenaphthene												
Anthracene												
Benzo(a)anthracene												
Benzo (a) Pyrene												
Benzo(b)fluoranthene												
Benzo(k)fluoranthene												
Chrysene												
Ethylene dibromide												
Fluoranthene												
Fluorene												
Indeno (1,2,3-cd) Pyrene												
1-Methylnapthalene												
2-Methylnapthalene												
Naphthalene												
Pyrene												
Arsenic												
Barium												
Beryllium												
Cadmium (diet)												
Cadmium (water)												
Chromium (III)												
Chromium (VI)												
Chromium (total)												
Lead												
Manganese (non-diet)												
Mercury (elemental)												
Selenium												
Silver												

NDRBCA REPORT	FORM NO. 25 - OFF-SITE RESIDENT (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE RESIDENT (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane												
Pentachloroethane												
1,1,1,2-Tetrachloroethane												
1,1,2,2-Tetrachloroethane												
1,1,2-Trichloroethane												
1,1,1-Trichloroethane												
1,2-Dichloroethane												
1,1-Dichloroethane												
Chloroethane												
Perchloroethene (PCE)												
Trichloroethene (TCE)												
1,1-Dichloroethene												
cis-1,2-Dichloroethene												
trans-1,2-Dichloroethene												
VinyL chloride (VC)												
Bromide												
Chloride												
Nitrate as total nitrogen												
Strontium												

Notes: **Page 7 of**

Enter the representative concentration (Rep. Conc.) and indicate (Select One):
Maximum
Arithmetic Average
Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

Attachments: (1) Attachment 8: Documentation for calculation of representative concentrations; (2) Attachment 9: Laboratory analytical report**;** (3) Attachment 11: Output tables from the NDRBCA Computational Software

NDRBCA REPORT	25 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene									
Ethylbenzene									
Isopropylbenzene (Cumene)									
Methyl tert-Butyl Ether (MTBE)									
Naphthalene									
1,2,4-Trimethylbenzene									
1,3,5-Trimethylbenzene									
Toluene									
Xylene (total)									
Acenaphthene									
Anthracene									
Benzo(a)anthracene									
Benzo (a) Pyrene									
Benzo(b)fluoranthene									
Benzo(k)fluoranthene									
Chrysene									
Ethylene dibromide									
Fluoranthene									
Fluorene									
Indeno (1,2,3-cd) Pyrene									
1-Methylnapthalene									
2-Methylnapthalene									
Naphthalene									
Pyrene									
Arsenic									
Barium									
Beryllium									
Cadmium (diet)									
Cadmium (water)									
Chromium (III)									
Chromium (VI)									
Chromium (total)									
Lead									
Manganese (non-diet)									
Mercury (elemental)									
Selenium									
Silver									

NDRBCA REPORT	25 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane									
Pentachloroethane									
1,1,1,2-Tetrachloroethane									
1,1,2,2-Tetrachloroethane									
1,1,2-Trichloroethane									
1,1,1-Trichloroethane									
1,2-Dichloroethane									
1,1-Dichloroethane									
Chloroethane									
Perchloroethene (PCE)									
Trichloroethene (TCE)									
1,1-Dichloroethene									
cis-1,2-Dichloroethene									
trans-1,2-Dichloroethene									
VinyL chloride (VC)									
Bromide									
Chloride									
Nitrate as total nitrogen									
Strontium									

Notes:

Enter the representative concentration (Rep. Conc.) and indicate (Select One):
- Maximum
- Arithmetic Average
- Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	FORM NO. 25 - OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SOIL UP TO DEPTH OF CONSTRUCTION			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [μg/L]	SSTL [μg/L]	E/NE
Benzene						
Ethylbenzene						
Isopropylbenzene (Cumene)						
Methyl tert-Butyl Ether (MTBE)						
Naphthalene						
1,2,4-Trimethylbenzene						
1,3,5-Trimethylbenzene						
Toluene						
Xylene (total)						
Acenaphthene						
Anthracene						
Benzo(a)anthracene						
Benzo (a) Pyrene						
Benzo(b)fluoranthene						
Benzo(k)fluoranthene						
Chrysene						
Ethylene dibromide						
Fluoranthene						
Fluorene						
Indeno (1,2,3-cd) Pyrene						
1-Methylnapthalene						
2-Methylnapthalene						
Naphthalene						
Pyrene						
Arsenic						
Barium						
Beryllium						
Cadmium (diet)						
Cadmium (water)						
Chromium (III)						
Chromium (VI)						
Chromium (total)						
Lead						
Manganese (non-diet)						
Mercury (elemental)						
Selenium						
Silver						

NDRBCA REPORT	FORM NO. 25 - OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE CONSTRUCTION WORKER (CURRENT CONDITIONS)

CHEMICALS OF CONCERN	SOIL UP TO DEPTH OF CONSTRUCTION			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane						
Pentachloroethane						
1,1,1,2-Tetrachloroethane						
1,1,2,2-Tetrachloroethane						
1,1,2-Trichloroethane						
1,1,1-Trichloroethane						
1,2-Dichloroethane						
1,1-Dichloroethane						
Chloroethane						
Perchloroethene (PCE)						
Trichloroethene (TCE)						
1,1-Dichloroethene						
cis-1,2-Dichloroethene						
trans-1,2-Dichloroethene						
VinyL chloride (VC)						
Bromide						
Chloride						
Nitrate as total nitrogen						
Strontium						

Notes:

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Enter the representative concentration (Rep. Conc.) and indicate (Select One):

☐ Maximum
☐ Arithmetic Average
☐ Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	FORM NO. 25 - OFF-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene												
Ethylbenzene												
Isopropylbenzene (Cumene)												
Methyl tert-Butyl Ether (MTBE)												
Naphthalene												
1,2,4-Trimethylbenzene												
1,3,5-Trimethylbenzene												
Toluene												
Xylene (total)												
Acenaphthene												
Anthracene												
Benzo(a)anthracene												
Benzo (a) Pyrene												
Benzo(b)fluoranthene												
Benzo(k)fluoranthene												
Chrysene												
Ethylene dibromide												
Fluoranthene												
Fluorene												
Indeno (1,2,3-cd) Pyrene												
1-Methylnapthalene												
2-Methylnapthalene												
Naphthalene												
Pyrene												
Arsenic												
Barium												
Beryllium												
Cadmium (diet)												
Cadmium (water)												
Chromium (III)												
Chromium (VI)												
Chromium (total)												
Lead												
Manganese (non-diet)												
Mercury (elemental)												
Selenium												
Silver												

NDRBCA REPORT	FORM NO. 25 - OFF-SITE RESIDENT (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE RESIDENT (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	**SURFACE SOIL**			**SOIL VAPOR**			**GROUNDWATER**					
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Indoor inhalation of vapors		**NC**	Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		**NC**	Indoor inhalation of vapors		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Hexachloroethane												
Pentachloroethane												
1,1,1,2-Tetrachloroethane												
1,1,2,2-Tetrachloroethane												
1,1,2-Trichloroethane												
1,1,1-Trichloroethane												
1,2-Dichloroethane												
1,1-Dichloroethane												
Chloroethane												
Perchloroethene (PCE)												
Trichloroethene (TCE)												
1,1-Dichloroethene												
cis-1,2-Dichloroethene												
trans-1,2-Dichloroethene												
VinyL chloride (VC)												
Bromide												
Chloride												
Nitrate as total nitrogen												
Strontium												

Notes: **Page 4 of**

Enter the representative concentration (Rep. Conc.) and indicate (Select One):
- Maximum
- Arithmetic Average
- Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT	FORM NO. 25 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Benzene									
Ethylbenzene									
Isopropylbenzene (Cumene)									
Methyl tert-Butyl Ether (MTBE)									
Naphthalene									
1,2,4-Trimethylbenzene									
1,3,5-Trimethylbenzene									
Toluene									
Xylene (total)									
Acenaphthene									
Anthracene									
Benzo(a)anthracene									
Benzo (a) Pyrene									
Benzo(b)fluoranthene									
Benzo(k)fluoranthene									
Chrysene									
Ethylene dibromide									
Fluoranthene									
Fluorene									
Indeno (1,2,3-cd) Pyrene									
1-Methylnapthalene									
2-Methylnapthalene									
Naphthalene									
Pyrene									
Arsenic									
Barium									
Beryllium									
Cadmium (diet)									
Cadmium (water)									
Chromium (III)									
Chromium (VI)									
Chromium (total)									
Lead									
Manganese (non-diet)									
Mercury (elemental)									
Selenium									
Silver									

NDRBCA REPORT	FORM NO. 25 - OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (FUTURE CONDITIONS)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE COMMERCIAL/INDUSTRIAL WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)

CHEMICALS OF CONCERN	SURFACE SOIL			SOIL VAPOR			GROUNDWATER		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		NC	Indoor inhalation of vapors		NC	Indoor inhalation of vapors		NC
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [mg/kg]	SSTL [mg/kg]	E/NE	Rep. Conc. [µg/L]	SSTL [µg/L]	E/NE
Hexachloroethane									
Pentachloroethane									
1,1,1,2-Tetrachloroethane									
1,1,2,2-Tetrachloroethane									
1,1,2-Trichloroethane									
1,1,1-Trichloroethane									
1,2-Dichloroethane									
1,1-Dichloroethane									
Chloroethane									
Perchloroethene (PCE)									
Trichloroethene (TCE)									
1,1-Dichloroethene									
cis-1,2-Dichloroethene									
trans-1,2-Dichloroethene									
VinyL chloride (VC)									
Bromide									
Chloride									
Nitrate as total nitrogen									
Strontium									

Notes: Page 5 of

Enter the representative concentration (Rep. Conc.) and indicate (Select One):
- Maximum
- Arithmetic Average
- Other

E: Representative concentration exceeds Tier 2 SSTL
NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete
NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

NDRBCA REPORT						FORM NO. 25 - OFF-SITE CONSTRUCTION WORKER
Facility ID number (if any):		**Site address:**				
Date form completed:		**Form completed by:**				
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)						
CHEMICALS OF CONCERN (FUTURE CONDITIONS)	**SOIL UP TO DEPTH OF CONSTRUCTION**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Benzene						
Ethylbenzene						
Isopropylbenzene (Cumene)						
Methyl tert-Butyl Ether (MTBE)						
Naphthalene						
1,2,4-Trimethylbenzene						
1,3,5-Trimethylbenzene						
Toluene						
Xylene (total)						
Acenaphthene						
Anthracene						
Benzo(a)anthracene						
Benzo (a) Pyrene						
Benzo(b)fluoranthene						
Benzo(k)fluoranthene						
Chrysene						
Ethylene dibromide						
Fluoranthene						
Fluorene						
Indeno (1,2,3-cd) Pyrene						
1-Methylnapthalene						
2-Methylnapthalene						
Naphthalene						
Pyrene						
Arsenic						
Barium						
Beryllium						
Cadmium (diet)						
Cadmium (water)						
Chromium (III)						
Chromium (VI)						
Chromium (total)						
Lead						
Manganese (non-diet)						
Mercury (elemental)						
Selenium						
Silver						

NDRBCA REPORT						FORM NO. 25 - OFF-SITE CONSTRUCTION WORKER
Facility ID number (if any):		**Site address:**				
Date form completed:		**Form completed by:**				
COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SSTLs- OFF-SITE CONSTRUCTION WORKER (REASONABLY ANTICIPATED FUTURE CONDITIONS)						
CHEMICALS OF CONCERN (FUTURE CONDITIONS)	**SOIL UP TO DEPTH OF CONSTRUCTION**			**GROUNDWATER**		
	Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates		**NC**	Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors from groundwater		**NC**
	Rep. Conc. [mg/kg]	SSTL [mg/kg]	**E/NE**	Rep. Conc. [µg/L]	SSTL [µg/L]	**E/NE**
Hexachloroethane						
Pentachloroethane						
1,1,1,2-Tetrachloroethane						
1,1,2,2-Tetrachloroethane						
1,1,2-Trichloroethane						
1,1,1-Trichloroethane						
1,2-Dichloroethane						
1,1-Dichloroethane						
Chloroethane						
Perchloroethene (PCE)						
Trichloroethene (TCE)						
1,1-Dichloroethene						
cis-1,2-Dichloroethene						
trans-1,2-Dichloroethene						
VinyL chloride (VC)						
Bromide						
Chloride						
Nitrate as total nitrogen						
Strontium						

Notes:

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Enter the representative concentration (Rep. Conc.) and indicate (Select One):

Maximum

Arithmetic Average

Other

E: Representative concentration exceeds Tier 2 SSTL

NE: Representative concentration does not exceed Tier 2 SSTL

C: Pathway complete

NC: Pathway not complete

Enter the calculated Site-Specific Target Levels (SSTLs) for all complete pathways. Use the NDRBCA Computational Software to calculate the SSTLs.

Facility ID number (if any): | **Site address:**

Date form completed: | **Form completed by:**

SUMMARY OF EXCEEDANCES (EXCEEDANCES FOR COMPLETE ROUTES OF EXPOSURE HIGHLIGHTED)

ROUTES OF EXPOSURE	ON-SITE RECEPTOR						OFF-SITE RECEPTOR					
	CURRENT CONDITIONS			REASONABLY ANTICIPATED FUTURE CONDITIONS			CURRENT CONDITIONS			REASONABLY ANTICIPATED FUTURE CONDITIONS		
	Resident	Commercial/ Industrial Worker	Construction Worker	Resident	Commercial/ Industrial Worker	Construction Worker	Resident	Commercial/ Industrial Worker	Construction Worker	Resident	Commercial/ Industrial Worker	Construction Worker
SURFACE SOIL FOR RESIDENT AND COMMERCIAL/INDUSTRIAL WORKER AND SOIL UPTO DEPTH OF CONSTRUCTION FOR CONSTRUCTION WORKER												
Ingestion of and dermal contact with, and outdoor inhalation of vapors and particulates												
SUBSURFACE SOIL (SOIL VAPOR)												
Indoor inhalation of vapors			NA			NA			NA			NA
GROUNDWATER												
Domestic use of water (ingestion of and dermal contact with, and inhalation of vapors due to indoor water use)		NA	NA		NA	NA		NA	NA		NA	NA
Indoor inhalation of vapors			NA			NA			NA			NA
Accidental ingestion of, dermal contact with, and outdoor inhalation of vapors	NA	NA		NA	NA		NA	NA		NA	NA	

Notes

E: representative concentration for at least one chemical exceeded the Tier 2 SSTL

NE: representative concentration for none of the chemicals exceeded the Tier 2 SSTLs

NA: not applicable

NDRBCA REPORT	FORM NO. 26
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 GROUNDWATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOURCE SOIL			COMPARISON FOR SOURCE GROUNDWATER			COMPARISON FOR POINT OF DEMONSTRATION WELLS								
	Soil Source Rep. Conc. [1]	Allowable Soil Conc. [2]	NC	GW Source Rep. Conc. [3]	Allowable GW Conc. at the Source [4]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC	POD Rep. Conc. [5]	Allowable GW Conc. at a POD [6]	NC
	[mg/kg]	[mg/kg]	E/NE	[µg/L]	[µg/L]	E/NE	[µg/L]	[µg/L]	E/NE	[µg/L]	[µg/L]	E/NE	[µg/L]	[µg/L]	E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Benzene															
Ethylbenzene															
Isopropylbenzene (Cumene)															
Methyl tert-Butyl Ether (MTBE)															
Naphthalene															
1,2,4-Trimethylbenzene															
1,3,5-Trimethylbenzene															
Toluene															
Xylene (total)															
Acenaphthene															
Anthracene															
Benzo(a)anthracene															
Benzo (a) Pyrene															
Benzo(b)fluoranthene															
Benzo(k)fluoranthene															
Chrysene															
Ethylene dibromide															
Fluoranthene															
Fluorene															
Indeno (1,2,3-cd) Pyrene															
1-Methylnapthalene															
2-Methylnapthalene															
Naphthalene															
Pyrene															
Arsenic															
Barium															
Beryllium															
Cadmium (diet)															
Cadmium (water)															
Chromium (III)															
Chromium (VI)															
Chromium (total)															
Lead															
Manganese (non-diet)															
Mercury (elemental)															
Selenium															

NDRBCA REPORT	FORM NO. 26
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 GROUNDWATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOURCE SOIL			COMPARISON FOR SOURCE GROUNDWATER			COMPARISON FOR POINT OF DEMONSTRATION WELLS								
	Soil Source Rep. Conc. [1] [mg/kg]	Allowable Soil Conc. [2] [mg/kg]	NC E/NE	GW Source Rep. Conc. [3] [µg/L]	Allowable GW Conc. at the Source [4] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Silver															
Hexachloroethane															
Pentachloroethane															
1,1,1,2-Tetrachloroethane															
1,1,2,2-Tetrachloroethane															
1,1,2-Trichloroethane															
1,1,1-Trichloroethane															
1,2-Dichloroethane															
1,1-Dichloroethane															
Chloroethane															
Perchloroethene (PCE)															
Trichloroethene (TCE)															
1,1-Dichloroethene															
cis-1,2-Dichloroethene															
trans-1,2-Dichloroethene															
VinyL chloride (VC)															
Bromide															
Chloride															
Nitrate as total nitrogen															
Strontium															

NOTE: Use the ***NDRBCA Computational Software*** to calculate the (i) soil source conc., (ii) GW source conc., and (iii) the point of demonstration (POD) well conc.

1: The soil source representative concentrations have to be calculated and entered here.

2: Allowable soil concentrations at the source protective of groundwater at the POE. **C:** Pathway complete

3: The groundwater source representative concentrations have to be calculated and entered here.

