Risk-based Closure Guide

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PRELIMINARY DRAFT

Office of Land Quality
Indiana Department of Environmental Management

Disclaimer

This Nonrule Policy Document (NPD) is being established by the Indiana Department of Environmental Management (IDEM) consistent with its authority under IC 13-14-1-11.5. It is intended solely as guidance and shall be used in conjunction with applicable rules or laws. It does not replace applicable rules or laws, and if it conflicts with these rules or laws, the rules or laws shall control. Pursuant to IC 13-14-1-11.5, this NPD will be available for public inspection for at least forty-five (45) days prior to presentation to the appropriate State Environmental Board, and may be put into effect by IDEM thirty (30) days afterward. If the NPD is presented to more than one board, it will be effective thirty (30) days after presentation to the last State Environmental Board. IDEM also will submit the NPD to the Indiana Register for publication.

Acknowledgements

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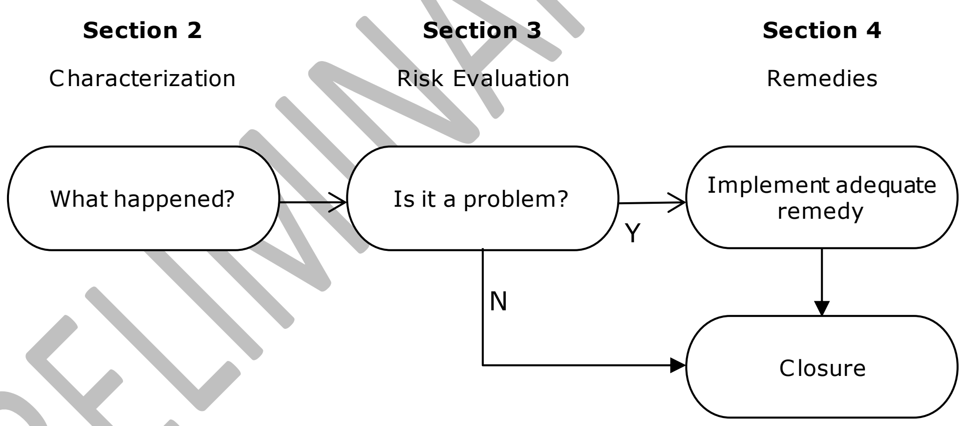
1: Introduction

The *Risk-based Closure Guide* (*R2*[1]) exists to provide for consistent application of Indiana Code (IC) 13-12-3-2 and IC 13-25-5-8.5, which together form the statutory basis for implementation of risk-based closure in Indiana. The *R2* sets forth a framework for characterizing releases, evaluating resulting risk and, when necessary, selecting and implementing appropriate remedies that allow closure.

The *R2* follows an outline (Figure 1-A) with three major sections that address, in turn, characterization, risk evaluation, and remedy selection and implementation. Content within these major sections is arranged into a total of nine[2] broadly defined tasks necessary to comply with statutory requirements for risk-based closure. Each task is defined, justified via legal citation and scientific basis, and illustrated with one or more examples of approaches that the Indiana Department of Environmental Management (IDEM) has determined to be acceptable.

Except where required by statute or rule, the emphasis throughout the *R2* is on achieving ends – adequate characterization, an appropriate evaluation of risk and, where necessary, control of risk through selection and implementation of a remedy – rather than dictating specific procedures for doing those things. IDEM recognizes that there are many possible ways to investigate releases and evaluate and control risk, and that approaches different than those described herein may be just as or more appropriate in some situations. Responsible parties are free to propose methods that do not appear in the *R2*, and *IDEM will evaluate proposals to use alternate approaches on their merits.*

Figure 1-A: *R2* Outline



IDEM will correct, update, or revise the *R2* as necessary. Updates will appear on IDEM's [Technical Guidance for Cleanups web page](https://www.in.gov/idem/cleanups/2329.htm).[3] In addition, IDEM staff can provide clarification regarding updates to, or specific contents of, this volume.

[1] The *Risk-based Closure Guide* (*R2*) supersedes IDEM's 2012 *Remediation Closure Guide (RCG)*.

[2] Seven when a remedy proves unnecessary.

[3] https://www.in.gov/idem/cleanups/2329.htm

1.1 Applicability

Per IC 13-12-3-2, the *R2* applies to the following IDEM remediation programs:

- Leaking Underground Storage Tank (LUST) Program
- Voluntary Remediation Program (VRP)
- Resource Conservation and Recovery Act (RCRA) Subtitle C Programs, including RCRA Treatment Storage and Disposal (TSD) facility closures, interim status TSD closures and RCRA Corrective Action projects.
- State Cleanup Program (SCP)
- Indiana Brownfields Program (IBP)

Cleanups completed under these programs may use risk-based remediation objectives established by IC 13-25-5-8.5.

As a non-rule policy, the *R2* is guidance that helps explain IDEM's expectations, but does not have the effect of law. If a conflict exists between the *R2* and state or federal rules and statutes, the rules and statutes will prevail.

Some conditions require quick response action to mitigate any potential imminent and substantial threat to human health or the environment. Examples include:

- Releases covered under the Spill Rule[4]
- Acute exposures to release-related chemicals
- Presence of corrosive, explosive, flammable, or toxic vapors
- Actual or imminent threat to a drinking water supply well.

The *R2* does not specifically address emergency situations. However, where appropriate, *R2* activities may proceed concurrently with emergency response measures.

[4] 327 IAC 2-6.1

1.2 Types of Closure

Closure is IDEM's written recognition that a party has demonstrated attainment of remediation objectives for a chemical release. Closure approval depends on an adequate characterization of the release and potential receptors that allows informed decisions about the necessity, selection, implementation, and effectiveness of remedies for the release. For releases with more than one chemical in more than one medium, closure will require meeting remediation objectives for each chemical in all affected media.

There are two fundamental types of closure:

Unconditional closure means an ongoing remedy is not required at a property. For example, if release-related chemical concentrations at a property are below residential screening levels, that property is suitable for unrestricted use and would be eligible for unconditional closure. IDEM does not anticipate requiring any additional action at a property that closes unconditionally.[5] Unconditional closure is a true "walk away" closure.

Conditional closure means an ongoing remedy is necessary to reduce exposure risk to an acceptable level. Examples of controls which might prove effective in reducing exposures include physical barriers like engineered caps or slurry walls, active remediation systems such as sub-slab depressurization systems for controlling vapor intrusion, or land use controls like residential use prohibitions or groundwater extraction and use restrictions. Many projects may need to combine more than one remedy to adequately control risk. Whether a remedy fulfills its purpose will depend on factors like the characteristics of the release-related chemicals and affected media, the means by which those chemicals may move from source to potential receptors, and the nature of the potential receptors.

Unless acceptable lines of evidence show otherwise, adequately controlling risk requires that exposure controls remain in place for as long as release-related chemicals remain at the property at levels exceeding unconditional remediation objectives (Section 3.3). For persistent chemicals, this means that controls will need to remain in place for a long time, perhaps even in perpetuity. Though not always necessary, removal or treatment of release-related chemicals will usually reduce the number, scale, and/or duration of ongoing risk-reducing activities or restrictions associated with conditional closure.

Closure always requires a demonstration that release-related chemical concentrations, taking controls into account, do not pose unacceptable risks to human health or the environment, both at closure and over the likely lifetime of the chemicals in the environment. Responsible parties will need to weigh the short-term advantages of conditional closure against the potential costs of maintaining remedies for as long as necessary to address unacceptable risk.

[5] New information about the presence of release-related chemicals at a property may require post-closure responses, and IDEM may require further action where the conditions that formed the basis for IDEM's approval have changed, not been met, or where scientific advances provide new knowledge regarding a threat to human health that was not previously investigated.

1.3 Process Overview

The generalized closure[6] process begins when IDEM learns of a release that requires characterization and continues through risk evaluation and, where necessary, remedy selection and implementation. Some of the tasks described below do not necessarily need to occur in the order listed. For example, it may also prove necessary or useful to implement an interim remedy prior to complete characterization. Refer to the sections in parentheses sections for additional guidance on these tasks.

Characterization Tasks (Section 2)

Task 1 (Section 2.1): *Identify release source(s).* Determine the type of activity or facility associated with the release and, to the extent possible, the physical location of the source point or source area;

Task 2 (Section (2.2): *Identify and quantify release-related chemical(s).* Develop and implement appropriate data quality objectives (DQOs), and determine the chemicals and breakdown products likely associated with the release and their concentrations in affected media;

Task 3 (Section 2.3): *Determine the extents of release-related chemical(s).* Determine the present and reasonably likely future horizontal and vertical extents of release-related chemicals, against media-specific unconditional remediation objectives;

Risk Evaluation Tasks (Section 3)

Task 4 (Section 3.1): *Specify decision unit(s) and use(s).* Define the areas, volumes, and/or structures potentially affected by the release, along with their current and reasonably likely future uses.

Task 5 (Section 3.2): *Determine representative concentrations.* Develop estimates of release-related chemical concentrations within each decision unit;

Task 6 (Section 3.3): *Specify remediation objectives.* Specify risk-based concentrations or risk levels suitable for unrestricted use or, where ongoing risk controls are contemplated, suitable for use considering those controls;

Task 7 (Section 3.4): *Determine whether a remedy is necessary.* Determine whether one or more representative concentrations in a decision unit exceeds unconditional remediation objectives and take applicable lines of evidence into account when deciding whether a remedy is necessary.

Remedy Selection and Implementation Tasks (Section 4)

Task 8 (Section 4.1): *Select a remedy that is likely to be adequate:* Choose a remedy that is likely to adequately control risk, taking into account the present and future extents of release-related chemicals, their concentrations, their overlap with potential receptors, land-use specific remediation objectives, and proposed controls, if any;

Task 9 (Section 4.2): *Implement a remedy and show that it is adequate:* Implement the proposed remedy and demonstrate, using sampling data and other means as appropriate, that it adequately controls risk, that it is likely to do so for as long as release-related chemicals are present at concentrations above remediation objectives suitable for residential use, assure compliance with restricted activities, and that future obligations related to ongoing operation and maintenance of the remedy are adequately specified and memorialized.

[6] Under RCRA, the term closure refers to a series of formal procedures required to minimize the need for maintenance and control, minimize or eliminate post-closure releases of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the environment.

2: Characterization

For purposes of this document, **characterization** is a determination of the source, nature, and extents of release-related chemicals. IC 13-25-5-8.5(c) requires adequate characterization as a prerequisite to determining whether action is necessary to protect human health and the environment.

Characterization must be sufficient to allow evaluation of the risks, if any, posed by release-related chemicals. The level of effort necessary to adequately characterize a release may vary considerably. In some cases, limited sampling may qualify releases for closure without further investigation. Other releases may require complex multi-stage investigations that span several media. Unfortunately, it is rarely possible to know in advance how much work will be necessary to support an adequate evaluation of risk. Any investigation may reveal the need for further investigation.

Information obtained during characterization activities may be sufficient to determine that certain actions to protect human health and the environment are necessary, *even before characterization is complete*. For example, when initial investigation shows that water from a drinking water well, or indoor air in an occupied structure, contains release-related chemicals at unacceptable levels, action to protect human health is appropriate. Any such action need not, and in many cases should not, await full characterization of the release. In other cases, removal or treatment of source material, even prior to full characterization, may substantially reduce overall risk, expense, and time to closure. Where such opportunities exist, it is appropriate to pursue them, as long as doing so does not unacceptably increase associated risks.

Conversely, preemptive implementation of a remedy in the absence of adequate characterization does not meet the requirement set forth in IC 13-25-5-8.5(c). Adequate characterization is always necessary to support a *final* decision regarding the necessity of action to protect human health and the environment.

Conceptual Site Models: Definition and General Expectations

IDEM's evaluation of characterization adequacy relies on submission of supporting documentation by the responsible party or its consultant. This is typically accomplished through development of a **conceptual site model** (CSM) – a comprehensive description of the release, including its setting, characterization, an evaluation of risks associated with the release, and any remedy proposed and implemented to address those risks. As well as organizing what is known about a release, CSMs can also help identify what is not known, what is uncertain, and what must still be determined.

The broad scope of CSMs means that they should change as new information becomes available throughout the project life cycle, all the way through to closure. CSMs are not limited to the characterization phase. CSMs may ultimately comprise a suite of documents and information submittals, and not necessarily a single constantly updated document.

The form and content of CSMs will change as new information becomes available. For example, a CSM adequate for the initial phases of an investigation may consist of a map of the project vicinity showing primary areas of concern along with accompanying text. Subsequent iterations of the CSM should include new information and may incorporate by reference pre-existing information and any number of documents that provide supporting information. As the project moves into the risk evaluation and remedy selection and implementation phases, the CSM should expand to adequately describe those activities, justify any conclusions, and identify any uncertainties.

CSMs should not only capture what is known about a project, but also serve as a tool to identify data gaps and uncertainties. Subsequent work should fill data gaps and reduce uncertainty to a level that is acceptable, and allow for decision making and progress toward closure. Since the CSM evolves as new data is collected, it is never “complete” until final closure occurs. The complexity of the CSM is commensurate with the complexity of the release and its environs, including its geology, history, release-related chemicals, etc.

CSMs: Anthropogenic Setting

The initial CSM is developed from what is already known about the release and its environs. Relevant information will vary according to the characteristics of the facility and release, but typically includes items such as:

- Facility boundaries and surrounding property use;
- A description of past and present activities conducted at the facility;
- Locations of surface structures (e.g., buildings, tanks, etc.) depicted on a map;
- Locations of process areas depicted on a map;
- Locations and construction of groundwater supply wells and monitoring wells, including drilling logs;
- Locations of storm water drainage system, and sanitary sewer system, past and present, including floor drains, drainages tiles, septic tank(s), other underground utilities (telephone, eletrical, water, etc.), subsurface disposal field(s), and other underground structures, depicted on a map;
- Copies of reports, information, or data related to previous environmental investigations;
- Past and current aerial photographs and analysis or interpretation of such photographs;
- Source of drinking water for the facility and for adjacent properties;
- Location of any significant water withdrawals, including public water supply wells located less than 3,000 feet or within the five year time of travel of a wellhead protection area; and
- Identity and locations of sensitive populations adjacent to the facility, including but not limited to daily care facilities (e.g. childcare facilities, schools and senior citizen facilities).

CSMs: Geologic Setting

Accurate and detailed geologic information is necessary for all characterizations regardless of the type of release. A thorough understanding of the subsurface environment and geologic setting allows the practitioner to place environmental subsurface data in a geologic and hydrogeologic context, and interpolate geologic characteristics where subsurface data is absent. Geologic and hydrologic information is sometimes available, but is usually collected concurrently with investigation of the release source and extents (see Sections 2.1 and 2.3). Relevant geologic setting information typically includes:

Regional Landforms

Characterization of major landforms (rivers, lakes, topography, karst, etc.) in the vicinity of a release provides a broad understanding of the geologic framework controlling chemical distribution and movement. For example, topography drives surface runoff and regional groundwater typically flows towards streams and rivers. This portion of the CSM can be developed from facility records and visits, and published literature on regional geology.

Subsurface Composition and Structure

While regional landforms provide an overview, subsurface investigation (soil borings, monitoring wells, geophysical investigations, high resolution site characterization, soil analysis, etc.) is important to characterization of the subsurface and provides insight on the relationships between materials surrounding the release. Investigative activities should provide, where relevant to the release and its behavior, detailed descriptions of unconsolidated and consolidated materials; determination of the thickness, depth, and horizontal extent of distinct geologic features (sand lenses, confining layers, bedrock topography, etc.); identification of natural and anthropogenic preferential pathways (sand stringers, utility corridors, karst, soil fractures, etc.); and any correlation of release-related chemical distribution to the project-specific geology. Descriptions of subsurface materials should employ standard terminology [i.e. the Unified Soil Classification System (ASTM, 2017; or as described in U.S. EPA, 1991), or the U.S. Department of Agriculture (USDA) soil texture classification system (USDA, 1951)].

<u>Groundwater Flow</u>

Identifying the flow direction(s) and horizontal and vertical gradients for every discernable permeable unit within the subsurface is necessary to understand the distribution and movement of release-related chemicals. As noted in (Shultz, et al., 2017), related goals include improving the ability to:

1. Interpret lateral continuity between borehole data and correlate project data in three dimensions;

2. Identify groundwater flow paths and preferential pathways;

3. Map and predict release-related chemical mass transport (high permeability) and matrix diffusion related storage (low permeability) zones;

4. Identify data gaps and assess the need for, and cost benefit of, different investigation techniques (e.g., high resolution site characterization);

5. Determine appropriate locations and screen intervals for monitoring and remediation wells, and

6. Improve efficiency of groundwater remediation and monitoring.

The variable nature of groundwater flow dynamics is often sensitive to local and/or regional natural or anthropogenic changes [e.g., precipitation, flooding, pumping, utilities; see IDEM (2019c) for additional guidance and discussion], and typically requires regular monitoring to characterize the magnitude and significance of changes in flow.

<u>Vapor Migration</u>

Similar to groundwater flow, vapor migration is a complex and dynamic process. To understand the migration of vapors from release-related chemicals, CSM development should include characterization of the flow direction(s) for each identified permeable unit within the vadose zone. Factors that may affect this include source concentration, source depth, soil matrix properties (e.g., porosity and moisture content), anthropogenic changes, and time since the release occurred.

The CSM should relate all the components of the geologic setting to the distribution of all phases of the release-related chemicals (e.g., isoconcentration maps) to provide a clear understanding of the mechanisms controlling their migration through saturated and unsaturated media, and areas where saturation levels fluctuate. This can help guide further investigative efforts; identify, evaluate, and control exposure; and evaluate the applicability of various remediation techniques.

2.1 Task One: Identify Release Source(s)

In this document, the unmodified word **source** may take on one or more of the meanings listed below, depending on context.

- **Source facility** refers to the building, land, or enterprise used for one or more purposes (e.g., gasoline sales and storage, dry cleaning, manufacturing, etc.), where the release occurred.
- **Source point** refers to the physical location where release-related chemicals first entered the environment. Examples of source points include a hole in an underground storage tank, a leaky joint in an underground pipe, the location of a surface spill, etc.
- **Source area** refers to the two dimensional projection in horizontal space of a three dimensional volume where release-related chemicals are present in one phase at concentrations high enough to enable them to readily transfer to a different phase at concentrations that require a remedy. Examples of this include the area underlain by chemicals in soil that are, or are capable of, leaching to groundwater at concentrations that require a remedy, the area underlain by chemical concentrations in groundwater that volatilize into soil gas at concentrations that require a remedy, or the area underlain by non-aqueous phase liquid (NAPL) that is feeding a plume in groundwater that requires a remedy. Note that chemicals volatilizing from groundwater may do so at a considerable distance from the source point. Similarly, chemicals released to soil may dissolve into groundwater, travel some distance, and then resorb to soil, where they may subsequently dissolve into groundwater at unacceptable concentrations. Therefore, source area identification may not be possible until delineation activities are well underway or complete.
- **Source mass** refers to the mass of release-related chemicals in source areas.

Some or all of these aspects of the **source** concept will be important for every release.

2.1.1 Basis for Requirement

Source identification is necessary for effective implementation of IC 13-25-5-8.5(c)(1), which requires adequate characterization of the nature and extents of releases. For example, some knowledge of the source facility or likely source facility is necessary to decide where to look for release-related chemicals.

There may be instances where the age or diffuse nature of a release makes locating a source point impossible. Where knowledge of the source point is available, that information can help focus investigations, particularly when the release occurs at a large facility. Knowledge of the source area is an important component of understanding how and when chemicals are likely to move, what media may be affected by the release, and ultimately how receptors may be affected. Estimates of source mass may be important in the design of certain remedies. While it may not always be necessary or even possible to identify every aspect of sources, source identification should be comprehensive enough to enable adequate release characterization, risk evaluation, and (when necessary) remedy selection and implementation.

2.1.2 How to Identify Release Sources

Identification of source facilities, source points, source areas, and source mass are different problems, although some information may help solve more than one of them. Source identification often starts with an evaluation of source facility activities, review of previous investigative work, and a facility visit.

2.1.2.1 Identifying Source Facilities

Means of identifying source facilities include one or more of the following:

- Release reports submitted to IDEM or other agencies
- Environmental investigation reports that contain evidence of releases or potential releases, including reports generated for nearby properties or facilities
- Evidence of releases (stained soil, stressed vegetation, etc.) observed during facility visits
- Interviews with current or past owners and employees, local fire and police departments, county health officials, and facility neighbors
- Records of operational processes, chemical use, and waste storage and disposal practices, including regulatory databases and files maintained by the United States Environmental Protection Agency (U.S. EPA), IDEM, and local health departments
- Aerial photographs, fire insurance maps, property tax or land title records, city directories, satellite imagery, and geographic information system maps
- Other relevant resources

2.1.2.2 Identifying Source Points

Means of identifying source points include one or more of the following:

- Release reports submitted to IDEM or other agencies
- Environmental investigation reports that contain evidence of releases or potential releases
- Evidence of releases (stained floors or soil, stressed vegetation, etc.) observed during facility visits
- Locations of chemical and waste storage and disposal areas, operational areas, maintenance areas, drains, sumps, oil/water separators, parts cleaners, electrical transformers, pits, ponds, lagoons, septic systems, etc.
- Records pertaining to operational processes, chemical use, and waste storage and disposal practices
- Interviews with current or past owners and employees, local fire and police departments, county health officials, and facility neighbors
- Other relevant resources

2.1.2.3 Identifying Source Areas

Identifying and, where necessary, determining the extent(s) of source areas can help explain the behavior and distribution of release-related chemicals, and may also aid in the design of remedies. There are several kinds of source areas:

A soil source area exists wherever release-related chemicals in soils are capable of leaching to groundwater and causing dissolved concentrations of those chemicals to exceed unconditional groundwater remediation objectives, or when those chemicals are capable of volatilizing into soil gas at concentrations that exceed unconditional vapor remediation objectives.

A non-aqueous phase liquid (NAPL) source area exists wherever release-related chemicals in NAPLs are capable of sorbing to soil at concentrations that exceed unconditional soil remediation objectives, dissolving into groundwater at concentrations that exceed unconditional groundwater remediation objectives, or volatilizing into soil gas at concentrations that exceed unconditional vapor remediation objectives.

A groundwater source area exists wherever release-related chemicals in groundwater are capable of volatilizing into soil gas at concentrations that exceed unconditional vapor remediation objectives. It is unusual for release-related chemicals in groundwater to cause concentrations in soils to exceed unconditional soil remediation objectives, but if this happens then the area where release-related chemicals in groundwater are capable of doing so should be considered a source area.

It is very unusual for vapor concentrations to be high enough to cause concentrations in other media to exceed unconditional remediation objectives for those media, but if this happens then the area where release-related chemicals in vapor are capable of doing so should be considered a source area.

Professional judgment and adequate sampling are necessary to establish the dimensions of source areas. Soil-to-groundwater source areas are delineated by evaluating the leaching potential of soil samples, typically using the synthetic precipitation leaching procedure (SPLP) or a similar technique that meets project-specific DQOs. Other technologies that may prove useful when it is necessary to delineate various types of source areas (especially NAPL source areas) include membrane interface probes or laser-induced fluorescence devices, typically in conjunction with sampling at locations indicated by those technologies. Groundwater-to-vapor source areas are delineated by collecting soil gas samples from the vadose zone just above the groundwater table.

2.1.2.4 Determining Source Mass

For many releases, knowledge of the source facility, point, and/or area, as well as observation of release system behavior, will be sufficient for purposes of characterization, risk evaluation, and remedy selection and implementation. However, for some releases, and especially for certain remedies, an estimate of source mass will be necessary. If the release is of a known quantity the source mass should be calculated from that known quantity, otherwise, derive a mass estimate using sample concentration data and knowledge of the spatial distribution of those concentrations.

2.1.3 How IDEM will Evaluate Release Source Identifications

Is adequate evidence presented to identify one or more of:

Source facility or facilities

- Items listed in Section 2.1.2.1, as relevant

Source point(s)

- Items listed in Section 2.1.2.2, as relevant
- Sampling data showing concentration gradients

Source area(s)

- Items listed in Section 2.1.2.3, as relevant
- Sampling data showing concentration gradients
- Leaching test data, if relevant
- Soil gas data, if relevant

Source mass

- Known quantities of release-related chemicals
- Mass estimates derived from sample concentration data and knowledge of the spatial distribution of those concentrations

2.2 Task Two: Determine the Nature of Release-related Chemicals

The **nature** of release-related chemicals refers to their identity and concentrations in various media. Determining the nature of release-related chemicals requires an understanding of the source of the release and the use of appropriate sampling and analysis procedures. Section 2.2 provides guidance on chemicals typically associated with certain types of facilities or operations, sample collection, handling, and analysis, and appropriate quality control procedures, including documentation of results. It also describes how IDEM will evaluate the sufficiency of efforts to identify and quantify release-related chemicals. It is not a complete compendium of acceptable procedures. Other procedures may also produce acceptable results, and IDEM will evaluate use of those procedures on their merits.

2.2.1 Basis for Requirement

Indiana Code (IC) 13-12-3-2 and IC 13-25-5-8.5(c) requires adequate characterization of the nature and extents of release-related chemicals with respect to remediation objectives. Sampling is vital to development of an adequate CSM, and underpins any understanding of the distribution and concentrations of release-related chemicals, whether receptors might be affected, and the pathways by which release-related chemicals may reach receptors. Even modeling requires project-specific sample data for calibration and validation.

2.2.2 Sample Planning

Careful planning is essential in executing environmental projects, and this is especially true with respect to the sample planning phase. A Quality Assurance Project Plan (QAPP) documents the sample planning process. QAPPs describe the decision making process, plans for data acquisition, quality criteria, and procedures for assessing investigation results. The scope of QAPPs will generally increase with the complexity of the projects they support. New information and/or changes in project scope may also necessitate revisions to the QAPP.

The Data Quality Objectives Process (DQOP) establishes project quality objectives and criteria. The DQOP is used for systematic planning to collect environmental data of a known quality and quantity to support decisions. The seven-step DQOP defines the problem, identifies the decision needed, identifies the inputs of the decision, defines the boundaries, develops a decision rule, specifies limits for decision errors, and optimizes the design for obtaining data.

The DQOP is also iterative. Project quality objectives and criteria are reviewed and updated as additional information becomes available. Additional information may and often does change the objectives of a project.

A complete description of QAPPs and their components is beyond the scope of this document. U.S. EPA (2000, 2002, 2002b, 2006, and 2006b) provides guidance on QAPP development and implementation. A program-specific generic QAPP (like the UST Program QAPP) can be referenced with a notation of any deviations in any given project. Deviations from the generic QAPP can be documented in a project-specific Sampling and Analysis Plan (SAP). A project-specific SAP specifies where and when samples will be collected, the number of samples to be collected, sampling method(s) for various media, and procedures for sample preservation during transportation and storage.

Choosing Areas to Sample

Sampling areas depend on investigation objectives. Investigation objectives vary widely, and so will the sampling areas necessary to pursue those objectives. Possible investigation objectives include:

- Determine the extents of release-related chemicals

- Determine representative concentrations in a decision unit
- Determine background concentrations of release-related chemicals
- Collect information needed for remedial system design
- Demonstrate achievement of remediation objectives in a decision unit

There are many other possibilities. Whatever the investigation objective(s), reports should include the rationale and supporting evidence for selection of specific sampling areas. Note that different decision units may have different likely future exposures (e.g., paved parking, places used by sensitive populations, break area, factory floor, etc.). Separate sampling plans for each identifiable exposure area allow subsequent separate exposure evaluations in those areas, rather than using the same exposure assumptions across the entire release area.

Sampling Design

There are many possible ways to place sample locations across a release area. This document focuses on two general approaches, described below. Other approaches may be preferable for some projects. IDEM will evaluate other approaches on their merits. Whatever the approach, the number of samples necessary for an adequate characterization is project-specific.

Judgmental sampling uses professional judgment and existing knowledge of the release to place sample locations. Judgmental sample placement typically starts near a source point or facility and steps out until sample locations approximate the extent of release-related chemicals. However, it is also possible to start near potential receptors and step in toward a source. Stepping in may be preferable when there is a concern that receptors are experiencing exposure to release-related chemicals, because it may allow earlier identification of any unacceptable exposures and therefore earlier implementation of a remedy to address those exposures. Delineation efforts that begin by stepping in will still need to delineate extents, often by stepping out once initial step-in activities are complete. The effectiveness of judgmental sampling depends on the quality of the information used to guide sample placement, but if good information is available regarding the likely locations of release-related chemicals, extents delineation using judgmental sample placement is often less expensive than alternatives.

Systematic sampling places samples at fixed intervals beginning from a random starting point (as along a drainage way, excavation wall, or perimeter) or according to a predefined pattern that distributes samples uniformly over an area. Systematic methods are suitable for any project, but are especially useful for projects where there is limited information about the likely distribution of release-related chemicals (e.g., fields, vacant lots, or sediment deposition zones). It is appropriate to use the results of systematic samples to calculate representative concentrations (Section 3.2) across decision units. Because it starts with less information than the judgmental approach, systematic sample placement often requires more sample locations than does judgmental sample placement to achieve adequate coverage of the area under investigation. In some cases it may be possible to use pre-existing information (e.g., topography or regional groundwater flow direction information) to modify the systematic sampling array in a way that reduces the required number of sample locations. In other instances, a systematically placed sample may reveal release-related chemicals at concentrations exceeding unconditional remediation objectives, thus enabling that location to serve as the starting point for a stepping out procedure.