4: Allowable groundwater concentrations at the source protective of groundwater at t **NC:** Pathway not complete

5: Represents the representative concentrations in the POD well

6: Represents the allowable groundwater concentrations at a POD protective of a POE.

For representative concentrations, refer **Attachment 8**:

E: Representative on-site concentration exceeds calculated POD well concentration.

NE: Representative on-site concentration does not exceed calculated POD well concentration.

Attachments: (1) Figure 21: Showing the location(s) of the soil source(s), location of POE, and location(s) of POD. (2) Attachment 8: Documentation for Calculation of Representative Concentrations (3) Attachment 9: Laboratory analytical report; (3) Attachment 11: Output tables from the NDRBCA Computational Software

NDRBCA REPORT **FORM NO. 27**

Facility ID number (if any): **Site address:**

Date form completed: **Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SURFACE WATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	**COMPARISON FOR SOURCE SOIL**			**COMPARISON FOR SOURCE GROUNDWATER**			**COMPARISON FOR POD WELL AT THE STREAM BANK**			**COMPARISON FOR POD WELLS BETWEEN THE SOURCE AND THE STREAM BANK**					
	Soil Source Rep. Conc. [1] [mg/kg]	Allowable Soil Conc. [2] [mg/kg]	**NC** **E/NE**	GW Source Rep. Conc. [3] [µg/L]	Allowable GW Conc. at the Source [4] [µg/L]	**NC** **E/NE**	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	**NC** **E/NE**	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	**NC** **E/NE**	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	**NC** **E/NE**
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Benzene															
Ethylbenzene															
Isopropylbenzene (Cumene)															
Methyl tert-Butyl Ether (MTBE)															
Naphthalene															
1,2,4-Trimethylbenzene															
1,3,5-Trimethylbenzene															
Toluene															
Xylene (total)															
Acenaphthene															
Anthracene															
Benzo(a)anthracene															
Benzo (a) Pyrene															
Benzo(b)fluoranthene															
Benzo(k)fluoranthene															
Chrysene															
Ethylene dibromide															
Fluoranthene															
Fluorene															
Indeno (1,2,3-cd) Pyrene															
1-Methylnapthalene															
2-Methylnapthalene															
Naphthalene															
Pyrene															
Arsenic															
Barium															
Beryllium															
Cadmium (diet)															
Cadmium (water)															
Chromium (III)															
Chromium (VI)															
Chromium (total)															
Lead															
Manganese (non-diet)															
Mercury (elemental)															
Selenium															

NDRBCA REPORT	FORM NO. 27
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

COMPARISON OF REPRESENTATIVE CONCENTRATIONS WITH TIER 2 SURFACE WATER PROTECTION TARGET CONCENTRATIONS

Distance from source to the point of exposure (POE):

CHEMICALS OF CONCERN	COMPARISON FOR SOURCE SOIL			COMPARISON FOR SOURCE GROUNDWATER			COMPARISON FOR POD WELL AT THE STREAM BANK			COMPARISON FOR POD WELLS BETWEEN THE SOURCE AND THE STREAM BANK					
	Soil Source Rep. Conc. [1] [mg/kg]	Allowable Soil Conc. [2] [mg/kg]	NC E/NE	GW Source Rep. Conc. [3] [µg/L]	Allowable GW Conc. at the Source [4] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE	POD Rep. Conc. [5] [µg/L]	Allowable GW Conc. at a POD [6] [µg/L]	NC E/NE
POD WELL NO.															
DISTANCE FROM SOURCE															
RECENT TREND															
Silver															
Hexachloroethane															
Pentachloroethane															
1,1,1,2-Tetrachloroethane															
1,1,2,2-Tetrachloroethane															
1,1,2-Trichloroethane															
1,1,1-Trichloroethane															
1,2-Dichloroethane															
1,1-Dichloroethane															
Chloroethane															
Perchloroethene (PCE)															
Trichloroethene (TCE)															
1,1-Dichloroethene															
cis-1,2-Dichloroethene															
trans-1,2-Dichloroethene															
VinyL chloride (VC)															
Bromide															
Chloride															
Nitrate as total nitrogen															
Strontium															

NOTE: Use the ***NDRBCA Computational Software*** to calculate the (i) soil source conc., (ii) GW source conc., and (iii) the point of demonstration (POD) well conc.

1: The soil source representative concentrations have to be calculated and entered here.

2: Allowable soil concentrations at the source protective of surface water at the POE. **C:** Pathway complete

3: The groundwater source representative concentrations have to be calculated and entered here.

4: Allowable groundwater concentrations at the source protective of surface water at t **NC:** Pathway not complete

5: Represents the representative concentrations in the POD well

6: Represents the allowable groundwater concentrations at a POD protective of surface water at the POE.

For representative concentrations, refer **Attachment 8**:

E: Representative on-site concentration exceeds calculated POD well concentration.

NE: Representative on-site concentration does not exceed calculated POD well concentration.

Attachments: (1) Figure 21: Showing the location(s) of the soil source(s), location of POE, and location(s) of POD. (2) Attachment 8: Documentation for Calculation of Representative Concentrations (3) Attachment 9: Laboratory analytical report; (3) Attachment 11: Output tables from the NDRBCA Computational Software

NDRBCA REPORT	FORM NO. 28(a)
Facility ID number (if any):	**Site address:**
Date form completed:	**Form completed by:**

CONCLUSION AND RECOMMENDATION (ON-SITE RECEPTORS)

Instructions: Based on the results of Tier 2 Evaluation, (refer Form 25(13)), discuss each media, pathway and receptor combination that exceeds the Tier 2 SSTLs. For each exceedance, propose actions to manage the risk. Actions can include (i) request closure, (ii) active remediation, (iii) Tier 3 evaluation or a combination of these.

Media	Receptor	Complete Exposure Pathway for Which Representative Conc. Exceeds Screening Level	Proposed Management Strategy
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Active remediation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other

ADDITIONAL NOTES FOR CONCLUSION AND RECOMMENDATION

NDRBCA REPORT	FORM NO. 28(b)

Facility ID number (if any): **Site address:**

Date form completed: **Form completed by:**

CONCLUSION AND RECOMMENDATION (OFF-SITE RECEPTORS)

Instructions: Based on the results of Tier 2 Evaluation, (refer Form 25(13)), discuss each media, pathway and receptor combination that exceeds the Tier 2 SSTLs. For each exceedance, propose actions to manage the risk. Actions can include (i) request closure, (ii) active remediation, (iii) Tier 3 evaluation or a combination of these.

Media	Receptor	Complete Exposure Pathway for Which Representative Conc. Exceeds Screening Level	Proposed Management Strategy
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Active remediation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other
			☐ Request closure ☐ Active remediation ☐ Tier 3 evaluation ☐ Other

ADDITIONAL NOTES FOR CONCLUSION AND RECOMMENDATION

APPENDIX C
ECOLOGICAL RISK EVLAUATION CHECKLISTS

TABLE OF CONTENTS Page

Ecological Risk Evaluation
Screening Checklist for Potential Receptors and Habitat
Level 1, Checklist A

1. Is the boundary of the contaminated area less than ½ mile to a surface water body (stream, river, pond, lake, etc.)?

2. Are wetlands (as defined by the 1987 Corps of Engineers' Delineation Manual) on or adjacent to the site?

3. Are contaminated soils uncovered or otherwise accessible to ecological receptors and the elements?

4. Are there federal or state rare, threatened, or endangered species on or within ½ mile of the contaminated area? Contact the NDDEQ for state-listed species and the U.S. Fish and Wildlife Service for federally listed species.

5. Are there one or more environmentally sensitive areas at or within ½ mile of the contaminated area?

6. Are commercially or recreationally important species (fauna or flora) on or within ½ mile of the contaminated area?

If the answer is "Yes" to any of the above questions, then complete Ecological Risk Assessment Checklist for Potential Exposure Pathways, Checklist B.

Ecological Risk Evaluation
Screening Checklist for Potential Receptors and Habitat
Level 1, Checklist B

Question 1: Could contaminants associated with the site reach ecological receptors via groundwater?

1.a.) Can contaminants associated with the site leach, dissolve, or otherwise migrate to groundwater?
1.b.) Are contaminants associated with the site mobile in groundwater?
1.c.) Does groundwater from the site discharge to ecological receptor habitat?

Question 2: Could contaminants from the site reach ecological receptors via migration of NAPL?

2.a.) Is Non-Aqueous Phase Liquid (NAPL) present at the site?
2.b.) Is NAPL migrating?
2.c.) Could NAPL discharge occur where ecological receptors are found?

Question 3: Could contaminants reach ecological receptors via erosional transport of contaminated soils or via precipitation runoff?

3.a.) Are contaminants present in surface soils?
3.b.) Can contaminants be leached from or be transported by erosion of surface soils?

Question 4: Could contaminants reach ecological receptors via direct contact?

4.a.) Are contaminants present in surface soil or on the surface of the ground?
4.b.) Are potential ecological receptors on the site?

Question 5: Could contaminants reach ecological receptors via inhalation of volatilized contaminants or contaminants adhered to dust in ambient air or in subsurface burrows?

5.a.) Are contaminants present on the site volatile?
5.b.) Could contaminants on the site be transported in air as dust or particulate matter?

Question 6: Could contaminants reach ecological receptors via direct ingestion of soil, plants, animals, or contaminants?

6.a.) Are contaminants present in surface and shallow subsurface soils or on the surface of the ground?
6.b.) Are contaminants found in soil on the site taken up by plants growing on the site?
6.c.) Do potential ecological receptors on or near the site feed on plants (e.g., grasses, shrubs, forbs, trees, etc.) found on the site?
6.d.) Could contaminants present on the site bioaccumulate?

If the answer to one or more of the six above questions is “Yes”, NDDEQ may require further assessment to determine whether the site poses an unacceptable risk to ecological receptors.

Ecological Risk Assessment
Figure #1: Environmentally Sensitive Areas

An Environmentally Sensitive Area is of special significance due to its flora or fauna, the sensitive nature of its natural features, historical considerations, or other reasons associated with the environment.

Examples of environmentally sensitive areas include, but are not limited to, the following:

- National and state parks,
- Designated and proposed federal and state wilderness and natural areas,
- Endangered, rare, and threatened species habitat as designated by the U.S. Department of the Interior or the NDDEQ,
- National monuments,
- National and state historic sites,
- Federal or state designated scenic or wild rivers,
- Habitat of federal or state designated or proposed endangered, rare, or threatened species, and species under review as to their endangered, rare, or threatened status,
- National and state preserves and forests,
- National and state wildlife refuges,
- Critical fish and shellfish spawning areas,
- Critical migratory pathways and feeding areas for anadromous fish species within river reaches or areas in lakes where such species spend extended periods of time,
- Terrestrial areas used for breeding by large or dense aggregations of faunal species,
- State lands designated by the NDDEQ for wildlife or game management,
- Wetlands as defined by the 1987 Corps of Engineers Delineation Manual, and
- Outstanding state resource waters as designated by the NDDEQ.

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D.1 Dry Bulk Density

Dry bulk density is the dry weight of a soil sample divided by its field volume. An accurate measurement of dry bulk density requires determination of 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 an equivalent method. The sample must not be disturbed prior to laboratory analysis.

Dry bulk density is estimated using the American Society for Testing and Materials (ASTM) Method D2937, ***"Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method."*** At sites where multiple, widely differing soil types occur in the vadose zone, one sample must be collected from each distinct, predominant soil type. At such sites, the percentage of each soil type relative to the overall volume of the vadose zone should be considered in collecting samples and calculating bulk density. Where soil at a site is homogeneous or nearly so, a single sample for bulk density analysis may suffice.

D.2 Total Porosity

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

$$n = 1 - \rho_b/\rho_s \qquad \text{(D-1)}$$

where,

n	=	porosity (cc/cc)
ρ_b	=	dry bulk density (g/cc)
ρ_s	=	specific gravity or particle density (g/cc).

Thus, specific gravity and soil dry bulk density are needed to determine total porosity.

The ***"Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer,"*** ASTM Method D854, may be used to determine specific gravity. If specific gravity or particle density is not available, 2.65 g/cc can be assumed for most mineral soils. However, the use of this value must be justified.

If a site-specific total 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 justified. Effective porosity is the amount of void space available for fluid flow. Various studies have identified that even in very fine clays, such as lacustrine deposits, the effective porosity is practically the same as total porosity (Fetter, 2001). Where the total and effective porosities differ significantly, the department may require a sensitivity analysis.

D.3 Volumetric Water Content/Moisture Content

Volumetric water content is the ratio of the volume of water to the volume of field or undisturbed soil. The ASTM Method D2216, **"Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soils and Rock by Mass,"** may be used to calculate this ratio. However, this is a gravimetric method that uses the mass of the sample, not the volume, to determine the ratio of water to soil. Therefore, to obtain the volumetric water content, the following conversion should be used:

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

where,

θ_{wv} = volumetric water content (cc water/cc 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/cc of soil)

ρ_l = density of water (g/cc).

Multiple samples from across the site at varying depths should be analyzed for water content to estimate a representative water content value for the vadose zone. Each soil sample analyzed for one or more of the applicable COCs must also be analyzed for water content (at sites where multiple samples from multiple depths are analyzed for COCs on a dry weight basis, additional samples solely for analysis of water content may not be necessary). In addition, water content values representative of each of the lithologic units that comprise the vadose zone must be determined. Because all soil COC concentration data must be reported on a dry weight basis, the water content for each soil sample must be compiled, reported and used as needed in calculating target levels.

D.4 Fractional Organic Carbon Content in Soil

Fractional organic carbon 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. Organic carbon content must be determined using soil samples <u>not impacted by petroleum or other anthropogenic chemicals.</u> Therefore, a soil boring away from the contaminated area but within a soil type that is the same as, or very similar to, that found at the site must be drilled to determine fractional organic carbon content. At a screening level, one method of determining if certain anthropogenic chemicals have impacted the sample is to take a PID reading.

Samples representative of the vadose zone must be collected for fractional organic carbon content analysis. At sites where the vadose zone consists of several different soil types, each predominant soil type must be sampled. Multiple aliquots of soil samples from the same lithologic unit may be collected vertically from a boring and horizontally from different borings and composited in the field to create a single sample. While creating a composite sample, care should be taken not to combine samples collected from different lithologic units. Surficial soils typically have the highest organic carbon content, and care should be taken not to bias the samples by collecting too much surficial soil.

For sites where subsurface soil types vary significantly, soil samples from the vadose and saturated zones should be collected at two or more boring or probe points that represent the differing soil types. As appropriate, the resulting fractional organic carbon content can then be averaged to establish a fractional organic carbon content for each media. If the individual data are representative of significantly different volumes of soil, a weighted average is preferable to the arithmetic average.

Fractional organic carbon content may be estimated using the Walkley Black Method (Page et al., 1982). However, some labs may not be familiar with this method. An alternative, though less preferred, method is ASTM Method D2974 ***(Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils).*** This method measures the organic matter content of a sample. When using Method D2974, the result must be divided by 1.724 to get fractional organic carbon content. If the laboratory results are reported as a percent, fractional organic carbon content is obtained by dividing the results by 100.

D.5 Thickness of Capillary Fringe

The capillary fringe is the zone immediately above the saturated zone where capillary attraction causes 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 and saturated zones. In a Tier 2 risk assessment, the thickness or height of the capillary fringe can be measured, or an appropriately justified value 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.

The thickness of the capillary fringe can impact the concentrations in groundwater that are protective of indoor inhalation. Because this zone is not usually measured, the NDDEQ may require that the remediating party estimate the most likely ranges of capillary zone thickness and depth to contamination and perform a sensitivity analysis. Most models used to perform this calculation assume the capillary fringe to be uncontaminated, which may not be accurate.

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E.1 BACKGROUND

A receptor would typically be exposed to contaminants of concern (COC) over a defined geographical area, for a specified exposure duration, and through one or more routes of exposure (ROEs). The geographical area over which a receptor is exposed to COC is called the exposure domain (ED). Because COC concentrations typically vary over the ED and exposure duration, it is necessary to estimate a representative COC concentration consistent with the ED. The representative concentrations (RCs) are compared with the RBSLs to decide the next course of action, as explained in Sections 6.0, 7.0, and 8.0.

A representative COC concentration is the average concentration to which the receptor is exposed over the specified exposure duration, within the ED, and for a specific ROE. In most risk assessments, the concentration is assumed constant over the exposure duration, in effect disregarding the temporal variability in concentrations. The average concentration calculated based on the available sample data is not the same as the population or true average. Therefore, to account for this fact, USEPA recommends (USEPA, 1989) the use of the upper limit of the 95% two-sided confidence interval (CI) about the sample mean. Assuming sufficient amount of unbiased data is available (at least 8 samples) within an ED, the publicly available PROUCL software (USEPA, 2022a) maybe used.

The calculation of RCs is complicated due to the following factors:

- Spatial variability in the concentrations over the ED,
- Temporal variability in the concentrations over the exposure duration, and
- Lack of sufficient ED specific concentration data.

Further, complications arise because environmental data is 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 systematically over the ED, and the concept of RC is often mistakenly associated with the site as opposed to an exposure pathway and receptor. Because there may be several receptors and several complete exposure pathways for a receptor, several RCs, one for each complete pathway and for each receptor must be estimated. The following sections discusses the methodology used to estimate the RCs for each complete ROE.

E.2 STEPS FOR CALCULATION OF RC

The calculation of the RC requires the following steps for each receptor:

1. Identification of all the media of concern, (surficial soil, subsurface soil, soil up to the depth of construction, and groundwater),
2. Identification of all the complete ROE under current and future conditions,
3. Identification of the ED for each media and each complete ROE identified,
4. Identification of the monitoring points and available COC concentration data within the ED for each media, and

5. Calculation of the RC.

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

1. Clearly understand and document the ED for each complete exposure pathway
2. Do not use data outside the exposure domain
3. Within the ED replace the “reporting limit” concentrations with half the reporting limit. Concentrations with a J laboratory qualifier, which is a judgement made at the laboratory, should use the laboratory-estimated value.
4. As a simple or red flag check, determine if the maximum concentration of any COC within the ED exceeds ten times the RC of that COC for the ED. Possible reasons for an exceedance could be:

   - The maximum concentration is an outlier,
   - The average concentration was inaccurately calculated,
   - The ED is not adequately characterized,
   - A hot spot may not have been adequately characterized, or
   - Depending on the reason for the exceedance, take appropriate action to revise or validate the RC.

5. When calculating the representative groundwater concentration, assuming multiple wells are located within the ED, first estimate the average concentration in each well based on recent data, assuming data from multiple events is available, then use the average of each well to estimate the RC.
6. If free product is present at a monitoring point, use the effective solubility or effective vapor pressure to estimate the groundwater or soil vapor concentration at that point.
7. For wells with multiple years of groundwater data, use the most recent two years of data (6-8 events) to estimate the RC. In certain cases, data that is more than two years old may be used, but it must be justified.
8. If the area of impact is smaller than the ED, the exposure factors may be modified (in Tier 2 or 3 evaluation) to account for this circumstance.
9. For the subsurface-soil-to-indoor-inhalation pathway, do not use soil data collected below the water table. Similarly, for the groundwater-to-indoor-inhalation pathway, groundwater data from the first encountered saturated zone must be used.
10. If sufficient data is available, the upper bound of the 95th percentile confidence interval about the mean may be used.

In an effort to reduce evaluation time, if the historical maximum concentrations do not exceed the RBTL, it would not be necessary to compute a RC.

E.3 CALCULATION OF RCs FOR SOIL AND GROUNDWATER

E.3.1 Surficial Soil (0-2 feet below ground surface)

The NDRBCA process requires the evaluation of the following routes of pathways associated with surficial soil:

1. The protection of groundwater,
2. The protection of surface water (if applicable),
3. Direct contact with soil pathway that comprises accidental ingestion of soil, outdoor inhalation of vapors and particulates from surficial soil emissions, and dermal contact with surficial soil.

The latter three pathways are combined and referred to as the "direct contact with soil" pathway. Thus at least two different surficial soil RCs are required, one for leaching to groundwater and one for direct contact with soil.

E.3.1.1 Representative Surficial Soil Concentration for Groundwater Protection

The ED for this pathway is the area of impact through which leachate generation may occur and COCs can migrate to the water table. The representative surficial soil concentration should be calculated using the surficial soil data collected within the ED. Thus, prior to calculating the RC, it is necessary to clearly define the ED and to clearly identify the surficial soil data available within this area.

E.3.1.2 Representative Concentrations for Direct Contact Pathway

The exposure domain for this pathway is the portion of the site over which the receptor might be exposed to the surficial soil. Areas of the site that are paved may be excluded in the calculation of the RC for this pathway.

E.3.2 Subsurface Soil (greater than 2 feet below ground surface)

The NDRBCA process includes the following exposure pathways associated with subsurface soil:

1. The protection of groundwater,
2. The protection of surface water (if applicable),
3. Indoor inhalation of vapors emissions.

The indoor inhalation pathway is complete only if the soil is impacted with chemicals that are volatile. The calculation of RC is discussed below.

E.3.2.1 Representative Subsurface Soil Concentration for Protection of Groundwater

The RC for this pathway should be the average concentration in subsurface soil measured within the area of impact.

E.3.2.2 Representative Subsurface Soil Concentration for Protection of Indoor Inhalation

Subsurface soil concentrations protective of indoor inhalation may be estimated using an emission model such as the Johnson and Ettinger model (USEPA, 2017) that calculates the attenuation factor or using an empirical attenuation factor. The model assumes that chemicals volatilize from the subsurface soil source, travel vertically upwards without any lateral or transverse spreading, and enter the building through cracks in the foundation and floor and utilities. To ensure consistency with the model, the RC for this pathway should be based on soil concentrations measured directly below or immediately adjacent to the footprint of the enclosed space.

To evaluate the potential future indoor inhalation pathway, (i.e., an enclosed structure is constructed over contaminated soil), the size (footprint) and location of the planned structure must be estimated. In the absence of site-specific information regarding planned structures, the future location and size of the structure must be approximated based on the evaluator's professional judgement. A conservative option is to locate the hypothetical structure over the area of highest impact (that is, the area of maximum COC concentrations). For sites where the footprint of a current on-site structure is or might be different from that of a structure erected in the future, a representative subsurface soil concentration must be calculated for both the current and potential future structure.

To estimate the RC, the evaluator must:

1. Identify the footprint of the structure within which the receptor is located,
2. Identify the footprint of the potential future enclosed structure,
3. Identify the soil concentration data available within each of these two footprints, and
4. Calculate the average of these concentrations.

If sufficient data are not available within the building footprint, data collected within 20 feet of the building footprint may be used to calculate average COC concentrations in soil Data from locations beyond the 20-foot building footprint buffer may be considered/needed in cases where preferential pathways such as soil macropores, utility conduits, or soil fractures may cause vapor migration towards the building. Generally, vapor concentrations are expected to decrease with increasing distances from the source.

If several samples within and adjacent to the building footprint are available, more weight should be given to the samples collected within the footprint.

In recent years, USEPA has expressed strong preference for the use of soil vapor concentrations as opposed to the use of soil concentrations to evaluate the indoor inhalation pathway. In which case, RCs would be calculated using soil vapor concentrations.

E.3.3 Representative Concentration for Construction Worker

The NDRBCA process requires the evaluation of the following routes of exposure for the construction worker for Tier 2 and Tier 3 evaluations:

1. Accidental ingestion, dermal contact and outdoor inhalation of vapors and particulates from soil,
2. Outdoor inhalation of vapors from groundwater, and
3. Dermal contact with groundwater.

Thus, three RCs are required. Each of these is discussed below.

E.3.3.1 Representative Soil Concentration

For the construction worker, no distinction is made between surficial and subsurface soil because, during construction, the construction worker might be exposed to both. To estimate the RC for the construction worker, it is necessary to identify the depth of construction, areal extent of construction, and the horizontal and vertical extent of soil impacts within the area of construction including the number of samples available to calculate the RC within the zone of construction. If the areal extent of the construction area is not known, a conservative option, would be to assume that the construction zone will be entirely within/across the area of impact. The RC would be the average concentration within this zone of construction.

E.3.3.2 Representative Groundwater Concentration

It is necessary to estimate the areal extent of the construction below the water table and identify the groundwater data available within this area. The RC would then be calculated as the average concentration within this area. Temporal variations in groundwater concentrations should be evaluated.

E.3.4 Groundwater

The NDRBCA process requires the evaluation of the following two routes of exposure associated with groundwater:

1. Domestic use of water that includes ingestion, dermal contact with groundwater, and indoor inhalation due to indoor water use, and
2. Indoor inhalation of vapor emissions from groundwater.

Where multiple water bearing zones are present, only the shallowest zone would be considered for the volatilization pathway. All zones must be evaluated for domestic water use of water. RCs must be calculated for each zone. Thus, depending on the number of complete pathways, multiple different groundwater RCs may have to be calculated.

E.3.4.1 Representative Demonstration Well Concentration for Groundwater Protection

For the ingestion of groundwater pathway, maximum contaminant levels (MCLs) or, where MCLs are lacking, calculated risk-based concentrations, must be met at the POE well. Often the POE well is hypothetical and, therefore, data for the POE might not be available. When this pathway is complete, one or more point of demonstration (POD) wells must be identified target concentrations calculated.

The RC at the POD and POE (if water supply well is available) should be as discussed below:

- If COC concentrations in groundwater are stable, the RC is the arithmetic average of the most recent data collected over a period of no more than two years on at least a quarterly basis.
- If COC concentrations are decreasing, the RC is the arithmetic average of the most recent data collected over a period of no more than one and one-half years on at least a quarterly basis.
- If COC concentrations are increasing, the arithmetic average of the most recent data collected over a period of no more than one year on at least a quarterly basis.

E.3.4.2 Representative Groundwater Concentration for Protection of Indoor Inhalation

Groundwater concentrations protective of indoor inhalation are typically estimated using an empirical attenuation factor or an attenuation factor calculated by a model, (Refer Appendix A). This model assumes no lateral or transverse spreading of the vapors as they migrate upward from the water table through the capillary fringe and the vadose zone and into the enclosed space. Thus, RCs for this pathway should be based on groundwater concentrations measured within the footprint of the building or up to 20 feet from the building.

For the groundwater to indoor air pathway, multiple RCs might be needed if the plume has migrated below several current or potential future buildings. For example, if a plume has migrated or is likely to migrate below two different buildings, one on-site and one off-site, a RC would have to be calculated for each building.

After identifying the location of the building footprints (whether real or hypothetical) and the available groundwater monitoring data within or adjacent (within 20 feet beyond the footprint to the building, the average concentration within each footprint must be estimated. However, groundwater data may not be available for each footprint; therefore, several options are available. These include:

1. Installation of additional monitoring wells within or adjacent to the footprint lacking data,
2. Interpolation or extrapolation of existing data (in the case where the plume

originates under a building, extrapolated data gathered from areas adjacent to the footprint may not be adequate) or,

3. As a conservative approach, use of data from wells located upgradient of the building that are between the building and the source of contamination.

E.3.4.3 Representative Groundwater Concentration for Dermal Contact

The average concentration of COCs in the groundwater that a receptor might come in contact with is used as the RC. Note that temporal variations in COC concentrations will be considered. More than one RC might be needed where a receptor might contact groundwater from more than one aquifer or saturated zone.

E.4 ANALYTICAL REPORTING LIMITS

The analytical reporting limit for certain COCs may be higher (sometimes by orders of magnitude) than the corresponding RBTL for that chemical often due to limitations of the analytical method. In such circumstances, the following approaches may be useful:

- Check the data to confirm that the standard detection limits are indeed higher than the RBTLs and that no errors were made (for example, transposing numbers, unit conversion, or misplacing a decimal point),
- With NDDEQ approval, use alternative analytical methods that achieve lower detection limits than the Tier 2 target levels.
- Perform a higher Tier evaluation to determine if the levels that can be analytically quantified are protective, given the complete and/or potentially complete exposure pathways.

APPENIDX F
EQUATIONS INCLUDED IN THE NDRBCA SOFTWARE

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Volatilization Factors

Groundwater Protection

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Saturated Soil and Vapor Concentrations

INDOOR INHALATION OF VAPORS
(CHILD AND ADULT RESIDENT; AND COMMERCIAL/INDUSTRAIL WORKER)

Carcinogenic Effects

$$RBTL_{ininh} = \frac{TR \times AT_c \times 365 \times 24}{ET_{in} \times ED \times EF \times IUR \times 10^3}$$

Non-carcinogenic Effects

$$RBTL_{ininh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 24}{ET_{in} \times ED \times EF}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

where:

$RBTL_{ininh}$	=	Risk based target level (RBTL) for indoor inhalation of vapors [mg/m^3]
TR	=	Target risk [-]
THQ	=	Target hazard quotient [-]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ET_{in}	=	Indoor exposure time [hr/day]
ED	=	Exposure duration [year]
EF	=	Exposure frequency [day/year]
RfC	=	Chemical-specific reference concentration [mg/m^3]
IUR	=	Chemical-specific inhalation unit risk [$(\mu g/m^3)^{-1}$]
365	=	Converts AT_c, AT_{nc} in years to days [days/year]
10^3	=	Converts RBTL in µg to mg [ug/mg]
24	=	Converts ET_{in} hours to day [hours/day]

OUTDOOR INHALATION OF VAPORS (CHILD AND ADULT RESIDENT; COMMERCIAL/INDUSTRAIL WORKER; AND CONSTRUCTION WORKER)	
<u>Carcinogenic Effects</u> $$RBTL_{outinh} = \frac{TR \times AT_c \times 365 \times 24}{ET_{out} \times ED \times EF \times IUR \times 10^3}$$ <u>Non-carcinogenic Effects</u> $$RBTL_{outinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 24}{ET_{out} \times ED \times EF}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where: $RBTL_{outinh}$ = Risk based target level for outdoor inhalation of vapors [mg/m^3] TR = Target risk [-] THQ = Target hazard quotient [-] AT_c = Averaging time for carcinogens [year] AT_{nc} = Averaging time for non-carcinogens [year] ET_{out} = Outdoor exposure time [hr/day] ED = Exposure duration [year] EF = Exposure frequency [day/year] RfC = Chemical-specific reference concentration [mg/m^3] IUR = Chemical-specific inhalation unit risk [(µg/m^3)$^{-1}$] 365 = Converts AT_c, AT_{nc} in years to days [days/year] 10^3 = Converts RBTL in µg to mg [ug/mg] 24 = Converts ET_{in} hours to day [hours/day]

INGESTION OF FISH (ADULT RESIDENT)	
Carcinogenic Effects $$RBTL_{fing} = \frac{TR \times AT_c \times BW \times 365}{SF_o \times 10^{-6} \times ED \times EF \times IR_f}$$ Non-carcinogenic Effects $$RBTL_{fing} = \frac{THQ \times AT_{nc} \times 365 \times BW \times RfD_o}{ED \times EF \times IR_f \times 10^{-6}}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where: $RBTL_{fing}$ = Risk based target level for ingestion of fish [mg-chemical/kg-fish tissue] TR = Target risk [-] THQ = Target hazard quotient [-] AT_c = Averaging time for carcinogens [year] AT_{nc} = Averaging time for non-carcinogens [year] BW = Body weight [kg] ED = Exposure duration [year] EF = Exposure frequency [day/year] IR_f = Fish ingestion rate [mg/day] SF_o = Oral cancer slope factor [(mg/kg-day)$^{-1}$] RfD_o = Chemical-specific oral reference dose [mg/kg-day] *365* = Converts AT_c, AT_{nc} in years to days [day/year] 10^{-6} = Converts kg to mg [kg/mg]

INDOOR INHALATION OF VAPORS
(AGE-ADJUSTED RESIDENT)

<u>Carcinogenic Effects</u>

$$RBTL_{ininh} = \frac{TR \times AT_c \times 365 \times 24}{ET \times ED_{aa} \times EF \times IUR \times 10^3}$$

<u>Non-carcinogenic Effects</u>

$$RBTL_{ininh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 24}{ET \times ED_{aa} \times EF}$$

where,

$$ED_{aa} = ED_c + ED_a$$

<u>Mutagenic Effects</u>

$$RBTL_{c-ininh} = \frac{TR \times AT_c \times 365 \times 24}{IUR \times 10^3 \times \begin{bmatrix} EF_{0-2} \times ED_{0-2} \times ET_{0-2} \times 10 + \\ EF_{2-6} \times ED_{2-6} \times ET_{2-6} \times 3 + \\ EF_{6-16} \times ED_{6-16} \times ET_{6-16} \times 3 + \\ EF_{16-26} \times ED_{16-26} \times ET_{16-26} \times 1 \end{bmatrix}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

where:

$RBTL_{ininh}$	=	Risk based target level (RBTL) for indoor inhalation of vapors [mg/m^3]
TR	=	Target risk [-]
THQ	=	Target hazard quotient [-]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ET	=	Indoor exposure time [hr/day]
ED_{aa}	=	Age-adjusted exposure duration [year]
ED_c	=	Exposure duration for child [year]
ED_a	=	Exposure duration for adult [year]
EF	=	Exposure frequency [day/year]
EF_{0-2}	=	Exposure frequency for 0-2 years [day/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [day/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [day/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [day/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_{0-2}	=	Exposure time for 0-2 years [hr/day]
ET_{2-6}	=	Exposure time for 2-6 years [hr/day]
ET_{6-16}	=	Exposure time for 6-16 years [hr/day]
ET_{16-26}	=	Exposure time for 16-26 years [hr/day]
RfC	=	Chemical-specific reference concentration [mg/m^3]

	IUR = Chemical-specific inhalation unit risk [(µg/m^3)$^{-1}$] *365* = Converts AT_c, AT_{nc} in years to days [day/year] 10^3 = Converts RBTL in mg to µg [1000 µg/mg] *24* = Converts ET_{in} hours to day [24 hrs/day] 10 = Age-dependent adjustment factor for 0-2 yr [-] 3 = Age-dependent adjustment factor for 2-6 yr [-] 3 = Age-dependent adjustment factor for 6-16 yr [-] 1 = Age-dependent adjustment factor for 16-26 yr [-]

OUTDOOR INHALATION OF VAPORS (AGE-ADJUSTED RESIDENT)

Carcinogenic Effects

$$RBTL_{oinh} = \frac{TR \times AT_c \times 365 \times 24}{ET \times ED_{aa} \times EF \times IUR \times 10^3}$$

Non-carcinogenic Effects

$$RBTL_{oinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 24}{ET \times ED_{aa} \times EF}$$

where,

$$ED_{aa} = ED_c + ED_a$$

Mutagenic Effects

$$RBTL_{c-ininh} = \frac{TR \times AT_c \times 365 \times 24}{IUR \times 10^3 \times \begin{bmatrix} EF_{0-2} \times ED_{0-2} \times ET_{0-2} \times 10 + \\ EF_{2-6} \times ED_{2-6} \times ET_{2-6} \times 3 + \\ EF_{6-16} \times ED_{6-16} \times ET_{6-16} \times 3 + \\ EF_{16-26} \times ED_{16-26} \times ET_{16-26} \times 1 \end{bmatrix}}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

where:

$RBTL_{oinh}$ = Risk based target level (RBTL) for indoor inhalation of vapors [mg/m^3]
TR = Target risk [-]
THQ = Target hazard quotient [-]
AT_c = Averaging time for carcinogens [year]
AT_{nc} = Averaging time for non-carcinogens [year]
EF = Exposure frequency [day/year]
ET = Indoor exposure time [hr/day]
ED_{aa} = Exposure duration for an age-adjusted individual [year]
ED_c = Exposure duration for child [year]
ED_a = Exposure duration for adult [year]
EF_{0-2} = Exposure frequency for 0-2 years [day/year]
EF_{2-6} = Exposure frequency for 2-6 years [day/year]
EF_{6-16} = Exposure frequency for 6-16 years [day/year]
EF_{16-26} = Exposure frequency for 16-26 years [day/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_{0-2} = Exposure time for 0-2 years [hr/day]
ET_{2-6} = Exposure time for 2-6 years [hr/day]
ET_{6-16} = Exposure time for 6-16 years [hr/day]
ET_{16-26} = Exposure time for 16-26 years [hr/day]

RfC = Chemical-specific reference concentration [mg/m^3]

	IUR = Chemical-specific inhalation unit risk [(μg/m^3)$^{-1}$] *365* = Converts AT_c, AT_{nc} in years to days [day/year] 10^3 = Converts RBTL in mg to μg [1000 μg/mg] *24* = Converts ET_{in} hours to day [24 hrs/day] *10* = Age-dependent adjustment factor for 0-2 yr [-] *3* = Age-dependent adjustment factor for 2-6 yr [-] *3* = Age-dependent adjustment factor for 6-16 yr [-] *1* = Age-dependent adjustment factor for 16-26 yr [-]

INGESTION OF CHEMICALS IN SOIL (CHILD AND ADULT RESIDENT; COMMERCIAL/INDUSTRAIL WORKER; AND CONSTRUCTION WORKER)	
Carcinogenic Effects $$RBTL_{sing} = \frac{TR \times BW \times AT_c \times 365}{ED \times EF \times IR_{soil} \times RBA \times SF_o \times 10^{-6}}$$ Non-carcinogenic Effects $$RBTL_{sing} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_o}{ED \times EF \times IR_{soil} \times 10^{-6}}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where: $RBTL_{sing}$ = Risk based target level for ingestion of chemicals in soil [mg/kg] TR = Target risk [-] THQ = Target hazard quotient [-] THQ = Target hazard quotient for individual constituents [-] 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 [day/year] IR_{soil} = Soil ingestion rate [mg/day] RBA = Relative bioavailability [-] SF_o = Oral cancer slope factor [(mg/kg-day)$^{-1}$] RfD_o = Chemical-specific oral reference dose [mg/kg-day] 365 = Converts AT_c, AT_{nc} in years to days [day/year] 10^{-6} = Converts kg to mg [kg/mg]

DERMAL CONTACT WITH CHEMICALS IN SOIL (CHILD AND ADULT RESIDENT; COMMERCIAL/INDUSTRAIL WORKER; AND CONSTRUCTION WORKER)	
Carcinogenic Effects $$RBTL_{sd} = \frac{TR \times AT_c \times 365 \times BW}{EF \times ED \times SF_d \times SA_{soil} \times AF \times ABS_d \times 10^{-6}}$$ Non-carcinogenic Effects $$RBTL_{sd} = \frac{THQ \times AT_{nc} \times 365 \times BW \times RfD_d}{EF \times ED \times SF_d \times AF \times ABS_d \times 10^{-6}}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where, $RBTL_{sd}$ = Risk based target level for dermal contact with soil [mg/kg] TR = Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-] THQ = Target hazard quotient for a chemical [-] 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 [day/year] SA = Skin surface area available for contact with soil [cm^2/day] AF = Soil to skin adherence factor [mg/cm^2] ABS_d = Chemical-specific dermal absorption fraction [-] SF_d = Chemical-specific dermal cancer slope factor [$(mg/kg\text{-}day)^{-1}$] RfD_d = Chemical-specific oral reference dose [mg/kg-day] 365 = Converts AT_c, AT_{nc} in years to days [day/year] 10^{-6} = Converts mg to kg [kg/mg]

INHALATION OF VAPORS AND PARTICULATES OF CHEMICALS IN SOIL (CHILD AND ADULT RESIDENT; COMMERCIAL/INDUSTRAIL WORKER; AND CONSTRUCTION WORKER)

Carcinogenic Effects

$$RBTL_{sinh} = \frac{TR \times AT_c \times 365 \times 24}{EF \times ED \times ET_{out} \times IUR \times (VF_s + VF_p) \times 10^3}$$

Non-carcinogenic Effects

$$RBTL_{sinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 24}{EF \times ED \times ET_{out} \times (VF_s + VF_p)}$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

where,

$RBTL_{sinh}$	=	Risk based target level for inhalation of vapors and particulates from soil [mg/kg]
TR	=	Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-]
THQ	=	Target hazard quotient for a chemical [-]
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_{out}	=	Outdoor exposure time [(hr/day)×(1 day/24 hours)]
IUR	=	Chemical-specific inhalation unit risk [$(\mu g/m^3)^{-1}$]
RfC	=	Chemical-specific inhalation reference dose [mg/m^3]
365	=	Converts AT_c, AT_{nc} in years to days [day/year]
24	=	Converts ET_{out} hours to day [1 day/24 hours]
10^3	=	Converts mg to µg [µg/mg]
VF_s	=	Volatilization factor for vapor emissions from soil [kg-soil/m^3-air]
VF_p	=	Volatilization factor for particulate emissions from soil [kg-soil/m^3-air]

INGESTION OF, DERMAL CONTACT WITH, AND INHALATION OF VAPORS AND PARTICULATES FROM SOIL (CHILD AND ADULT RESIDENT, COMMERCIAL/INDUSTRIAL WORKER, AND CONSTRUCTION WORKER)

$$RBTL_s = \frac{1}{\frac{1}{RBTL_{sing}} + \frac{1}{RBTL_{sd}} + \frac{1}{RBTL_{sinh}}}$$

where,

$RBTL_s$ = Risk based target level for ingestion of, dermal contact with, and inhalation of vapors and particulates for soil [mg/kg]
$RBTL_{sing}$ = Risk based target level for ingestion of soil [mg/kg]
$RBTL_{sd}$ = Risk based target level for dermal contact with soil [mg/kg]
$RBTL_{sinh}$ = Risk based target level for inhalation of vapors and particulates from soil [mg/kg]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

INSTGESION OF DOMESTIC WATER (CHILD AND ADULT RESIDENT)	
Carcinogenic effects $$RBTL_{wing} = \frac{TR \times BW \times AT_c \times 365}{ED \times EF \times IR_w \times SF_o}$$ Non-carcinogenic Effects $$RBTL_{wing} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_o}{ED \times EF \times IR_w}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where: $RBTL_{wing}$ = Carcinogenic risk based target level for ingestion of chemicals in water [mg/L] TR = Target risk [-] THQ = Target hazard quotient [-] 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 [day/year] IR_w = Water ingestion rate [mg/day] SF_o = Oral cancer slope factor [(mg/kg-day)$^{-1}$] RfD_o = Chemical-specific oral reference dose [mg/kg-day] 365 = Converts AT_c, AT_{nc} in years to days [day/year] 10^3 = Converts mg to µg [mg/µg]

DERMAL CONTACT WITH CHEMICALS IN DOMESTIC WATER (CHILD AND ADULT RESIDENT)

Carcinogenic Effects

$$RBTL_{wd} = \frac{TR \times BW \times AT_c \times 365 \times 10^3}{ED \times EF \times SA_w \times EV_w \times Z \times SF_d}$$

Non-carcinogenic Effects

$$RBTL_{wd} = \frac{THq \times BW \times AT_{nc} \times RfD \times 365 \times 10^3}{ED \times EF \times SA_w \times EV_w \times Z}$$

For organic chemicals with $t_{event} \leq t^*$, then

$$Z = 2 \times FA \times K_p \sqrt{6\tau_{event} \frac{t_{event}}{\pi}}$$

For organic chemicals with $t_{event} > t^*$, then

$$Z = FA \times K_p \left[\frac{t_{event}}{1+B} + 2\tau_{event}\left(\frac{1+3B+3B^2}{(1+B^2)}\right)\right]$$

For inorganic chemicals $Z = K_p \times t_{event}$

where,

$RBTL_{wd}$	= Risk-based target level for dermal contact with groundwater [mg/L]
TR	= Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-]
THQ	= Target hazard quotient for individual constituents [-]
BW	= Body weight [kg]
AT_c	= Averaging time for carcinogens[year]
AT_{nc}	= Averaging time for non-carcinogens[year]
SA_w	= Skin surface area available for contact with water [cm^2]
EV_w	= Event frequency [event/day]
ED	= Exposure duration [year]
EF	= Exposure frequency [day/year]
RfD_d	= Chemical-specific dermal reference dose [mg/kg-day]
SF_d	= Chemical-specific dermal cancer slope or potency factor $[mg/(kg\text{-}day)]^{-1}$
365	= Converts AT_c, AT_{nc} in years to days [day/year]
10^3	= Conversion factor from cm^3 to L [cm^3/L]
t_{event}	= Event duration [hr/event]
t^*	= Chemical-specific time to reach steady-state [hr]
Z	= Chemical-specific dermal factor [cm/event]
K_p	= Chemical-specific dermal permeability coefficient [cm/hr]
FA	= Chemical-specific fraction absorbed in water [-]
τ_{event}	= Chemical-specific lag time [hr/event]
B	= Chemical-specific relative contribution of permeability coefficient [-]

$$B = K_P \frac{\sqrt{MW}}{2.6}$$ $$\log K_P = -2.80 + 0.66 \log K_{OW} - 0.0056MW$$ If B<0.6 or B=0.6, then, $t^* = 2.4\tau_{event}$ If B>0.6 then, $t^* = 6\tau_{event} \times (b - \sqrt{b^2 - c^2})$ where, $$c = \frac{1 + 3B + 3B^2}{3(1 + B)}$$ $$b = 2 \times \frac{(1 + B)^2}{\pi} - c$$ $$\tau_{event} = 0.105 \times 10^{(0.0056MW)}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where: MW = Molecular weight [g/mole] K_{ow} = Octanol water partition coefficient [L/kg] *b, c* = Correlation coefficient which have been fitted to the data from Flynn, G.L. (1990)

INHALATION OF VAPORS FROM DOMESTIC WATER USE (CHILD AND ADULT RESIDENT)	
Carcinogenic effects $$RBTL_{c-winh} = \frac{TR \times AT_c \times 365 \times 24}{ED \times EF \times ET \times K_f \times IUR \times 10^3}$$ Non-carcinogenic Effects $$RBTL_{nc-winh} = \frac{THQ \times RfC \times AT_{nc} \times 365 \times 24}{ED \times EF \times ET \times K_f}$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	where: $RBTL_{c-winh}$ = Carcinogenic risk based target level for inhalation of chemicals in water [mg/L] *TR* = Target risk [-] *THQ* = Target hazard quotient [-] 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_w = Exposure time [hr/day] K_f = Adelman volatilization factor [L/m^3] *RfC* = Chemical-specific reference concentration [mg/m^3] *IUR* = Chemical-specific inhalation unit risk [(µg/m^3)$^{-1}$] *365* = Converts AT_c, AT_{nc} in years to days [day/year] *24* = Converts ET_{in} hours to day [24 hrs/day] *10* = Converts micrograms to milligrams [-]

INGESTION OF, DERMAL CONTACT WITH, AND INHALATION OF VAPORS FROM DOMESTIC WATER USE (CHILD AND ADULT RESIDENT)

$$RBTL_w = \frac{1}{\frac{1}{RBTL_{wing}} + \frac{1}{RBTL_{wd}} + \frac{1}{RBTL_{winh}}}$$

where,

$RBTL_w$ = Risk based target level for ingestion of, dermal contact with, and inhalation of vapors from domestic use of water [µg/L]
$RBTL_{wing}$ = Risk based target level for ingestion of water [µg/L]
$RBTL_{wd}$ = Risk based target level for dermal contact with water [µg/L]
$RBTL_{winh}$ = Risk based target level for inhalation of vapors from domestic use of water [µg/L]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

INGESTION OF CHEMICALS IN SOIL
(AGE-ADJUSTED RESIDENT)

Carcinogenic Effects

$$RBTL_{sing} = \frac{TR \times AT_c \times 365}{IR_{saa} \times RBA \times SF_o \times 10^{-6}}$$

Non-carcinogenic Effects

$$RBTL_{sing} = \frac{THQ \times AT_{nc} \times 365 \times RfD_o}{IR_{saa} \times RBA \times 10^{-6}}$$

where,

$$IR_{saa} = \frac{ED_c \times EF_c \times IR_c + ED_a \times EF_a \times IR_a}{BW_c + BW_a}$$

Mutagenic Effects

$$RBTL_{sing} = \frac{TR \times AT_c \times 365}{IR_{saam} \times RBA \times SF_o \times 10^{-6}}$$

where,

where:

$RBTL_{sing}$	=	Risk based target level for ingestion of chemicals in soil [mg/kg]
TR	=	Target risk [-]
THQ	=	Target hazard quotient [-]
THQ	=	Target hazard quotient for individual constituents [-]
BW_c	=	Child body weight [kg]
BW_a	=	Adult body weight [kg]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED_c	=	Child exposure duration [year]
ED_a	=	Adult exposure duration [year]
EF_{0-2}	=	Exposure frequency for 0-2 years [day/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [day/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [day/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [day/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}	=	Soil ingestion rate for 16-26 years [year]
IR_{0-2}	=	Soil ingestion rate for 0-2 years [hr/day]
IR_{2-6}	=	Soil ingestion rate for 2-6 years [hr/day]
IR_{6-16}	=	Soil ingestion rate for 6-16 years [hr/day]
IR_{16-26}	=	Soil ingestion rate for 16-26 years [hr/day]

$$IR_{saam} = \left[\begin{array}{c} \frac{EF_{0-2} \times ED_{0-2} \times IR_{0-2} \times 10}{BW_{0-2}} + \\ \frac{EF_{2-6} \times ED_{2-6} \times IR_{2-6} \times 3}{BW_{2-6}} + \\ \frac{EF_{6-16} \times ED_{6-16} \times IR_{6-16} \times 3}{BW_{6-16}} + \\ \frac{EF_{16-26} \times ED_{16-26} \times IR_{16-26} \times 1}{BW_{16-26}} \end{array} \right]$$

EF_c = Child exposure frequency [day/year]
EF_a = Adult exposure frequency [day/year]
IR_c = Child soil ingestion rate [mg/day]
IR_a = Adult soil ingestion rate [mg/day]
IR_{saa} = Age-adjusted soil ingestion rate for carcinogens [mg/kg]
IR_{saam} = Age-adjusted soil ingestion rate for mutagens [mg/kg]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

RBA = Relative bioavailability [-]
SF_o = Oral cancer slope factor [(mg/kg-day)$^{-1}$]
RfD_o = Chemical-specific oral reference dose [mg/kg-day]
365 = Converts AT_c, AT_{nc} in years to days [day/year]
10^{-6} = Converts kg to mg [kg/mg]
10 = Age-dependent adjustment factor for 0-2 yr [-]
3 = Age-dependent adjustment factor for 2-6 yr [-]
3 = Age-dependent adjustment factor for 6-16 yr [-]
1 = Age-dependent adjustment factor for 16-26 yr [-]

DERMAL CONTACT WITH CHEMICALS IN SOIL
(AGE-ADJUSTED RESIDENT)

Carcinogenic Effects

$$RBTL_{ds} = \frac{TR \times AT_c \times 365}{DF_{aa} \times SF_d \times ABS_d \times 10^{-6}}$$

Non-carcinogenic Effects

$$RBTL_{ds} = \frac{THQ \times AT_{nc} \times 365 \times RfD_d}{DF_{aa} \times ABS_d \times 10^{-6}}$$

where,

$$DF_{saa} = \frac{ED_c \times EF_c \times SA_c \times AF_c + ED_a \times EF_a \times SA_a \times AF_a}{BW_c + BW_a}$$