Sometimes it is useful to combine the two approaches. For example, judgmental sampling may identify specific areas of concern, followed by systematic sampling within those areas. The resulting exposure estimate may be more representative than judgmental sampling of release-related chemical concentrations in a decision unit. U.S. EPA (2002c) includes guidance on numerous sampling designs.

Appropriate sample media will depend on project-specific factors and the exposure scenarios under evaluation. For example, IDEM may not require collection of surficial soil samples for characterization of subsurface releases. Conversely, a surficial release followed immediately by removal might achieve closure with only post-removal surficial soil samples. IDEM anticipates that adequate characterization of most releases will require analytical data for both soil and groundwater, and that vapor phase samples will also be required for some types of releases.

Note that IDEM may conduct field audits during any sampling event[7]. The scope of audits may vary by program and may include split sampling. For this reason, program areas and project managers may request advance notice of proposed field activities.

When there is incomplete or unreliable information about activities at a facility, IDEM programs may specify pre-defined lists of chemicals for analysis. For example, the comprehensive list for Resource Conservation and Recovery Act (RCRA) Subtitle C facilities may include Appendix VIII[8] (for soil) and Appendix IX[9] (for groundwater). Less comprehensive lists, such as the Comprehensive Environmental Response, Compensation, and Liability Act target compound list or target analyte list may be more appropriate if they include release-related chemicals. Ecological risk assessment may involve evaluation of different or additional release-related chemicals than those relevant to human health risk assessment.

The types of release-related chemicals will dictate which analytical methods are most appropriate for different media. Table 2-A summarizes analytical recommendations for various facilities and release types. IDEM's Site Characterization and Sampling Guidance[10] offers lists of the release-related chemicals most commonly encountered at several types of facilities and provides recommended analytical methods.

[7] Under authority in IC 13-14-2-2; IC 13-23-13-12; IC 13-24-1-6; and IC 13-25-4-6.

[8] Code of Federal Regulations (CFR) Title 40, Part 261

[9] CFR Title 40, Part 264

[10] https://www.in.gov/idem/cleanups/2342.htm

Table 2-A: Chemicals Often Associated with Various Facilities and Releases

	Chemical or Chemical Class									
Release Type/Industry	VOCs	PAHs[1]	PCBs	SVOCs	Metals	CVOCs[3]	Phenols	Cresols	Cyanide	Misc.[2]
Dry Cleaning Industry	X[4]					X				
E-85 Fuel	X[5]						X	X	X	X
Manufactured Gas Plants	X	X	X[7]		X[6]					X
Auto Salvage Yard	X	X	X		X				X	X
Metal Finishing	X			X	X					
Gasoline Range Product[9]	X[5,8]				X[8]					
Diesel Range Product[10]	X	X								
Hydrocarbon Oil Range Product		X								
Waste/Used Oil; Unknown Petroleum Product	X[8]	X								

Notes:

[1]Polyaromatic hydrocarbons (PAHs) should include all compounds on the U.S. EPA SW-846 Method 8310 analyte list.

[2]Misc. – See relevant technical guidance document(s) and/or contact IDEM for additional testing recommendations

[3]Chlorinated volatile organic chemicals (CVOCs) include, among other chemicals, tetrachloroethene, trichloroethene, 1,1,1-trichloroethane, 1,2-cis- and 1,2-trans-dichloroethenes, and vinyl chloride

[4]Analyze full VOCs if solvents other than tetrachloroethene, trichloroethene, and/or 1,1,1-trichloroethane were used

[5]Include naphthalenes (naphthalene, 1-methylnaphthalene, 2-methylnaphthalene)

[6]See relevant technical guidance document for list of metals

[7]Report total polychlorinated biphenyls (PCBs) and Arochlors

[8]Report total lead and lead scavengers (1,2-dibromoethane and 1,2-dichloroethane) when investigating aviation gas and racing fuel, or when automotive gas was used or stored before January 1, 1996

[9]Includes automotive gas, aviation gas, racing fuel, Stoddard solvent, naphtha, JP-4, and ethanol fuel

[10]Diesel #1 and 2, kerosene, JP# 5, 7, & 8, light oil, heating oil, and biodiesel <100%

2.2.3 General Sampling Guidance

Sampling is the process of collecting an aliquot of some medium for analysis, with the intent of using the resulting concentration to represent, singly or in concert with other results, a representative concentration in a decision unit. **Sampling procedures matter.** If samples are not collected properly they will not adequately represent the decision unit under investigation, and subsequent laboratory work may be pointless.

In general, minimize the possibility of cross-contamination by using disposable sampling equipment. If disposable sampling tools are not available or not practical, specify the cleaning procedures used. Wear clean sampling gloves at each sampling point. Wash reusable sampling equipment with a detergent solution (e.g., Liquinox or equivalent), and rinse before each use. Adequate sample volume must be collected to allow for the analysis of release-related chemicals.

Several field-portable instruments and detectors (for example photoionization detector, flame ionization detector, colorimetric test kits, immunoassay kits, portable gas chromatographs, x-ray fluorescence units, etc.) can be used to screen environmental media. All field instruments have advantages and limitations. The instrument used must be capable of detecting release-related chemicals and users must be familiar with and follow operating instructions recommended by the manufacturer. SAPs should describe the field instruments and their use as appropriate for the release-related chemicals. The discussion should also include any limitations that could affect the use of an instrument (e.g., chemicals not detected, moisture, cold weather, etc.)

A project SAP should describe proper disposal of purge water, borehole cuttings, or other investigation-derived wastes (IDW). IDW management must ensure protection of human health and the environment and comply with other applicable state and federal regulations. See U.S. EPA (1992) for guidance on management of IDW.

IDEM may request documentation that persons conducting sampling have received adequate training to do so and are using the most current version of the project SAP, including the most recent version that IDEM has approved. Training records and field notes are examples of such documentation.

2.2.4 Sampling Soils

There are many possible reasons for sampling soil. Examples include:

- Delineating horizontal and vertical extents of release-related chemicals
- Evaluating direct contact risk
- Identifying source location(s), including NAPL
- Guiding placement of monitoring well screens
- Guiding remedy design, selection, and implementation
- Evaluating the adequacy of a remedy
- Meeting program-specific requirements.

Depending on their purpose, soil samples may be collected from the ground surface, below the surface, and/or from excavation walls and bottoms. Collect separate soil aliquots or sufficient sample volume to allow determination of percent solids to enable reporting soil sample results on a dry weight basis.

When investigating a surface release, it may be necessary to begin soil sampling at the ground surface, proceeding downward until direct contact exposure is adequately understood. This may involve collecting more than one surface or near surface sample. If release-related chemicals extend into the subsurface, additional samples may be necessary to understand their distribution and associated risk potential. When release-related chemicals are likely confined to the subsurface (e.g., following a release from an underground storage tank), surficial soil samples may not be necessary.

The following conditions may identify one or more subsurface soil locations suitable for sampling, whatever the purpose of the sampling:

- Locations that elicit the highest field screening result
- Stained, discolored, oily, shiny, or visibly altered soil
- Soil in strata likely to be contain release-related chemicals based on chemical characteristics and soil type. For example, potential accumulation of metals in clay or silt, accumulation on the top of clay strata or at the bottom of sand strata, or other locations *based on the expected behavior of the release-related chemical in the environment*.

In the absence of positive screening results or visual cues, samples from borings submitted for laboratory analysis should be from a material within the core interval displaying the greatest apparent effective porosity. Other options include analyzing a sample from each stratum, or from each two-foot interval.

When describing soils, start by using standardized soil classification systems such as USCS or USDA. These systems provide a description of the soil composition and texture only. Additional important characteristics when evaluating soil cores for environmental characterization include the following: soil structure, sedimentary features, consistency, moisture content (qualitative determination), boundary or contact, and zones of secondary porosity. Munsell soil charts, or a suitable alternative, are useful when evaluating and describing soil color.

<u>Sampling Excavation Walls and Bottoms</u>

IDEM's underground storage tank (UST) programs have specific guidance for collecting soil samples along excavation walls and across excavation bottoms, summarized in Table 2-B. Similar procedures are usually appropriate in other programs. IDEM will evaluate alternative procedures on their merits.

Table 2-B: Excavation Sampling[11]

The sample types and frequencies specified in this table are required for underground storage tank excavations. IDEM has determined that they are also generally acceptable for other types of excavations.

Bottom Samples	**USTs < 10,000 gallons** Two samples within two feet below both ends of each UST
	USTs > 10,000 gallons One additional sample within two feet below the middle of the UST
Sidewall Samples	**UST perimeter < 80 feet** Four sidewall samples collected from half the distance between the surface and the bottom of the UST excavation or the area most likely to contain the highest levels of release-related chemicals based on field observation
	UST perimeter > 80 feet One sidewall sample every 20 linear feet collected from half the distance between the surface and the bottom of the UST excavation or the area most likely to contain the highest concentrations of release-related chemicals based on field observation
Piping Samples	**Pipe run < 20 feet** One sample half way between UST and dispenser or fill port
	Pipe run > 20 feet One sample for every 20 linear feet of pipe run
	One sample under every piping elbow or connector
Dispenser Samples	One sample under each dispenser
Excavated Material	Sampling of excavated material must occur for every 50 cubic yards of material that is treated, disposed, or returned to the excavation area as backfill. Soils with release-related chemicals at concentrations exceeding relevant remediation objectives should not be returned to the excavation.
Pit Water	One sample of any water encountered in the excavation. If water is not encountered during the excavation, see 329 IAC 9-6-2.6 for requirements specific to underground storage tank excavations.

<u>Sampling Volatile Organic Chemicals in Soils</u>

As their name suggests, volatile organic chemicals (VOCs) evaporate readily. This property can lead to significant VOC losses during sample collection and handling, and result in biased analytical data. When sampling VOCs in soils, use U.S. EPA SW-846 Method 5035A (as updated) to minimize VOC loss. Appendix A of Method 5035A describes several options for collection, preservation, and storage of

[11] Per IC 13-23-1-2 and 329 IAC 9-6-2.5(c)

samples for VOC analysis. However, the specialized containers and preservation techniques described in Method 5035A may be unnecessary for samples collected within areas where release-related chemicals are known or suspected to exceed remediation objectives, as long as the sampling method meets DQOs.

SW-846 Method 5035A, Appendix A, Section 7.1 states:

"After a fresh surface of the solid material is exposed to the atmosphere, the subsample collection process should be completed in the least amount of time in order to minimize the loss of VOCs due to volatilization. Removing a subsample from a material should be done with the least amount of disruption (disaggregation) as possible. Additionally, rough trimming of the sampling location's surface layers should be considered if the material may have already lost VOCs (been exposed for more than a couple of minutes) or if it may be contaminated by other waste, different soil strata or vegetation. Removal of surface layers can be accomplished by scraping the surface using a clean spatula, scoop, knife, or shovel".

Use screening instrument results, professional judgment, and knowledge of the release-related chemicals and soils to decide which samples to send to the laboratory. To minimize VOC loss, collect subsamples from the soil core as quickly as possible, taking special care to limit exposure and disaggregation of the soil. Any samples not sent to the lab are considered investigation-derived waste and should be treated as such. The field record should clearly document reasons for choosing particular samples for lab analysis.

Photoionization detectors (PIDs) detect most VOCs and are probably the most commonly used VOC field screening instrument at both gasoline and chlorinated solvent releases. PIDs are suitable for chemicals with an ionization energy less than the PID's lamp voltage – typically 10.6 electron volts. Higher voltage PID lamps exist and can somewhat extend the range of detected chemicals. A flame ionization detector (FID) may be a suitable alternative when working with unknown chemicals, or when the chemicals have higher ionization potentials than the PID lamp. FIDs may prove especially useful when screening for diesel fuel, and weathered to heavy petroleum products.

When sampling under this procedure:

- Allow sufficient time between subsurface soil core retrievals to avoid sampling backlogs
- Protect soil cores from direct sunlight, rain, wind, etc.
- Collect subsamples soon after removing the soil core from the borehole. It is not appropriate to collect subsamples from previously iced material, or to wait five or more minutes for a standard headspace analysis before deciding whether or not to collect subsamples from soil left in the core barrel liner (or similar device) or soil screening container.

IDEM's Office of Land Quality Site Characterization and Sampling Guidance[12] contains additional information on sampling soils for VOCs. IDEM will consider alternatives to the procedures and equipment described in Method 5035A and supplemental guidance on a project-specific basis.

Evaluating Leaching Potential

Release-related chemicals sorbed to vadose zone soils or NAPLs may move down through the soil column (leach) and cause or contribute to concentrations of those chemicals in groundwater that exceed unconditional remediation objectives. Evaluating leaching potential is of particular concern when release-related chemicals have not had time to leach to groundwater, or when vadose zone NAPL or impacted soils are overlain by concrete, asphalt, buildings, or other barriers to precipitation infiltration. In the latter

[12] https://www.in.gov/idem/cleanups/2342.htm

case, the results of such evaluation are an important line of evidence when deciding whether the existing or similar barrier should remain in place to prevent creation of, or significant contributions to, any release-related chemical plume in groundwater.

When evaluating leaching potential, consider using the synthetic precipitation leaching procedure (SPLP, U.S. EPA Method 1312) or a similar method. When using SPLP, collect a minimum of three vadose zone soil samples from the area of highest release-related chemical concentration and analyze them using SPLP. Existing analytical information, knowledge of stratigraphy, and professional judgment are also important when selecting the locations and appropriate number of samples. SPLP uses a blend of dilute inorganic acids to simulate acid rain and its effects on chemicals in soils (U.S. EPA, 1994). The method produces a leachate solution, and the laboratory reports the concentrations of chemicals in that solution.

2.2.5 Sampling Groundwater

Appropriate groundwater sampling procedures and equipment will vary depending on local conditions and individual program requirements. Yeskis and Zavala (2002) provides general guidance on preparing for and performing groundwater sampling. U.S. EPA (2005) addresses sampling groundwater from direct-push wells. IDEM (2009) addresses the use of monitoring wells and groundwater grab samples. All sampling methods and equipment should be clearly documented, including purge criteria and field readings, to allow for verification of sampling procedures and data interpretation.

It is often useful to collect groundwater samples from boreholes prior to installing permanent monitoring wells. Groundwater grab samples can be collected using a variety of methods. Method choice depends on the type of drilling equipment and sample interval. Groundwater grab samples are often turbid and analytical results may not be representative of dissolved chemical concentrations. Purging multiple borehole volumes may reduce turbidity in samples. However, under most circumstances (e.g., when limited groundwater availability or the sampling technique does not allow it), purging may not be possible. IDEM (2005) addresses filtration of turbid samples. Groundwater grab sample data is typically used for screening purposes, initial extents determinations, directing further investigation, or as a line of evidence in combination with groundwater monitoring well data.

Low-flow (also called “micro-purge” or “minimal drawdown”) sampling procedures may improve groundwater sample quality. Puls and Barcelona (1996) is the primary U.S. EPA guidance on this procedure. Note, however, that Svavarsson et al. (1995) compared low-flow sampling and bailers and found no significant differences in recovery of volatile organics. A non-purge sampling option may be suitable for petroleum releases; IDEM (2017 and 2017b) contain low-flow and non-purge sampling guidance.

Groundwater sampling equipment should be capable of meeting the project’s data quality objectives. Peristaltic pumps, high-speed submersible pumps, and inertial lift pumps may cause excessive agitation of groundwater samples, and IDEM does not recommend their use when collecting samples for VOC analysis (Nielsen 2005; Yeskis and Zavala 2002; U.S. EPA 2005). However, use of a peristaltic pump may be acceptable in some instances discussed in IDEM (2017c). Polyethylene diffusion bag samplers and other types of passive sampling devices may also be acceptable for long-term groundwater monitoring for projects that meet a strict set of criteria (ITRC 2007 and IDEM 2019d). The Federal Remediation Technologies Roundtable website[13] includes descriptions of many types of sampling

[13] http://www.frtr.gov/

equipment and a matrix that compares the advantages and disadvantages of different types of sampling equipment.

When historical groundwater data is available, sample collection should begin with those wells containing the lowest concentrations of release-related chemicals, and proceed to wells with increasingly higher concentrations. Otherwise, begin with wells upgradient of likely source points, continue with downgradient wells, and finish with wells in or closest to suspected source points. If NAPL is suspected or if strong odors are present in a well, attempt to measure NAPL thickness. Sampling groundwater at monitoring wells with NAPL is not a common occurrence and is typically not required. However, sampling of wells with NAPL may be performed if it is necessary to address a clearly defined project-specific objective.

IDEM recommends using laboratory supplied sampling containers and preservative(s) for groundwater samples. Collect enough samples to allow for possible breakage and quality assurance needs. For VOC analysis, groundwater samples must be collected in 40 ml glass vials with Teflon® septa. The vials may be either preserved with concentrated hydrochloric acid or they may be unpreserved. Preserved samples have a two-week holding time, whereas unpreserved samples have only a seven-day holding time. Groundwater with dissolved carbonates may effervesce and produce bubbles if placed in a vial with hydrochloric acid. This will render the sample unacceptable. In this case, unpreserved vials should be used and arrangements should be made with the laboratory to ensure that they can meet the shorter sample holding times. A trip blank is recommended when collecting samples for VOC analysis to document any sample contamination attributable to shipping and field handling.

2.2.6 Sampling Vapor

Though perhaps not as well understood as soil and groundwater sampling procedures, vapor sampling has been underway in Indiana and elsewhere for well over a decade. Detailed guidance on many vapor sampling procedures is available in U.S. EPA (2015, 2015b) and the documents they reference. Therefore, consistent with its treatment of soil and groundwater sampling procedures, the *Risk-based Closure Guide* provides only a brief summary of some standard approaches to vapor sampling. There are many other possible approaches. The optimal approach will depend on circumstances and may change as the investigation proceeds. IDEM will evaluate alternate approaches on their merits, but because the conclusions of a vapor intrusion investigation are typically based upon a relatively limited data set that typically represents highly variable vapor concentrations, IDEM has determined that conservative approaches are generally preferable when investigating vapor risk.

Paired indoor air (IA) and subslab soil gas (SGss) or crawl space air (CSA) sampling helps establish the relationship between concentrations of release-related chemicals in subsurface vapor and indoor air. It is a strong line of evidence that also helps to explain sources of release-related chemicals within the building. IDEM does not recommend sampling only IA because indoor sources may make interpretation of the results difficult.

Preferential pathways, including conduits, can allow vapors to reach indoor air without significantly affecting the subsurface beneath a building. For this reason, vapor characterization must include sampling in preferential pathways, including conduits.

Exterior soil gas sampling (SGe) is appropriate for delineating soil vapor plumes, use as a stand-alone investigative tool to evaluate vapor intrusion potential at structures whose owners do not grant access for sub-slab sampling, during preferential pathway investigations, or when evaluating vapor intrusion potential at undeveloped properties. Depending on the SGe sampling density, SGe sample results that are not paired with indoor air sample results may not be sufficient to rule out current vapor intrusion.

As noted in U.S. EPA (2015) there are several types of vapor sampling technologies. IDEM will accept vapor data collected using any type of vapor sampling technology that meets project-specific DQOs.

- Evacuated canisters use a vacuum to draw in whole air samples. Batch-certified clean canisters are acceptable for high concentration applications, such as soil gas or conduit vapor sampling. Individually certified clean canisters are necessary for indoor air sampling[14]. Canisters usually arrive from the laboratory equipped with flow regulators and a vacuum gauge. Laboratories typically pre-set flow regulators, so it is important to determine appropriate flow rates prior to delivery.
- Active sorbent samplers that use pumps to mechanically draw air through the sorbent, or passive sorbent samplers that rely on diffusion from the air, are often able to function over longer time periods than evacuated canisters, and may have significant advantages for evaluating long-term vapor exposure risk. Both sorbent sampling approaches are typically coupled with U.S. EPA Method TO-17.
- Tedlar® bags are only acceptable in very specific circumstances, due to concerns about leaks, pressure changes during transport, cleanliness certification, and very short holding times (two to three hours).

Note that smoking, solvent use, and similar activities near vapor sampling areas may compromise analytical results.

2.2.6.1 Soil Gas Sampling: General Considerations

Soil gas samples are whole air samples collected from within the soil matrix. Exterior soil gas (SGe) samples are from soils outside a building footprint, while subslab soil gas (SGss) samples are from soils underneath the basement or slab of a building. In very general terms, collecting soil gas samples requires installing a probe into the vadose zone, drawing gas out of the vadose zone, and collecting that gas for analysis (U.S. EPA 2015, Vapor Guidance). Appropriate procedures vary somewhat depending on whether the soil gas is exterior or subslab.

2.2.6.2 Sampling Exterior Soil Gas (SGe)

Exterior soil gas samples come from boreholes advanced into the vadose zone in areas outside the footprint of a structure. Exterior soil gas samples are also useful when identifying and delineating a chlorinated solvent source via the soil gas plume, evaluating preferential pathways, vapor intrusion potential at undeveloped properties, or when a property owner will not permit installation of subslab soil gas sampling ports.

Exterior Soil Gas: Appropriate Sampling Conditions

Soil moisture content strongly affects migration of vapors through the subsurface (Tillman and Weaver, 2007). Wetting fronts moving downward though the unsaturated zone can cause underestimation of vapor concentrations. Significant precipitation may cause high vacuum readings, extended sample collection time, and visible moisture droplets within the sampling train during sample collection. Therefore, IDEM generally recommends waiting at least 72 hours after a significant precipitation event (at least one inch of rain) before collecting SGe samples. The amount of precipitation required to affect the movement of vapors will depend on a number of factors, including soil type, the soil moisture conditions prior to the precipitation, ground cover, and other factors that influence infiltration. Because of this, IDEM relies on

[14] A percentage of batch-certified clean canisters have been tested by the laboratory supplying them. Canisters that are individually certified clean have been separately checked by the laboratory.

the *professional judgment of the consulting geologist to determine when sampling conditions are appropriate.* Soil boring logs should note soil moisture conditions for each soil gas sampling port.

Exterior Soil Gas: Sample Number and Placement

Volatile release-related chemicals in both soil and groundwater may be a source of subsurface vapors. To evaluate subsurface vapors, U.S. EPA recommends soil gas surveys that include a "near-source" soil gas sample collected immediately above each potential source (U.S. EPA, 2015). Near source soil gas samples are expected to have the highest concentrations and be the best indicator of vapor intrusion potential. Source depths vary. Therefore, U.S. EPA (2015) recommends that soil gas samples be collected from multiple locations and depth intervals between the vapor source and potential receptors. For purposes of this document, IDEM generally considers shallow soil gas to include samples collected no more than five feet below ground surface, and deep soil gas samples to include samples collected at more than five feet below ground surface.

IDEM recommends sampling stratified/nested soil gas points to evaluate vertical attenuation of vapors through the soil column, especially where subsurface geology is complex. When collecting stratified/nested soil gas samples, one sample should be collected closest to the source(s) and one sample should be collected closest to the potential receptor.

In some instances, deeper samples are unrealistic due to shallow groundwater. In these instances, shallow soil gas samples should be collected. Because soil gas concentrations can exhibit considerable spatial variability due to atmospheric influence, precipitation, advective flow, etc., particularly in shallow soil gas samples, additional sampling events or locations may be appropriate to ensure representative values.

Stand-alone SGe samples typically cannot accurately estimate SGss or IA concentrations. Soil gas concentrations tend to be higher beneath a building than at the same depth in adjacent open areas when the vapor source is underneath the building, even if the source is laterally extensive relative to the building footprint (U.S. EPA, 2015). When it is necessary to use SGe samples to evaluate vapor intrusion potential, collect SGe samples from depths below the building's foundation and along the side of the building closest to the source as a reasonable worst-case representation of conditions underneath the building in the absence of routes for preferential vapor migration or soil gas entry.

Active Soil Gas Sampling Procedures

1. **Advance a borehole.** Exterior soil gas sampling requires a borehole, advanced using a hand auger, a hollow-stem auger, or direct-push methods. Small-diameter (less than two inches) boreholes, installed using direct-push methods, minimize disturbance of surrounding soils. Placement of exterior soil gas samples depends on the purpose of the sampling. When delineating soil gas plumes, placement should be governed by the needs associated with that task – typically, stepping out from a known or suspected source. When evaluating the potential for soil gas to enter a nearby structure, it is generally preferable to place the borehole as close as possible to the structure.

   Unless professional judgment suggests otherwise, collect SGe samples from two locations near residential buildings: the side of the building closest to any known vapor source, and the upgradient side of the building. If these locations are on the same side of the building, collect two SGe samples from separate locations on that side of the building. For large commercial buildings, two or more SGe samples per side of the building may be necessary to characterize vapor conditions in the subsurface, and additional SGe sampling locations will be necessary along multiple sides of the building.

All else equal, soil gas samples collected from a depth just above a known or suspected vapor source are preferable to shallow soil gas samples for purposes of predicting the potential of vapors to enter structures (U.S. EPA, 2015). As with groundwater, local geology, preferential pathways, and chemical characteristics will often have a considerable influence on subsurface transport, and must be taken into account when choosing sampling locations.

2. **Install a vapor sampling probe and seal the sampling port.** To avoid cross-contamination of vapor samples by the sampling equipment, use vapor probes made of inert materials (e.g., stainless steel, copper, brass, polyvinyl chloride, polyethylene). Where practical, use permanent sample ports, as this allows repeated testing of vapors from the same location. Permanent sampling port materials should be durable enough to last through multiple sampling events. Minimize the number of fittings and tighten them as necessary to avoid system leaks. As part of preventing ambient air from entering the sampling train, seal the annulus between the probe and the borehole.
3. **Allow the subsurface to equilibrate.** U.S. EPA (2015) notes that installing soil gas probes can disturb subsurface soil conditions, and recommends allowing the subsurface to equilibrate prior to sample collection. Appropriate equilibration times depend on installation technique. For example, the California Environmental Protection Agency (Cal EPA, 2015) recommends an equilibration time of two hours for temporary driven probes and two days for probes installed using an auger.
4. **Perform a leak test.** All connections or fittings in the sampling equipment need to be tight, so that outside air leakage into the sample collection container does not occur. For this reason, perform a leak test to check the integrity of the sampling system. Common tracers used during leak checks include: helium, propane, isopropanol, pentane, and butane. Choose a tracer that will not interfere with the analytical method for the sample. See Hartman (2006), NYDoH (2006) and Cal EPA (2015) for detailed guidance on leak testing.
5. **Purge the sampling apparatus dead volume.** Purge three times the dead volume of the sampling apparatus. A large graduated syringe or hand-operated vacuum pump are suitable for this purpose. The dead volume of the sampling apparatus includes the implant screen and the tubing, but not the sample container volume nor the sand pack volume. Avoid over-purging. Minimal purging reduces the risk of inducing air flow from outside the area of interest. Sampling equipment with the smallest possible internal volume that can meet project DQOs will reduce the need for purging.
6. **Collect the vapor sample.** Vacuum during sampling should be as low as possible, subject to acceptable leak test results. Low vacuum and a low sample collection rate will minimize short-circuiting of vapors from outside the area of interest. A sampling rate of 100 to 200 milliliters per minute is preferable (Cal EPA, 2015). A very slow draw rate will improve results where wet or fine-grained soils necessitate high vacuum.

Passive Soil Gas Sampling

Passive soil gas sampling procedures are similar to those used to collect active soil gas samples. Passive sampling relies on the diffusion of compounds in the vapor state to absorbent(s) housed in a chemically-inert container designed to protect sample integrity (Hodny et al., 2009). For passive soil vapor sampling, a hole must be drilled, the sampling device should be protected from direct contact with soil, and the sampling device should be sealed in place with a seal that is at a depth just above the sampling device, and capped at the ground surface (McAlary et al., 2014a, 2014b, 2014c; Hodny et al., 2009; Odencrantz and O'Neill, 2009). For soil gas sampling, it may not be necessary to purge when using passive samplers (McAlary, 2014). After a number of days, chemical vapors amass onto the absorbent material. The sampling device is then removed and analyzed.

Possible advantages of passive sampling include longer-term sample collection periods, lower costs, and simpler procedures. Possible problems include poor retention of target chemicals, starvation effects, matching target chemicals with appropriate sorbents, and unplanned uptake of non-target chemicals. McAlary et al. (2014a, 2014b, 2014c) have determined that passive samplers can be used to quantify soil vapor concentrations provided the uptake rate of the sampling device is less than the supply rate of vapors from the surrounding materials. This avoids low bias from the starvation effect.

Dawson et al. (2015) provides an overview of different passive samplers and factors to consider when selecting an appropriate passive sampling device. For soil gas sampling, passive permeation sampling devices may be particularly suited to soil vapor sampling as the hydrophobic nature of the membrane limits soil moisture uptake. IDEM recommends consulting your analytical laboratory for the latest information on passive sampling technology, uptake rates, sorbents, sampling protocols, and necessary quality assurance procedures.

2.2.6.3 Sampling Subslab Soil Gas (SGss)

SGss sampling means collection of air samples from immediately below the basement or slab of a building. The process involves drilling one or more holes through the concrete floor, placing a sleeve or probe through the concrete, and then collecting an air sample into an evacuated canister. SGss ports may be permanent or temporary.

IDEM considers paired SGss and IA samples best for evaluating vapor intrusion potential into IA. Paired samples allow quantification of the actual increased risk from vapor intrusion, while reducing concerns about potential background sources within the building. However, SGss sampling is acceptable as a stand-alone screening tool, provided there is an adequate investigation of preferential pathways and subslab spatial variability. In instances where subslab sampling is conducted without IA sampling, IDEM recommends a more structured preferential pathway investigation at each building location (e.g., one conduit vapor sample per residence within the potential preferential pathway).