Mutagenic Effects

$$RBTL_{ds} = \frac{TR \times AT_c \times 365}{DF_{saam} \times SF_d \times ABS_d \times 10^{-6}}$$

where,

$RBTL_{ds}$	=	Risk based target level for dermal contact with soil [mg/kg]
TR	=	Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-]
THQ	=	Target hazard quotient for a chemical [-]
DF_{saa}	=	Age-adjusted soil dermal factor for carcinogens [cm^2/kg]
BW_c	=	Child body weight [kg]
BW_a	=	Adult body weight [kg]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
DF_{aa}	=	Dermal factor [mg/kg]
ED_c	=	Child exposure duration [year]
ED_a	=	Adult exposure duration [year]
EF_c	=	Child exposure frequency [day/year]
EF_a	=	Adult exposure frequency [day/year]
SA_c	=	Child skin surface area [cm^2/day]
SA_a	=	Adult skin surface area [cm^2/day]
AF_c	=	Child soil to skin adherence factor [mg/cm^2]
AF_a	=	Adult soil to skin adherence factor [mg/cm^2]
DF_{saam}	=	Age-adjusted soil dermal factor for mutagens [cm^2/kg]
$EF_{0\text{-}2}$	=	Exposure frequency for 0-2 years [day/year]
$EF_{2\text{-}6}$	=	Exposure frequency for 2-6 years [day/year]
$EF_{6\text{-}16}$	=	Exposure frequency for 6-16 years [day/year]
$EF_{16\text{-}26}$	=	Exposure frequency for 16-26 years [day/year]
$ED_{0\text{-}2}$	=	Exposure duration for 0-2 years [year]
$ED_{2\text{-}6}$	=	Exposure duration for 2-6 years [year]

where,

$$DF_{saam} = \left[\begin{array}{c} \dfrac{EF_{0-2} \times ED_{0-2} \times IR_{0-2} \times 10}{BW_{0-2}} + \\ \dfrac{EF_{2-6} \times ED_{2-6} \times IR_{2-6} \times 3}{BW_{2-6}} + \\ \dfrac{EF_{6-16} \times ED_{6-16} \times IR_{6-16} \times 3}{BW_{6-16}} + \\ \dfrac{EF_{16-26} \times ED_{16-26} \times IR_{16-26} \times 1}{BW_{16-26}} \end{array}\right]$$

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

ED_{6-16}	=	Exposure duration for 6-16 years [year]
ED_{16-26}	=	Exposure duration for 16-26 years [year]
SA_{0-2}	=	Skin surface area for 0-2 years [day/year]
SA_{2-6}	=	Skin surface area for 2-6 years [day/year]
SA_{6-16}	=	Skin surface area for 6-16 years [day/year]
SA_{16-26}	=	Skin surface area for 16-26 years [day/year]
AF_{0-2}	=	Adherence factor for 0-2 years [day/year]
AF_{2-6}	=	Adherence factor for 2-6 years [day/year]
AF_{6-16}	=	Adherence factor for 6-16 years [day/year]
AF_{16-26}	=	Adherence factor for 16-26 years [day/year]
BW_{0-2}	=	Body weight for 0-2 years [day/year]
BW_{2-6}	=	Body weight for 2-6 years [day/year]
BW_{6-16}	=	Body weight for 6-16 years [day/year]
BW_{16-26}	=	Body weight for 16-26 years [day/year]
ABS_d	=	Chemical-specific dermal absorption fraction [-]
SF_d	=	Chemical-specific dermal cancer slope factor [(mg/kg-day)$^{-1}$]
RfD_d	=	Chemical-specific oral reference dose [mg/kg-day]
365	=	Converts AT_c, AT_{nc} in years to days [day/year]
10^{-6}	=	Converts mg to kg [kg/mg]
10	=	Age-dependent adjustment factor for 0-2 yr [-]
3	=	Age-dependent adjustment factor for 2-6 yr [-]
3	=	Age-dependent adjustment factor for 6-16 yr [-]
1	=	Age-dependent adjustment factor for 16-26 yr [-]

INHALATION OF VAPORS AND PARTICULATES OF CHEMICALS IN SOIL (AGE-ADJUSTED RESIDENT)

Carcinogenic Effects

$$RBTL_{sinh} = \frac{TR \times AT_c \times 365 \times 24}{EF \times ED_{aa} \times ET \times IUR \times (VF_s + VF_p) \times 10^3}$$

Non-carcinogenic Effects

$$RBTL_{sinh} = \frac{THQ \times AT_{nc} \times 365 \times RfC \times 24}{EF \times ED_{aa} \times ET \times (VF_s + VF_p)}$$

where,

$$ED_{aa} = ED_c + ED_a$$

Mutagenic Effects

$$RBTL_{sinh} = \frac{TR \times AT_c \times 365 \times 24}{EF \times ED_{aa} \times ET_{out} \times IUR \times (VF_s + VF_p) \times 10^3 \times \left[\left(\frac{EF_{0-2} \times ED_{0-2} \times ET_{0-2} \times 10}{BW_{0-2}}\right) + \left(\frac{EF_{2-6} \times ED_{2-6} \times ET_{2-6} \times 3}{BW_{2-6}}\right) + \left(\frac{EF_{6-16} \times ED_{6-16} \times ET_{6-16} \times 3}{BW_{6-16}}\right) + \left(\frac{EF_{16-26} \times ED_{16-26} \times ET_{16-26} \times 1}{BW_{16-26}}\right) \right]}$$

where,

$RBTL_{inhs}$	=	Risk based target level for inhalation of vapors and particulates from soil [mg/kg]
TR	=	Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-]
THQ	=	Target hazard quotient for a chemical [-]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED_{aa}	=	Age-adjusted exposure duration [year]
ED_c	=	Child exposure duration [year]
ED_a	=	Adult exposure duration [year]
EF	=	Exposure frequency [day/year]
ET	=	Outdoor exposure time [(hr/day)×(1 day/24 hours)]
EF_{0-2}	=	Exposure frequency for 0-2 years [day/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [day/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [day/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [day/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_{0-2}	=	Exposure time for 0-2 years [year]
ET_{2-6}	=	Exposure time for 2-6 years [year]
ET_{6-16}	=	Exposure time for 6-16 years [year]
ET_{16-26}	=	Exposure time for 16-26 years [year]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.	*10* = Age-dependent adjustment factor for 0-2 yr [-] *3* = Age-dependent adjustment factor for 2-6 yr [-] *3* = Age-dependent adjustment factor for 6-16 yr [-] *1* = Age-dependent adjustment factor for 16-26 yr [-] *IUR* = Chemical-specific inhalation unit risk [(µg/m^3)$^{-1}$] *RfC* = Chemical-specific inhalation reference dose [mg/m^3] *365* = Converts AT_c, AT_{nc} in years to days [day/year] *24* = Converts ET_{out} hours to day [1 day/24 hours] 10^3 = Converts ug to mg [-] VF_s = Volatilization factor for vapor emissions from soil [kg-soil/m^3-air] VF_p = Volatilization factor for particulate emissions from soil [kg-soil/m^3-air]

INGESTION OF, DERMAL CONTACT WITH, AND INHALATION OF VAPORS AND PARTICULATES FROM SOIL (AGE-ADJUSTED RESIDENT)

$$RBTL_s = \frac{1}{\frac{1}{RBTL_{sing}} + \frac{1}{RBTL_{sd}} + \frac{1}{RBTL_{sinh}}}$$

where,

$RBTL_s$ = Risk based target level for ingestion of, dermal contact with, and inhalation of vapors and particulates for soil [mg/kg]
$RBTL_{sing}$ = Risk based target level for ingestion of soil [mg/kg]
$RBTL_{sd}$ = Risk based target level for dermal contact with soil [mg/kg]
$RBTL_{sinh}$ = Risk based target level for inhalation of vapors and particulates from soil [mg/kg]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

INSTGESION OF DOMESTIC WATER
(AGE-ADJUSTED RESIDENT)

Carcinogenic Effects

$$RBTL_{wing} = \frac{TR \times AT_c \times 365}{IRW_{aa} \times SF_o}$$

Non-carcinogenic Effects

$$RBTL_{wing} = \frac{THQ \times AT_{nc} \times 365 \times RfD_o}{IRW_{aa}}$$

where,

$$IR_{waa} = \frac{ED_c \times EF_c \times IRW_c}{BW_c} + \frac{ED_a \times EF_a \times IRW_a}{BW_a}$$

Mutagenic Effects

$$RBTL_{wing} = \frac{TR \times AT_c \times 365}{IR_{waam} \times SF_o}$$

where,

where:

$RBTL_{wing}$	=	Risk based target level for ingestion of chemicals in water [mg/L]
TR	=	Target risk [-]
THQ	=	Target hazard quotient [-]
BW	=	Body weight [kg]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
IRW_{aa}	=	Age-adjusted water ingestion rate [L/kg]
ED_c	=	Child exposure duration [year]
ED_a	=	Adult exposure duration [year]
EF_c	=	Child exposure frequency [days/year]
EF_a	=	Child exposure frequency [days/year]
IRW_c	=	Child water ingestion rate [L/day]
IRW_a	=	Adult water ingestion rate [L/day]
EF_{0-2}	=	Exposure frequency for 0-2 years [day/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [day/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [day/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [day/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]
IRW_{0-2}	=	Water ingestion rate for 0-2 years [year]
IRW_{2-6}	=	Water ingestion rate for 2-6 years [year]
IRW_{6-16}	=	Water ingestion rate for 6-16 years [year]
IRW_{16-26}	=	Water ingestion rate for 16-26 years [year]
10	=	Age-dependent adjustment factor for 0-2 yr [-]

$$IR_{waam} = \left[\frac{EF_{0-2} \times ED_{0-2} \times IRW_{0-2} \times 10}{BW_{0-2}} + \frac{EF_{2-6} \times ED_{2-6} \times IRW_{2-6} \times 3}{BW_{2-6}} + \frac{EF_{6-16} \times ED_{6-16} \times IRW_{6-16} \times 3}{BW_{6-16}} + \frac{EF_{16-26} \times ED_{16-26} \times IRW_{16-26} \times 1}{BW_{16-26}} \right]$$ **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	*3* = Age-dependent adjustment factor for 2-6 yr [-] *3* = Age-dependent adjustment factor for 6-16 yr [-] *1* = Age-dependent adjustment factor for 16-26 yr [-] SF_o = Oral cancer slope factor [(mg/kg-day)$^{-1}$] RfD_o = Chemical-specific oral reference dose [mg/kg-day] *365* = Converts AT_c, AT_{nc} in years to days [day/year]

DERMAL CONTACT WITH CHEMICALS IN DOMESTIC WATER (AGE-ADJUSTED RESIDENT)

Carcinogenic Effects

$$RBTL_{dw} = \frac{TR \times AT_c \times 365 \times 10^3}{DF_{waa} \times Z \times SF_d}$$

Non-carcinogenic Effects

$$RBTL_{dw} = \frac{THQ \times AT_{nc} \times RfD \times 365 \times 10^3}{DF_{waa} \times Z}$$

$$DF_{waa} = \frac{ED_c \times EF_c \times SA_{wc} \times EV_{wc}}{BW_c} + \frac{ED_a \times EF_a \times SA_{wa} \times EV_{wa}}{BW_a}$$

Mutagenic Effects

$$RBTL_{dw} = \frac{TR \times AT_c \times 365 \times 10^3}{DF_{waam} \times Z \times SF_d}$$

where,

$RBTL_{dw}$ = Risk-based target level for dermal contact [mg/L]
TR = Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-]
THQ = Target hazard quotient for individual constituents [-]
AT_c = Averaging time for carcinogens[year]
AT_{nc} = Averaging time for non-carcinogens[year]
DF_{waa} = Dermal exposure factor [cm^2-event/kg]
ED_c = Child exposure duration [year]
ED_a = Adult exposure duration [year]
EF_c = Child exposure frequency [day/year]
EF_a = Adult exposure frequency [day/year]
SA_{wc} = Child skin surface area [cm^2]
SA_{wa} = Adult skin surface area [cm^2]
EV_{wc} = Child event frequency [event/day]
EV_{wa} = Adult event frequency [event/day]
BW_c = Child body weight [kg]
BW_a = Adult body weight [kg]
EF_{0-2} = Exposure frequency for 0-2 years [day/year]
EF_{2-6} = Exposure frequency for 2-6 years [day/year]
EF_{6-16} = Exposure frequency for 6-16 years [day/year]
EF_{16-26} = Exposure frequency for 16-26 years [day/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]

where,

$$DF_{waam} = \left[\frac{EF_{0-2} \times ED_{0-2} \times SA_{0-2} \times EV_{0-2} \times 10}{BW_{0-2}} + \frac{EF_{2-6} \times ED_{2-6} \times SA_{0-2} \times EV_{2-6} \times 3}{BW_{2-6}} + \frac{EF_{6-16} \times ED_{6-16} \times SA_{0-2} \times EV_{6-16} \times 3}{BW_{6-16}} + \frac{EF_{16-26} \times ED_{16-26} \times SA_{0-2} \times EV_{16-26} \times 1}{BW_{16-26}} \right]$$

t_{event} = Event duration [hr/event]
t^* = Chemical-specific time to reach steady-state [hr]
Z = Chemical-specific dermal factor [cm/event]
K_p = Chemical-specific dermal permeability coefficient [cm/hr]
FA = Chemical-specific fraction absorbed in water [-]
τ_{event} = Chemical-specific lag time [hr/event]
B = Chemical-specific relative contribution of permeability coefficient [-]

For organic chemicals with $t_{event} \leq t^*$, then

$$Z = 2 \times FA \times K_p \sqrt{6\tau_{event} \frac{t_{event}}{\pi}}$$

For organic chemicals with $t_{event} > t^*$, then

$$Z = FA \times K_p \left[\frac{t_{event}}{1+B} + 2\tau_{event} \left(\frac{1+3B+3B^2}{(1+B^2)} \right) \right]$$

SA_{0-2} = Skin surface area for 0-2 years [cm^2]
SA_{2-6} = Skin surface area for 2-6 years [cm^2]
SA_{6-16} = Skin surface area for 6-16 years [cm^2]
SA_{16-26} = Skin surface area for 16-26 years [cm^2]
EV_{0-2} = Event frequency for 0-2 years [events/day]
EV_{2-6} = Event frequency for 2-6 years [events/day]
EV_{6-16} = Event frequency for 6-16 years [events/day]
EV_{16-26} = Event frequency for 16-26 years [events/day]
10 = Age-dependent adjustment factor for 0-2 yr [-]
3 = Age-dependent adjustment factor for 2-6 yr [-]
3 = Age-dependent adjustment factor for 6-16 yr [-]
1 = Age-dependent adjustment factor for 16-26 yr [-]
RfD_d = Chemical-specific dermal reference dose [mg/kg-day]
SF_d = Chemical-specific dermal cancer slope or potency factor [mg/(kg-day)]$^{-1}$
365 = Converts AT_c, AT_{nc} in years to days [day/year]
1000 = Conversion factor from cm^3 to L [cm^3/L]

For inorganic chemicals $Z = K_p \times t_{event}$

$$B = K_P \frac{\sqrt{MW}}{2.6}$$

$$\log K_P = -2.80 + 0.66 \log K_{OW} - 0.0056 MW$$

If B<0.6 or B=0.6, then, $t^* = 2.4\tau_{event}$

If B>0.6 then, $t^* = 6\tau_{event} \times (b - \sqrt{b^2 - c^2})$

where,

	$$c = \frac{1 + 3B + 3B^2}{3(1 + B)}$$ $$b = 2 \times \frac{(1 + B)^2}{\pi} - c$$ $$\tau_{event} = 0.105 \times 10^{(0.0056MW)}$$ Source: Modified from RAGS, Vol. I, Part E, 2004. where: *MW* = Molecular weight [g/mole] K_{ow} = Octanol water partition coefficient [L/kg] *b, c* = Correlation coefficient which have been fitted to the data from Flynn, G.L. (1990) **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**

INHALATION OF VAPORS FROM DOMESTIC WATER USE (AGE-ADJUSTED RESIDENT)

Carcinogenic ffects

$$RBTL_{c-winh} = \frac{TR \times AT_c \times 365 \times 24}{ED_{aa} \times EF \times ET \times K_f \times IUR}$$

Non-carcinogenic Effects

$$RBTL_{nc-winh} = \frac{THQ \times RfC \times AT_{nc} \times 365 \times 24}{ED_{aa} \times EF \times ET \times K_f}$$

where,

$$ED_{aa} = ED_a + ED_a$$

Mutagenic Effects

$$RBTL_{c-winh} = \frac{TR \times AT_c \times 365 \times 24}{K_f \times IUR \times \left[\left(\frac{EF_{0-2} \times ED_{0-2} \times ET_{0-2} \times 10}{BW_{0-2}}\right) + \left(\frac{EF_{2-6} \times ED_{2-6} \times ET_{2-6} \times 3}{BW_{2-6}}\right) + \left(\frac{EF_{6-16} \times ED_{6-16} \times ET_{6-16} \times 3}{BW_{6-16}}\right) + \left(\frac{EF_{16-26} \times ED_{16-26} \times ET_{16-26} \times 1}{BW_{16-26}}\right) \right]}$$

where:

$RBTL_{c-winh}$	=	Risk based target level for inhalation of chemicals in water [mg/L]
TR	=	Target risk [-]
THQ	=	Target hazard quotient [-]
AT_c	=	Averaging time for carcinogens [year]
AT_{nc}	=	Averaging time for non-carcinogens [year]
ED_{aa}	=	Age-adjusted exposure duration [year]
ED_c	=	Child exposure duration [year]
ED_a	=	Adult exposure duration [year]
EF	=	Exposure frequency [day/year]
ET_w	=	Exposure time [hr/day]
K_f	=	Adelman volatilization factor [L/m^3]
EF_{0-2}	=	Exposure frequency for 0-2 years [day/year]
EF_{2-6}	=	Exposure frequency for 2-6 years [day/year]
EF_{6-16}	=	Exposure frequency for 6-16 years [day/year]
EF_{16-26}	=	Exposure frequency for 16-26 years [day/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_{0-2}	=	Exposure time for 0-2 years [year]
ET_{2-6}	=	Exposure time for 2-6 years [year]
ET_{6-16}	=	Exposure time for 6-16 years [year]
ET_{16-26}	=	Exposure time for 16-26 years [year]
10	=	Age-dependent adjustment factor for 0-2 yr [-]
3	=	Age-dependent adjustment factor for 2-6 yr [-]
3	=	Age-dependent adjustment factor for 6-16 yr [-]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.	*1* = Age-dependent adjustment factor for 16-26 yr [-] *RfC* = Chemical-specific reference concentration [mg/m^3] *IUR* = Chemical-specific inhalation unit risk [(µg/m^3)$^{-1}$] *365* = Converts AT_c, AT_{nc} in years to days [day/year] *24* = Converts ET_{in} hours to day [24 hrs/day]

INGESTION OF, DERMAL CONTACT WITH, AND INHALATION OF VAPORS FROM DOMESTIC WATER USE (AGE-ADJUSTED RESIDENT)

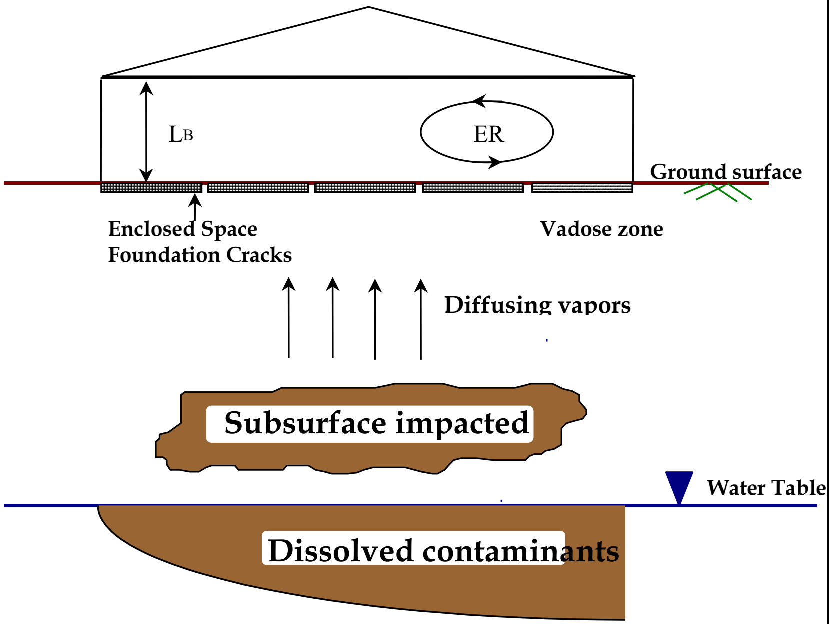
$$RBTL_w = \frac{1}{\frac{1}{RBTL_{wing}} + \frac{1}{RBTL_{wd}} + \frac{1}{RBTL_{winh}}}$$

where,

$RBTL_w$	=	Risk based target level for ingestion of, dermal contact with, and inhalation of vapors from domestic use of water [µg/L]
$RBTL_{wing}$	=	Risk based target level for ingestion of water [µg/L]
$RBTL_{wd}$	=	Risk based target level for dermal contact with water [µg/L]
$RBTL_{winh}$	=	Risk based target level for inhalation of vapors from domestic use of water [µg/L]

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

SOIL VAPOR CONCENTRATION PROTECTIVE OF INDOOR INHALATION OF VAPORS

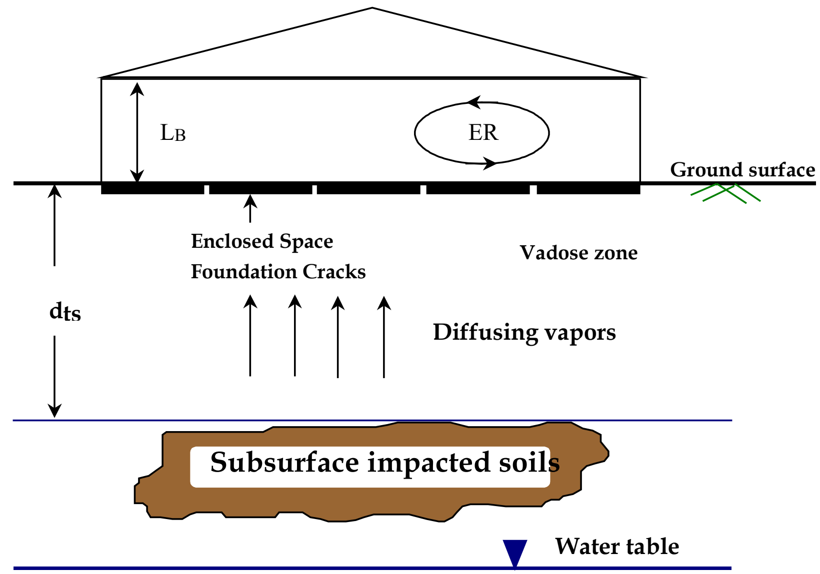


$$RBTL_{svi} = \frac{RBTL_{ininh}}{\alpha_{sv}}$$

where:

$RBTL_{svi}$	=	Risk based target level for indoor inhalation of vapors from soil vapor [mg/m^3-air]
$RBTL_{ininh}$	=	Risk based target level for indoor inhalation of air [mg/m^3-air]
α_{sv}	=	Attenuation factor from subsurface soil vapor to indoor (enclosed space) air [-]

Source: ASTM E1739-95

SUBSURFACE SOIL CONCENTRATION PROTECTIVE OF INDOOR INHALATION OF VAPORS	
$$RBTL_{si} = \frac{RBTL_{ininh}}{VF_{sesp}}$$ where: $RBTL_{si}$ = Risk based target level for indoor inhalation of vapors from subsurface soil [mg/kg-soil] $RBTL_{ininh}$= Risk based target level for indoor inhalation of air [mg/m^3-air] VF_{sesp} = Volatilization factor from subsurface soil to indoor (enclosed space) air [(mg/m^3-air)/(mg/kg-soil)] **Source: ASTM E1739-95**	

GROUNDWATER CONCENTRATION PROTECTIVE OF INDOOR INHALATION OF VAPORS

$$RBTL_{wi} = \frac{RBTL_{ininh}}{VF_{wesp}}$$

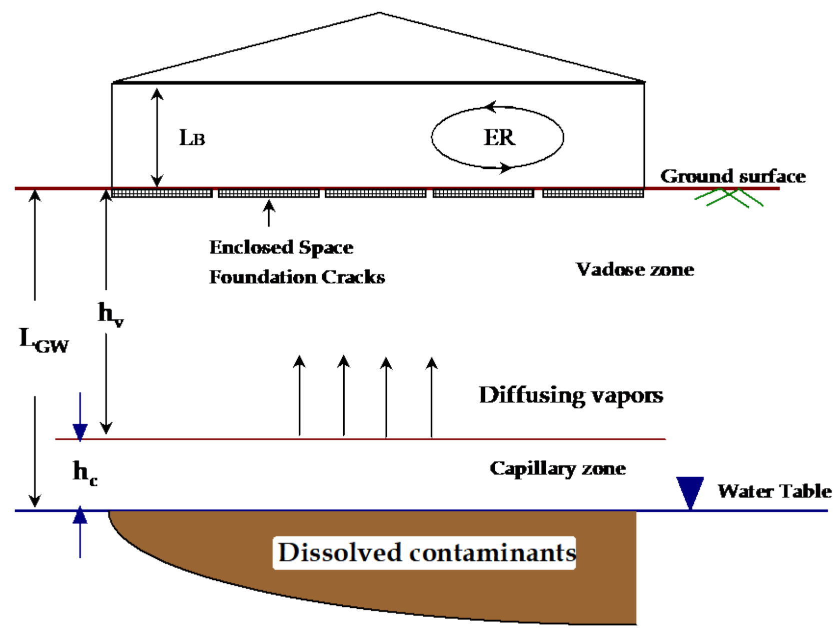
where:

$RBTL_{wi}$ = Risk based target level protective of indoor inhalation of vapors from groundwater [mg/L-water]

$RBTL_{ininh}$ = Risk based target level for indoor inhalation of air [mg/m^3-air]

VF_{wesp} = Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-water)]

Source: ASTM E1739-95



Chronic Volatilization Factors for Emissions from Surficial Soil to Outdoor Air (Residential and Commercial/Industrial Worker)

For Infinite Source

$$VF_{ss} = \left[Q/C \times \frac{(3.14 \times D_A \times \tau)^{1/2}}{2 \times p_s \times D_A} \times 10^{-4}\right]^{-1}$$

where:

$$D_A = \frac{\left(\theta_{as}^{10/3} \times D^a \times H + \theta_{ws}^{10/3} \times D^w\right)/\theta_T^2}{\rho_s \times K_{sv} + \theta_{ws} + \theta_{as} \times H}$$

or

For Mass Limit Source

$$VF_{ss} = \left[Q/C \times \frac{\tau}{p_s \times d_s} \times 10^{-4}\right]^{-1}$$

Use smaller of the two VF_{ss}.

Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.

VF_{ss}	=	Volatilization factor from surficial soil to outdoor (ambient) air [kg-soil/m^3-air]
Q/C	=	Inverse of the mean concentration at the center of square source [(g/m^2-s)/(kg/m^3)]
D_A	=	Apparent diffusivity [cm^2/s]
τ	=	Averaging time for vapor flux [s]
ρ_s	=	Vadose zone dry soil bulk density of surficial soil [g-soil/cm^3-soil]
K_{sv}	=	Chemical-specific solid-water sorption coefficient [cm^3-water/g-soil]
D_a	=	Chemical-specific diffusion coefficient in air [cm^2/s]
D_w	=	Chemical-specific diffusion coefficient in water [cm^2/s]
θ_T	=	Total soil porosity in the surficial soils [cm^3/cm^3-soil]
θ_{as}	=	Volumetric air content in the surficial soils [cm^3-air/cm^3-soil]
θ_{ws}	=	Volumetric water content in the surficial soils [cm^3-water/cm^3-soil]
H	=	Chemical-specific Henry's Law constant [(L-water)/(L-air)]
10^{-4}	=	Conversion factor [m^2/cm^2]
W_a	=	Dimension of soil source area parallel to wind direction [cm]
d_s	=	Depth to base of surficial soil zone [cm]

Note: Surficial soil properties are assumed same as the vadose zone pro properties.

Sub Chronic Volatilization Factors for Emissions from Surficial Soil to Outdoor Air (Construction Worker)	
For Infinite Source $$VF_{ss} = \left[Q/C \times \frac{\frac{1}{F_D} \times (3.14 \times D_A \times \tau)^{1/2}}{2 \times p_s \times D_A} \times 10^{-4} \right]^{-1}$$ where: $$D_A = \frac{\left(\theta_{as}^{10/3} \times D^a \times H + \theta_{ws}^{10/3} \times D^w\right)/\theta_T^2}{\rho_s \times K_{sv} + \theta_{ws} + \theta_{as} \times H}$$ or For Mass Limit Source $$VF_{ss} = \left[Q/C \times \frac{\frac{1}{F_D} \times \tau}{p_s \times d_s} \times 10^{-4} \right]^{-1}$$ Use smaller of the two VF_{ss}. **Source: Regional Screening Level (RSL) User's Guide, USEPA, May 2022.**	VF_{ss} = Volatilization factor from surficial soil to outdoor (ambient) air [kg-soil/m^3-air] Q/C = Inverse of the mean concentration at the center of square source [(g/m^2-s)/(kg/m^3)] F_D = Dispersion correction factor [-] D_A = Apparent diffusivity [cm^2/s] τ = Averaging time for vapor flux [s] ρ_s = Vadose zone dry soil bulk density of surficial soil [g-soil/cm^3-soil] K_{sv} = Chemical-specific solid-water sorption coefficient [cm^3-water/g-soil] D_a = Chemical-specific diffusion coefficient in air [cm^2/s] D_w = Chemical-specific diffusion coefficient in water [cm^2/s] θ_T = Total soil porosity in the surficial soils [cm^3/cm^3-soil] θ_{as} = Volumetric air content in the surficial soils [cm^3-air/cm^3-soil] θ_{ws} = Volumetric water content in the surficial soils [cm^3-water/cm^3-soil] H = Chemical-specific Henry's Law constant [(L-water)/(L-air)] 10^{-4} = Conversion factor [m^2/cm^2] W_a = Dimension of soil source area parallel to wind direction [cm] d_s = Depth to base of surficial soil zone [cm] *Note: Surficial soil properties are assumed same as the vadose zone pro properties.*

Volatilization Factors (Particulate Emissions from Surficial Soil for Resident, Commercial/Industrial Worker, and Construction Worker)	
$$VF_p = \left[Q/C \times \frac{3600}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}\right]^{-1}$$ **Source: Regional Screening Level (RSL) User Guide, USEPA, May 2022.**	where: VF_p = Volatilization factor for particulate emissions from surficial soil [kg-soil/m^3-air] Q/C = Inverse of the mean concentration at the center of square source [(g/m^2-s)/(kg/m^3)] V = Fraction of vegetative cover [-] 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 [-] *0.036* = Empirical constant [g/m^2-hr]

VOLATILIZATION/ATTENUATION FACTORS (SUBSURFACE SOIL VAPOR TO INDOOR AIR)	

For advection and diffusion,

$$\alpha_{sv} = \frac{\left[\left(\frac{D_T^{eff} \times A_B}{Q_{bldg} \times L_T}\right) \times \exp\left(\frac{Q_{soil} \times L_{crack}}{D_{crack}^{eff} \times A_{crack}}\right)\right]}{\left[\exp\left(\frac{Q_{soil} \times L_{crack}}{D_{crack}^{eff} \times A_{crack}}\right) + \left(\frac{D_T^{eff} \times A_B}{Q_{bldg} \times L_T}\right) + \left(\frac{D_T^{eff} \times A_B}{Q_{soil} \times L_T}\right)\left[\exp\left(\frac{Q_{soil} \times L_{crack}}{D_{crack}^{eff} \times A_{crack}}\right) - 1\right]\right]}$$

where,

$$L_T = D_{source} - L_F$$

If $L_F > L_{crack}$, $A_B = (L_B \times W_B) + (2 \times L_F \times L_B) + (2 \times L_F \times W_B)$

If $L_F \leq L_{crack}$, $A_B = (L_B \times W_B)$

$$Q_{bldg} = \left(\frac{L_B \times W_B \times H_B \times ER}{3600}\right)$$

$$A_{crack} = 2 \times (L_B + W_B) \times w$$

where,

α_{sv}	=	Attenuation factor for soil vapor to indoor air [-]
$D_T{}^{eff}$	=	Total overall effective diffusion coefficient [cm^2/s]
A_B	=	Area of enclosed space below grade [cm^2]
Q_{bldg}	=	Building ventilation rate [cm^3/s]
L_T	=	Source to building separation [cm]
Q_{soil}	=	Volumetric flow rate of soil-vapor into the enclosed space [cm^3/s]
L_{crack}	=	Slab thickness [cm]
$D_{crack}{}^{eff}$	=	Effective diffusion coefficient through the cracks [cm^2/s]
A_{crack}	=	Area of total cracks [cm^2]
D_{source}	=	Depth below grade to top of contamination [cm]
L_F	=	Depth below grade to bottom of enclosed space floor [cm]
L_B	=	Length of building [cm]
W_B	=	Width of building [cm]
Q_{bldg}	=	Building ventilation rate [cm^3/s]
H_B	=	Height of building [cm]
ER	=	Air exchange rate [l/h]
3600	=	Conversion factor [sec/h]
ΔP	=	Soil-building pressure differential [g/cm-s^2]
k_v	=	Soil gas permeability[cm^2]
X_{crack}	=	Floor-wall seam perimeter [cm]
μ	=	Viscosity of air at soil temperature [g/cm-s]
r_{crack}	=	Equivalent crack radius [cm]
Z_{crack}	=	Crack depth below grade [cm]

$Q_{soil} = \dfrac{2\pi \times \Delta P \times k_v \times X_{crack}}{\mu \times \ln\left(\dfrac{2Z_{crack}}{r_{crack}}\right)}$ $X_{crack} = 2 \times (L_B + W_B)$ $r_{crack} = \left(\dfrac{A_{crack}}{X_{crack}}\right)$ **Source: USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.**	

VOLATILIZATION FACTORS
(SUBSURFACE SOIL TO INDOOR AIR)

$$VF_{sesp} = \frac{H \times \rho_s}{[\theta_{ws} + (K_{sv} \times \rho_s) + (H \times \theta_{as})]} \times \alpha_s \times 10^3$$

Note: α_s is calculated using equation for α_{sv} with depth to subsurface soil source.