Subslab Soil Gas Sampling: Appropriate Conditions

Most indoor air measurements represent a narrow “snapshot in time” because of problems with getting repeat access and uncertainty over seasonal and building variations. Due to these uncertainties and limited sampling data, IDEM recommends sampling during “worst case” conditions. Sampling during worst-case conditions provides limited exposure data that are likely to be biased high. This bias may be considered when evaluating the need for action if indoor air sampling can be conducted at a frequency that addresses seasonal and building variability. IDEM will consider alternative SGss sampling schedules, especially where sampling needs are urgent, seasonal variation is insignificant, or where building conditions, weather conditions, or other factors suggest that worst case conditions occur outside of the winter heating and dry summer seasons.

Collect SGss samples during at least two different time periods to account for worst case conditions related to seasonal variability. Historically, the winter heating and summer cooling seasons have been considered the worst case sampling scenarios for vapor intrusion, because there is normally less external ventilation and HVAC systems can create a pressure differential that pulls gases up from the subsurface. One round of SGss samples should be collected during the winter heating season (approximately mid-November through March), when the indoor temperature is typically at least ten degrees higher than the outdoor temperature. Winter heating season SGss samples should be collected with building windows and doors closed and the building heating system in operation.

A second round of SGss samples should be collected during the dry summer season. Soil moisture content and water table fluctuation may have a more significant impact on vapor intrusion than winter heating season conditions. The highest transfer rates for VOCs from groundwater to soil gas occur during falling water table conditions (McHugh and McAlary, 2009). Generally, the water table is falling during the hot, dry summer months in Indiana (typically July through mid-September). Additionally, buildings equipped with cooling systems will have the windows and doors closed.

Subslab Soil Gas Sampling: Number and Placement

Investigative goals, utility locations, owner preferences, and other practical considerations will affect the number and locations of SGss samples. Monitoring points should be installed at locations with minimal potential for AA infiltration via floor penetration (e.g., cracks, floor drains, utility perforations, sumps, etc.)

U.S. EPA (2015) recommends collecting at least three SGss samples at structures with a footprint less than 1,500 square feet. However, IDEM recognizes that this may be impractical or unobtainable in residential structures. Generally, IDEM recommends collecting at least one SGss sample in residential structures. Additional SGss sample locations may be necessary pending evaluation of the building structure and data collected.

For commercial/industrial buildings IDEM recommends collecting an adequate number of SGss samples to evaluate spatial distribution of vapors. Multiple SGss ports can help interpret anomalous SGss/IA data or support conclusions about surrounding buildings that are not well-sampled. Sampling locations should take into account: areas highly susceptible to releases (e.g., machine pits, dry cleaning machine locations, etc.), internal building partitions, HVAC layout, chemical distribution, utility conduits, and openings for preferential soil gas entry.

For both residential and commercial/industrial buildings, centrally located sampling ports are appropriate where the subsurface vapor source is laterally extensive relative to the building footprint (e.g., a groundwater source). Other approaches may be necessary for atypical situations, which include:

- Very large or small homes or buildings;
- Buildings with more than one foundation floor type;
- Subsurface structures or conditions that might facilitate or mitigate vapor intrusion; and
- Multi-use buildings with distinct segmented areas that differ significantly by occupying population or exposure frequency.

Subslab Soil Gas Sampling: Frequency and Duration

Assessing the risk posed from the vapor intrusion pathway through the subslab of a building generally requires at least two rounds of SGss sampling (one during the winter heating season and one during the dry summer season). Collect the second round of SGss samples from the same locations as the first. The second sampling event is especially important when confirming SGss results used as a stand-alone determination of the vapor intrusion pathway. If the results of the first two SGss sampling events are contradictory or inconclusive, IDEM may request additional sampling.

In order to minimize air infiltration, maximum flow rates through the SGss probe and related tubing should not exceed 200 mL/min during purging and sampling. Most subslab samples are collected as grab samples, though canister fill rates and durations may vary depending on project objectives.

Subslab Soil Gas Sampling: Recommended Procedures

Subslab soil gas sampling is similar to exterior soil gas sampling (Section 2.2.6.2), though there are some key differences. U.S. EPA (2015) describes a procedure for collecting subslab soil gas grab samples in six liter evacuated canisters. IDEM has determined that the Vapor Pin® or similar subslab soil gas sampling technology is acceptable, as are canisters as small as one liter, as long as they meet project DQOs. Considerations to keep in mind when collecting subslab soil gas samples include:

- During colder months, building occupants should operate heating systems to maintain normal temperatures of 65-75˚F for at least 24 hours prior to and during sampling.
- Purge three volumes of the sample probe and tubing immediately prior to sampling. Use a large graduated syringe or hand-operated vacuum pump to purge the sampling point. Avoid exceeding a maximum flow rate of 200 mL/min during purging and sampling in order to minimize air infiltration.

When subslab soil gas sampling is no longer needed at a particular building, remove the sampling ports and seal the remaining holes to prevent migration of vapors through the slab.

2.2.6.4 Sampling Conduit Vapor

Sewers and other open conduits can receive, intercept, and transmit vapors or liquids containing volatile chemicals to receptors. While there are differences between conduits (within an open pipe) and utility corridors (backfill around underground utilities), IDEM considers both to be anthropogenic preferential pathways[15]. As Roghani et al. (2017) note, there is increasing recognition of the importance of conduits as a pathway for vapor intrusion, as vapors can migrate into occupied structures through plumbing systems that are not properly maintained.

Sampling Conduit Vapor: Appropriate Conditions

Collect conduit vapor samples during both high and low groundwater conditions. When collecting conduit vapor samples via grab techniques, collect those samples when baseline flow is relatively low – typically, between 9 AM and 3 PM (McHugh and Beckley, 2018). Wait at least 72 hours following a significant rain event (defined for this purpose as being at least one inch) to collect conduit vapor samples.

While conduit vapor samples are generally preferable, liquid samples collected from within the conduit may provide information about vapor sources. To reduce the influence of ambient air, collect conduit vapor samples prior to collecting conduit liquid samples. If possible, collect liquid samples when the water table is above the conduit. This allows for potential infiltration of release-related chemicals into the conduit.

Sampling Conduit Vapor: Number and Placement

Collect conduit vapor and/or liquid samples from those conduits most likely to have the highest concentrations of release-related volatile chemicals. For example, if chemicals were disposed of directly down a sink drain leading to the sanitary sewer, a conduit vapor sample should be collected at the closest point of access to this source (e.g., behind the u-bend of the sink, the sewer cleanout leading from the property, or closest connected conduit access point). If shallow groundwater containing release-related chemicals intersects a potential preferential pathway, a conduit liquid sample will show whether those chemicals are infiltrating the conduit, thus functioning as a continuing source of vapor into the conduit. In this scenario, conduit vapor samples should be collected with conduit liquid samples.

Sample each conduit that may be a preferential pathway for vapors. Additionally, collect one up-gradient and one down-gradient conduit vapor sample from each conduit (where gradient is determined by the flow direction of liquids inside the conduit). Delineation of conduit vapor should continue in the appropriate direction(s).

[15] For more information refer to IDEM's *Investigation of Manmade Preferential Pathways* technical guidance document.

Sampling Conduit Vapor: Frequency and Duration

Temporal variability in vapor concentrations is relatively high (McHugh et al., 2007; Houlton et al., 2013; U.S. EPA, 2015c; McHugh and Beckley, 2018), and is much higher over a timescale of months compared to a timescale of days. McHugh and Beckley (2018) show that short-term time integrated samples (24-hour evacuated canisters or 7-day passive samplers) provide little benefit compared to grab samples for estimation of long-term average vapor concentrations in a sewer. For this reason, perform quarterly sampling events or use longer term passive samplers.

Sampling Conduit Vapor: Procedures

The following is a brief outline of procedures for sampling conduit vapor using evacuated canisters. See IDEM's Sewer Manhole Sampling Guidance (under development) for more detailed information. Procedures are similar for passive samplers, though obtaining accurate results using passive samplers requires selection of a proper sampler and sorbent combination to avoid starvation, poor retention, and poor recovery (U.S. EPA, 2014b; McHugh, et al., 2017). Passive sampler choice should consider uptake rates and moisture fluctuations within the conduit.

- Approximately 48 hours prior to sampling, assess sewer access point types and accessibility, along with the approximate depth of the utility and depth of any liquid (if previously unknown).
- Document appropriate sampling information. IDEM's Sewer Manhole Sampling Guidance (under development) contains an example of an air sampling field data sheet suitable for this purpose.
- When using evacuated canisters, perform a leak check on each canister and attach Teflon® tubing (potentially weighted) to the canisters.
- Open sewer access points as little as possible to minimize ambient air influence. If possible, the sewer access point should be completely closed prior to and during sampling activities.
- After opening sewer access points, use appropriate screening instruments to measure concentrations of volatile organic chemicals and oxygen. Check results against lower explosive limits.
- Tubing attached to evacuated canisters should be lowered approximately two to three feet above the water within the sewer. If sampling time exceeds five minutes, suspend evacuated canisters below the access point.
- Submit samples to the laboratory within holding times.

Refer to IDEM's Sewer Manhole Sampling Guidance document (under development) for more detailed information.

2.2.6.5 Sampling Crawl Space Air (CSA)

SGss samples are not an option in buildings constructed over a crawl space. Such buildings will require collection of SGe or CSA samples, preferably in conjunction with IA samples and/or SGss samples (if there is a partial basement or slab). However, CSA samples may suffice in certain situations as a stand-alone method for investigating vapor intrusion.

Sampling Crawl Space Air: Appropriate Conditions

CSA samples should be collected during at least two different time periods to account for seasonal variability. Samples should be collected under the worst case conditions and time periods described in Section 2.2.6.3. Close crawl space vents during all sampling events. IDEM will consider alternative sampling schedules, especially where sampling needs are urgent, seasonal variation is insignificant, or where building conditions, weather conditions, or other factors suggest that worst case conditions occur outside of the winter heating and dry summer seasons.

Sampling Crawl Space Air: Number and Placement

One centrally-located CSA sampling point is typically sufficient for most residential buildings. Crawl spaces are rare in commercial/industrial buildings. Such structures will require a project-specific sampling plan that includes enough samples to adequately characterize CSA concentrations. Placement of samples should take into consideration the location of the highest subsurface vapor concentrations.

IDEM recommends collecting an AA sample in conjunction with CSA sampling to determine whether an AA source may be contributing to concentrations of release-related chemicals in the CSA. Measured AA concentrations should be used as a qualitative line of evidence, and not directly subtracted from the measured CSA concentrations.

Sampling Crawl Space Air: Frequency and Duration

Assessing the risk posed from the vapor intrusion pathway within a building over a crawl space requires collection of at least two sets of CSA samples, with the second set of samples collected from the same locations as the first. Additional sampling may be necessary if the results of the first two sampling events are contradictory or inconclusive.

IDEM recommends collecting CSA samples over a 24-hour period in residential buildings and over an eight-hour period in commercial/industrial buildings. However, project objectives may dictate alternative canister fill rates.

The sample duration for commercial/industrial decision units should capture normal working conditions. For example, if shifts are a twelve hour period, then the samples should be collected for a twelve hour period. Alternatively, if multiple shifts occur it may be necessary to collect one 24-hour sample or two eight-hour samples.

To minimize the impact of indoor background sources on indoor air sampling, building occupants should suspend (where practical) activities such as smoking, dry cleaning, painting, mowing, pesticide application, and the use of sprays, cleaners, solvents, etc. prior to sampling. Document exceptions observed during sampling. IDEM has Vapor Intrusion Investigation Documentation guidance that may prove useful when looking for potential indoor background sources of release-related chemicals. Interviewing building occupants may reveal potential indoor background sources. If feasible, identify and remove potential background sources prior to sampling. U.S. EPA (2011c) and Commonwealth of Massachusetts (2002) contain discussions of background levels.

2.2.6.6 Sampling Indoor Air (IA)

It can be difficult to interpret indoor air sample results in the absence of vapor sample results from outside the structure.

Sampling Indoor Air: Appropriate Conditions

IDEM has determined that indoor air samples should be collected during at least two different seasons that provide the best opportunities to capture worst-case conditions. Historically, the winter heating and summer cooling seasons have been considered the worst-case sampling scenarios for vapor intrusion. This is because windows and doors are typically closed during the heating and cooling seasons, and HVAC systems can create a pressure differential that draws vapors up from the subsurface. In addition, falling water table conditions that commonly prevail in the summer can expose source material.

Therefore, unless there is an immediate need to characterize indoor air and current human exposures, or evidence shows that seasonal variation in indoor air concentrations is not significant:

- Collect one round of indoor air samples during the winter heating season when building windows and doors are closed and the building heating system is in operation (when the indoor air temperature is consistently at least ten degrees higher than the outdoor temperature), and
- Collect one round of indoor air samples during the summer cooling season when building windows and doors are closed and the building cooling system is in operation.

Differential pressure measurements are a valid line of evidence when evaluating vapor intrusion that is unrelated to sewer or other conduit transport. The difference in pressure between the IA and SGss provides a primary advective force for vapor intrusion. Vapor intrusion is likely when the pressure inside a building is lower than the pressure in soil gas below the building. If the pressure inside is positive compared to the subslab, there should be little or no vapor intrusion potential. Pressure differential measurements over hours, days, or weeks using small diameter subslab sampling ports or pressure taps can be used as a line of evidence to demonstrate whether conditions conducive to vapor intrusion exist during a sampling event.

Sampling Indoor Air: Number and Placement

For residential buildings, worst case IA samples are generally located in the basement or area where vapors first enter the building. Generally, IDEM recommends at least three 24-hour samples: one indoor air sample in the basement or assumed worst case location, one indoor air sample in the general living area, and one ambient air sample. If the building has multiple levels, IDEM recommends one indoor air sample from each floor. Place evacuated canisters within the breathing zone (three to five feet above the floor) and collect the ambient air sample upwind of the building.

Project-specific vapor sampling plans should account for atypical situations, which include: (1) very large homes or buildings; (2) multi-use buildings, particularly ones with segmented areas that are occupied by different populations (e.g., day care within office) or have different occupancy patterns over time. Additional samples may also be warranted, depending on internal building partitions, HVAC layout, chemical distribution in the subsurface, and occurrence of observable locations of potential soil gas entry (e.g., basement sumps or drains, relatively large holes or spaces in the foundation floor, entry points for utilities). Closed rooms located below ground may have significantly higher concentrations originating from vapor intrusion. Closed rooms may warrant sampling to characterize reasonable maximum exposure levels, if occupied, or to diagnose vapor intrusion (e.g., see below), even if not occupied.

When planning IA sample locations in commercial/industrial buildings, consider the following:

- Individual offices within a building.
- Individual retail spaces within a larger commercial/industrial complex.
- Areas operating under separate HVAC systems.
- Areas with higher exposure potential (where occupants spend most of their time).
- Areas above the highest subsurface chemical concentrations.
- Areas with utility inlets.

Sampling Indoor Air: Frequency and Duration

Assessing the risk posed from the vapor intrusion pathway requires the collection of at least two rounds of indoor air samples. To minimize the variability between indoor air samples collected over time, collect the second round of indoor air samples from the same locations as the first. Pairing indoor air samples with subslab soil gas samples can help assess indoor air background issues. If the results of the first two sampling events are contradictory or inconclusive, IDEM may request additional sampling.

IDEM recommends completing indoor air sample collection over a 24-hour period for current (or when evaluating future) residential use, and an 8-hour period for commercial/industrial use. Alternative canister fill rates are possible depending on project objectives. However, the fill rate must be established prior to obtaining canisters from the laboratory, since the pre-set flow regulators for the canisters are typically supplied by the laboratory. All else equal, a longer collection period for each individual sample would be expected to yield a more reliable basis for estimating long-term, time-averaged exposure than would a one-day sample collection period.

2.2.6.7 Ambient Air Sampling

If AA is a concern due to operations in the vicinity of the proposed sampling area(s), AA samples should be collected over the same time period as indoor air. U.S. EPA generally recommends beginning AA sampling at least one hour, but preferably two hours, before indoor air monitoring begins (U.S. EPA, 2015). However, to reasonably account for air exchange rates in building(s), IDEM generally recommends setting up the AA canister(s) prior to placing the indoor air canisters. U.S. EPA recommends this practice because most residential buildings have an hourly air exchange rate in the range of 0.25 to 1.0, causing air that enters the building before indoor air sampling to remain in the building for a long time. The AA sample can serve as a reference for background conditions and allow comparison to IA results. Measured AA sample concentrations should be used as a qualitative line of evidence. AA sample concentrations should not be directly subtracted from the measured IA concentrations.

2.2.6.8 Background (IAb) Sources

Atmospheric and indoor chemical sources may complicate interpretation of indoor air (IA) sample results. Many VOCs common to environmental investigations are present in tobacco smoke, cleaning supplies, craft and hobby supplies, stored fuels, and other common household products, and may exceed chronic screening levels for chemicals such as benzene, carbon tetrachloride, chloroform, methylene chloride, trichloroethene, and tetrachloroethene. For this reason, it is important to assess IAb sources and concentrations at a decision unit when evaluating the vapor intrusion to IA pathway. For more information, see the U. S. Department of Health and Human Services Household Products Database.[16]

Lines of evidence useful when determining whether IA chemicals are attributable to background sources or chemicals in the subsurface include:

- Factors listed in IDEM's Vapor Intrusion Investigation Document
- AA sample results
- Concentration gradients within a building
- Atmospheric concentration gradients
- Subslab soil gas (SGss) to IA concentration ratios
- Individual chemical concentration ratios across media
- Presence of indicator chemicals
- Use of radon as a tracer gas to determine a structure-specific attenuation factor

[16] http://householdproducts.nlm.nih.gov/

If an indoor source is suspected, conduct a detailed inspection of the building's contents and survey occupant activities. Identify the presence of common household items (e.g., cleaning supplies, craft and hobby supplies, and fuels) that contain VOCs common to the release, as well as recent activities such as dry cleaning, or home improvements (e.g., painting or new carpet) that may contribute to exposures. See IDEM's Indoor Air Building Survey Checklist (Appendix IV) or U.S. EPA (2002a) for examples of building surveys.

Comparing the SGss, AA and IA results to each other may reveal the relative contribution of vapor intrusion and background sources to indoor air concentrations. In this case, time-integrated sampling methods are recommended for indoor air, because concentrations of vapor-forming chemicals can vary significantly over time.

2.2.7 Sample Handling

Some samples require physical and/or chemical preservation in order to maintain sample integrity from time of collection until delivery to the laboratory. Laboratories can provide information on appropriate sample preservation methods. Alternatively, U.S. EPA (2009d, Chapter 2) contains summary tables showing preservation methods and holding times for SW-846 analytical methods. It is important to deliver samples to the laboratory as soon as possible after collection or within a set time frame if the method requires it (U.S. EPA, 2009h). Samplers should maintain and document custody of the samples from collection until shipment or delivery to the laboratory.

2.2.8 Sample Analysis

It is important to choose analytical methods that can meet project DQOs. The QAPP, SAP, or other relevant project-specific sampling document should list sample analysis methods and any deviations from those methods. Reference to standard published methods is typically acceptable as long as the laboratory performs the analysis exactly as stated in the method. Sources for standard analytical methods include U.S. EPA (2019, 2019b, 2019c, 2019d). When analyzing solid samples (e.g., soils, sediments, and solid waste) for VOCs, IDEM recommends collecting and extracting them using U.S. EPA SW-846 Method 5035A. IDEM (2016) contains additional guidance on this topic.

Key considerations regarding sample analysis include:

- Can the analytical methods deliver reporting limits at least as low as relevant remediation objectives?
- Can the laboratory provide data that meet project DQOs?[17]

2.2.9 Data Reporting

Documentation needed to evaluate data will depend on the intended use(s) of the data. A quality assurance/quality control (QA/QC) program is the means of judging whether or not the data meet DQOs. QA/QC programs use information from sampling, laboratory operations, and method-specific procedures to make this decision.

Table 2-C lists elements that IDEM has determined are essential to support two levels of QA/QC. For example, every element in Table 2-C is, where appropriate to the particular type(s) of analysis, necessary for data validation. A smaller set of elements that IDEM calls minimum data documentation recommendations (MDDRs) are appropriate to support investigations where data validation may not be

[17] Note that Indiana does not currently certify laboratories for remediation work.

necessary. Analytical results submitted to OLQ shall meet the IDEM/OLQ *Electronic Data File Submittal Guidelines for Monitoring and Sampling Data*.

Sampling documentation is an important component of demonstrating that sample results meet project DQOs. IDEM's Office of Land Quality does not typically require specific field documentation forms. In addition to the elements in Table 2-C, the following sampling-related documentation should support every investigation:

- Completed chain of custody with sample date, time, and identification
- Map or diagram of sample locations
- Sample field sheets that document sample identifiers, locations, date and time, sampling methods and equipment, samplers, calibration methods, and any notable observations (color, clarity, texture, reactions with preservatives, etc.)
- Blanks – trip, field, or equipment rinsate blanks, as appropriate
- Identity of field duplicates – typically at least one per twenty samples per matrix for each method.

IDEM (2016) provides a template for recording information on various vapor intrusion investigations. Vapor investigation sampling documentation should include, where appropriate:

- Certification of evacuated canister cleanliness (batch or individual)
- Leak test procedures and results
- Purge volume
- Field records of the initial and final canister pressures, start and stop times for canister filling, and fill rate

The following laboratory-related items should support every investigation:

- Completed chain of custody with date and time of receipt
- Condition of samples on receipt
- Sample identification – project identification and lab identification
- Sample preparation logs with extraction, cleanup or digestion details
- Certificates of analysis with method, analysis date, results and associated qualifiers, method detection limits, reporting limits, and any dilution factors
- Case narrative detailing any deviations, problems, and corrective actions

Table 2-C: Elements for MDDRs and Full QA/QC

Element	Method Type	IDEM MDDRs	Full QA/QC
Case Narrative	All	✓	✓
Sample introduction method (e.g., direct injection, purge-and-trap)	Specific gas chromatography (GC) detector method	✓	✓
Tuning criteria and results	Gas chromatography/mass spectroscopy (GC/MS)		✓
Initial calibration and verification	All		✓
Continuing calibration(s)	All		✓
Method Blank	All	✓	✓
Laboratory control sample	All	✓	✓
Internal standard summary	GC/MS, GC		✓
Surrogate recoveries	GC/MS, GC	✓	✓
Matrix spike/matrix spike duplicate recoveries	All (except TO-14A, TO-15, TO-15 SIM, and TO-17)	✓	✓
Interference check sample	Inductively coupled plasma methods		✓
Serial dilutions	Inductively coupled plasma methods		✓
Method of standard additions (if applicable)	Inductively coupled plasma methods		✓
Raw data (instrument printouts, chromatograms, and/or mass spectra as applicable)	All		✓
Confirmation on second column (or GC/MS)	Pesticides, polychlorinated biphenyls, benzene, toluene, ethylbenzene, and xylenes, and other volatile organic chemicals by GC		✓

2.2.10 Data Evaluation

The data evaluation process assesses whether the sample results meet project objectives. The process has three major components: verification, validation, and comparison against user requirements. The process verifies that sample collection, documentation, and delivery occurred as planned. If necessary, the results are validated against predetermined quality criteria. Analytical results are then compared against user requirements.

The usability of any data set is based on assessing sampling and laboratory activities. This assessment is based on the evaluation of data quality indicators: precision, accuracy (as bias), representativeness, comparability, completeness, and sensitivity.

2.2.11 How IDEM will Evaluate Nature Determinations

IDEM evaluation of nature determinations will include consideration of the following:

- Appropriate field screening methods used
- Sampling procedures appropriate for the release-related chemicals and/or per SAP
- Samples handled appropriately
- Given release/facility history, appropriate release-related chemicals
- Appropriate analytical methods used
- Holding times met
- Reporting/detection limits as low as relevant delineation or remediation objectives
- Cooler temperatures acceptable on laboratory arrival
- Laboratory sample condition noted on receipt form
- Analytical data meets MDDRs (or larger element list if necessary)
- Case narrative submitted
- Surrogate recoveries within lab control limits
- Method blank results submitted
- Laboratory control sample results submitted
- Matrix spike/matrix spike duplicate recoveries within acceptable ranges: 20% relative percent difference for aqueous media, 40% relative percent difference for soils
- Field duplicates in agreement: 20% relative percent difference for aqueous media, 40% relative percent difference for soils
- Summary tables correspond with certificates of analysis
- Data on exhibits/figures correspond with certificates of analysis
- Is data validation (submission of full QA/QC) needed

2.3 Task Three: Determine Extents of Release-related Chemicals

Extent is the boundary of the volume of a medium containing one or more release-related chemicals that exceed **unconditional remediation objectives**[18], and may therefore limit a property's use. Extents are most often determined for chemicals in soil, groundwater, and vapor, but may be relevant for sediment, surface water, or other media. For releases that involve more than one chemical, the extents of individual chemicals are likely to differ from each other. In such cases, the extent in a particular medium is the union of all the individual extents in that medium. While IDEM recognizes that non-aqueous phase liquids (NAPL) may be a risk driver or subject to other regulations, for purposes of this document it is assumed that NAPL delineation will be bounded by delineation in other media.

2.3.1 Basis for Requirement

Indiana Code (IC) 13-12-3-2 and IC 13-25-5-8.5(c) require adequate characterization of the nature and extent of release-related chemicals. The present and likely future extents of release-related chemicals define the boundaries of the volumes of media where one or more remedy decisions are necessary under IC 13-25-5-8.5(c). Remedies may be necessary to control risks associated with soil direct contact, plumes of release-related chemicals in groundwater, leaching of release-related chemicals from soil to groundwater, or vapors arising from volatile release-related chemicals in soils, NAPL, or groundwater that enter or have the potential to enter occupied structures. For these reasons, an understanding of the present and likely future extents of release-related chemicals is necessary to protect human health and the environment.

IDEM will not require a determination of likely future extents under every conceivable circumstance. Determinations should focus on scenarios that are *reasonably* likely to occur. Where there is disagreement about what is reasonable, responsible parties must submit lines of evidence in support of their position. IDEM will consider those lines of evidence on their merits, using professional judgment and knowledge of the circumstances specific to the release.

Sometimes determining extents is impractical or unnecessary. Proposals to forego or limit extents determinations must be supported by lines of evidence provided by the responsible party. IDEM will not provide them. Applicable lines of evidence are necessarily project-specific but may include:

- Distance and/or time of travel from known extents to existing or potential receptors including, where applicable, sensitive receptors (e.g., schools, daycare facilities, wellhead protection areas, ecologically important habitats, etc.)
- Characteristics of release-related chemicals (e.g., mobility, toxicity, volatility, persistence)
- Current and likely future use of the property, including groundwater use and the presence of structures susceptible to vapor intrusion
- Magnitude of release-related chemical concentrations relative to unconditional remediation objectives
- Extent of the area in which the release(s) occurred
- Underground utilities or other preferential pathways that may affect chemical migration
- Possible aquitard influences
- Potential for changes in groundwater or vapor flow direction and pressure gradient (e.g., start up or shut down of existing or planned production wells; construction of utility corridors, basements, fill areas, etc.)

[18] Defined in Section 3.3

IDEM will evaluate proposals to forego or limit extents determinations on their merits.

2.3.2 Present Extents: Soil

Soil is the unconsolidated mineral or organic material lying between the ground surface and unaltered parent material below. This guidance does not define specific depth intervals as comprising either surface soils or subsurface soils. However, consistent with U.S. EPA (2002d, page 2-7), IDEM's soil direct contact published levels are applicable to soils where current or future direct contact with the soil is likely. Depths are typically shallow but also consider soils that may be brought to the surface in the future.

2.3.2.1 When is a Present Extents Determination Necessary in Soil?

A present extents determination for release-related chemicals in soil is necessary for most of the chemical releases addressed by IDEM's Office of Land Quality. The principal exceptions are releases to surface water addressed by OLQ's Emergency Response Section under the Spill Rule[19] and instances in which adequate initial soil sampling does not reveal concentrations of release-related chemicals exceeding unconditional remediation objectives.

2.3.2.2 How to Determine Present Extents in Soils

This subsection describes acceptable procedures for determining present extents of release-related chemicals in soils. IDEM will evaluate other approaches on their merits. Unless compelling lines of evidence show otherwise, present extents determinations are required in both the horizontal and vertical dimensions. For guidance on sampling design, see Section 2.2.2. If a remedy has already reduced concentrations of release-related chemicals and it is necessary to determine whether additional remedies are required, see Section 3.

Horizontal Extent Determination Beginning at or Near a Source Point

Horizontal extent determinations that begin at or near a source point are sometimes referred to as step out procedures. When selecting sample points for the step-out procedure, start at locations where release-related chemical concentrations are likely to be highest. Factors to consider when selecting sample locations include:

- Known release points (Section 2.1)
- Vertical location of highest concentrations (surficial, buried, under a barrier)
- Phase (soil, NAPL, mixture)
- Release-related chemical solubility and volatility

If soil samples collected in locations most likely to have the highest concentrations are below unconditional remediation objectives, determination of extents in soil is not necessary. Conversely, if soil concentrations of release-related chemicals exceed unconditional remediation objectives, step out until present extents are determined.