Source: USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.

where,

VF_{sesp}	=	Volatilization factor from subsurface soil to indoor (enclosed space) air [m^3-air/(mg/kg-soil)]
H	=	Chemical-specific Henry's Law constant [L-water/L-air]
ρ_s	=	Dry soil bulk density [g-soil/cm^3-soil]
θ_{ws}	=	Volumetric water content in vadose zone soil [cm^3-water/cm^3-soil]
θ_{as}	=	Volumetric air content in vadose zone soil [cm^3-air/cm^3-soil]
K_{sv}	=	$f_{ocv} \times K_{oc}$ = Chemical-specific soil-water sorption coefficient in vadose zone [cm^3/g]
α_s	=	Attenuation factor from subsurface soil to indoor
10^3	=	Conversion factor [(cm^3-kg)/(m^3-g)]

VOLATILIZATION FACTORS (GROUNDWATER TO INDOOR AIR)	
$VF_{wesp} = H \times \alpha_{gw} \times 10^3$ Note: α_{gw} is calculated using equation for α_{sv} with depth to groundwater. **Source: USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.**	where, VF_{wesp} = Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-water)] H = Vadose zone chemical specific Henry's Law constant [L-water/L-air] α_{gw} = Attenuation factor from groundwater to indoor 10^3 = Conversion factor [L/m^3]

EFFECTIVE DIFFUSION COEFFICIENTS

D_s^{eff} : effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s]

$$D_s^{eff} = D^a \times \frac{\theta_{as}^{3.33}}{\theta_T^2} + D^w \times \frac{1}{H} \times \frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

where:

D^a	=	Chemical-specific diffusion coefficient in air [cm^2/s]
D^w	=	Chemical-specific diffusion coefficient in water [cm^2/s]
θ_{as}	=	Volumetric air content in vadose zone soils [cm^3-air/cm^3-soil]
θ_{ws}	=	Volumetric water content in vadose zone soils [cm^3-water/cm^3-soil]
θ_T	=	Total soil porosity in the impacted zone [cm^3/cm^3-soil]
H	=	Chemical-specific Henry's Law constant [L-water/L-air]

D_{ws}^{eff} : effective diffusion coefficient between groundwater and surface soil [cm^2/s]

$$D_{ws}^{eff} = \left(h_{cap} + h_v\right) \times \left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1}$$

where:

h_{cap}	=	Thickness of capillary fringe [cm]
h_v	=	Thickness of vadose zone [cm]
D_{cap}^{eff}	=	Effective diffusion coefficient through capillary fringe [cm^2/s]
D_s^{eff}	=	Effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s]
L_{GW}	=	Depth to groundwater (h_{cap} + h_v) [cm]

D_{cap}^{eff} : effective diffusion coefficient for the capillary fringe [cm^2/s]

$$D_{cap}^{eff} = D^a \times \frac{\theta_{acap}^{3.33}}{\theta_T^2} + D^w \times \frac{1}{H} \times \frac{\theta_{wcap}^{3.33}}{\theta_T^2}$$

where:

D^a	=	Chemical-specific diffusion coefficient in air [cm^2/s]
D^w	=	Chemical-specific diffusion coefficient in water [cm^2/s]
θ_{acap}	=	Volumetric air content in capillary fringe soils [cm^3-air/cm^3-soil]
θ_{wcap}	=	Volumetric water content in capillary fringe soils [cm^3-water/cm^3-soil]
θ_T	=	Total soil porosity [cm^3/cm^3-soil]
H	=	Chemical-specific Henry's Law constant [L-water/L-air]

D_{crack}^{eff} : effective diffusion coeff. through foundation cracks [cm^2/s]

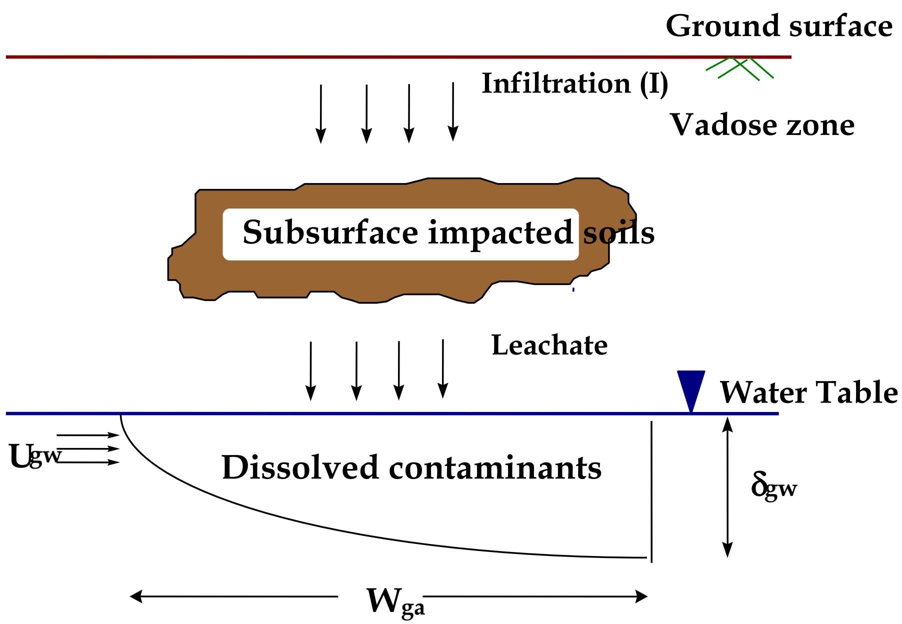
$$D_{crack}^{eff} = D^a \times \frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D^w \times \frac{1}{H} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$$

where:

D^a	=	Chemical-specific diffusion coefficient in air [cm^2/s]
D^w	=	Chemical-specific diffusion coefficient in water [cm^2/s]
θ_{acrack}	=	Volumetric air content in foundation/wall cracks [cm^3-air/cm^3-total volume]
θ_{wcrack}	=	Volumetric water content in foundation/wall cracks [cm^3-water/cm^3-total volume]
θ_T	=	Total soil porosity [cm^3/cm^3-soil]
H	=	Chemical-specific Henry's Law constant [L-water/L-air]

Source: ASTM E1739-95

SUBSURFACE SOIL CONCENTRATION PROTECTIVE OF LEACHING TO GROUNDWATER



$$RBTL_{SL} = \frac{RBTL_w}{LF_{SW}}$$

where:

$RBTL_{SL}$	=	Risk-based target level for leaching to groundwater from subsurface soil [mg/kg-soil]
$RBTL_w$	=	Risk-based target level for ingestion of groundwater [mg/L-water]
LF_{SW}	=	Leaching factor (from subsurface soil to groundwater) [(mg/L-water)/(mg/kg-soil)]

Source: ASTM E1739-95

LEACHING FACTOR FROM SUBSURFACE SOIL TO GROUNDWATER

$$LF_{SW} = \frac{\rho_s}{[\theta_{ws} + K_{sv} \times \rho_s + H \times \theta_{as}] \times \left(1 + \frac{U_{gw} \times \delta_{gw}}{1 \times W_{ga}}\right)}$$

where:

LF_{SW}	=	Leaching factor from subsurface soil to groundwater [(mg/L-water)/(mg/kg-soil)]
ρ_s	=	Vadose zone dry soil bulk density [g-soil/cm^3-soil]
θ_{ws}	=	Volumetric water content in vadose zone soils [cm^3-water/cm^3- soil]
K_{sv}	=	$f_{ocv} \times K_{oc}$ = Chemical-specific soil-water sorption coefficient in vadose zone [cm^3-water/g-soil]
H	=	Chemical-specific Henry's Law constant [L-water/L-air]
θ_{as}	=	Volumetric air content in the vadose zone soils [cm^3-air/cm^3-soil]
U_{gw}	=	Ki = Groundwater Darcy velocity [cm/yr]
K	=	Hydraulic conductivity of the saturated zone [cm/year]
i	=	Hydraulic gradient in the saturated zone [-]
δ_{gw}	=	Groundwater mixing zone thickness [cm]
I	=	Infiltration rate of water through vadose zone [cm/year]
W_{ga}	=	Groundwater dimension parallel to groundwater flow direction [cm]

This equation consists of two parts (i) the Summer's model and (ii) equilibrium conversion of the leachate concentration to a soil concentration on a dry weight basis.

Source: ASTM E1739-95

DOMENICO MODEL: DILUTION ATTENUATION FACTOR (DAF) IN THE SATURATED ZONE

Domenico model for multi-dimensional transport with decay and continuous source:

$$\frac{C(x,y,z,t)}{C_o} = (1/8)\ exp\left[\frac{x}{2\,\alpha_x}\left[1 - \sqrt{1+\frac{4\,\lambda\,\alpha_x}{v}}\right]\right] \times erfc\left[\frac{\left[(x - vt)\sqrt{1+\frac{4\,\lambda\,\alpha_x}{v}}\right]}{2\sqrt{\alpha_x \times v \times t}}\right] \times$$

$$\left[erf\left[\frac{(y+Y/2)}{2\sqrt{\alpha_y\,x}}\right] - erf\left[\frac{(y-Y/2)}{2\sqrt{\alpha_y\,x}}\right]\right] \times \left[erf\left[\frac{(z+Z)}{2\sqrt{\alpha_z\,x}}\right] - erf\left[\frac{(z-Z)}{2\sqrt{\alpha_z\,x}}\right]\right]$$

where:

C	=	Dissolved-phase concentration [mg/L]
C_o	=	Dissolved-phase concentration at the source (at x=y=z=0) [mg/L]
v	=	Retarded seepage velocity [m/sec]
λ	=	Overall first order bio-decay rate [1/day]
α_x	=	Longitudinal dispersivity [m]
α_y	=	Lateral dispersivity [m]
α_z	=	Vertical dispersivity [m]
x, y, z	=	Spatial coordinates [m]
t	=	Time [day]
x	=	Distance along the centerline measured from the downgradient edge of the groundwater source [m]
Y	=	GW source dimension perpendicular to GW flow direction [m]
Z	=	GW source (mixing zone) thickness [m]
DA F_{sat}	=	$C_o/C(x)$

At the centerline, for steady-state (after a long time) the concentration can be obtained by setting $y = 0$, $z = 0$, and $x << v \times t$ as:

$$\frac{C(x)}{C_o} = exp\left[\frac{x}{2\,\alpha_x}\left[1 - \sqrt{1+\frac{4\,\lambda\,\alpha_x}{v}}\right]\right] \times erf\left[\frac{Y}{4\sqrt{\alpha_y\,x}}\right] \times erf\left[\frac{Z}{2\sqrt{\alpha_z\,x}}\right]$$

At the centerline, for steady-state the concentration without decay can be obtained by setting y = 0, z = 0, x << vt, and $\lambda = 0$ as:

$$\frac{C(x)}{C_o} = erf\left[\frac{Y}{4\sqrt{\alpha_y\,x}}\right] \times erf\left[\frac{Z}{2\sqrt{\alpha_z\,x}}\right]$$

Note: Compare to ASTM E1739-95, p. 31, where $Y = S_w$ $Z = S_d$, $v = u$, and $C_o = C_{source}$

Source: Domenico, P.A. and F.W. Schwartz, 1990, Physical and Chemical Hydrogeology. John Wiley and Sons, NY, 824 p. (Eqn. 17.21)

ALLOWABLE SOIL AND GROUNDWATER CONCENTRATION FOR GROUNDWATER RESOURCE PROTECTION

Allowable soil concentration at the source [mg/kg] = Target groundwater concentration at the POE $\times \frac{DAF_{POE}}{LF_{SW}} \times DAF_{unsat}$

Allowable groundwater concentration at the POD [mg/L] = Target groundwater concentration at the POE $\times \frac{DAF_{POE}}{DAF_{POD}}$

where,

POE	=	Point of exposure
POD	=	Point of demonstration
DAF_{POE}	=	Dilution attenuation factor between the point of exposure and source estimated using Domenico's equation
DAF_{POD}	=	Dilution attenuation factor between the point of demonstration and source estimated using Domenico's equation
DAF_{unsat}	=	Dilution attenuation factor in the unsaturated zone
LF_{SW}	=	Dry soil leaching factor [(mg/L-water)/(mg/kg-soil)]

Concentration at POE is expressed in mg/L-water. Additional relationships used in the calculation of allowable soil and groundwater concentration with chemical degradation:

First order decay rate [1/day] = $\frac{0.693}{Half\ Life}$; $\mathcal{V} = \frac{Ki}{\theta_{TS}\, R_s}$

Retardation factor for organics in the saturated zone (R_s) = 1 + $\left(\frac{\rho_{ss} \times K_{ss}}{\theta_{TS}}\right)$, $K_{ss} = f_{ocs} \times K_{oc}$ (for organics only)

where:

v	=	Regarded seepage velocity [cm/year]
K	=	Hydraulic conductivity in saturated zone [cm/year]
i	=	Hydraulic gradient in saturated zone [-]
p_{ss}	=	Saturated zone dry soil bulk density [g-soil/cm^3-soil]
K_{ss}	=	Chemical-specific soil-water sorption coefficient in the saturated zone [cm^3-water/g-soil]
K_{oc}	=	Chemical-specific normalized partition coefficient [cm^3/g-C]
θ_{TS}	=	Total porosity in the saturated zone [cm^3/g-C]
f_{ocs}	=	Fractional organic carbon content in the saturated zone [g-C/g-soil]

STREAM PROTECTION: ALLOWABLE GROUNDWATER CONCENTRATION AT THE POINT OF DISCHARGE

$$C_{gw} = \frac{C_{sw}\left(Q_{gw} + Q_{sw}\right)}{Q_{gw}} - C_{su}\left(\frac{Q_{sw}}{Q_{gw}}\right)$$

$$Q_{gw} = \left(Z + \sqrt{\alpha_z X_s}\right) \times \left(Y + 2\sqrt{\alpha_y X_s}\right) \times U_{gw}$$

where:

Q_{gw}	=	Impacted groundwater discharge into the stream [ft^3/day]
C_{gw}	=	Allowable concentration in groundwater at the point of discharge into the stream [mg/L]
Q_{sw}	=	Stream flow upstream of the point of groundwater discharge (stream flow rate) [ft^3/day]
C_{sw}	=	Allowable concentration at the downstream edge of the stream's mixing zone, i.e., the applicable stream water quality criteria [mg/L]
C_{su}	=	The COCs' concentration upstream of the groundwater plume discharge [mg/L]
Y	=	GW source dimension perpendicular to GW flow direction [ft]
Z	=	GW source (mixing zone) thickness [ft]
α_y	=	Lateral dispersivity [ft]
α_z	=	Vertical dispersivity [ft]
X_s	=	Distance from the downgradient edge of the groundwater source to the stream [ft]
U_{gw}	=	Darcy velocity [ft/day]

STREAM PROTECTION: ALLOWABLE SOIL AND GROUNDWATER CONCENTRATION AT THE SOURCE & POD

Allowable soil concentration at the source [mg/kg] = Target concentration at the POE [mg/L] $\times \frac{DAF_{POE}}{LF_{SW}} \times DAF_{unsat}$

Allowable groundwater concentration at the POD [mg/L] = Target concentration at the POE [mg/L] $\times \frac{DAF_{POE}}{DAF_{POD}}$

where:

POE	=	Point of exposure
POD	=	Point of demonstration
DAF_{POE}	=	Dilution attenuation factor between the point of exposure and source estimated using Domenico's equation
DAF_{POD}	=	Dilution attenuation factor between the point of demonstration and the source estimated using Domenico's equation
DAF_{unsat}	=	Dilution attenuation factor in the unsaturated zone
LF_{SW}	=	Dry soil leaching factor [(mg/L-water)/(mg/kg-soil)]

For calculation of DAF_{POE} and DAF_{POD}, please refer to Domenico's model.

SOIL CONCENTRATION AT WHICH DISSOLVED PORE WATER AND VAPOR PHASES BECOME SATURATED

Single Component

$$C_s^{SAT} = \frac{S}{\rho_s} \times [H \times \theta_{as} + \theta_{ws} + K_{sv} \times \rho_s]$$

Multiple Components

$$C_s^{SAT} = \frac{S_{ei}}{\rho_s} \times [H \times \theta_{as} + \theta_{ws} + K_{sv} \times \rho_s]$$

where:

C_s^{SAT}	=	Soil concentration at which dissolved pore water and vapor phases become saturated [(mg/kg-soil)]
S	=	Pure component solubility in water [mg/L-water]
S_{ei}	=	Effective solubility of component i in water = $x_i \times S$ [mg/L-water]
x_i	=	Mole fraction of component $i = (w_i \times MW_{\text{avg}})/MW_i$ [-]
w_i	=	Weight fraction of component i [-]
MW_{avg}	=	Average molecular weight of mixture [g/mole]
MW_i	=	Molecular weight of component i [g/mole]
ρ_s	=	Vadose zone dry soil bulk density [g-soil/cm^3-soil]
H	=	Chemical-specific Henry's Law constant [L-water/L-air]
θ_{as}	=	Volumetric air content in the vadose zone soils [cm^3-air/cm^3-soil]
θ_{ws}	=	Volumetric water content in vadose zone soils [cm^3-water/cm^3- soil]
K_{sv}	=	$f_{ocv} \times K_{oc}$ = Chemical-specific soil-water sorption coefficient in vadose zone [cm^3-water/g-soil]
f_{ocv}	=	Fraction organic carbon in vadose zone [g-C/g-soil]

Source: ASTM E1739-95

SOIL VAPOR CONCENTRATION AT WHICH VAPOR PHASE BECOMES SATURATED

Single Component

$$C_v^{SAT} = \frac{P^s \times MW}{R \times T} \times 10^6$$

Multiple Components

$$C_v^{SAT} = \frac{x_i \times P_i^s \times MW_i}{R \times T} \times 10^6$$

where:

C_v^{SAT}	=	Soil vapor concentration at which vapor phase become saturated [mg/m^3-air]
P^s	=	Saturated vapor pressure [atm]
P_i^s	=	Effective vapor pressure of component *i* in water = $x_i \times P^s$ [atm]
R	=	Ideal gas constant [0.08206 atm•L/mol•K]
T	=	Temperature [K]
S_{ei}	=	Effective solubility of component *i* in water = $x_i \times S$ [mg/L-water]
x_i	=	Mole fraction of component $i = (w_i \times MW_{avg})/MW_i$ [-]
w_i	=	Weight fraction of component *i* [-]
MW_{avg}	=	Average molecular weight of mixture [g/mole]
MW_i	=	Molecular weight of component *i* [g/mole]
ρ_s	=	Vadose zone dry soil bulk density [g-soil/cm^3-soil]
10^6	=	Conversion factor [(g/L)/(mg/m^3)]

Source: ASTM E1739-95

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G.1 OVERVIEW

Contaminated groundwater and vapors can flow preferentially into and through underground utility lines and conduits. Gasoline, diesel/light fuel oils, jet fuel, kerosene, heavy fuel oils, used oil, crude oil, solvents, pesticides, and fertilizers present in the groundwater or vadose zone can enter drinking water/sanitary sewer/storm sewer pipe trenches, permeate plastic piping, gaskets, and linings, or leak through mechanical defects in pipe walls and joints.