Horizontal Extent Determination Beginning at or Near a Potential Receptor

Horizontal extent determinations that begin at or near a receptor and proceed toward a source point are sometimes referred to as the step-in approach. The step-in approach may be preferable when there is

[19] 327 IAC 2-6.1

concern that unacceptable exposures are already occurring. If unacceptable exposures are occurring, the step-in approach may allow those exposures to be identified and controlled earlier.

The step-in approach should not stop once soil extents based on unconditional remediation objectives are determined. It will be necessary to continue at least until excavation worker levels are delineated. In some cases, continuing until the source point is reached may be necessary for evaluation of leaching potential and/or active remedy design. For volatile release-related chemicals, continuing the step-in process until the source point is reached allows focus of soil gas screening efforts.

Vertical Extent Determination

Vertical extent determinations for surficial releases to soil typically begin with soil sampling at the ground surface and proceed downward until the potential for soil direct contact exposure is adequately understood. This may involve collecting more than one surface or near surface sample. If chemicals were released directly into the subsurface or have leached or otherwise moved into the subsurface over time, subsurface samples will usually be necessary to understand the potential for soil direct contact exposure. However, sampling below 15 feet to evaluate direct contact isn't generally necessary unless exposure to soil below that depth is likely to occur (e.g., as the result of excavation or movement of soil). Soils with the potential for soil direct contact exposure should be sampled regardless of their moisture content. Even saturated soils can contribute to soil direct contact exposure, particularly if they are brought to the surface and left there.

Interpolation and Extrapolation

IDEM has determined that approximate extents determinations are usually acceptable. Soil sample results that fall within a range reasonably close to unconditional remediation objectives will suffice. If soil concentration data display a discernable trend, it is often appropriate to extrapolate or interpolate soil sample results when drawing unconditional remediation objective isoconcentration lines, or isoconcentration lines for other relevant remediation objectives. Specify methods used and any identified error estimates.

2.3.3 Likely Future Extents: Soil

Although significant increases in the extents of release-related chemicals in soil are relatively unusual, responsible parties must consider the possibility that this can occur. Where an increase in soil extents is *reasonably* likely, responsible parties must provide an estimate of the likely future extents of release-related chemicals in soil.

2.3.3.1 When is a Likely Future Extents Determination Necessary in Soils?

IDEM has identified several scenarios that require consideration of the possibility that the extents of release-related chemicals in soil will increase:

- When soil containing release-related chemicals is exposed to the action of wind or surface water
- When mobile NAPL is present
- When release-related chemicals in soil migrate downward or horizontally
- When soil containing release-related chemicals is subject to movement via excavation or similar activities

Further discussion of each of these scenarios follows.

2.3.3.2 How to Determine Future Extents in Soils

Soils Exposed to the Action of Wind or Surface Water

Release-related chemicals bound to soil particles may move under the influence of wind or surface water. Movement under the influence of wind is most likely with exposed, dry, fine soil particles. Vehicular traffic, areas where vegetation is sparse due to the effects of release-related chemicals or other factors, and even pedestrians creating bare soil paths may expose soils and promote wind borne transport. Signs that this is occurring include visible dust, depositional areas, or dust complaints. Predicting future extents is difficult as wind direction and speed vary considerably in most places. An interim remedy may be necessary prior to full characterization and risk assessment.

Movement under the influence of surface water is most likely with exposed, sloping soils. It may also occur on steeply sloping soils, even when those soils are mostly vegetated. Surface water and erosion can transport release-related chemicals as sediments. Signs that this is occurring might include rills, gullies, sediment deposits, or cloudy surface water bodies during and after precipitation.

Likely future extents under the influence of surface water may be more predictable than with wind erosion, as surface water flows downhill and often follows a discernable path, either until it is absorbed into the soil column or discharges into a surface water body. As with wind erosion, interim remedies may be advisable prior to full characterization and risk assessment.

When Mobile NAPL is Present

When present as a sufficient mass of NAPL, release-related chemicals will move down through the soil column and, depending on geology and preferential pathways, may also move horizontally. Soil moisture may impede flow rates, while increased soil porosity may facilitate flow. IDEM has most often encountered horizontal movement at manufactured gas plants and facilities where NAPL under building footprints intercepts drains or other preferential pathways.

Downward Vertical Migration (Leaching) in the Soil Column

Release-related chemicals sorbed to vadose zone soils may dissolve into infiltrating precipitation and travel downward, either resorbing to deeper soil particles or reaching the groundwater table. Horizontal movement, typically via diffusion, may also occur, though significant horizontal movement via diffusion is unusual, except at very recent or large releases. An increase in the vertical interval that exceeds relevant remediation objectives will increase the volume of soil that requires a remedy. From a risk perspective, the more important phenomenon is usually leaching to groundwater, discussed in Section 3.4.5.

Soil Subject to Movement by Excavation or Similar Activities

Excavation and similar activities move and expose soil, and with it any chemicals in that soil. It is rarely possible to determine in advance when, whether, where, and to what depth soil excavation may occur. However, IDEM publishes soil direct contact levels for excavation worker and five other soil direct contact exposure scenarios, and those levels combined with adequate characterization of soils affected by a release may be useful when evaluating the potential need for a soil direct contact remedy.

2.3.4 Present Extents: Groundwater

Groundwater is water beneath the ground surface. The present extent of release-related chemicals in groundwater is the boundary of the volume of groundwater in which concentrations of, or risks associated with, one or more release-related chemicals exceed their unconditional remediation objectives.

2.3.4.1 When is Present Extents Delineation Necessary in Groundwater?

IDEM will typically require groundwater sampling whenever a release is known or suspected. Possible exceptions include surficial releases of insoluble chemicals, or releases known to be restricted to vadose zone soils in conjunction with leaching test results that show leaching of release-related chemicals to groundwater is unlikely.

When a Rule[20] applies to investigation of a release to groundwater, the Rule takes precedence over this guidance document. Otherwise, collect at least three groundwater grab samples from depths appropriate for the release. The initial groundwater grab samples must be collected at or near the suspected source point, if known. If the source point is not known, then adequate coverage of the area under investigation is required. Three groundwater grab samples usually suffice for an area like a typical city lot (50 feet by 150 feet). Larger areas, or areas with heterogeneous subsurface geology, may require more than three initial groundwater grab samples.

If any groundwater grab results exceed one or more unconditional remediation objectives, extents delineation is required for the chemicals with exceedances. Otherwise, and assuming the sample locations adequately cover the area under investigation, extents delineation is not required in groundwater.

2.3.4.2 How to Delineate Present Extents in Groundwater

This subsection describes some acceptable procedures for delineating present extents of release-related chemicals in groundwater. IDEM will evaluate other procedures on their merits. When present extents delineations are required in groundwater, horizontal extent delineation is always required. Vertical extent delineation may or may not be required depending on the chemicals and geological characteristics in the area under investigation. For example, chemicals that are less dense than water may extend only a few feet into the water-bearing zone and can often be vertically delineated within the length of a standard well screen interval.

Sampling Technology

Grab groundwater samples collected using push probe technology are usually sufficient for extents delineation. Monitoring wells may be necessary in areas with heaving soils, deep groundwater, where turbidity issues cannot be overcome by other means, or in some cases for delineation of plumes that extend into more than one water-bearing unit. Monitoring wells are required for any purpose that requires long-term monitoring of release-related chemicals in groundwater.

Horizontal Extents Delineation

Horizontal extents delineation of release-related chemicals in groundwater requires determining the area underlain by groundwater that exceeds one or more unconditional remediation objectives. Unconditional groundwater remediation objectives for groundwater are most often IDEM's published groundwater direct contact levels. However, they can also be site-specific residential remediation objectives or concentrations corresponding to naturally occurring concentrations of release-related chemicals in groundwater (the latter usually for one or more of a small subset of metals).

Extents delineation need not be "exact". In other words, it is not necessary to continue advancing borings and collecting groundwater samples until observed concentrations in those samples exactly match

[20] For example, 329 IAC 9-5-6(b) requires installation of a minimum of three groundwater monitoring wells and collection of samples from each, if at least three wells were not installed during the initial site investigation. Other Rules may have other requirements.

unconditional remediation objectives. The effort need only be sufficient to allow a reasonable estimate of the extent. Interpolation, extrapolation, knowledge of concentration gradients, groundwater flow direction, distance to receptors, and distance to property boundaries may all be reasonable lines of evidence to consider when deciding whether a delineation effort is sufficient.

Vertical Extents Delineation

In general, vertical delineation of release-related chemicals in groundwater begins at the water table and extends downward until samples show release-related chemicals below unconditional remediation objectives. However, in some cases the base of the water-bearing unit still contains concentrations of release-related chemicals that exceed unconditional remediation objectives, and there is low permeability material below. The sole presence of low permeability units is insufficient evidence to demonstrate vertical delineation without further investigation. See IDEM (2019) for information about low permeability units relevant to delineation and eventual CSM development.

Delineation Reporting

IDEM has determined that agency review of extent delineations requires that delineations be depicted as lines drawn on maps, and that any software used to generate those lines be specified. U.S. EPA (2000) provides guidance on delineation reporting, and ITRC (2016) describes software options applicable to transforming observed data into delineation maps. Isoconcentration lines may be useful for chlorinated chemicals. An overall extents depiction that combines or shows the union of the extents of individual chemicals will often suffice for petroleum chemicals.

2.3.5 Likely Future Extents: Groundwater

As dissolved chemicals travel within groundwater via advection[21], the extents of release-related chemical plumes (plume extents) change, and may reach previously unaffected receptors. Therefore, an adequate evaluation of release-related risk requires an understanding of likely future plume extents. This subsection describes when it is necessary to estimate likely future plume extents. Appendix C provides detailed guidance on the application of a specific statistical test to determine whether plumes are expanding or contracting.

2.3.5.1 When is a Likely Future Extents Delineation Necessary in Groundwater?

Likely future extents delineation is generally necessary in groundwater *unless*:

- There is no plume and a future plume is unlikely

  This may be true for insoluble chemicals, or for chemicals that leaching tests have shown to be tightly bound to soil.

- The plume has already reached a terminal receptor

  When data show that the plume has already reached a stream, pond, high capacity well, or other destination that is a terminal receptor, IDEM may agree that the extents of the plume are unlikely to expand significantly over time.

- The plume consists entirely of petroleum constituents and is of a certain age

[21] Diffusion and dispersion may also contribute to movement of chemicals in groundwater, though typically to a lesser extent than advection.

IDEM recognizes that petroleum plumes rarely extend more than 750 feet (Mace et al., 1997; Newell et al., 1998; Rice et al., 1995; Wiedemeier et al., 1999), are often much smaller, and usually stabilize within five years of the initial release (Rice et. al., 1995).

- Other lines of evidence show that likely future plume extents delineation is not necessary. Common lines of evidence that may be relevant for this purpose include:
    - Plumes shown to be shrinking, usually via statistical tests, modelling, the presence of non-regulated degradation products, or other means;
    - Plumes with low leading edge concentrations relative to unconditional remediation objectives;
    - Plumes with concentration gradients that decline rapidly with distance, coupled with sufficient distance to the source facility boundary or boundary of an area subject to exposure controls; or
    - Plumes with low release-related chemical flux.

See Section 2.3.5.3 for additional discussion of lines of evidence relevant to likely future extent.

A likely future extents delineation is usually not appropriate when:

- The nature and present extents of release-related chemicals is still under investigation.
- Active remediation is occurring, as active remediation alters plume dynamics. A project-specific equilibration period should separate active remediation from plume behavior evaluation.
- The groundwater remediation objective is an unconditional closure.
- The groundwater remediation objective is closure via a background or an unrelated source demonstration.
- A preferential pathway[22] controls groundwater flow within the affected area.
- Other lines of evidence demonstrate that the evaluation is unnecessary.

2.3.5.2 Monitoring Well Locations for Likely Future Extents

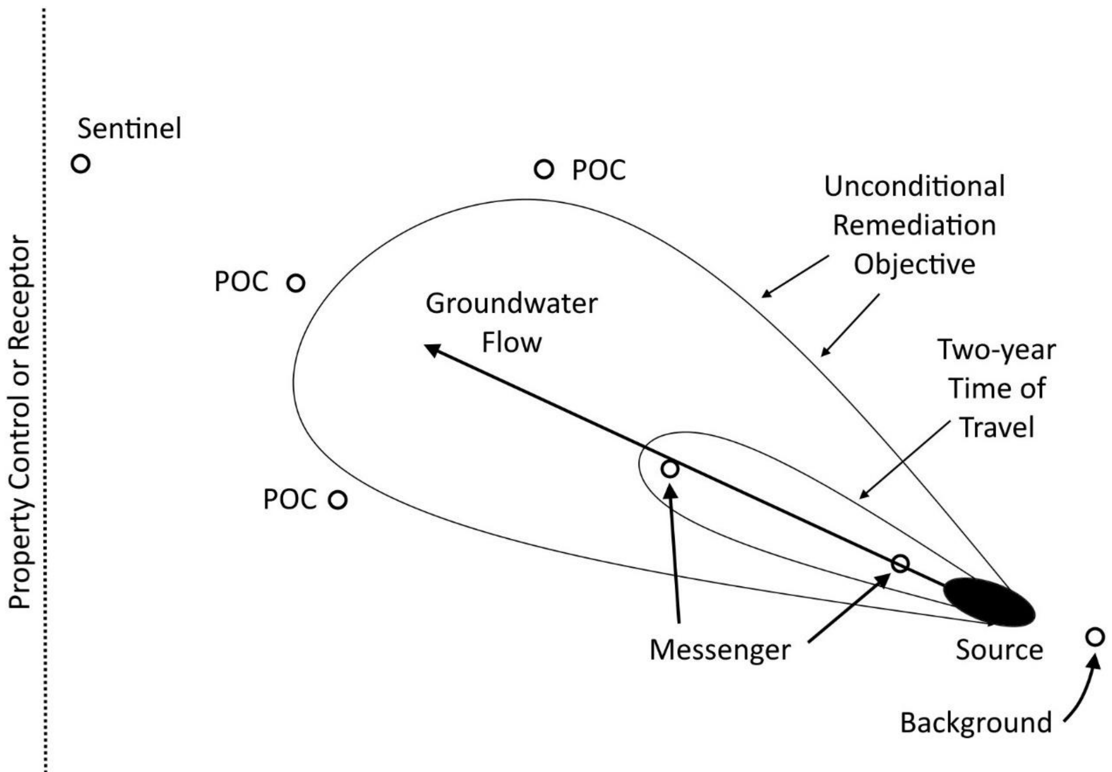
Well locations are important when characterizing likely future extents and how the monitoring wells relate to one another enables evaluation of the spatial component of the plume. If all the monitoring wells within the plume exhibit approximate trends in the same direction with comparable slopes, then a single summary statement across the well network is valid (EPA 2006b). If the time-trends do not show a consistent pattern, it is likely that one or more wells are not screened in the same flow zone, *or* a previously unknown source may be affecting the observed concentrations. New wells may be necessary for the first scenario. For the second, additional wells will be necessary to understand the contribution of the previously unknown source.

Data on chemical concentrations levels and aquifer characteristics should come from wells and boreholes capable of providing a clear three-dimensional picture of the hydrogeologic and geochemical characteristics of the location. If the wells do not meet appropriate criteria, or if conditions change, previously installed wells may no longer produce samples that adequately represent the plume. In such cases, new wells may be necessary.

All long-term groundwater monitoring requires properly designed, located, and installed groundwater monitoring wells. Figure 2-A depicts a typical likely future extents demonstration well network.

Figure 2-A: Plume Monitoring Network

[22] See Investigation of Manmade Preferential Pathways for more on this topic.



Messenger Wells are in the internal area of the plume, downgradient from the source, and within the two-year groundwater time-of-travel distance from the source. At least one messenger well must be adjacent to the source, and a second messenger well must be between the first messenger well and the two-year groundwater time-of-travel distance of the plume. Most groundwater closure demonstrations use two to four messenger wells. Some large or multi-lobed plumes may require more messenger wells. Messenger wells should be (1) as near to the center flow line or flow path as possible and (2) in an area where release-related chemical are likely to be highest and significantly exceed remediation objectives.

Perimeter of Compliance (POC) wells (at least three) are part of the network, located hydraulically downgradient and/or side-gradient from the messenger wells, where:

- Dissolved concentrations of release-related chemicals will likely exceed reporting limits for at least 75 percent of the monitoring events.
- Concentrations of release-related chemicals approximate unconditional remediation objectives.
- It is possible to monitor the plume after it has passed through the source and messenger well areas.

Install **sentinel wells** to define the extents of the plume and to evaluate the potential risk to downgradient receptors. Locate sentinel wells hydraulically downgradient from POC wells and along a line between the source and any potential receptors. Though sentinel wells are highly useful for signaling an expanding plume, they may be unnecessary if there are substantial lines of evidence to demonstrate that there is no unacceptable risk to a downgradient receptor.

Place **background wells** upgradient of the area of concern and out of the zone of influence of the source. Background wells are essential to understanding upgradient groundwater conditions. If both upgradient and downgradient concerns exist at a decision unit, at least one background well is necessary. However, additional background wells may be necessary, depending on conditions discussed below.

CSM development may require further characterization of plumes through additional groundwater monitoring and assessment of spatial and temporal data trends (e.g., plume area, chemical concentrations, chemical mass, and the center of mass over time). Evaluating the time trend of the wells individually may not provide sufficient information to adequately characterize likely future extents. Assessment of how the trends relate to each other helps understand plume behavior, and the potential for chemicals to migrate beyond the exposure control area (Appendix C).

If hydraulic conductivity, saturated thickness, flow gradients, or other important characteristics vary significantly over the evaluation area, it may prove difficult or impossible to confidently predict plume behavior. Similarly, preferential pathways (e.g., karst conditions, fracture flow, utility backfill, etc.) that control groundwater flow and chemical migration complicate assessment of likely future extents. Where this is the case, understanding plume behavior may require assessment of lines of evidence that do not appear in this document.

2.3.5.3 Qualitative Lines of Evidence Potentially Relevant to Likely Future Extents

Plume behavior is how release-related chemical concentrations change spatially and over time, and interact with potential receptors. Plume behavior evaluation is the use of applicable qualitative and quantitative lines of evidence to understand the likely future extent of release-related chemicals in groundwater and potential exposure scenarios. Plume behavior evaluation uses lines of evidence to determine whether release-related chemicals behave (and can be expected to behave in the future) with sufficient predictability.

Qualitative analysis of plume behavior relies on specific knowledge of local conditions rather than mathematical analysis. While quantitative examinations of concentration trends are powerful tools for evaluating the behavior of a plume, meaningful statistical tests require substantial monitoring timeframes and consistent monitoring periods to acquire sufficient data. In some situations, concentration trends are qualitatively discernible in shorter timeframes and/or with irregular time series data. Additionally, data may show chemical concentrations in individual wells fluctuate unpredictably, but the overall plume footprint remains unchanged over time. IDEM will evaluate such interpretations on their merits.

In the context of this section, qualitative lines of evidence are non-mathematical facts that are relevant to an evaluation of plume behavior. Qualitative lines of evidence are available or readily obtainable for nearly all projects with release-related chemicals in groundwater. Every likely future extent evaluation should begin with qualitative review of geologic, hydrologic, and release-related chemical characteristics. If qualitative analysis does not provide sufficient confidence in plume behavior, quantitative methods can be considered (see Appendix C).

This section describes several qualitative lines of evidence useful in understanding plume behavior. Each characteristic offers insight into the behavior of the plume, though some are more compelling than others. While no single characteristic is enough to understand the overall behavior of a plume, agreement among multiple lines of evidence provides greater confidence when assessing plume behavior. It is not necessary to develop any particular line of evidence discussed in this section – only those needed to provide adequate confidence in the understanding of plume behavior. Other lines of evidence may be submitted, and IDEM will evaluate them on a project-specific basis.

Age of the Release. This line of evidence applies only to petroleum chemicals. Given the well documented behavior of petroleum releases, the age of the release is an appropriate indicator of the plume lifecycle. Regardless of the size of the release or subsurface conditions, the extent of most petroleum related releases will stabilize within approximately five years (Rice et al., 1995). Given this relationship, IDEM will have greater confidence in the behavior of petroleum plumes that have documented historic release dates. Conversely, the behavior of recent petroleum releases merits less confidence.

Commingled Plumes. Plumes sometimes commingle with other plumes originating from the same or adjacent facilities. In these instances, it can be difficult to differentiate the behavior of one plume from the other. Thus, commingling of plumes reduces confidence in plume behavior. While the presence of commingled plumes does not preclude a thorough understanding of plume behavior, it does require additional information to obtain a greater degree of confidence in the plume behavior.

Groundwater Time of Travel (Exposure Control Area). This line of evidence estimates the time it will take for groundwater to travel from the furthest extent of concentrations exceeding unconditional remediation objectives to the edge of an exposure control area. This line of evidence provides perspective on the size of the plume relative to the exposure control area. Sometimes, the exposure control area will coincide with the property boundary. In other cases, environmental restrictive covenants or environmental restrictive ordinances may extend the exposure control area beyond the property boundary. Groundwater chemistry and chemical interactions with matrix materials complicate estimation of migration rates and may require location-specific data. IDEM will not consider time of travel estimates as representative if they are contradicted by the known plume extent.

Groundwater Time of Travel (Nearest Receptor). This line of evidence estimates the time it will take for groundwater to travel from the furthest extent of concentrations exceeding unconditional remediation objectives to the nearest receptor. This line of evidence provides perspective on the size of the plume relative to the location of receptors. IDEM will not consider time of travel estimates as representative if they are contradicted by the known plume extent. Exercise due diligence in identifying any receptors with a high probability of human exposure. Give special consideration to municipal well fields, wellhead protection areas, public reservoirs, rivers, or other potential receptors near plumes. IDEM recommends contacting public water utilities or other significant local water users to determine if there are any planned changes in well locations, pumping rates, or other activities that could influence groundwater elevation or flow direction.

Hydraulic Conductivity. Hydraulic conductivity affects the ability of chemicals to migrate within the subsurface. Hydraulic conductivity estimates must be location-specific, documented, reproducible, and representative of conditions at a scale relevant to chemical transport. Given the potential for greater mobility, high hydraulic conductivities require more robust demonstrations of plume behavior.

Maximum Concentration. The maximum groundwater chemical concentration is an appropriate measure of the relative magnitude of the problem and the confidence level needed to assess plume behavior. Groundwater plumes with maximum concentrations at or near unconditional remediation objectives require less confidence in plume behavior, while higher concentrations require more confidence.

Persistence. Chemical persistence determines the relative timeframe over which confidence in the plume behavior is needed. Highly persistent chemicals require a greater degree of confidence in plume behavior, while short-lived chemicals require less. Groundwater plumes resulting from petroleum-related releases have been extensively documented and shown to generally migrate and degrade within reasonably predictable parameters. For instance, data indicate that 95% of benzene, toluene, ethylbenzene, and xylene (BTEX) groundwater plumes will terminate within 750 feet of their origin, regardless of the physical properties of the subsurface or the nature of the release (Mace et al., 1997; Newell et al., 1990; Rice et al., 1995; Wiedemeier et al., 1999). Conversely, groundwater plumes of chlorinated solvents and other persistent chemicals can extend for long distances – sometimes more than a mile.

Plume Length. A significant body of research shows that regardless of the size of a petroleum release or hydrogeological conditions, benzene will stabilize to 10 parts per billion (ppb) within 750 feet of the release point (Newell and Connor, 1998). Evaluating the length of a plume of benzene against the statistical distribution of benzene plume lengths provides a reasonable indication of the plume's behavior. Longer plume lengths provide greater confidence that the petroleum related plume is nearing its maximum extent, while short plume lengths warrant additional information on the plume behavior. This line of evidence applies only to petroleum chemicals; it does not apply to petroleum additives or special blends (e.g., E85 or methyl *tert*-butyl ether).

Presence of Non-Aqueous Phase Liquid (NAPL). NAPL may be an ongoing source for dissolved plumes and create new source areas. While the presence of NAPL does not preclude understanding the behavior of a plume, it does complicate that understanding. In such cases, additional lines of evidence may bolster IDEM's confidence in the understanding of plume behavior. IDEM will consider NAPL a potential concern if measurable light NAPL (LNAPL) thickness lies between 0.01 and 0.1 foot, or if one or more dense NAPL (DNAPL)-forming chemicals are present at concentrations approximating one percent of their solubility. IDEM will consider NAPL to be a concern if measurable LNAPL thickness exceeds 0.1 feet, or if one or more DNAPL-forming chemicals are present at concentrations between one and ten percent of their solubility (Kueper and Davies, 2009).

Presence of an Ongoing Source. An ongoing source can prolong the monitoring duration necessary to evaluate plume behavior.

Solubility. Chemical solubility directly relates to mobility, which affects the level of confidence needed in plume behavior. Greater solubility implies a greater need for confidence in plume behavior. IDEM may also consider effective solubilities. See Wiedemeier et al. (1999) and U.S. EPA's Effective Solubility Calculator for more information on evaluating effective solubilities.

Toxicity. Toxicity is important when evaluating the threat that release-related chemicals pose to a receptor. Highly toxic chemicals require more confidence in plume behavior than do less toxic chemicals. For plume evaluation purposes, IDEM usually gives primary importance to human health effects when considering toxicity.

Variation in Groundwater Elevation. High variability in depth to groundwater reduces confidence in understanding plume behavior. Significant chemical mass can often remobilize when groundwater elevations undergo large fluctuations, which introduces uncertainty in understanding plume behavior. This line of evidence applies only to unconfined aquifers, and should be evaluated in the area of the highest dissolved chemical concentrations.

Variation in Groundwater Flow Direction. Groundwater flow is usually the primary driver of plume migration, so understanding groundwater flow direction is fundamental to evaluating plume behavior. A consistent groundwater flow direction lends confidence to the understanding of plume behavior, while highly variable or erratic groundwater flow direction yields less confidence. Highly variable groundwater flow also makes it difficult to determine proper locations for monitoring wells that consistently represent plume conditions. Evaluate this line of evidence based on changes in the calculated groundwater flow direction measured using a minimum of three representative monitoring wells determined to be appropriate by the facility representative and IDEM. While this approach cannot capture all the complexities of groundwater flow, it does provide a consistent measurement.

2.3.6 Present Extents: Vapor

In the context of this guidance, vapor may refer to either soil gas (i.e., gaseous-phase release-related chemicals occurring in the soil matrix), indoor air (i.e., gaseous-phase release-related chemicals in the breathing space of a building), or gaseous-phase release-related chemicals in underground conduits like sewers. Vapor intrusion occurs when volatile[23] chemicals move through the subsurface and enter the breathing space of buildings. Vapors may move through permeable soils, fractures in bedrock or clay tills, anthropogenic subsurface structures such as utility lines, sumps, foundations cracks, volatilize directly from groundwater in contact with structures, or any combination of these pathways, often in unexpected directions.

2.3.6.1 When is a Present Extents Determination Necessary in Vapor?

The vast majority of release-related vapor intrusion exposures arise from two classes of volatile chemicals – certain chlorinated solvents and their breakdown products and, to a lesser extent, petroleum-related chemicals. Because the characteristics of chemicals in these classes differ somewhat from each other, criteria that trigger a vapor intrusion evaluation differ between them. IDEM may require investigation of vapor intrusion potential arising from chemicals in other classes where lines of evidence suggest the need to do so. Vapor investigations should evaluate the vapor pathway for the potential use of a property. This includes both undeveloped properties and properties subject to potential redevelopment.

<u>Chlorinated Volatile Chemicals</u>

Unless compelling lines of evidence show that it is not necessary to do so, IDEM will require limited sampling of subsurface vapor at all facilities that currently or historically used, stored, dispensed, or disposed of chlorinated volatile chemicals. The limited sampling should include:

- A minimum of three soil gas grab samples collected from locations most likely to have exceedances. A limited list of such areas includes: known or suspected release points, the vadose zone above the highest groundwater concentrations, along significant preferential pathways that are not connected to sanitary sewer lines, etc. Where no information is available for suspected release points, soil gas grab samples should be placed in locations that adequately represent the area being evaluated. Soil gas samples should be taken as close as possible to area(s) most likely to have exceedances, at an appropriate depth to evaluate the source, and if the suspected source appears to be near/under a current structure, preferably from directly beneath the structure. It is likely that large facilities or facilities with more than one potential source area will require more than three soil gas grab samples. This should be evaluated by examining both the distance between the areas of interest and subsurface lithology/hydrology.
- One vapor sample collected within a drain, sewer, or open conduit closest to every suspected release point. Preference should be given to any drains, sewers, or other open conduits where chemicals may have been dumped or disposed of. There is a higher potential to form vapor within preferential pathways where impacted groundwater is being released into the sewer or the sewer line intersects NAPL or a vadose zone source (McHugh and Beckley, 2018). These higher risk scenarios should be considered when collecting conduit vapor samples. Large facilities, or facilities with complex sewer/drainage systems or multiple potential release points may require more than one such vapor sample, collected at different times (see Section 2.2.6.4).

[23] For purposes of this guidance, IDEM defines volatiles as those chemicals having a vapor pressure of one millimeter of mercury or greater at standard conditions.

Unless compelling lines of evidence show otherwise, a vapor extents determination should follow any exceedance of a soil gas or conduit vapor screening level. Conduit vapor screening levels currently apply an attenuation factor to the respective indoor air screening level for a particular chemical. Current conduit vapor screening levels are reflected in IDEM's published level table. Attenuation factors may change pending new developments in vapor intrusion research.

Petroleum-related Chemicals

Vapor intrusion by benzene and other petroleum-related chemicals occurs most often when release-related chemicals in groundwater are inside a building or in contact with a building foundation, or NAPL is located near a building foundation. Benzene, the petroleum-related chemical that most often drives risk resulting from petroleum vapor intrusion, readily degrades in unsaturated, oxygenated soils (U.S. EPA, 2012). Soils in Indiana are generally sufficiently aerated if they are unsaturated.

Evaluation of vapor intrusion may be appropriate at structures on properties near operating gasoline stations, or at structures on former gasoline station properties. For such facilities, IDEM will require, unless compelling lines of evidence show that it is not necessary to do so, limited sampling of subsurface vapor at or near facilities that currently or historically used, stored, dispensed, or disposed of petroleum products *if*:

Table 2-D: Petroleum Vapor Investigation Recommendation Matrix

Indicator	**Vapor Investigation Recommended if:**
NAPL	Building has less than 15 feet of vertical or horizontal separation from NAPL
Groundwater (below foundation)	Building has less than five feet of vertical separation from groundwater with benzene that exceeds 1,000 ug/L
Groundwater (contacts foundation)	Groundwater containing volatile organic chemicals is in contact with a building that has cracks in its foundation or basement, or has drains or a sump pump
Soil	Building has less than five feet of vertical or horizontal separation from soil containing volatile petroleum chemicals
Preferential pathway	Utilities transect a petroleum source area with vapor concentrations greater than conduit screening levels
Odors	Building occupants near the petroleum source area complain of chemical odors

Because of high benzene concentrations in ambient air at operating gasoline stations and an Occupational Safety and Health Administration (OSHA) exemption for benzene exposure at most operating gasoline stations, IDEM will not typically request vapor intrusion evaluations of structures at such facilities.

2.3.6.2 How to Determine Present Extents of Soil Gas

Soil gas (including vapors in conduits and other preferential pathways) delineation need only occur in the vadose zone. Otherwise, the same general principles that apply to delineation of present extents in groundwater are mostly applicable to soil gas delineation. Delineation activities typically being at or near the release source and proceed laterally until soil gas concentrations no longer exceed levels that would prompt either a vapor remedy or an investigation of vapor intrusion potential in nearby structures, or future evaluation of vapor intrusion at subsequently constructed structures.

For delineation purposes, the number, location, and depth of soil gas samples should be based on the CSM. Delineate soil gas in three dimensions. Vertical soil gas delineation is achieved by collecting soil gas samples at varying depths in a single location, or by using closely spaced soil gas points installed at varying depths, but need not extend outside the vadose zone. However, soil gas profiles may be affected by infiltration events where the source may be submerged. Base locations and depths for soil gas monitoring points on historical facility use, including known or likely source areas, location-specific lithologic information, and barometric and temperature changes.

If boring logs are not available, collect soil gas samples at the greatest depth of the soil gas investigation (typically near the top of the capillary fringe or soil source). Soil gas samples collected at less than five feet below ground surface may be subject to barometric pressure effects and prone to breakthrough of ambient air through the soil column. Also consider soil moisture and water level variation when determining sample depths.

If vapor is found within preferential pathways during initial assessments, vapor delineation, both up- and down-gradient, should occur within the pathway. While U.S. EPA currently does not produce screening levels for chemicals within preferential pathways for delineation purposes, IDEM will consider the most recent data and research presented to evaluate potential for vapor intrusion into connected structures. Until further notice, use conduit vapor screening levels to delineate the extent of release-related vapors within a conduit.

2.3.7 Likely Future Extents: Vapor

Because vapors can move through the subsurface their extents can change. In doing so, they may affect receptors that were not previously affected or present. For this reason, it is necessary to consider the likely future extents of subsurface vapor, both in soil gas and in preferential pathways.

2.3.7.1 When is a Likely Future Extents Determination Necessary in Subsurface Vapor?

Consider the following when making a likely future extents determination for subsurface vapor:

- Is the source of the subsurface vapor expanding (e.g., when a release-related chemical plume in groundwater is acting as a vapor source and is expanding) and unlikely to have reached its maximum extent?
- Is there a continuing release to a preferential pathway or subsurface conduit?

If the answer to either of the two questions above is yes, a likely future extents determination is necessary.

2.3.7.2 How to Determine Likely Future Extents in Subsurface Vapor

When a release-related chemical plume in groundwater is acting as a source of subsurface vapor, the future extents of subsurface vapor are likely to reflect the future extent of those chemicals in groundwater. In some cases, it may be necessary to iteratively sample subsurface vapors as they move laterally from a source until the likely future extent of those vapors is understood.

Properties with residual release-related chemicals in soil and/or groundwater may pose a threat of vapor exposure if buildings are constructed in the future. The potential for future exposure can be assessed through methods such as SGe sampling or groundwater sampling. It may be appropriate to address the potential for vapor migration at a property without a building by incorporating vapor controls into the new building design, such as a vapor barrier with passive or active venting. In many cases, IDEM's closure conditions will include an Environmental Restrictive Covenant that requires including vapor control measures in the new building design. If the building will be constructed at some point in the distant future, the property owner may conduct further evaluation of the vapor intrusion pathway at that time to determine if building control measures are needed. When suitably constructed, documented, and validated using data that fully characterize the potential subsurface vapor sources and associated conditions in the vadose zone, mathematical models can provide an acceptable line of evidence supporting risk management decisions pertaining to vapor intrusion.

2.3.8 Extents in Other Media

Sometimes releases extend into media other than soil, groundwater, or vapor. In the absence of compelling lines of evidence showing that it is not necessary to do so, IDEM will require delineation efforts to follow releases wherever they go, regardless of medium.

2.3.8.1 Extents in Fill

In the context of this document, fill is material used to modify land topography. Fill comprised of waste deposited onto the land as a means of disposal may be subject to solid or hazardous waste regulations and will require a project-specific approach that is beyond the scope of this guidance.

Fill areas can complicate CSM development. Fill alters local hydrogeologic conditions, and may contain chemicals in common with those from a release. Sometimes it is difficult to distinguish fill from waste fill that is subject to regulation. These challenges make it especially important to have a clear understanding of sampling objectives when sampling fill or in fill areas. Sometimes the objective may be to characterize a release in a fill area. In other cases, the objective may be to characterize the fill itself as a potential source.

With sufficient knowledge of the fill material(s) and their location(s), standard or slightly modified standard methods for sampling surface or subsurface soil may be suitable for collecting fill samples. However, it may be difficult to collect a representative sample of fill material, especially if the material is too heterogeneous, or there is little or no information on the source of the material. U.S. EPA (2019d) contains guidance on developing a sampling plan for fill material. In some cases, adequate characterization of fill material may cost more than removing it.

2.3.8.2 Extents in Sediment

Extents determinations in aquatic sediments typically employ different sampling equipment and techniques than those used in extents determinations in soils. Delineation criteria may also differ, as ecological criteria often apply and may result in lower concentrations than those that apply to human health risk assessment. U.S. EPA (2001) contains technical guidance on sediment sampling.

2.3.8.3 Extents in Surface Water

327 IAC 2-11-5(3) states that "for waters of the state[24], surface water quality standards shall be met in the surface water at the groundwater – surface water interface." Pore water samples are technically most appropriate for this purpose. Note that mixing zones, while applicable to some National Pollution Discharge Elimination System (NPDES) permits, do not apply to unpermitted releases to waters of the state.

2.3.9 How IDEM will Evaluate Extent Determinations

In most cases, IDEM will require the following to evaluate extents determinations:

- An overview map showing all relevant features including, but not necessarily limited to, property lines, facility property use, surrounding property use, and subsurface utilities.
- Source facility, source point(s), and source area(s) identified, as relevant and known.
- Observed concentrations for all affected media, legibly tabulated and supported by laboratory and field sheets.
- Map(s) illustrating the extents relative to unconditional remediation objectives in all directions for all affected media, including applicable cross sections. These map(s) and cross sections must be supported by legible tabulated results, laboratory and field sheets.
- Adequate documentation for unrelated sources, if relevant.

Every release is different, and the number, location, and quality of sample points will vary based on the chemicals released, local geology, and the location and nature of potential receptors. Extents evaluations that do not include the above information, or use conditional remediation objectives will be evaluated on a case-by-case basis. Non-standard extent determinations typically require more time to perform and review and may require more and/or higher data quality.

[24] IC 13-11-2-265 defines waters of the state.

3. Risk Evaluation

For purposes of this document, risk evaluation is the process of determining whether a chemical release warrants a remedy. Risk evaluation is necessary to fulfill statutory obligations under IC 13-25-5-8.5(c) to protect human health and the environment. Every chemical release that requires characterization also requires some level of risk evaluation.

Risk evaluation complexity varies. The risk evaluation process may be fairly simple, involving a few numerical comparisons, or it may include complex tasks like statistical evaluation of large sample data sets, target cancer risk adjustments, development of site-specific remediation objectives, or evaluating the relevance and sufficiency of different lines of evidence in a remedy decision.

Section 3 describes four broadly defined tasks that comprise a risk evaluation:

- Task Four: Specify decision units and their likely uses (Section 3.1)
- Task Five: Determine representative concentrations (Section 3.2)
- Task Six: Specify remediation objectives (Section 3.3)
- Task Seven: Determine whether a remedy is necessary (Section 3.4)

There is some flexibility with respect to the order in which tasks need to be performed. For example, a responsible party that decides to specify remediation objectives allowing unlimited use of a property might do so at the onset of a project, well before performing any risk evaluation tasks. Projects should proceed in a reasonably systematic way that makes sense given the circumstances of the release, and at a pace that results in timely implementation of remedies that address any unacceptable risks arising from the release. Note, however, that per IC 13-25-5-8.5(c)(1), a *complete* evaluation of risk relies on and requires adequate characterization of the nature and extent of release-related chemicals.

Each task subsection includes the statutory basis of IDEM's authority to require the task and related information, as well as the corresponding scientific reasons why the task is necessary. The task subsections also describe one or more ways to perform the tasks. *IDEM recognizes that alternative approaches to performing these tasks may exist, and that those alternatives may be acceptable or preferable for any number of reasons*. IDEM will evaluate alternative approaches on their merits.

It is sometimes immediately apparent that a chemical release poses an unacceptable risk, and that it is necessary to implement a remedy as soon as possible. In other cases, responsible parties may opt to implement an interim remedy (e.g., removal or treatment of known source material) before completing characterization, provided the interim remedy does not result in unacceptable risk. In many instances, implementation of an interim remedy may significantly reduce overall remedy cost and timeframes. Section 4 includes discussion of interim remedies and other remedy options.

3.1 Task Four: Specify Decision Unit(s) and Their Use(s)

A **decision unit** is a geographic location in which humans[25] may be exposed to release-related chemicals, that requires a decision about whether or not to implement a remedy for that potential exposure at that location. A decision unit might be a residential yard, a playground, an occupied structure, or any other place where exposure to release-related chemicals may occur. Every risk evaluation will involve at least one decision unit.

Some releases may lie wholly within a single decision unit. For example, a release may extend over a relatively small portion of a larger industrial facility, where future uses of the release area are expected to be similar over time. In such situations, and assuming the release is unlikely to expand into other, dissimilar areas, it is acceptable to define a single decision unit for purposes of evaluating risks arising from the release.

However, risk evaluation for some releases will require defining and evaluating multiple decision units. For example, a soil gas plume might extend under several structures. As each structure has different physical characteristics and a unique location with respect to the soil gas plume, each would likely require definition as a separate decision unit for risk evaluation purposes. Evaluation of risk at a single decision unit that is used by more than one population (e.g., adults *and* children) should consider risks to both populations.

Every location that overlaps with the present or reasonably likely future extent of release-related chemicals must be in at least one decision unit. Risks should be evaluated for both current and reasonably likely uses of the locations within decision units. IDEM acknowledges that predicting future extents and uses is often difficult, that some degree of uncertainty is inevitable and acceptable, and that *it is not reasonable to base future use projections on any conceivably possible use*. IDEM will apply available knowledge about the release and its setting when evaluating whether the projected future use is *reasonably* likely, and whether the proposed remediation objectives are *reasonably* likely to be protective. Any determination of reasonably likely future use is necessarily a judgment call. However, in the absence of an IDEM-enforceable environmental restrictive covenant that restricts the area(s) affected by a release to specific uses[26], IDEM will typically assume that future residential use is reasonably likely at most decision units. This is because land use changes are common (including, for example, conversion of former industrial facilities to residential use).

A proposed change in use of a decision unit will require IDEM to evaluate additional information to support an evaluation of risk with regard to the proposed change in use. The parties involved in any such transaction involving a change of use are responsible for coordinating with each other, collecting and evaluating the additional information, and presenting it to IDEM. *Examples* of appropriate questions to ask in such circumstances include (but are not limited to):

- Will existing buildings by demolished or renovated?
- If an existing building will be renovated, is it possible to determine in advance whether any proposed remedies are likely to be effective, or must that determination wait until the renovations are complete?
- Will building spaces (e.g., a basement) be used for storage, or to house sensitive populations?
- Will the grounds be used as a playground, or for gardening, or as public outdoor space?

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[25] Or, in circumstances described in Appendix D, ecological receptors.

[26] Or, in the case of groundwater, an environmental restrictive ordinance (Appendix F) may also be applicable.

These unknowns may have to be resolved by managing the exposure risk and restricting use of the decision unit until a transaction is complete and the person who intends to change the use of that decision unit collects the additional information and presents adequate evidence to IDEM regarding exposure risk before modifying the existing use restrictions. All parties must work together and coordinate plans to address both development and environmental concerns so that the goals of both can be effectively and expediently addressed.

3.1.1 Basis for Requirement

Specification of decision units is necessary to fulfill statutory obligations under IC 13-25-5-8.5(b)(2). Specifying decision units defines geographical boundaries for risk evaluation activities. Defining current and likely future use of decision units is necessary when selecting remediation objectives that are adequately protective for those uses under IC 13-25-5-8.5(b)(2)(A). Unless the boundaries of the decision units are specified, it is not possible to know whether they meet the requirements for characterization described in Section 2, or whether a remedy is necessary under IC 13-25-5-8.5(c). Every location that overlaps with the present or reasonably likely future extents of release-related chemicals must be in at least one decision unit.

3.1.2 How to Specify Decision Units

Specification of decision units involves describing the boundaries of locations (areas or volumes) where a remedy decision needs to be made, listing those locations, and depicting them on a map. Every location that overlaps the present and likely future extents of release-related chemicals must be in at least one decision unit. Decision units can overlap each other. For example, an entire property may coincide with a decision unit for groundwater, at the same time that an occupied structure on that same property may comprise its own decision unit for purposes of evaluating vapor risk. Note that while co-mingled plumes or multiple releases may complicate characterization or responsible party identification, risk evaluation should focus on release-related chemicals in the decision unit, regardless of source. Unacceptable risks must be controlled, even those arising from more than one source. IDEM will require parties associated with co-mingled plumes to prioritize and control unacceptable risks to human health and the environment before litigating financial responsibility related to the multiple releases. Assignment of financial responsibility for controlling risk is a separate question from determining the need for such control.

Appropriate boundaries for decision units will usually coincide with one or more of:

<u>Boundaries of locations with specific types of exposures or reasonably likely exposures</u>

Examples include boundaries of residences, areas in commercial use, agricultural land, playgrounds, sports fields, areas underlain by a release-related chemical plume in groundwater, wellhead protection areas, and any other boundary that divides different kinds of exposures or exposed populations. Exposures may vary for many different reasons. For example, differences in exposed populations, their activities, and their developmental stages mean that risks from soil direct contact exposure are likely to differ significantly between a children’s playground and an office building occupied by adults. For this reason, if a large property or area is divided into many different uses or subject to different types of exposures, each area subject to a different use or exposure should be designated as a separate decision unit.

<u>Property boundaries</u>

While property boundaries in themselves do not affect risk, they often have significant implications for acceptable remediation objectives and remedy options. For example, an adjacent property owner affected by a release may not be amenable to a land use restriction, even if that restriction adequately controls risk. For this and similar reasons, it is usually necessary to take property boundaries into account when defining decision units.

Building dividers

This is especially important when specifying decision units for evaluation of indoor air. Strip malls and apartment complexes are examples of subdivided structures where indoor air exposures may differ significantly across different parts of the same structure. Reasons for such differences might include proximity to release-related chemicals, indoor chemical use, differences in building construction, including ventilation systems and other design characteristics, and differences in the way that the structures have aged or been modified.

Although IDEM anticipates that the three preceding criteria will serve to delineate most decision units, it is possible that other types of boundaries may be appropriate for some projects. IDEM will evaluate alternative approaches on their merits. The examples that follow illustrate the concept of decision units and the roles of chemical migration and likely future use on the risk evaluation process. There are many possible scenarios, and IDEM recognizes that project-specific circumstances are an integral part of determining an appropriate course of action.

Example: *A release confined to a commercial property with a residential use restriction.*

This scenario is perhaps the simplest, requiring only evaluation of risk at a single property under one use.

Example: *A release confined to a single parcel that is divided into multiple tenant spaces, as in a strip mall that contains many different businesses that are subject to potential vapor intrusion.*

Each tenant is likely to have separate exposed populations, unique ventilation characteristics, differing proximity to the release-related chemicals, and may even employ chemicals specific to their business operations. A dry cleaner may be subject to Occupational Safety and Health Administration (OSHA) standards for chemicals they use, while an adjacent daycare warrants evaluation against remediation objectives appropriate for child exposure. For these reasons, each unit of the strip mall should be treated as a separate decision unit.

Example: *A release confined to a single commercial property, where use and related exposure is highly concentrated in one part of the property.*

An example of this would be an outdoor storage area where the most commonly accessed items are located near a building or a loading area. Other portions of the facility may see substantially less use, and consequently less exposure risk. If the difference in use levels and consequent exposure is great enough, these areas may warrant separate risk evaluation. Keep in mind, however, that any remedy that relies on differential land uses or exposure levels will require memorialization in an environmental restrictive covenant that enforces those differential uses.

Example: *A release that extends into a mixed-use neighborhood, potentially impacting multiple properties*.

This scenario most often occurs when release-related chemicals in groundwater and/or soil vapor extend beneath several properties. Each property warrants separate evaluation of risk when its physical characteristics and uses differ from those of other properties under evaluation (e.g., presence or absence of drinking water wells, residential versus commercial use, preferential vapor transport pathways, proximity to plumes, etc.). In general, IDEM will assume that no two structures are identical in all respects pertinent to potential vapor intrusion. This means that where vapor intrusion is a potential concern, each occupied structure should be evaluated as a separate decision unit.

Example: *A release that appears to be expanding over time, affecting previously unaffected properties*.

This complex scenario requires an evaluation of plume behavior (Section 2.3.5), prediction of locations reasonably likely to be affected in the future, the likely magnitude of those impacts, and/or ongoing monitoring of those locations. As in the previous example, and for similar reasons, each impacted or potentially impacted property and/or occupied structure requires separate evaluation of present and potential risk, and each should be treated as a separate decision unit. Depending on circumstances (e.g., for individual parcels already within a larger groundwater plume), it may be acceptable to conclude that a decision unit requires a remedy, even in the absence of sampling at that specific decision unit.

3.1.3 How IDEM Will Evaluate Decision Unit and Future Use Specifications

IDEM will use the following list of criteria to evaluate the specification of decision units and their current and likely future uses.

- Is every location within the present and reasonably likely future extents of release-related chemicals within at least one decision unit?
- Are decision units depicted on a map or figure, and listed?
- Is the present and reasonably likely future use of each decision unit specified?
- Where environmental restrictive covenants or environmental restrictive ordinances are either in place or planned for specific decision units, is that information included in the listing or description of those decision units?
- If an environmental restrictive covenant or environmental restrictive ordinance is not already in place, is it anticipated? What steps have been taken and are planned to obtain institutional controls on each decision unit?
- Are the decision unit boundaries reasonable, given likely exposures, property boundaries, building divisions (where applicable), or any other relevant delineation criteria?

3.2 Task Five: Determine Representative Concentration(s)

A **representative concentration** is an estimate of the concentration of a release-related chemical in a particular medium within a decision unit. Sampling errors, laboratory errors, and the typically heterogeneous nature of release-related chemical distribution in environmental media all contribute to uncertainty when determining representative concentrations. For these reasons, IDEM has determined that conservative approaches are appropriate when determining representative concentrations.

Sometimes it is necessary to resample an area and derive new representative concentrations. For example, resampling is necessary if a responsible party wishes to demonstrate that removal, natural processes, or treatment activities have reduced concentrations of release-related chemicals. As in all phases of environmental projects, obtaining meaningful data requires that data collection activities be consistent with achievement of appropriate DQOs. See Section 2.2 for guidance on DQOs.

3.2.1 Basis for Requirement

Representative concentrations are required to perform either the comparison described in IC 13-25-5-8.5(c)(2), or as part of a formal risk assessment consistent with IC 13-25-5-8.5(b)(2).

Absent controls that eliminate exposure, there is a direct relationship between the concentrations of released chemicals in a given decision unit and the dose received by persons or organisms in that decision unit. Dose received is in turn related to the probability or intensity of adverse health effects, if any. For this reason, knowledge of the concentrations of release-related chemicals in media within decision units is a critical component of the risk evaluation process.

3.2.2 How to Determine Representative Concentrations

Sampling and analysis of environmental media are typically used to determine concentrations of release-related chemicals in those media[27]. Acceptable approaches may differ significantly across media or by chemical. The remainder of Section 3.2 describes different methods that IDEM considers acceptable for determining representative concentrations. It is not a comprehensive treatment, and *IDEM recognizes that other approaches may be acceptable or even preferable, depending on project-specific circumstances*. IDEM will evaluate representative concentration determinations on their merits.

3.2.2.1 How to Determine Representative Concentrations in Soil

There are several possible approaches to deriving representative concentrations for release-related chemicals in soils. Preferred approaches will likely vary with present and reasonably likely future land use, likelihood of excavation, and the physical characteristics of the chemicals under investigation. Knowing where to collect samples based on likely exposure is important when determining representative concentrations in soil.

For example, the greatest risk from recreational exposure at a city park is often from routine exposure to release-related chemicals in the top few centimeters of soil. Gardening or landscaping activities may result in soil direct contact risk from soils to a depth of two feet or more. Deeper soils, once excavated and left on the surface, may pose a future direct contact risk. Similarly, where excavation or utility work is reasonably likely to expose workers to soils below the ground surface, the chemicals in those soils warrant evaluation for direct contact risk. The most relevant samples for evaluating risk are those from locations and depths where exposure is most likely to occur, now and/or in the future.

[27] Modeling (when predicting future concentrations), interpolation (for decision units inside plumes), and extrapolation (decision units outside plumes) may be preferable or necessary in some circumstances.

The distribution of release-related chemicals is important when evaluating potential soil direct contact risk. For example, an isolated “hot spot” of release-related chemicals in subsurface soil is less likely to be excavated and become surface soil than is a larger area of subsurface soil that also contains release-related chemicals. Vertical distribution is also important. Shallower soils are more likely to be excavated than deeper soils. IDEM considers it generally unlikely that soils deeper than 15 feet below ground surface will be brought to the surface in the future, and in *most* cases it is not necessary to evaluate soils deeper than 15 feet for soil direct contact risk. However, if there is reason to believe that excavation work will occur at depths greater than 15 feet below ground surface and release-related chemicals are reasonably likely to extend more than 15 feet below the ground surface, then soils deeper than 15 feet below the ground surface should be sampled and evaluated for risks associated with those chemicals. Data on the concentrations of release-related chemicals under physical barriers are necessary to determine whether the barrier needs to remain in place to control future soil direct contact risk.[28]

Treat Each Sample Result as a Representative Concentration

The simplest and most common approach is to treat each observed concentration as a representative concentration. This approach can, and often does, use data already collected during characterization activities, and for that reason may offer significant cost savings. It may also reduce the number of samples necessary outside the area of known impacts, if the source and extents of the release are well understood and there is good reason to believe that there have been no additional releases.[29]

Where screening instruments or other indicators of chemical presence are used to preferentially choose sampling locations with the highest indications within a given decision unit, observed concentrations are likely to be on the high end of the concentration distribution for that area. This means that the representative concentrations obtained in this manner are likely to overestimate actual exposures, and that those representative concentrations are likely to be conservative, sometimes very much so.

When compositing, analyze an aliquot of the composite and treat the result as a representative concentration of the area covered by the individual sample locations that comprise the composite. Compositing may be advantageous when analytical costs are high and there is no need for information on concentration variability or extreme observations. Compositing is *not* appropriate when the compositing process itself is likely to result in significant attenuation of the chemicals of interest. This is a particular concern for volatile chemicals.

Calculate an Upper Confidence Limit of the Mean (UCL) and use it as a Representative Concentration

This is a good approach when evaluating risk over an entire decision unit without giving undue weight to the highest observed concentrations. It is appropriate for randomly or systematically placed sample arrays, and occasionally for judgmentally placed sample arrays that sufficiently cover a decision unit. Random sampling involves placing sampling locations on a defined grid using a random number generator, so that each location in a decision unit has an equal chance of being sampled. Systematic sampling uses a random number generator to guide placement of the initial sample, and then arrays additional sample locations across the decision unit at predetermined distance intervals or in a fixed pattern.

[28] A related purpose for such sampling, though it does not determine a representative concentration, is to decide whether the barrier should remain in place to prevent or impede leaching of release-related chemicals to groundwater.

[29] Note that some IDEM programs may require sampling of all areas covered under a closure document.

Sampling subsurface soils under this approach is a two-step process. First, use a procedure from the preceding paragraph to establish boring locations. Then collect at least one sample from each boring at the depth(s) with the highest screening instrument response and/or other indicator of the presence of release-related chemicals.

IDEM will not accept systematic or random sample arrays that fail to include sample locations within a reasonably representative selection of areas affected by the release, including areas close to the source. Representative concentrations derived from systematic or random sample arrays that do not include sample results from a representative selection of areas affected by the release ignore important information and are likely to result in inadequate representative concentrations.

For systematically collected samples, the representative concentration is an appropriate upper confidence limit of the mean (UCL), one for each release-related chemical, using results from a sample array that represents the decision unit under evaluation. There are many kinds of UCLs, and the appropriate UCL depends on several factors, particularly the distribution of the data. Further discussion of the mechanics of UCL calculation and selection are beyond the scope of this document.[30] Instead, IDEM recommends using a software application that can perform the necessary calculations and recommend an appropriate UCL. For example, ProUCL is an application suitable for this purpose, and is available for free download.[31] Whatever the approach or software used, IDEM review of UCL calculations will require submission of algorithm inputs and outputs.

Where judgmentally collected soil samples are of sufficient spatial density and distribution to adequately cover the area under evaluation, it may be appropriate to use the data to calculate a UCL for use as a representative concentration. The acceptability of this approach is necessarily a judgment call, and will depend on whether the spacing and distribution of sample results provides sufficient confidence that the data adequately represent potential exposure to release-related chemicals across the decision unit.

<u>Calculate an Arithmetic Average and use it as a Representative Concentration</u>

This approach is appropriate for lead. Because the models[32] that U.S. EPA and IDEM use to derive published levels for lead use central tendency parameters, U.S. EPA (2003, 2007) suggests basing representative concentrations for evaluation of soil direct contact risk from lead on the arithmetic mean (unweighted average) of lead samples. For this reason, appropriate lead representative concentrations are arithmetic averages of results from each decision unit. While U.S. EPA guidance (U.S. EPA, 2003b) focuses on residential yards, the arithmetic mean is also appropriate for larger areas, including those used for nonresidential purposes, provided the sample design reasonably represents exposure across those areas. Sample depths should reflect exposures associated with the reasonably likely land use. Section 4.3.2 of U.S. EPA (2003b) discusses appropriate lead sampling depths, and Section 4.2 of the same document provides detailed guidance on appropriate lead sampling design.

<u>Future Concentrations of Release-related Chemicals in Soil</u>

Release-related chemicals in soils are potentially subject to a number of influences (e.g., volatilization, leaching, microbial degradation, etc.) that may affect their concentrations over time. For example, volatile chemicals are unlikely to persist in the top two centimeters of the soil profile for a significant fraction of the

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[30] Singh and Maichle (2015) contains details on the ProUCL software and the statistical procedures it employs.

[31] ProUCL is available for free download at https://www.epa.gov/land-research/proucl-software.

[32] The Integrated Exposure Uptake Biokinetic (IEUBK) Model for residential child exposure and the Adult Lead Methodology (ALM) for commercial and industrial exposures.

years of exposure assumed when calculating published levels for residential soil direct contact. Other chemicals are relatively nonvolatile and insoluble and may remain available for soil direct contact for centuries or more. Effects on the concentrations of other chemicals are more difficult to predict, and may vary according to many factors (chemical characteristics, including volatility; the soil matrix; environmental conditions, etc.) For this reason, *IDEM will assume, unless presented with sufficient lines of evidence to the contrary, that release-related chemicals in soil are likely to remain indefinitely at concentrations similar to those observed during the last round of sample collection*.

3.2.2.2 How to Determine Representative Concentrations in Groundwater

IDEM recommends either of two basic approaches, both described below, when determining groundwater representative concentrations. However, IDEM will consider other approaches on their merits. As with soil, it is sometimes necessary to resample groundwater and derive new representative concentrations prior to making or re-evaluating a remedy decision. For example, resampling from adequately installed monitoring wells is appropriate following active remediation of release-related chemicals, or when other forces have attenuated concentrations of those chemicals in groundwater. Sampling after active remediation should continue for as long as necessary to determine whether or not release-related chemical concentrations in groundwater rebound. The length of that monitoring period will necessarily depend on project-specific conditions and the adequacy of the CSM. Four quarters is typical (eight when calculating a UCL), with some releases requiring more extended monitoring.