Plastic pipe material, gaskets, and linings can react with petroleum and not petroleum-based contaminants in the gas, liquid, or solid phases in the surrounding external environment. The pipe materials most vulnerable to permeation when immersed in volatile organic compounds (VOCs) in descending order are polybutylene (PB), polyethylene (PE), chlorinated polyvinyl chloride (CPVC), polyvinyl chloride (PVC), and metal with gaskets.

Petroleum and non-petroleum VOCs can contaminate drinking water supplies through permeation of plastic pipes and gaskets. There are instances where US EPA Maximum Contaminant Level (MCL) violations have occurred at the point of consumption, although current provisions of the Safe Drinking Water Act do not require monitoring for VOCs beyond the point of entry to the distribution system. In most instances, the health risk threshold of chemical contaminants is substantially lower than either the taste or odor thresholds, suggesting that utilities cannot rely confidently on customers' perception of taste and odor for identifying contamination events. VOCs permeation is typically of most concern and most severe for small diameter, low-flow plastic drinking water pipes (e.g., water service lines).

Installation and repair of drinking water and other utility piping provide additional opportunity for contaminants in the subsurface environment to pose intrusion hazards into the pipeline as well as worker exposure.

This document in conjunction with the attached process flowcharts is designed to provide guidance to environmental consultants for assessing potential impacts on drinking water, sanitary sewer, and storm sewer lines as part of the North Dakota Risk-Based Corrective Action (NDRBCA) process. The NDRBCA process begins when a contaminated site is identified.

G.2 UTILITY LINES IMPACT ASSESSMENT

When a contaminated site is identified, a utility impact assessment must be performed. Locate all underground utility lines and conduits within the area of known or suspected soil and groundwater impact, both on-site and off-site, where the release may have migrated or may migrate in the future. Create a site map (Figure No. 3 of Appendix B-NDRBCA Technical Guidance) that shows the location of watermains and water service lines, sanitary and storm sewer mains and laterals, natural gas lines, and buried cables on-site and adjacent off-site. Label the map with the type of pipe material and gasket, backfill around the pipe, depth of the pipe, and direction of water flow in the pipe. This information can be obtained from the property owner and city/rural water system manager. Indicate the depth, thickness, and extent of non-aqueous phase liquid (NAPL) if any, and soil and groundwater contamination. Determine the depth of the water table and its seasonal fluctuation. All this information must be included in the Conceptual Site Model.

G.3 DRINKING WATER TESTING PROTOCOL

If a potential for petroleum and non-petroleum VOCs contamination to permeate drinking water lines exists based on plume location and pipe material, drinking water testing must be performed. Follow NDDEQ's VOC sampling instructions included in this appendix. Choose sample sites that are expected to yield the highest contamination levels in the drinking water. If necessary to valve off a water main to ensure that the water remains undisturbed, contact city/rural water system manager for assistance with locating and opening/closing valves. To accurately determine the degree of drinking water contamination that has occurred, the water contained in the pipe immersed in the plume should be sampled: to accomplish this, the volume of water between the pipe immersed in the plume and the tap must be calculated and purged. This will ensure that the water sample (at the tap) is drawn from pipe section immersed in the plume. To test for VOCs in drinking water, use US EPA methods: 502.2, 524.1 or 524.2. Attach documentation of drinking water monitoring results to Form No. 2 of NDRBCA report.

If the sample exceeds the drinking water criteria, immediately contact the public water system and the North Dakota Department of Environmental Quality.

G.4 SANITARY SEWERS

Petroleum and non-petroleum hydrocarbons can enter sanitary sewer trenches, permeate plastic pipes and gaskets, or leak through mechanical defects in pipe walls and joints.

Use field instrumentation to measure the vapor concentrations in underground manholes at sites where COCs are volatile. Attach documentation of utility vapor monitoring results to Form No. 2 in Appendix B of the NDRBCA technical guidance. If explosive conditions are believed to be present (Refer to *5.6.1 Protection Against Explosive Risk*), first responders must be contacted immediately. If sanitary sewers are suspected to contribute to vapor intrusion issues within nearby building(s), refer to *4.13 Distribution of Chemicals of Concern in the Vapor Migration to Indoor Air Pathway*.

In addition, COCs permeation/inflow into sanitary sewer pipes may have an adverse effect on the sewage treatment system. If the presence of COCs in a sanitary sewer collection system is confirmed, contact the North Dakota Department of Environmental Quality.

G.5 STORM SEWERS

Petroleum and non-petroleum hydrocarbons can enter storm sewer trenches and permeation/inflow into storm sewer pipes may provide a direct pathway for contamination to migrate to surface water. Use field instrumentation to measure the vapor concentrations in underground manholes at sites where COCs are volatile. Attach documentation of utility vapor monitoring results to Form No. 2 in Appendix B of the NDRBCA technical guidance.

If the presence of COCs in a storm sewer collection system is confirmed, contact the North Dakota Department of Environmental Quality. If explosive conditions are believed to be present (Refer to *5.6.1 Protection Against Explosive Risk*), first responders should be contacted immediately.

G.6 PIPING MATERIALS AND ENGINEERING CONTROLS

If the utility exists or must be placed within a contaminated area, appropriate pipe materials and engineering controls must be selected to prevent residual and migrating contamination from entering the pipe trenches and impacting the piping.

Using the most protective pipe materials based on the level of contamination, encasing the pipe immersed in contamination plume, or rerouting the pipe around the contamination plume must be considered for watermains. Copper piping must be used for water service lines immersed in contamination plume. Although be aware that stray current corrosion can occur on underground copper water pipes when a source of stray DC electricity (e.g., an impressed-current cathodic protection system used for UST facilities or oil and gas transmission pipelines) exists in the area. Welded joints or petroleum resistant nitrile gaskets must be utilized for water pipes. Hydrant weep holes must be plugged.

Replace any water plastic pipes and gaskets permeated by VOCs contamination as decontamination is not feasible.

Since contamination migrates along pipe trenches, engineering controls (e.g., impermeable bentonite clay barriers) must be utilized where necessary.

The most protective materials and engineering controls must be used as well for sanitary sewers suspected to contribute to VI issues within nearby building(s).

Contact the NDDEQ UST Program for assistance with pipe material and engineering controls selection.

Figure G1: Protection of Drinking Water Lines

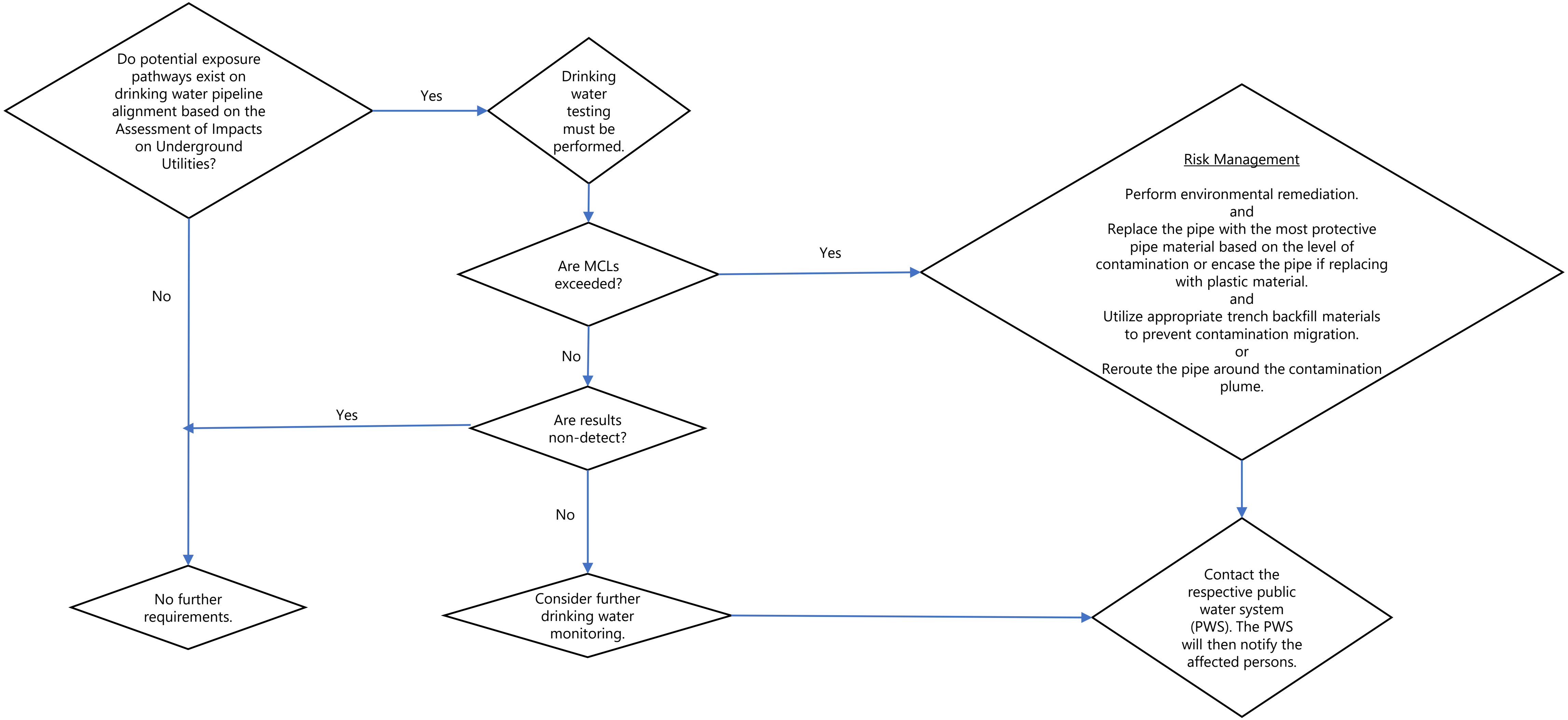

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Figure G2: Protection of Sanitary Sewers

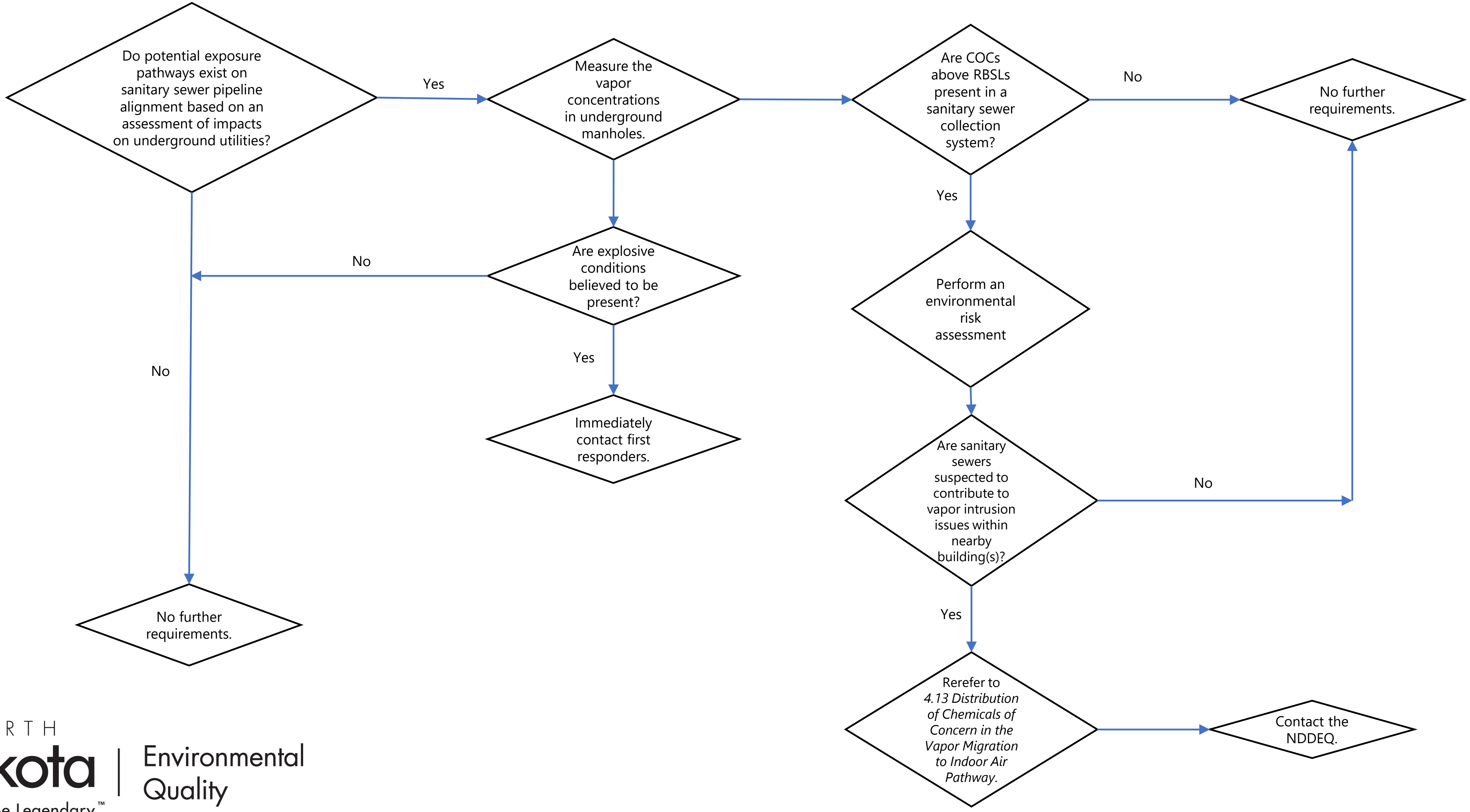

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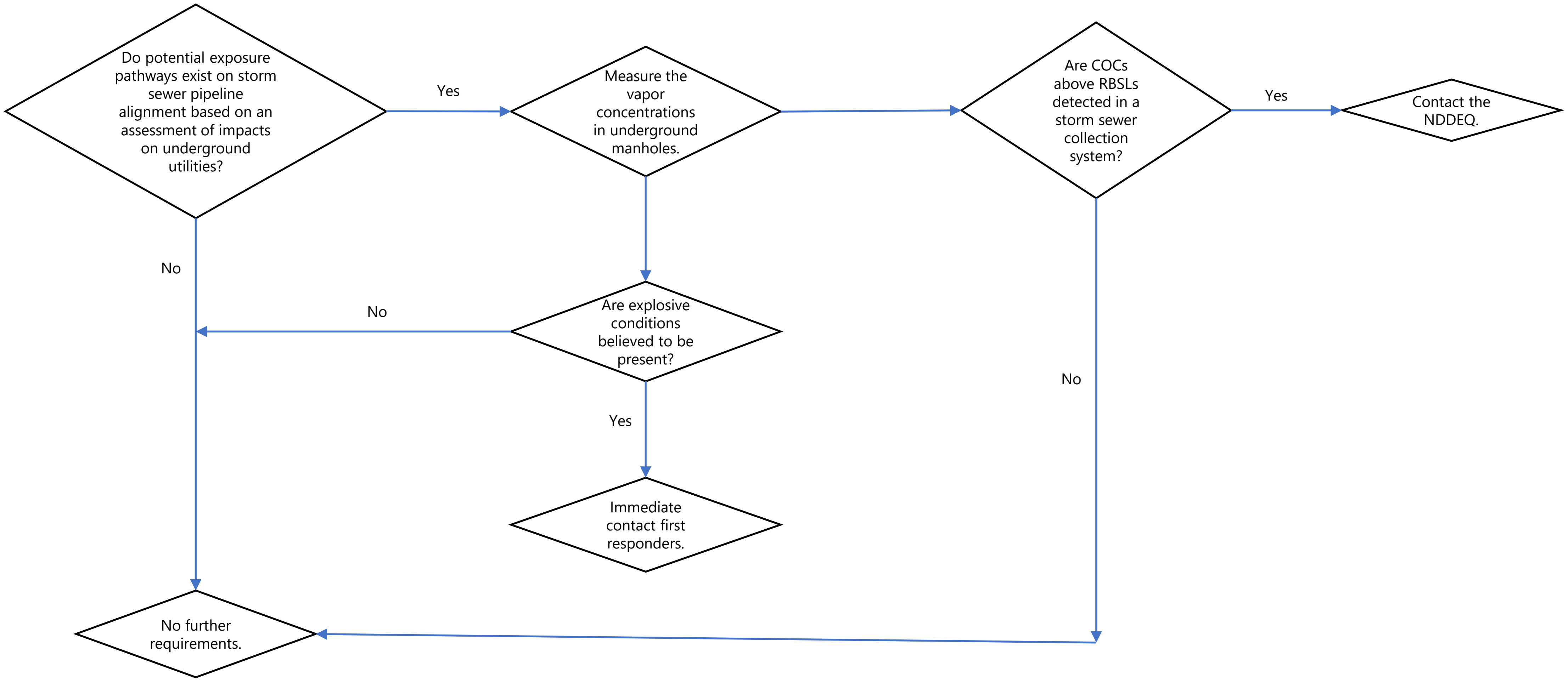
Figure G3: Protection of Storm Sewers



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