Some releases may affect groundwater in more than one aquifer. Where this is the case, remedy decisions for a decision unit must be based on the worst-case aquifer. Because release-related chemicals dissolved in groundwater can move from unusable water-bearing units into aquifers, remedy decisions for groundwater must consider the possibility of future unacceptable risk to aquifers from such movement.

<u>Treat Each Sample Result as a Representative Concentration</u>

The first approach defines each groundwater analytical result for each release-related chemical as a representative concentration. This is the simplest and most common approach. It can and often does use data collected during characterization activities. Although the potential number of representative concentrations under this approach can be quite large (as large as the arithmetic product of the number of release-related chemicals, the number of monitoring points, and the number of sampling events) it is common and acceptable to focus on those release-related chemicals most likely to trigger the need for a remedy.

Where groundwater concentrations of release-related chemicals vary significantly (e.g., due to drought, seasonal groundwater elevation changes, irrigation, or other withdrawal, etc.), use the highest observed concentrations within the decision unit as the representative concentration or calculate an appropriate UCL (see below). However, because release-related chemical concentrations in groundwater tend to change over time, it is generally preferable, unless project-specific circumstances suggest otherwise, to base remedy decisions on relatively recent data. Unless there is reason to believe that a recurrence of release-related chemical concentrations in groundwater is reasonably likely, IDEM will not typically require a remedy based on superseded groundwater sampling results.

<u>Calculate an Upper Confidence Limit of the Mean (UCL)</u>

The second approach calculates an appropriate UCL for each release-related chemical in each monitoring well, and defines those UCLs as representative concentrations. UCL calculation requires at least eight quarters of groundwater data, collected *after* an equilibration period following any active remediation. For wells with many quarters of data, UCLs calculated using only the last eight quarters usually provide a better indicator of current conditions than UCLs calculated using the entire data set.

UCLs based on strongly trending groundwater concentrations may be elevated due to large variation in observed concentrations. Strongly trending concentration data typically indicate either an improving or worsening situation, and trend analysis will often weigh heavily when making remedy decisions. Appendix C provides additional guidance on those decisions.[33]

There are many kinds of UCLs, and the appropriate UCL depends on several factors, particularly the distribution of the data. Further discussion of the mechanics of UCL calculation and selection are beyond the scope of this document. Instead, IDEM recommends using a software application that can perform the necessary calculations and recommend an appropriate UCL. For example, ProUCL is an application suitable for this purpose, and is available for free download.[34] Whatever the approach or software used, IDEM review of UCL calculations will require submission of algorithm inputs and outputs.

Future Concentrations of Release-related Chemicals in Groundwater

Because groundwater flows, it can sometimes transport release-related chemicals over long distances. For this reason, it is important to consider the likely future extents of release-related chemical concentrations in groundwater that exceed residential remediation objectives, and therefore define areas requiring a groundwater remedy. Section 2.3.5 provides guidance on estimating likely future extents of release-related chemicals in groundwater. If establishing the likely future extents of release-related chemicals in groundwater is not possible, then other actions may be necessary, such as active remediation of the plume or long-term monitoring.

3.2.2.3 How to Determine Representative Concentrations in Vapor

One or more of several vapor sampling approaches may be relevant when predicting whether indoor air exposure is likely to occur, and results from those sampling efforts may drive a remedy decision that is independent of current indoor air results. For example, while indoor air concentrations most often drive remedy decisions, crawl space air, subslab vapor, or soil gas results may also indicate significant potential for future vapor intrusion and the need for a remedy, regardless of indoor air results. However, *actual exposure* to vapors arising from releases to the land usually occurs via the air within structures (indoor air). Indoor air samples intended to measure actual exposure should be collected in breathing zones in the most frequently occupied interior area(s) of structures.

An exceedance of a published level in indoor air does not necessarily mean that the exceedance is the result of vapor intrusion from the subsurface. Indoor sources of release-related chemicals are surprisingly common, and that is the basis of this document's emphasis on paired sampling and, where applicable, surveys of building contents to identify stored or frequently used products that contain the same chemicals as those associated with the release. Experience has shown that batch-certified canisters may produce false positive results. For this reason, canisters used for indoor air sampling should be individually certified.

Vapor concentrations, particularly in structures, are highly variable, and may exhibit marked changes based on season, time of day, ventilation system operation, or any number of other factors, some of which are poorly understood. For this reason, IDEM recommends a conservative approach to determining vapor representative concentrations. Unless potentially acute exposures are likely and immediate

[33] Singh and Maichle (2015) contains details on the ProUCL software and the statistical procedures it employs.

[34] ProUCL is available for free download at https://www.epa.gov/land-research/proucl-software.

sampling is necessary, or some other compelling reason prevents doing so, indoor air sampling should occur during “worst case” conditions as defined in Section 2.2.6. Further, the inherent variability of vapor sampling results means that, unless sample results exceed indoor air action levels, IDEM is reluctant to make remedy decisions on the basis of a single round of sampling. A single sample result above or below a published level usually does not constitute enough evidence to establish or rule out unacceptable vapor risk.

Treat Each Sample Result as a Representative Concentration

This is by far the most common approach. Note that because of the inherent uncertainty associated with vapor sampling, pooling indoor air data and calculating arithmetic averages or UCLs from samples collected at multiple sampling locations within a structure during a single monitoring event is not acceptable.

Calculate an Upper Confidence Limit of the Mean (UCL)

IDEM will consider indoor air UCLs calculated using at least eight sample results collected over eight worst-case sampling rounds from the same location within a structure. However, proposals to do this are very rare, perhaps because the expense of collecting so many indoor air samples is almost always greater than the expense associated with indoor air mitigation, or because the inherent variability in air sample concentrations is likely to result in very high UCLs.

Future Concentrations of Release-Related Chemicals in Vapor

Like groundwater, vapors flow, sometimes over long distances. This is particularly true when preferential pathways exist. The nature of the vapor source can also affect the future extents of soil vapors. For example, vapors arising from release-related chemicals in soils underneath a building foundation *may* eventually assume a relatively steady-state distribution. However, the distribution of vapors arising from a migrating chlorinated solvent plume in groundwater may change as that solvent plume flows. If release-related chemicals in groundwater are a source of vapors that result in indoor air risk, then predicting the likely future extent of potential vapor exposure will depend in part on understanding the behavior of the groundwater. If establishing the likely future extents of release-related chemicals in vapor is not possible, then other actions may be necessary, such as active remediation of the vapor source, or long-term monitoring.

3.2.2.4 How to Determine Representative Concentrations in Other Media

It is occasionally necessary to sample other media affected or potentially affected by a release to the land. Sediments and surface water are probably the most common examples. Representative concentration calculation procedures suitable for soil are, in general, applicable to sediments. For example, it is acceptable to treat each sediment sample result as a representative concentration, to calculate a UCL from a systematic array of sediment sample results, or to calculate an arithmetic average for lead results.

327 IAC 2-11-5(3) states that “for waters of the state[35], surface water quality standards shall be met in the surface water at the groundwater – surface water interface.” Pore water samples are technically most appropriate for this purpose. IDEM will evaluate proposals to use UCLs as representative concentrations when those UCLs are calculated based on systematic arrays of pore water samples, but in the vast majority of cases, IDEM expects that each pore water sample result will be treated as a representative

[35] IC 13-11-2-265 defines waters of the state.

concentration. Note that mixing zones, while applicable to some National Pollution Discharge Elimination System (NPDES) permits, do not apply to unpermitted releases to waters of the state.

3.2.3 How IDEM Will Evaluate Representative Concentration Determinations

IDEM evaluation of the adequacy of representative concentration determinations will include, but may not be limited to, the following factors, where relevant:

General Considerations

- Were representative concentrations determined for each release-related chemical in all affected media in each decision unit?
- Were sample locations and sample density representative for each decision unit?
- Did the sample array include locations in the area(s) where concentrations of release-related chemicals are likely to be highest?
- Do the sample data reflect current conditions?
- Did enough time separate active remediation activities and post-remediation sampling to allow sufficient subsurface re-equilibration?
- Are UCL calculations based on at least eight spatially and/or temporally independent sample results?
- Were copies of software inputs and outputs provided along with UCL results?

Soils

- Were samples collected at depths most relevant for likely exposure(s)?
- Were samples collected from beneath barriers that are expected to control future soil direct contact risk, or to prevent groundwater impacts via leaching?
- Were lead results averaged?

Groundwater

- Were representative concentrations determined for release-related chemicals in each affected aquifer?
- Is there reason to believe that current concentrations of release-related chemicals in groundwater are only temporarily attenuated?
- Are groundwater data trending?

Vapor

- Were indoor air samples collected during worst-case conditions?
- Were indoor air samples collected from breathing zones?
- Were indoor air samples accompanied by paired samples collected from outside the occupied part of the structure?
- Were at least two rounds of paired sampling conducted?
- Were preferential pathways evaluated as exposure route(s) for structures that were not sampled or otherwise screened out?

Other Media

- Were representative concentrations for sediments determined analogously to those for soils?

- Were representative concentrations for surface water based on pore water samples?

3.3 Task Six: Specify Remediation Objectives

Per IC 13-25-5-8.5(b), a **remediation objective** is either (1) a concentration of a substance equal to the naturally occurring concentration of that substance on the site (see Section 3.3.2), or (2) an environmental concentration of a substance that is, given the conditions, uses, and restrictions prevailing on the site, protective of human health and the environment. IC 13-25-5-8.5(d) further divides the latter category into three further types, discussed in Sections 3.3.3, 3.3.4, and 3.3.5. IDEM has determined that another type of remediation objective (see Section 3.3.6), is also acceptable due to its mathematical equivalence to those described in IC 13-25-5-8.5(d).

Per IC 13-25-5-8.5(b)(2), the activities taking place on the site and the expected future use of the site are essential factors to consider when choosing appropriate remediation objectives. For example, uses that include frequent and long-term occupancy by children (e.g., residences and schools) are likely to result in different exposures and levels of risks than those when exposures are relatively short-term (e.g., along a portion of a paved rail trail) or restricted to adults (e.g., in an office or factory). IDEM refers to remediation objectives that permit unrestricted use of a decision unit as **unconditional remediation objectives**.

3.3.1 Basis for Requirement

IC 13-25-5-8.5(a) directs responsible parties to specify remediation objectives as part of a remediation work plan. Concentration-based remediation objectives provide standards against which to directly compare representative concentrations. As discussed in Section 3.3.6, remediation objectives stated in terms of the cancer risk range (for carcinogens) or hazard quotients (for non-carcinogens) are also acceptable.

3.3.2 Using Background Concentrations as Remediation Objectives

IC 13-25-5-8.5 defines “background levels of hazardous substances and petroleum that occur naturally on the site” as acceptable remediation objectives. IDEM and U.S. EPA (2002e) define **naturally occurring background** as substances present in the environment in forms that have not been influenced by human activity (e.g., arsenic in New Albany shale). IDEM does not anticipate requiring a responsible party to implement a remedy to address naturally occurring concentrations of chemicals, even if those concentrations exceed IDEM’s published levels.

Responsible parties that choose naturally occurring background concentrations as remediation objectives take steps to reduce concentrations of released chemicals to levels at least as low as those that existed at the decision unit prior to any release of the same chemicals. Note that naturally occurring background concentrations *may* be substantially lower than concentrations that are protective of human health and the environment, and that achieving them may prove unnecessarily difficult and/or stringent.

IDEM anticipates that only a relatively small percentage of projects will require or benefit significantly from background demonstrations. For those that do, Appendix B provides detailed example procedures for conducting background demonstrations.

Sometimes release-related chemicals at a decision units are from an **off-site source**. An off-site source is an identifiable, localized source outside the facility of interest that contributed release-related chemicals to the facility property (e.g., chlorinated solvents from a dry cleaner impacting a neighboring business that has no history of using those solvents). The presence of an off-site source cannot simply be asserted. It must be demonstrated. An adequate off-site source demonstration will identify the chemicals attributed to an off-site source, along with their concentrations (including any significant spatial or temporal variation) and the particular locations where those chemicals are coming onto the subject property. Suitable lines of evidence might include groundwater concentration gradients, surface and/or groundwater flow direction, suspected source operating history, surface or subsurface soil sample results, prevailing wind direction, etc. Each off-site source demonstration is inherently project-specific and IDEM will evaluate each demonstration on its merits. A successful off-site source demonstration shifts responsibility for the identified release to the party responsible for that release in many, but not all situations. The most common exception is when the party presenting the off-site source demonstration is attempting to maintain an exemption from liability and must prevent exposure, regardless of the source.

3.3.3 Using IDEM's Published Levels as Remediation Objectives

IC 13-25-5-8.5(d)(1) – Levels of hazardous substances and petroleum calculated by the department using standard equations and default values for particular hazardous substances or petroleum.

Risk-based remediation objectives recognize that there is a relationship between the concentration of a chemical in a particular medium to which a population is exposed and the likelihood that members of that population will suffer adverse effects. The risk-based approach to development of remediation objectives uses equations that mathematically relate toxicity data, exposure assumptions, and chemical concentrations to the risk of adverse effects, structured so that the result is a set of environmental concentrations considered acceptable *subject to the underlying assumptions*. As the underlying assumptions change, the calculated acceptable environmental concentrations also change.

Many regulatory agencies use this approach to generate tables of acceptable concentrations for chemicals in various media under specific exposure scenarios. IDEM calculates such concentrations and calls them **published levels**. In doing so, IDEM relies on data from U.S. EPA's Regional Screening Levels (RSL) Tables[36] (U.S. EPA, 2019e; updated periodically) and guidance from the accompanying Regional Screening Levels User's Guide[37] (U.S. EPA, 2019f; updated periodically). Appendix A describes the specific methods that IDEM uses to derive its published levels. Links to IDEM's published level tables appear on the IDEM Screening and Closure Level Tables[38] web page.

Many responsible parties choose to use IDEM's published levels as remediation objectives. This is entirely appropriate as long as the likely exposures in a decision unit reasonably match the assumptions embodied in the published levels. While responsible parties may find it convenient to use IDEM's published levels as remediation objectives, doing so is not required. As noted earlier, other options exist and are described in Subsections 3.3.4 through 3.3.6. Depending on circumstances, there may be significant advantages to pursuing other options.

The remaining portions of Subsection 3.3.3 describe the different types of levels published by IDEM, some of the assumptions they incorporate, scenarios where their use is appropriate, and how to use them.

3.3.3.1 Using IDEM's Published Levels for Soil Direct Contact

Because most routine soil direct contact exposure to chemicals occurs in the top few centimeters of the soil profile, it is important to evaluate soil direct contact risk for both soils currently exposed at or near the ground surface, and also for those soils that are reasonably likely to be exposed in the future. However,

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[36] http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[37] http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[38] From 2012 to 2019, IDEM referred to its published levels as *screening levels*, and from 2001 to 2010 as *closure levels*. Levels included in the 1994 VRP Guidance were called *Tier II* levels. The term *published level* is more general than either *screening level* or *closure level*, and reflects the fact that many of IDEM's published levels may have more than one appropriate use, depending on circumstances.

soil exposures and appropriate sample depths are highly dependent on present and likely future land use and conditions. For example, bare soil typically constitutes a greater soil direct contact exposure risk than vegetated soil. Conversely, soils under barriers may not be available for soil direct contact exposure for as long as the barrier remains in place.

Exposure may also occur to soils at depth. For example, gardening may result in routine exposure to soils at depths of six inches or more. Further, because many soils are potentially subject to excavation, it is often important to consider soil direct contact exposure risk either to workers in contact with soils that line excavations, or to persons in contact with previously excavated soil that currently resides at or near the ground surface. IDEM considers shallower soils more likely to undergo excavation than deeper soils, and that it is unlikely that soils deeper than 15 feet below ground surface will be exposed or brought to the surface. For this reason, it is not generally necessary to evaluate soils deeper than 15 feet below ground surface for soil direct contact exposure risk, unless project-specific information is available indicating that deeper excavation is likely to occur.

IDEM publishes levels for six different soil direct contact exposure scenarios. With some exceptions, IDEM's published levels for soil direct contact take into account exposure via four different routes:

- absorbing chemicals through the skin when touching soil;
- inhaling chemicals that volatilize from soil;
- inhaling chemicals in soil particles (e.g., dust); and
- ingesting chemicals in soil.

Because these exposure routes often exist simultaneously for a given receptor, IDEM's published levels combine the ingestion, inhalation, and dermal absorption routes into a single value for each of the exposure scenarios in our published levels table. Appendix A describes the procedures that IDEM uses when deriving published levels for soil direct contact exposure.

<u>Residential Soil Direct Contact</u>

IDEM's published levels for residential soil direct contact exposure assume that residents, *including children*, undergo frequent exposure to release-related chemicals – an assumption that generally results in the highest potential exposures and lowest published levels. IDEM's published levels for residential soil direct contact are appropriate for use in any area that does or is reasonably likely to contain occupied residences and other areas where children may be present on a daily basis (e.g., playgrounds, schools, day care facilities, and similar areas or uses).

<u>Commercial Soil Direct Contact</u>

IDEM's published levels for commercial soil direct contact exposure assume 25 years of frequent exposure to adult workers. They are appropriate for use when evaluating risk at factories, warehouses, office buildings, retail businesses, and other commercial properties. If portions of a commercial property have different exposures (e.g., a day care facility within an office complex or a strip mall), those areas warrant separate consideration and, where appropriate, different remediation objectives.

<u>Excavation Worker Soil Direct Contact</u>

IDEM's published levels for excavation worker soil direct contact assume relatively short term (45 days) exposure to adult workers. They are appropriate for use when evaluating risk to workers in contact with, or potentially in contact with soils in or from trenches and other excavations (basements, swimming pools, etc.)

Recreational Soil Direct Contact – Trail Scenario

IDEM's recreational trail soil direct contact published levels are suitable for use at capped trails, such as a paved or gravel-covered multi-use path for walking, cycling, jogging, skating, and other similar activities. IDEM assumes a vegetative cover fraction of 0.99 for this scenario.

Recreational Soil Direct Contact – Playing Field Scenario

IDEM's recreational playing field soil direct contact published levels are suitable for use at properties where organized sports activities occur (e.g., soccer, baseball, softball, lacrosse, football, etc.) Note that this scenario assumes an exposure frequency of thirty days. At some high-use sports fields it may be necessary to evaluate whether this assumption is reasonable. If a higher frequency is appropriate, then adjust the exposure frequency accordingly. IDEM assumes a vegetative cover fraction of 0.8 for this scenario.

Recreational Soil Direct Contact – Community Park Scenario

IDEM's published levels for the community park recreational soil direct contact exposure scenario are suitable for use at properties that may host a wide variety of recreational activities. Such properties may have picnic shelters, basketball courts, tennis courts, dog walking areas, amphitheaters, and perhaps trails, sports fields, and/or children's play areas. Because they assume greater exposures than those assumed in the trail and playing field scenarios, IDEM's published levels for the community park scenario are generally lower than those for trails or playing fields. Therefore, IDEM's published levels for the community park scenario are also protective for the trail and playing field scenarios. However, residential remediation objectives are generally better suited for playground areas where preschool children may have high daily soil contact rates. IDEM assumes a vegetative cover fraction of 0.8 for this scenario.

3.3.3.2 Using IDEM's Published Levels for Groundwater Direct Contact

IDEM considers both current and potential exposures when evaluating groundwater direct contact risk. Both groundwater currently in use and groundwater reasonably subject to future use should be evaluated for groundwater direct contact risk.

For chemicals with maximum contaminant levels (MCLs) established under the Safe Drinking Water Act, IDEM uses those MCLs as published levels for groundwater direct contact. For other chemicals, IDEM's published levels for groundwater direct contact take into account exposure via three different routes:

- absorbing chemicals through the skin when touching groundwater;
- inhaling chemicals that volatilize from groundwater; and
- ingesting chemicals in groundwater.

Because these exposure routes often exist simultaneously for a given receptor, IDEM's published levels for groundwater direct contact combine the ingestion, inhalation, and dermal absorption routes into a single value for each chemical that does not have an MCL. Appendix A describes the procedures that IDEM uses when deriving published levels for groundwater direct contact exposure.

IDEM publishes levels only for residential groundwater direct contact exposure. IDEM does not attempt to define or publish levels for any of the many possible commercial groundwater uses. Responsible parties that wish to derive project-specific groundwater remediation objectives for commercial uses can do so, and IDEM will evaluate those proposals on their merits.

IDEM's published levels for groundwater direct contact exposure apply to water below the ground surface, within water supply systems, or at the tap, and assume use typical of that which occurs in residences (e.g., drinking, cooking, bathing, etc.) by both children and adults. IDEM considers water that is below published levels for residential groundwater direct contact to be acceptable for unrestricted use.

3.3.3.3 Using IDEM's Published Levels for Indoor Air Direct Contact

Indoor air direct contact exposure occurs inside occupied structures. For this reason, IDEM's published levels for indoor air are only suitable for evaluating current indoor air risk. Risks from potential vapor exposures, both at existing and yet-to-be-built structures, are evaluated using soil gas data, described in Section 3.3.3.4.

IDEM's published levels for indoor air direct contact take into account exposure via inhaling chemicals present in indoor air. IDEM publishes levels for two different indoor air direct contact exposure scenarios, and defines (but does not publish) two sets of indoor air action levels that are easily derived from published levels for indoor air. Appendix A describes the procedures that IDEM uses when deriving published levels for indoor air direct contact exposure.

<u>Residential Indoor Air</u>

IDEM's published levels for residential vapor direct contact assume 26 years of exposure, including child exposure. They are suitable for evaluating risk from long-term indoor air exposure inside residential structures. IDEM's published levels for residential indoor air are based on a subset of the residential indoor air screening levels appearing in U.S. EPA's RSL table, and include only those chemicals that IDEM defines *for this purpose* as volatile.[39]

IDEM defines the **residential indoor air action level** for a chemical as ten times that chemical's published level for residential indoor air. This corresponds to a carcinogenic risk of 10^{-4} or a hazard quotient of ten, whichever results in a lower concentration. Residential indoor air action level exceedances warrant prompt action to reduce exposures.

<u>Commercial Indoor Air</u>

IDEM's published levels for commercial indoor air exposure assume 25 years of exposure to adult workers. They are suitable for evaluating risk from long-term indoor air exposure inside commercial structures. IDEM's published levels for commercial indoor air are based on a subset of the commercial indoor air screening levels appearing in U.S. EPA's RSL table, and include only those chemicals that IDEM defines *for this purpose* as volatile.

IDEM defines the **commercial indoor air action level** for a chemical as ten times that chemical's published level for commercial indoor air. This corresponds to a carcinogenic risk of 10^{-4} or a hazard quotient of ten, whichever results in a lower concentration. Commercial indoor air action level exceedances warrant prompt action to reduce exposures.

[39] Defined *for this purpose* as having a vapor pressure greater than or equal to 1 millimeter of mercury.

3.3.3.4 Using IDEM's Published Levels for Soil Gas

IDEM's published levels for soil gas are intended as indicators of vapor intrusion potential or, in conjunction with indoor air concentrations, as a strong line of evidence for or against actual vapor intrusion. Soil gas concentrations can drive remedy decisions even in the absence of current indoor air exceedances. IDEM publishes levels for six different soil gas scenarios. As noted in Section 2.2.6.2, IDEM generally considers shallow soil gas to include samples collected no more than five feet below ground surface, and deep soil gas samples to include samples collected more than five feet below ground surface. Appendix A describes the procedures that IDEM uses when deriving published levels for soil gas.

Residential: *Subslab/Deep Exterior Soil Gas/Conduit Vapor*

IDEM's published levels for residential subslab/deep exterior soil gas/conduit vapor assume an attenuation factor of 0.03 between residential subslab/deep exterior soil gas/conduit vapor and residential indoor air. They are suitable for determining whether additional delineation of soil gas/conduit vapor, investigation of indoor air in nearby residential structures, and/or implementation of a vapor remedy is necessary. IDEM assumes that residential conduit vapor published levels will be used for most remedy determinations.

Commercial: *Subslab/Deep Exterior Soil Gas/Conduit Vapor*

IDEM's published levels for commercial subslab/deep exterior soil gas/conduit vapor assume an attenuation factor of 0.03 between commercial subslab/deep exterior soil gas/conduit vapor and commercial indoor air. They are suitable for determining whether additional delineation of soil gas/conduit vapor, investigation of indoor air in nearby commercial structures, and/or implementation of a vapor remedy is necessary. While delineation of commercial deep exterior soil gas/conduit vapor is acceptable for determining if current investigations of indoor air in nearby commercial structures are necessary, future property use will need to be considered for the decision unit as property use can change.

Large Commercial: *Subslab Soil Gas/Deep Exterior Soil Gas/Conduit Vapor*

IDEM's published levels for large commercial subslab/deep exterior soil gas/conduit vapor assume an attenuation factor of 0.003 between subslab/deep exterior soil gas/conduit vapor and the indoor air of large commercial structures. See Section 3.3.4 for guidance on the characteristics of large commercial buildings. While large commercial deep exterior soil gas/conduit vapor published levels can be used for delineation of soil gas/conduit vapor, investigation of indoor air in nearby large commercial structures, and/or implementation of a vapor remedy, current building design and future property use must always be considered as it relates to vapor intrusion.

Residential: *Shallow Exterior/Utility Corridor Soil Gas*

IDEM's published levels for residential shallow exterior/utility corridor soil gas assume an attenuation factor of 0.1 between residential shallow exterior/utility corridor soil gas and residential indoor air. They are suitable for determining whether additional delineation of soil gas, investigation of indoor air in nearby residential structures, and/or implementation of a vapor remedy is necessary.

Commercial: *Shallow Exterior/Utility Backfill Soil Gas*

IDEM's published levels for commercial shallow exterior/utility corridor soil gas assume an attenuation factor of 0.1 between commercial shallow exterior/utility corridor soil gas and commercial indoor air. They are suitable for determining whether additional delineation of soil gas, investigation of indoor air in nearby commercial structures, and/or implementation of a vapor remedy is necessary.

<u>Large Commercial:</u> *Shallow Exterior/Utility Backfill Soil Gas*

IDEM's published levels for large commercial shallow exterior/utility corridor soil gas assume an attenuation factor of 0.01 between shallow exterior soil gas or utility backfill soil gas and the indoor air of large commercial structures. See Section 3.3.4 for guidance on the characteristics of large commercial buildings. While large commercial shallow exterior/utility corridor soil gas published levels can be used for delineation of soil gas, investigation of indoor air in nearby large commercial structures, and/or implementation of a vapor remedy, current building design and future property use must always be considered as it relates to vapor intrusion.

3.3.3.5 Using Other Published Levels

Per 327 IAC 2-11-5(3), surface water quality standards shall be met in the surface waters of the state at the groundwater – surface water interface. Pore water samples are technically most appropriate for this purpose. Indiana's surface water quality standards appear in 327 IAC 2-1-6. U.S. EPA Region 4 levels (U.S. EPA, 2018) are acceptable for those chemicals for which IDEM does not publish surface water quality standards.

Sediments intended for eventual land application should be evaluated against soil direct contact criteria and evaluated for leaching potential using SPLP or a similar procedure. U.S. EPA Region 4 publishes ecological screening levels for many chemicals in sediments (U.S. EPA, 2018), and those levels are acceptable for use in Indiana. Note that Indiana Department of Natural Resources permits are required for sediment removal.

3.3.4 Using Site-specific Levels as Remediation Objectives

IC 13-25-5-8.5(d)(2) – Levels of hazardous substances and petroleum calculated using site specific data for the default values in the department's standard equations.

IDEM has historically interpreted the term "site specific data" in IC 13-25-5-8.5(d)(2) to mean the physical and chemical characteristics of a site and associated release-related chemicals. For guidance on site-specific levels that rely on behaviors or behavior restrictions [institutional controls, installation and maintenance of engineering controls or other remedial measures, land use restrictions, etc. as defined in IC 13-25-5-8.5(d)(3)] to control risks, see Section 3.3.5.

Opportunities for derivation of site-specific levels under IDEM's historic interpretation of IC 13-25-5-8.5(d)(2) are essentially constrained by the equations that U.S. EPA and IDEM use to derive the levels that appear in their published tables (U.S. EPA, 2019e and Appendix A of this document). Those equations incorporate many different physical and chemical parameters, some of which are relatively fixed and others of which may exhibit a considerable range of values. U.S. EPA often employs parameter values at the conservative end of their observed distributions as default values when deriving screening levels. For this reason, default physical and chemical parameter values may not accurately reflect conditions for a particular release. Where that is the case, it *may* be worthwhile to collect site-specific data for one or more physical and/or chemical parameters and use those data in conjunction with the relevant equations to derive site-specific levels. Because of the conservative assumptions incorporated into published levels, IDEM expects that site-specific levels derived in this way will nearly always exceed IDEM's published levels. Nevertheless, when properly derived, site-specific levels of this sort are entirely appropriate for use in evaluating potential exposure risks.

Sometimes, even large changes in particular parameter values have little or no effect on the site-specific levels of a chemical. In other cases, effects may be substantial for some chemicals and negligible for others. IDEM suggests careful consideration of the potential benefits and expense of collecting site-specific data for the purpose of calculating site-specific levels. A sensitivity analysis using an iterative evaluation of the reasonable range of potential values for each parameter may prove useful. Detailed guidance on the derivation of site-specific levels using observed chemical and physical parameter values is beyond the scope of this document. See U.S. EPA (2019f) for explanation of the relevant equations and default parameter values.

Soil Direct Contact

The largest scope for calculation of site-specific soil direct contact levels probably relates to the inhalation risk associated with soils, and in particular the volatilization factor that appears in some of the soil direct contact equations. Other options, discussed elsewhere, include levels developed under IC 13-25-5-8.5(d)(3) (Section 3.3.5), background demonstrations (Appendix B) and remediation objectives that use different target cancer risk levels (Section 3.3.6).

Groundwater Direct Contact

The groundwater direct contact equations offer relatively few opportunities for derivation of site-specific levels based on observed chemical and physical parameters. Further, most of the chemicals that drive groundwater risk have maximum contaminant levels (MCLs) established under the Safe Drinking Water Act. IDEM considers MCLs to be the appropriate remediation objective for water intended for human consumption, and IDEM's published levels default to MCLs where the latter exists. Therefore, most groundwater direct contact risk evaluations employ IDEM's groundwater direct contact published levels as remediation objectives, rather than site-specific levels. Other options, discussed elsewhere, include levels developed under IC 13-25-5-8.5(d)(3) (Section 3.3.5), background demonstrations (Appendix B) and remediation objectives that use different target cancer risk levels (Section 3.3.6).

Vapor

The principal opportunity for derivation of site-specific indoor air levels for current exposures under IDEM's historic interpretation of IC 13-25-5-8.5(d)(2) probably involves adjustment of vapor intrusion attenuation factors based on the special characteristics of certain large structures. It may be appropriate to adjust attenuation factors downward by a factor of ten for certain commercial/industrial buildings. Lines of evidence that argue in favor of such adjustments include:

- *Large Building size*. Many commercial buildings have a significantly larger footprint than homes. The interior of the building should be open to air flow rather than subdivided into smaller offices or businesses.
- *Thick foundations and excellent structural integrity*. Many commercial buildings are often slab-on-grade construction with thicker, more intact concrete slabs than residences.
- *High ceilings and large building volumes*. Ceilings are often considerably higher in commercial buildings, increasing the air volume compared to residences.
- *High air exchange rates*. Commercial buildings with high ventilation rates should experience lower indoor air concentrations, if the rate of vapor intrusion from the subsurface is constant.

Other options, discussed elsewhere, include levels developed under IC 13-25-5-8.5(d)(3) (Section 3.3.5) and background demonstrations (Appendix B). Due to the inherent uncertainty associated with vapor intrusion, IDEM has determined that it is usually inappropriate to employ a target cancer risk greater than 10^{-5} when evaluating vapor intrusion risk (See Section 3.3.6 for possible exceptions).

3.3.5 Using Other Concentration-based Remediation Objectives

IC 13-25-5-8.5(d)(3) – Levels of hazardous substances and petroleum developed based on site-specific risk assessments that take into account site-specific factors, including remedial measures, restrictive covenants, and environmental restrictive covenants that (A) manage risk; and (B) control completed or potential exposure pathways.

IC 13-25-5-8.5(d)(3) permits site-specific levels that take risk management strategies into account to serve as remediation objectives. Risk management strategies reduce or eliminate specific exposures through engineering controls and/or institutional controls. Engineering controls physically limit contact with, or movement of, release-related chemicals. Examples include engineered caps, slurry walls, vapor mitigation systems, sheet piling, etc. Institutional controls limit use of a property. Common institutional controls include prohibitions on residential use, limits on the extraction or use of groundwater, or restrictions on soil excavation. Environmental restrictive covenants (ERCs) or environmental restrictive ordinances (EROs) are types of institutional controls.

Because effective institutional controls or engineering controls reduce or eliminate exposure via specific exposure pathways, they increase the allowable concentrations of release-related chemicals that can be left in place. A very effective control can virtually eliminate all exposure pathways, present and reasonably likely future, from the risk evaluation, and permit product to remain in place. However, effective risk management requires an ongoing commitment to monitor, operate, and/or maintain the control *for as long as the release-related chemicals persist at levels that make the control necessary*. Ongoing commitments will vary with the nature of the control, and could range from periodic inspections that monitor compliance with the terms of an ERC, all the way up to operation and maintenance of a complex engineered system. Memorializing any ongoing commitments, including operation, maintenance, and monitoring of an engineering control, in an IDEM-enforceable environmental restrictive covenant, or in an environmental restrictive ordinance[40] enacted by a municipal corporation, is an integral part of an effective remedy.

<u>Example: Soil contact barrier</u>

Installation and maintenance of a physical barrier, like an engineered cap, pavement, or structure that effectively eliminates dermal contact with chemicals in soils. Note that volatile chemicals remaining under such barriers may pose a vapor exposure risk, and may require other measures to adequately control risk.

<u>Example: Limiting soil access</u>

Maintenance of access restrictions on a parcel (e.g., a transformer enclosure where a polychlorinated biphenyls spill occurred) that effectively reduces worker access to a certain number of days per year that is significantly less than the 250 days per year assumed when IDEM calculates its published levels for commercial soil direct contact.

<u>Example: Property-specific groundwater use restriction</u>

A prohibition on extraction and use of groundwater found beneath a parcel, typically in conjunction with access to an alternative source of potable water.

<u>Example: Area-wide groundwater use restriction</u>

[40] Environmental restrictive ordinances apply to groundwater only.

An environmental restrictive ordinance (see Appendix F for additional details on legal requirements associated with environmental restrictive ordinances) that prevents extraction and use of groundwater found beneath an area defined by a municipal corporation.

Example: Vapor mitigation system

Installation, maintenance, and periodic performance monitoring of an engineered system that interrupts chemical vapor transport from the subsurface into an occupied structure.

3.3.6 Using Risk Levels as Remediation Objectives

As described in Appendix A, IDEM's published levels employ a target cancer risk of 10^{-5}. However, consistent with the National Contingency Plan[41] and U.S. EPA, IDEM will consider proposals to use a 10^{-4} target cancer risk level for soils and groundwater:

> "Generally, where a risk assessment indicates that a cumulative site risk to an individual using reasonable maximum exposure assumptions for either current or future land use exceeds the 10^{-4} lifetime excess cancer risk end of the risk range, action… is generally warranted at the site. For sites where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, action generally is not warranted, but may be warranted if a chemical specific standard that defines acceptable risk[42] is violated, or unless there are non-carcinogenic effects or an adverse environmental impact that warrants action. A risk manager may also decide that a lower level of risk to human health is unacceptable and that remedial action is warranted where, for example, there are uncertainties in the risk assessment results. [EPA decisions about] remedial actions taken at sites posing risks within the 10^{-4} to 10^{-6} risk range must explain why remedial action is warranted… Furthermore, the upper boundary of the risk range is not a discrete line at 10^{-4}, although EPA generally uses 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions…" (U.S. EPA, 1991b)

With respect to indoor air, IDEM will in most cases use a 10^{-5} target cancer risk on a per-chemical basis to protect from exceeding 10^{-4} cumulative risk over the long term. This is because of the inherent uncertainty in measuring vapor concentrations, the fact that most indoor air measurements represent a narrow "snapshot in time", and because access issues and the time and money expense of vapor sampling usually result in small vapor data sets. However, if indoor air sampling can be conducted in a way that that addresses these uncertainties, IDEM will consider accepting chronic remediation objectives where the cumulative target risk does not exceed 10^{-4} or a hazard index of one.

Proposals to set a 10^{-4} target cancer risk as a remediation objective should use standard U.S. EPA risk assessment methodologies (U.S. EPA 1989, 1991b, 1991c, 1991d, 1992b,1994c, 1995, 1996, 1996b, 2000b, 2002d, 2004, 2005b, 2007b, 2009b, 2011, 2014, 2019f) rather than calculating site-specific levels, as risk assessment methodologies are best suited to broad application of risk-based decision making. When proposing to use a target cancer risk of 10^{-4}, *It is not acceptable to simply multiply IDEM's published levels by ten.* Doing so ignores the fact that many carcinogenic release-related chemicals also have noncarcinogenic effects. It also ignores the potential for additive effects.

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[41] 40 Code of Federal Regulations (CFR) Section 300.430(d)(1)

[42] Examples include maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), or applicable or relevant and appropriate requirements (ARARs).

Risk-based screening and site-specific levels are usually based on chemical-specific toxic effects on a particular end point (target organ) or mode of action. However, people may experience simultaneous exposure to two or more chemicals that affect the same target organ, or exhibit the same mode of action. When this happens, it is possible for those chemicals to produce an additive effect where exposed persons may incur a risk that exceeds a noncarcinogenic hazard quotient of 1, or a carcinogenic risk of 10^{-4}. It is also appropriate to consider the potentially additive effects of multiple chemicals in a single medium when site-specific exposure factors are integrated into the derivation of site-specific levels, or a risk characterization suggests potential risks exceeding 10^{-4} or a hazard index of 1.

Detailed guidance on evaluation of additivity is beyond the scope of this document. See U.S. EPA (2000b and 2007b) for more information on performing an evaluation of additivity. U.S. EPA's Integrated Risk Information System (IRIS, on the web at http://www.epa.gov/iris) includes a search function that allows users to query chemicals that affect specific organs or physiological systems.

The cumulative hazard index of chemicals that affect the same target organ should not exceed 1, and the cumulative target risk of chemicals that exhibit the same mode of action should not exceed 10^{-4}. U.S. EPA risk assessment guidance views these criteria as "points of departure", and IDEM will generally require a remedy where these risks are exceeded.

3.3.7 How IDEM Will Evaluate Remediation Objective Specifications

General

- Are remediation objectives specified for each decision unit?
- Do specified remediation objectives include all release-related chemicals for which published levels exist?
- Are the specified remediation objectives appropriate given the activities currently taking place and reasonably likely to take place in the future in each decision unit?

Background

- For background demonstrations, are the evaluation criteria in Appendix B met?

Using IDEM's Published Levels

- If IDEM's published levels are used as remediation objectives, are those published levels from IDEM's most recent table?

Using Other Published Levels

- Are Indiana's surface water quality standards specified as remediation objectives for any surface/pore water samples?
- Are appropriate (e.g., U.S. EPA Region 4) remediation objectives specified for any sediment samples?

Site-specific Levels

- Are any proposals to employ a large building attenuation factor adjustment supported by sufficient lines of evidence?
- Are other proposed site-specific levels supported by documentation of any models, calculators, equations, parameter values, or any other inputs used to derive them, as well as outputs?

Other Concentration-based Remediation Objectives

- Do proposals to use engineering controls or institutional controls to manage risk limit exposure to acceptable levels for all relevant exposure pathways?
- If not, are unconditional remediation objectives specified for the uncontrolled pathways?

Using Risk Levels as Remediation Objectives

- Are proposed risk levels considering additivity no greater than 10^{-4} target cancer risk (generally no greater than 10^{-5} for indoor air exposures) and/or a hazard quotient of one?
- Are there sufficient data available to determine with confidence that incremental cancer risk does not exceed 10^{-4}?

3.4 Task Seven: Determine Whether a Remedy is Necessary

In the context of this guidance, a **remedy** is a means of reducing risk arising from a release-related chemical. Remedies either reduce the concentration of a release-related chemical, reduce exposure to that chemical, or both. An **adequate remedy** will reduce risks from release-related chemicals to an acceptable level.

The purpose of Task Seven is to determine whether or not a remedy is necessary to control unacceptable risk to human health and/or the environment that arises from a chemical release. If no remedy is necessary, then closure without restriction or further obligation is appropriate. Otherwise, it will be necessary to select an appropriate remedy, implement it, and show that it adequately controls risk. Closure can follow a demonstration that a remedy is effective.[43]

3.4.1 Basis for Requirement

Task Seven is required in order to determine per IC 13-25-5-8.5(c) whether or not additional action is necessary to protect human health or the environment. IC 13-25-5-8.5(c) states that

If the:

(1) nature and extent of the hazardous substance or petroleum is adequately characterized under the voluntary remediation work plan, considering the remediation objectives developed under this section; and

(2) the level of the hazardous substance or petroleum is demonstrated to be below:

(A) background levels of the hazardous substances and petroleum that occur naturally on the site; or

(B) risk levels developed under subsection (d);

additional action is not necessary to protect human health or the environment.

3.4.2 Remedy Necessity Determinations: General Considerations

IC 13-25-5-8.5(c), strictly interpreted, calls for a simple comparison of "the level of the hazardous substance or petroleum" (what this document refers to as a **representative concentration**) against a remediation objective. However, IDEM recognizes the comparison should consider any relevant factors, including circumstances specific to a release or decision unit, the uncertain but often conservative nature of representative concentration determination and the conservatism built into IDEM's published levels (when those are used). Doing so involves judgment, and those making remedy decisions should consider various lines of evidence (Section 3.4.3) before determining a reasonable course of action.

Unless acceptable lines of evidence indicate otherwise, closure requires a remedy for all chemicals that exceed unconditional remediation objectives, regardless of source. Notice to subsequent owners of each such chemical is required regardless of the source of the release. If it is possible to differentiate release sources, then each source is responsible for addressing its release. However, failure to address all release-related risks, regardless of source, may delay closure. For example, a gas station may be ready to close its petroleum releases, but if it is also affected by chlorinated solvents that have migrated onto the station property, it may be necessary for the gas station and the source of the chlorinated solvents to negotiate requirements necessary to address those chemicals prior to closure.

Note that per IC 13-25-5-8.5(c), adequate characterization is a prerequisite for final remedy determinations and, by extension, closure. Sections 2.1 through 2.3 of this document describe the basic requirements for characterization. However, IDEM cannot specify in advance how much work will be

[43] Administrative requirements also apply.

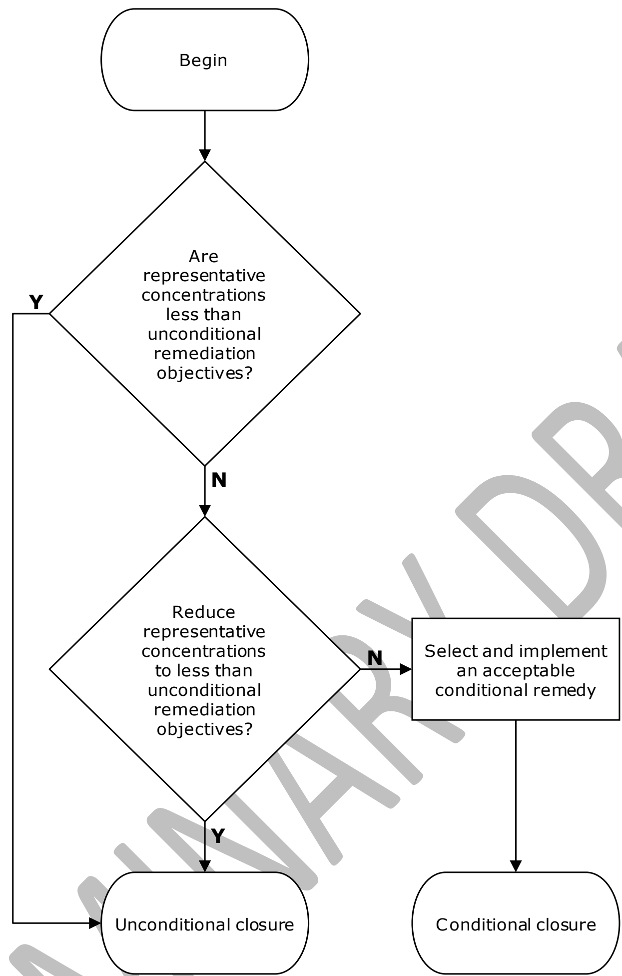
necessary to adequately characterize a release. Instead, IDEM defines the goals of characterization and will judge the adequacy of characterization efforts against those goals.

Note also that it will often be appropriate or even necessary to implement interim remedies based on preliminary characterization results. For example, if preliminary characterization data show that residents of a structure are undergoing unacceptable exposure to vapors arising from release-related chemicals, an interim remedy to address those exposures is necessary. It is not appropriate nor protective of human health to allow such exposures to continue throughout a long characterization process. Interim remedies implemented under less pressing circumstances are also often useful and appropriate. For example, preliminary characterization may suggest that source removal or treatment will reduce the overall expense and time to closure for a project. Under such circumstances, IDEM encourages responsible parties to consider implementing interim remedies, as long as they do not create an unacceptable hazard or worsen risks arising from a release.

Subject to the caveats noted in the preceding paragraphs, remedies will be necessary when representative concentrations of release-related chemicals in a decision unit exceed unconditional remediation objectives. A generic decision framework follows.

1. Compare representative concentrations or risk levels in a decision unit against unconditional remediation objectives (most commonly, *but not necessarily*, IDEM's published levels for residential exposure scenarios).
2. If representative concentrations or risk levels in a decision unit are no greater than unconditional remediation objectives, that decision unit is eligible for closure without restrictions or future obligations. Otherwise,
3. Reduce representative concentrations or risk levels in the decision unit to levels that are no greater than unconditional remediation objectives, in which case the decision unit is eligible for closure without restrictions or future obligations, *or*…
4. Select and implement an acceptable conditional remedy.

Figure 3-A: Generic Remedy Decision Framework



3.4.3 Remedy Necessity Determinations: Lines of Evidence

A **line of evidence** is a fact or a set of facts relevant to a decision. Examples of lines of evidence include information about the chemical or physical characteristics of release-related chemicals or media, the distribution of release-related chemicals, the behavior of potential receptors, the likelihood of exposure, etc. Depending on its nature, a line of evidence can suggest that risks from risk-related chemicals are either greater or lower than those assumed under standard risk evaluation approaches. However, because standard risk evaluation approaches are conservative by design, lines of evidence will often support a judgment that risks from release-related chemicals are lower than the standard approach suggests. When several lines of evidence apply to a decision unit, all of the lines of evidence, taken together, should be considered in the decision-making process. The remainder of Section 3.4.3 discusses a variety of lines of evidence, some of which may apply in a decision unit. Responsible parties that wish to use lines of evidence to support remedy decisions must propose and justify them. IDEM will not do so.

<u>Current and likely future use of the decision unit</u>

IC 13-25-5-8.5(b)(2)(A) states that remediation objectives shall be based in part on the "expected future use of the site". Because land use changes are common (including, for example, conversion of former industrial facilities to residential use), IDEM will typically assume that future residential use is reasonably likely at most decision units. Exceptions include cemeteries and public roadways, and IDEM will not routinely require the use of unconditional remediation objectives or residential use restrictions as a condition of closure for cemeteries or public roadways. However, IDEM may require notice of the presence of release-related chemicals be given to the owners of cemeteries or public roadways with a graphical depiction of the nature and extent of the release-related chemicals. In cases where excavation or exposure of soil may result in unacceptable risk, IDEM may require soil management plans be in place at those properties, and an affirmative obligation for future owners to comply with the approved soil management plan may be required as part of an environmental restrictive covenant.

<u>Sensitive populations</u>

Decision units routinely used by members of sensitive populations (most often children) warrant a conservative approach to risk. This is because members of those populations are often more susceptible to the adverse effects of release-related chemicals than are typical adults. For this reason, the routine and extended presence of children in a decision unit is a line of evidence favoring use of unconditional remediation objectives and less flexible application of the exceedance criteria described in IC 13-25-5-8.5(c).

<u>Amount of exceedance</u>

Given the conservative approaches recommended in this document for determination of representative concentrations and calculation of remediation objectives, minor exceedances of remediation objectives in a decision unit are not likely to result in unacceptable risk. For example, a single exceedance amongst an array of much lower sample results is unlikely to accurately reflect the risk of exposure to that chemical. It is not possible to define what constitutes a "minor" exceedance; the acceptable amount will vary according to other lines of evidence. For example, if receptors are known to congregate in or disproportionately use the area of the decision unit with the minor exceedance, that fact should be taken into account when considering the importance of the exceedance. On the other hand, a larger exceedance may represent a risk requiring a remedy, even if users of the decision unit do not congregate in, or disproportionately use, the area of the decision unit with the exceedance.

<u>Number of exceedances</u>

Sometimes a few (relative to the total sample size) minor exceedances are mixed in with a larger number of samples that are below an unconditional remediation objective. In such cases, the decision unit may not necessarily warrant a remedy. Typically, it won't be obvious that the exceedances are in a clear minority unless there are also enough samples (at least eight, and preferably more) to calculate an upper confidence limit of the mean (UCL), which is often IDEM's preferred approach. However, meaningful UCLs are dependent on either random or systematic sampling, or sufficient samples to ensure adequate coverage of the decision unit. A UCL that is below an unconditional remediation objective indicates that a remedy is not necessary for that chemical. A UCL that significantly exceeds an unconditional remediation objective means that a remedy is necessary, unless the responsible party advances compelling lines of evidence that show otherwise. IDEM will evaluate such proposals on their merits.

Spatially grouped exceedances

Spatially grouped exceedances of an unconditional remediation objective may suggest the presence of a release, and usually means that a remedy is warranted, at least for the part of the decision unit where the exceedances occur. One option is to segregate the spatially grouped exceedances into a separate decision unit, and the remainder of the sample results into another decision unit. This approach may reduce the scope and expense of any necessary remedy.

Nature of potential health effect

Potential health effects from exposure to release-related chemicals fall into two categories: carcinogenic effects, and non-carcinogenic effects. A given chemical may have either type of effect, or both. Levels published by U.S. EPA and IDEM typically assume that non-carcinogenic effects, if any, are binary - that is, they either occur, or they don't – at some concentration that is at least as high as, and often much higher than, the published level. Because of the conservative approach typically used to derive non-carcinogenic levels, the concentration at which an effect may occur is likely to be considerably higher than the published level. Possible arguments in favor of relaxing a non-carcinogenic remediation objective might include the degree of conservatism employed in its derivation, the existence of new toxicological data that shows the chemical is less toxic than previously thought, or characteristics of the decision unit or potentially exposed population. However, IDEM does not have the resources to evaluate arguments that a remediation objective based on a non-carcinogenic effect should be increased because of toxicity or population considerations, and in most cases will reject proposals to evaluate such arguments.

There is sometimes more flexibility with respect to IDEM's published levels for chemicals with carcinogenic effects. When calculating published levels based on carcinogenic risk, U.S. EPA and IDEM assume that there is at least some risk for any non-zero exposure, with risk increasing in direct proportion to exposure concentration. Because IDEM calculates its published levels using a 10^{-5} target cancer risk, and a remedy is generally not warranted for cancer risks less than 10^{-4}, there is some flexibility in the application of published levels based on carcinogenic risk. Note, however, that due to typically small sample sizes and the inherent variability of vapor sample results, IDEM is generally reluctant to move away from the 10^{-5} target cancer risk when evaluating indoor air risk.

Soils: Depth

IDEM considers it generally unlikely that excavations will extend deeper than 15 feet below ground surface, and does not typically require evaluation of deeper soils for soil direct contact risk. Of course, deeper excavations do sometimes occur, and if there is reason to believe that deeper excavations are likely within a decision unit, that information should be incorporated into the decision-making process.

Soils: Persistence of release-related chemical(s)

Some chemicals are highly persistent, even in exposed media, and are likely to remain available for direct contact virtually forever. Conversely, some chemicals may attenuate rapidly in *exposed* soils. For example, volatile organics are unlikely to remain for long in the top few centimeters of the soil profile, where soil direct contact is most likely to occur. This is because various phenomena (volatilization, leaching, biodegradation, etc.) generally act quickly to attenuate concentrations of those chemicals in exposed soils. Yet the equations that IDEM uses to calculate published levels for soil direct contact assume 25 years of exposure in the commercial scenario, and 26 years of exposure in the residential scenario. Because volatile chemicals in exposed soils are especially prone to attenuation, IDEM does not publish residential or commercial soil direct contact levels for chemicals with vapor pressures equal to or greater than one millimeter of mercury at standard conditions, nor does it require delineation of those chemicals for purposes of evaluating long-term soil direct contact risk[44].

<u>Soils: Existing cover</u>

Release-related chemicals in soils that are underneath certain types of barriers are not available for routine soil direct contact, and may also undergo substantially less leaching to groundwater. If the existing cover is likely to remain in place for at least as long as the likely residence time of the release-related chemical, then the likelihood of routine soil direct contact is significantly reduced. Examples of such barriers might include impervious public roadways, parking lots, engineered caps, or the footprints of buildings reasonably likely to remain in place for as long as the release-related chemicals are likely to persist. If release-related chemicals are likely to persist indefinitely at concentrations greater than unconditional remediation objectives, then a remedy such as maintenance of the existing cover or a soil management plan is likely necessary, depending on other lines of evidence that apply to the decision unit.

<u>Groundwater: Depth to Groundwater</u>

Sometimes dissolved release-related chemicals at concentrations greater than unconditional remediation objectives are confined to groundwater that is close to the ground surface. 312 IAC 13-4-1(c) states that wells "…must be cased to a depth of at least twenty-five (25) feet below ground surface unless otherwise approved…", and 312 IAC 13-3-2(a)(2)(B) states that wells shall be located as far as practicable from any known contamination source. IDEM recognizes that compliance with these rules (or any other rule) is not universal, and that it is possible for release-related chemicals in shallow groundwater to be drawn downward by active pumping. The extent to which such downward movement is likely to result in an exceedance of a remediation objective in extracted groundwater is necessarily project-specific, and depends on factors such as the concentration of the release-related chemical in the upper water bearing unit, the effectiveness of any aquitards that may impede vertical movement, and the likely dilution that would occur during downward movement. Nevertheless, the rules in 312 IAC 13 comprise a line of evidence relevant to decision making for release-related chemicals in groundwater.

<u>Groundwater: Productivity of Water-Bearing Unit</u>

Relatively unproductive water-bearing units may not yield enough water to be useful as drinking water wells. If release-related chemicals in groundwater are confined to formations that do not contain or produce sufficient water to be useful, this is a line of evidence suggesting that exposure to those chemicals via installation and use of drinking water wells in that water-bearing unit is unlikely. Application of this line of evidence must consider the possibility that chemicals in the unproductive water-bearing units may move to a deeper aquifer. If such movement may reasonably be expected to result in an

[44] Characterization of volatile chemicals and evaluation of risk associated with those chemicals is still necessary for other exposure scenarios.

exceedance of a unconditional groundwater remediation objective in an aquifer, then a remedy is warranted to address that potential risk.

Groundwater: Aquitards

There are instances in which aquitards largely separate release-related chemicals in shallow groundwater from deeper aquifers. In such circumstances, it may be possible to show that wells screened in deeper aquifers are unlikely to be significantly impacted by release-related chemicals in shallow aquifers. IDEM has published separate guidance on aquitards[45] that describes, among other things, how to investigate the effectiveness of aquitards as barriers to chemical transport.

Groundwater: Persistence of release-related chemical(s)

Several factors influence how long release-related chemicals will remain in groundwater at concentrations above unconditional remediation objectives. These include characteristics of the release-related chemicals, the saturated soil medium, and groundwater. For example, a small release of a highly soluble chemical into a large, fast flowing aquifer may attenuate to acceptable levels in much less time than the exposure durations assumed when calculating groundwater remediation objectives. Conversely, some chemicals are known to persist in groundwater for decades (at least) when conditions do not favor attenuation.

Groundwater: Plume Behavior

Plume behavior is a key component of both characterization and groundwater remedy decisions. Expanding plumes may move into previously unaffected decision units, thus making a remedy in those units necessary. Conversely, a shrinking plume may mean that one or more decision units no longer need a remedy after a time. Other behaviors are possible – for example, no discernable trend, a reasonably steady-state flow toward some ultimate destination like a surface water body, or variable flow direction caused by nearby intermittent pumping or some other phenomenon. All of these behaviors constitute potential lines of evidence relevant to remedy decisions.

Vapor: Size of data sets

Experience has shown that vapor concentrations, particularly indoor air vapor concentrations, can vary dramatically over time for a large number of reasons. This reduces the level of certainty associated with vapor remedy decisions relative to those made for other media. This is particularly true when, as is often the case, vapor remedy decisions are made on the basis of a small data set. Therefore, IDEM will be reluctant to make vapor remedy decisions based on a single set of sample results, unless the decision is to take immediate action to implement a remedy. For the same reasons, IDEM will not typically agree with proposals to derive vapor remediation objectives based on a target cancer risk of 10^{-4} unless the available data set is relatively large.

Commonly proposed but weak or inadequate lines of evidence

Availability of water from a public supply does not mean that persons in the service area are using that public supply, or that they will not install drinking water wells in the future.

The absence of wells in the Indiana Department of Natural Resources (IDNR) Water Well Database does not mean that drinking water exposure is not occurring. Though a very useful resource, the IDNR Water Well Database is not complete. There are many wells that do not appear in the database.

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[45] Aquitard Characterization. IDEM Office of Land Quality Technical Guidance Document. March, 2014.

Ordinances that prohibit installation of new drinking water wells may not necessarily prohibit the continued use of existing drinking water wells, and may not adequately address risks from releases to groundwater.

3.4.4 Deciding Whether a Remedy is Necessary for Soil Direct Contact

Soil remedies may control direct risks arising from soils, indirect risks (soils as sources of release-related chemicals in groundwater or vapor), or both. Risks arising directly from soils are referred to as soil direct contact risks. They include dermal exposure to chemicals in soil, exposure to chemicals in dust and chemical vapors arising from soil, and ingestion of chemicals in soil. For direct risk, the simplest approach to deciding whether a remedy is necessary is to compare representative concentrations of release-related chemicals in the soil of a decision unit to an unconditional remediation objective. If one or more representative concentrations exceed their unconditional remediation objectives, then a remedy is necessary, As noted earlier (Section 3.4.3), IDEM recognizes several lines of evidence that may allow for some deviation from strict application of that decision criterion.

3.4.4.1 Soil Direct Contact Remedy Decision Key

1. Are any representative concentrations significantly above their unconditional remediation objectives?

   Yes: Go to 2.

   No: Preliminary conclusion: A remedy *is not* necessary for soil direct contact. Go to 7.

2. Are all of the exceedances in soils deeper than 15 feet below ground surface?

   Yes: Go to 3.

   No: Go to 4.

3. Is excavation deeper than 15 feet below ground surface reasonably likely?

   Yes: Go to 4.

   No: Preliminary conclusion: A remedy *is not* necessary for soil direct contact. Go to 7.

4. Are all exceedances limited to volatile organic chemicals?

   Yes: Go to 5.

   No: Go to 6.

5. Are representative concentrations less than or equal to excavation worker remediation objectives?

   Yes: Preliminary conclusion: A remedy *is not* necessary for soil direct contact. Go to 7.

   No: Preliminary conclusion: A remedy *is* necessary for excavation worker risk. Go to 7.

6. Are representative concentrations less than or equal to excavation worker remediation objectives?

   Yes: Preliminary conclusion: A remedy *is* necessary for long-term soil direct contact. Go to 7.

   No: Preliminary conclusion: A remedy *is* necessary for both long-term soil direct contact risk *and* excavation worker risk. Go to 7.

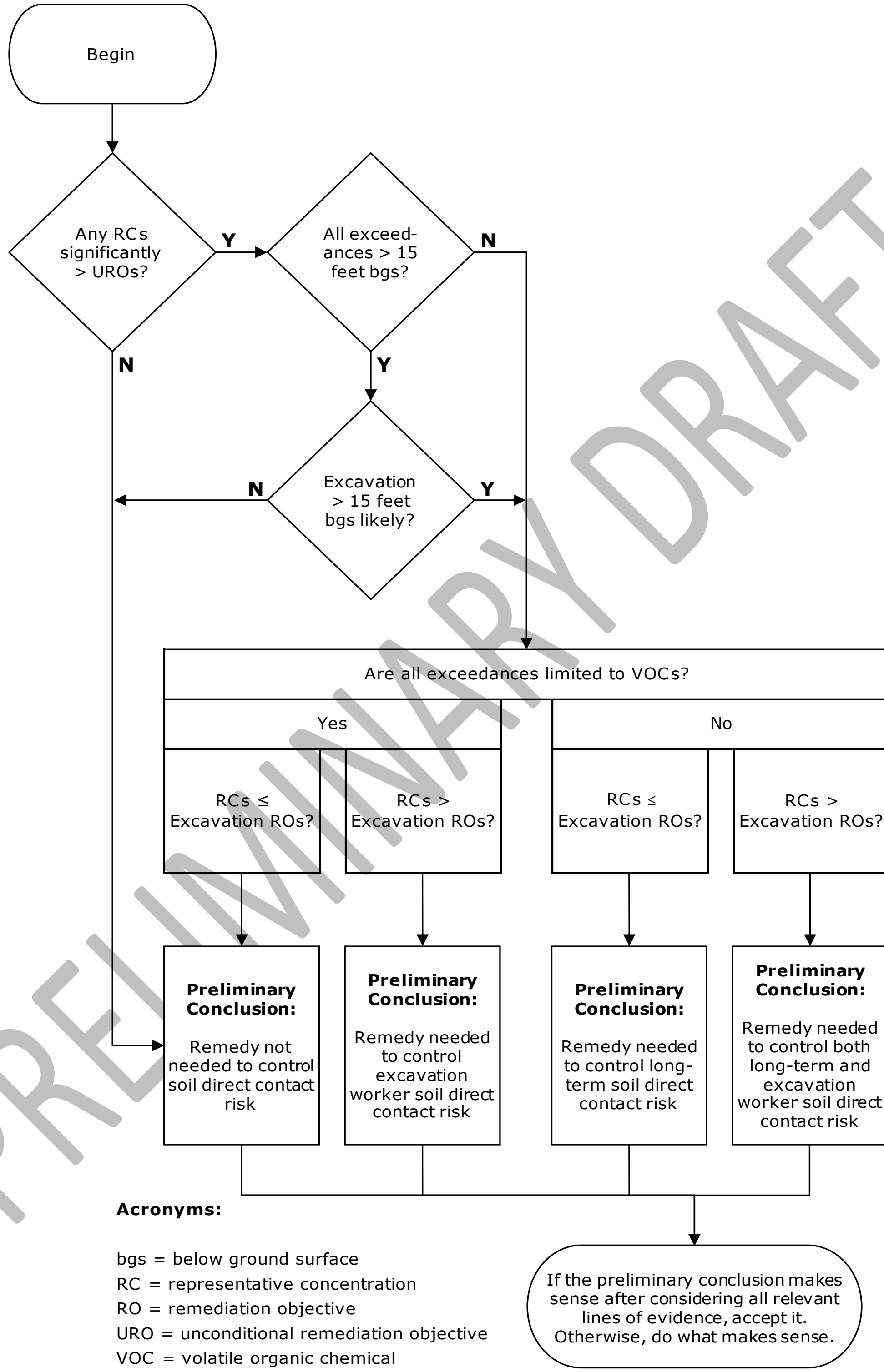
7. Considering all relevant lines of evidence, does the preliminary conclusion reached above make sense for the decision unit?

   Yes: Accept the preliminary conclusion. Go to 9.

   No: Consider collecting additional data that will support a decision and return to step 1 above, or advance arguments in favor of a different conclusion. Go to 9.

8. No remedy is necessary for long-term soil direct contact. Go to 9.
9. Proceed to evaluation of other risks, if relevant.

Figure 3-B: Soil Direct Contact Remedy Decision Tree



Acronyms:

bgs = below ground surface
RC = representative concentration
RO = remediation objective
URO = unconditional remediation objective
VOC = volatile organic chemical

3.4.4.2 Selected Soil Direct Contact Remedy Decision Scenarios

The discussion that follows describes some common soil direct contact remedy decision scenarios and discusses possible approaches to deciding whether a soil direct contact remedy is necessary. Remedy decisions are not always obvious. In many instances, it is necessary to consider multiple lines of evidence before making a decision. Some of those lines of evidence may point in different directions, and balancing those indications to arrive at a reasonable conclusion requires judgment.

The examples that follow are presented as illustrations and not as a complete survey of acceptable approaches. Other approaches may be possible and in some cases preferable. IDEM will evaluate other approaches on their merits.

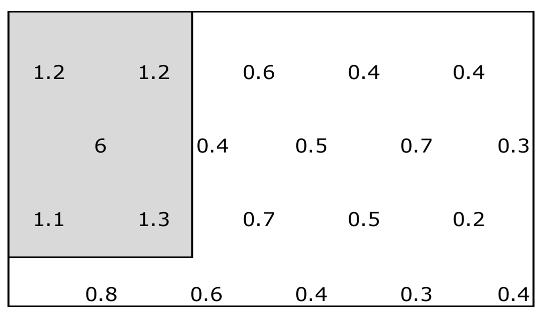
<u>Spatially grouped exceedances</u>

Figure 3-C below represents a plan view of a decision unit, where the numbers in the rectangle are soil sample results within that decision unit, expressed as multiples of an unconditional remediation objective. There are several exceedances in the upper left portion of the decision unit. One of the exceedances is clearly significant. Using the highest observed concentration within the decision unit as its representative concentration would result in a determination that the entire decision unit requires a remedy. Even a representative concentration calculated as the ProUCL-recommended upper confidence limit of the mean (UCL) of all sample results in the decision unit is more than twice the unconditional remediation objective. If that UCL were used as a representative concentration for the decision unit, the entire decision unit would need a remedy.

However, the spatially grouped nature of the exceedances suggests another possible approach, which is to subdivide the decision unit into two separate decision units, and then evaluate each separately. Figure 3-D, shown below, illustrates this approach using exactly the same data set. Under this approach, the shaded area in Figure 3-D represents the first of two newly defined decision units. In this example, only the shaded area would require a remedy. The second decision unit, represented by the unshaded area, would not require a remedy.

Figure 3-C

Figure 3-D



Subdivision of decision units is not required. For example, if a responsible party intends to pursue closure of the decision unit(s) by relying on institutional controls, it may not be worthwhile to subdivide decision units. As long as remedies adequately control risks, responsible parties are free to make those determinations and propose the solution for IDEM's review.

Isolated exceedances

Sometimes a systematically sampled decision unit contains a single significant exceedance amongst a number of other results that are below their unconditional remediation objectives. The simplest approach is to treat the highest observed concentration within a decision unit as the representative concentration for that chemical, and to use that highest concentration for comparison against the appropriate unconditional remediation objective. However, unless receptors spend a disproportionate amount of time in the portion of the decision unit with the exceedance, this approach will overestimate exposure and risk.

Other approaches may be applicable, depending on circumstances. The rectangles in Figures 3-E and 3-F represent plan views of decision units, where systematic sample results appear as multiples of an unconditional remediation objective. The decision unit in Figure 3-E contains a single exceedance. The other sample results are low enough to drive the ProUCL-recommended UCL (0.9) below the unconditional remediation objective. This suggests that decision unit in Figure 3-E does not require a remedy, assuming that receptors do not concentrate their time in the vicinity of the exceedance, and that the exceedance is not part of a hitherto undiscovered and significant release.

Figure 3-E

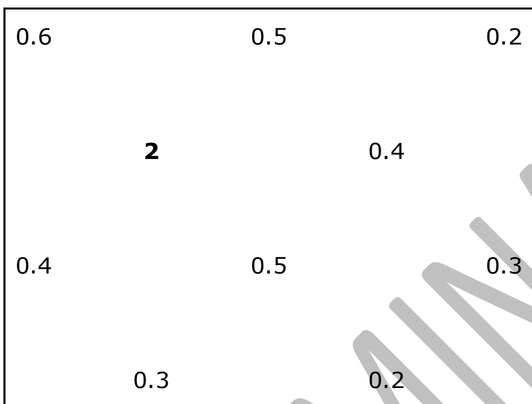
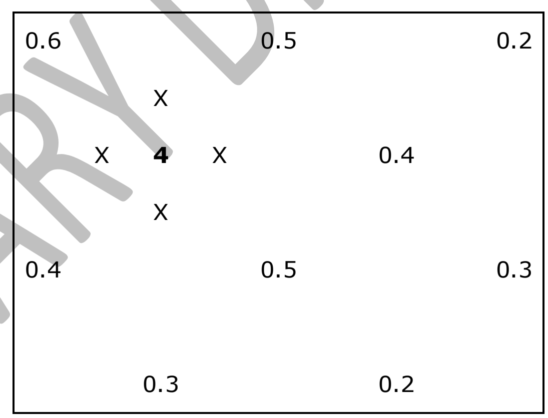


Figure 3-F



In Figure 3-F, the ProUCL-recommended UCL exceeds the unconditional remediation objective, suggesting that this decision unit requires a remedy. An alternative approach would be to undertake a focused evaluation of the area of the decision unit that surrounds the exceedance. Typically this involves *stepping out* from the exceedance, by collecting additional samples from the area immediately surrounding the original exceedance. Figure 3-F shows four potential step out sampling locations, each depicted as an "X", located some distance in one of the cardinal directions from the original exceedance. Step outs should continue until the results show that the extent of any release is fully defined. Results from the step out samples can be pooled with the original data set prior to recalculating a new UCL for the entire decision unit, or used to define a second decision unit that lies within the original decision unit and requires a remedy.

Multiple scattered exceedances in a large sample set make the remedy decision process more complicated. Options include applying a remedy to the entire decision unit; using step out procedures to define and separately evaluate portions of the original decision unit, or where the sample array or design makes it appropriate to do so, calculating a UCL for the entire sample set and comparing that UCL to the unconditional remediation objective.

Exceedance under a barrier

Per IC 13-25-5-8.5(c), adequate characterization is a prerequisite for final remedy determinations and, by extension, closure. For this reason, it is not acceptable to propose a pre-emptive soil direct contact remedy (such as maintenance of a barrier) *in lieu of* characterizing soils underneath barriers that may currently control soil direct exposure.

Sample design and results interpretation should focus on likely risks should the barrier no longer exist. In most cases, this will involve collecting soil samples from beneath the barrier as if the barrier did not exist, and treating the soil layer immediately beneath the barrier as the potential future soil surface.

Note that relatively impermeable barriers can significantly impede leaching of release-related chemicals from vadose zone soils to groundwater. Where this is the case, barrier removal may result in, or increase the magnitude of, release-related chemicals in groundwater, perhaps at concentrations that require a groundwater remedy. Section 2.2.4 describes approaches to evaluating the leaching potential of release-related chemicals in vadose zone soils.

Using levels that presume a remedy

IDEM's published levels for residential soil direct contact are one acceptable type of unconditional remediation objective. IDEM also publishes several types of soil direct contact levels that incorporate, as part of their derivation, specific restrictive assumptions regarding types and durations of exposures. For example, IDEM's published levels for commercial soil direct contact assume adults-only exposure, while IDEM's published levels for recreational soil direct contact include child exposure, but at much lower frequencies and durations than those assumed when calculating residential soil direct contact levels. For these reasons, *use of IDEM's published levels for commercial and/or recreational soil direct contact is appropriate only when a remedy that restricts certain uses is either anticipated or in place*.

3.4.5 Deciding Whether a Remedy is Necessary for Leaching Potential

Some chemicals released to soil may subsequently move downward through the soil profile (leach) and reach groundwater. If groundwater concentrations of leached chemicals subsequently exceed unconditional remediation objectives, a remedy is necessary. Depending on circumstances, adequate remedies may need to address release-related chemicals in soil, or groundwater, or both. Even if groundwater is already impacted, chemicals currently bound to soil may leach, either contributing to the ongoing groundwater problem, or making it worse.

3.4.5.1 Leaching Potential Remedy Decision Key

1. Are release-related chemical concentrations highest in the vadose zone?

   Yes: Go to 2.

   No: Go to 5.

2. Do adequate lines of evidence (Section 3.4.5.2) show that leaching of release-related chemicals to groundwater is unlikely?

   Yes: Go to 5.

   No: Go to 3.

3. Sample and analyze vadose zone soils using synthetic precipitation leaching procedure, or similar technique.Go to 4.

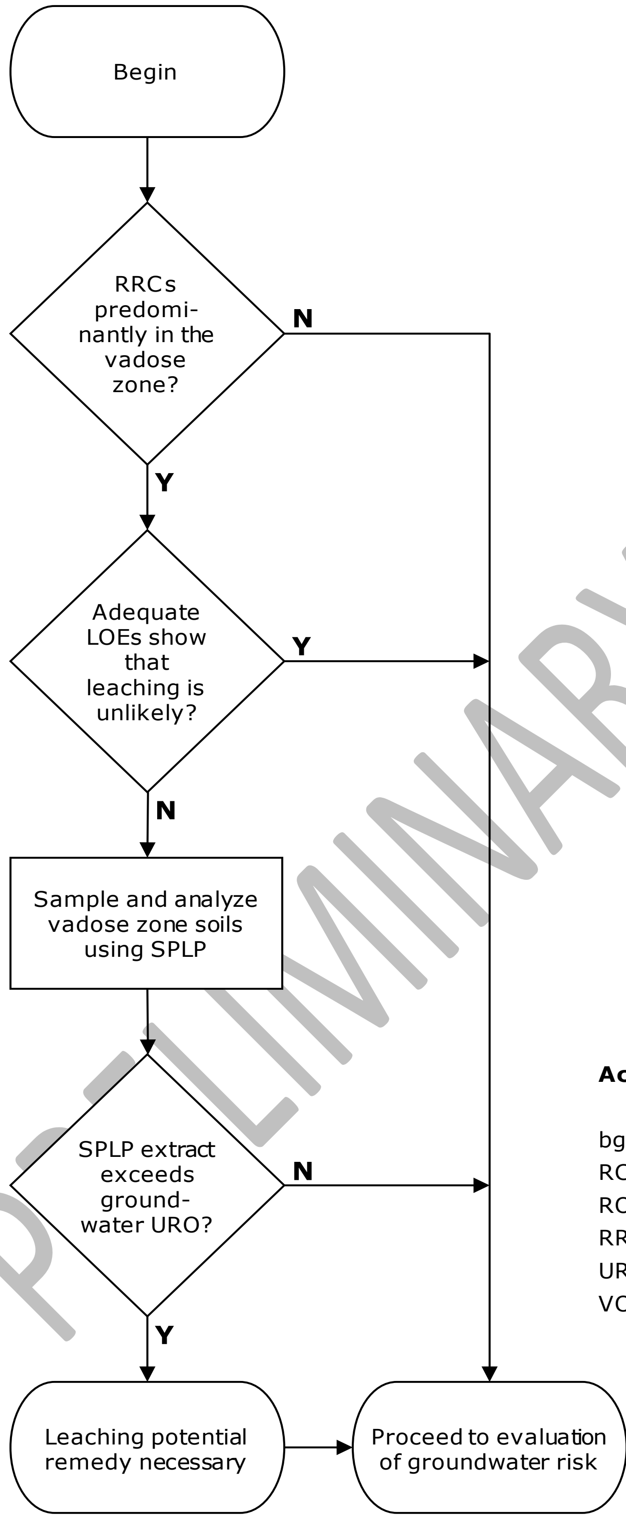
4. Do any of the SPLP extracts exceed unconditional groundwater remediation objectives?

   Yes: A leaching potential remedy is necessary. Go to 5.

   No: Go to 5.

5. Proceed to evaluation of groundwater direct contact risk.

Figure 3-G: Leaching Potential Remedy Decision Tree



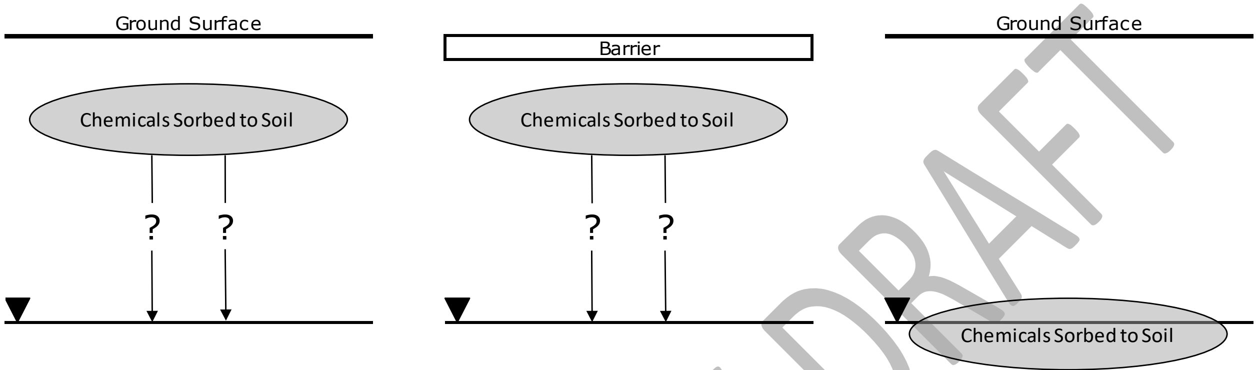
Acronyms:

bgs = below ground surface
RC = representative concentration
RO = remediation objective
RRC = release-related chemical
URO = unconditional remediation objective
VOC = volatile organic chemical

3.4.5.2 Selected Leaching Potential Remedy Decision Scenarios

Figure 3-H (below) depicts, in profile view, three common leaching potential scenarios. Each is discussed separately below, though they can also occur in combinations. The examples that follow are presented as illustrations and not as a complete survey of acceptable approaches. Other approaches may be possible and in some cases preferable. IDEM will evaluate other approaches on their merits.

Figure 3-H: Three Common Leaching Potential Scenarios



The leftmost scenario depicts release-related chemicals in the vadose zone, where those chemicals are subject to infiltrating precipitation. In this scenario, chemicals may or may not leach downward and cause groundwater to exceed an unconditional remediation objective. Whether they do so depends on many factors, including the concentrations and characteristics of the released chemicals, the properties of the soil column, depth to groundwater, amount of precipitation, and elapsed time since the release. It may be possible to demonstrate through various lines of evidence that vadose zone chemicals are unlikely to cause unacceptable risk in groundwater. For example, if release-related chemicals in the vadose zone have been subject to leaching for an extended period, yet have not caused an exceedance of unconditional groundwater remediation objectives, it may be possible to argue that they are unlikely to do so in the future.

However, the most straightforward way to determine whether or not a remedy is necessary for vadose zone soils in the leaching potential scenario is to collect samples of vadose zone soil containing the highest concentrations of release-related chemicals, and subject those samples to the synthetic precipitation leaching procedure (SPLP). If the leachate produced by SPLP exceeds an unconditional groundwater remediation objective, a soil remedy is necessary for the leaching potential scenario. If groundwater sampling shows that one or more release-related chemicals already exceed an unconditional groundwater remediation objective, then leaching or direct transport to groundwater has already occurred, and a groundwater remedy is also necessary.

The middle scenario is similar, except that there is a relatively impermeable barrier above the chemicals that eliminates or greatly reduces precipitation infiltration. Examples of such barriers include structures, pavement, or engineered caps. In this case, IDEM recommends SPLP as the most straightforward way to determine whether or not a remedy is necessary for vadose zone soils in the leaching potential scenario.

As noted earlier, IC 13-25-5-8.5(c) requires adequate characterization as a prerequisite for final remedy determinations and, by extension, closure. For this reason, it is not acceptable to propose maintenance of a barrier as a pre-emptive leaching potential remedy *in lieu of* characterizing soils underneath barriers that may currently control precipitation infiltration. As before, if groundwater sampling shows that one or more release-related chemicals already exceed an unconditional groundwater remediation objective, then leaching or direct transport to groundwater has already occurred, and a groundwater remedy is also necessary.

The rightmost scenario depicts the instance in which release-related chemicals have already leached to, and are in relatively continuous contact with, groundwater. The focus in this instance should be on sampling groundwater. If an exceedance of an unconditional groundwater remediation objective is going to occur, this is the most likely circumstance for it to do so. If groundwater sampling shows that one or more release-related chemicals exceed an unconditional groundwater remediation objective, then a groundwater remedy is necessary.

3.4.6 Deciding Whether a Remedy is Necessary for Groundwater Direct Contact

Groundwater direct contact risk includes risks arising from drinking and touching release-related chemicals in groundwater, and from breathing release-related chemicals that volatilize from groundwater that is used inside structures. IDEM will generally assume, unless convincing lines of evidence suggest otherwise, that release-related chemicals in any water originating from below the ground surface *may* pose a groundwater direct contact risk. IDEM will not limit groundwater direct contact risk evaluations to water issuing from a tap. Indirect groundwater risks occur mostly when release-related chemicals in groundwater volatilize in the subsurface and enter structures via vapor intrusion.

Other groundwater risk scenarios are less common or highly project-specific. Examples include uptake of chemicals in irrigation water by plants or domestic animals, or risks associated with chemicals in groundwater used as part of a specific industrial process. The universe of possible exposure scenarios is so vast and variable that IDEM only publishes levels for residential groundwater direct contact, and considers them an acceptable form of unconditional remediation objective. Risk evaluations that include other groundwater exposure scenarios are necessarily project-specific and beyond the scope of this document. IDEM will review such evaluations on their merits.

Because groundwater flows, it can serve as a transport mechanism for dissolved (and sometimes suspended) release-related chemicals, so that the area(s) requiring a groundwater remedy may change over time. This fact complicates groundwater remedy decisions, and makes it necessary to ask not just where release-related chemicals are in groundwater today, but also where they might be in the future.

IDEM acknowledges that it is rarely possible to precisely determine in advance the ultimate extents of release-related chemicals in groundwater. Nevertheless, adequate control of groundwater risk requires a remedy in areas reasonably likely to exceed unconditional remediation objectives. In general, IDEM prefers conservative approaches to predicting the ultimate extents of release-related chemicals in groundwater.

For groundwater direct contact risk, the simplest approach to deciding whether a remedy is necessary is to compare present and reasonably likely future representative concentrations of release-related chemicals in the groundwater of a decision unit to their unconditional remediation objectives. If one or more representative concentrations exceed their unconditional remediation objectives, then a remedy is necessary. However, as stated earlier, IDEM recognizes several lines of evidence (Section 3.4.3) that may allow for some deviation from this decision criterion.

3.4.6.1 Groundwater Direct Contact Remedy Decision Key

1. Do any representative concentrations of groundwater in the decision unit significantly exceed their unconditional remediation objectives and/or appear reasonably likely to do so in the future?

   Yes: Go to 2.

   No: Go to 4.

2. Are any representative concentrations in the decision unit that significantly exceed their unconditional remediation objectives located in an aquifer or location that is reasonably likely to be suitable for consumptive purposes?

   Yes: Preliminary conclusion: A remedy *is* necessary for groundwater direct contact. Go to 3.

   No: Preliminary conclusion: A remedy *is not* necessary for groundwater direct contact. Go to 3.

3. Considering all available lines of evidence (Section 3.4.6.2), does the preliminary conclusion reached above make sense for the decision unit?

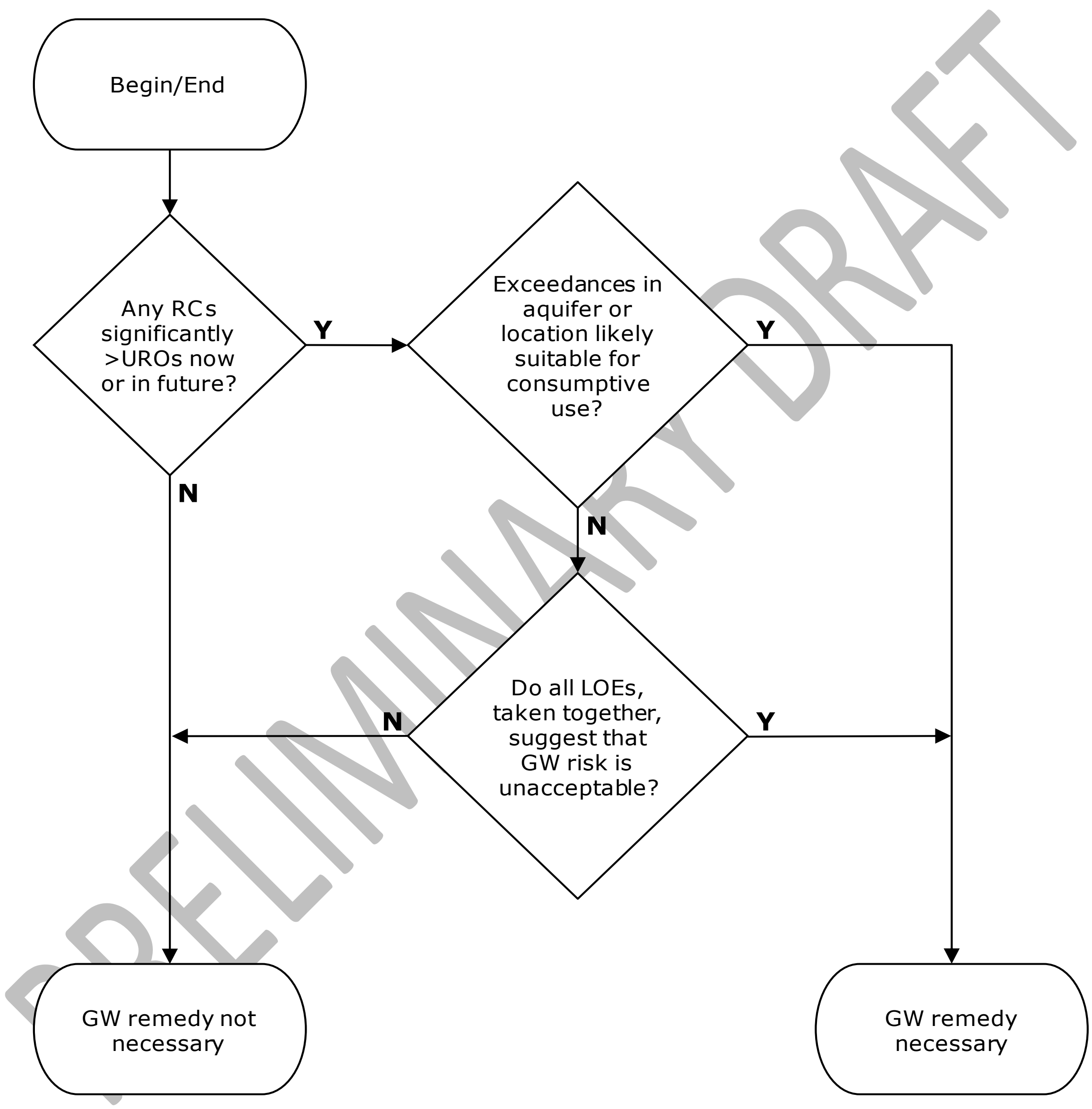
   Yes: Accept the preliminary conclusion. Go to 5.

   No: Collect additional data that will support a decision and return to step 1, or reject the preliminary conclusion. Go to 5.

4. The decision unit does not need a remedy for groundwater direct contact. Go to 5.

5. Continue with evaluation of other exposure scenarios.

Figure 3-I: Groundwater Direct Contact Remedy Decision Tree



3.4.6.2 Selected Groundwater Direct Contact Remedy Decision Scenarios

The discussion that follows describes some common groundwater remedy decision scenarios and discusses possible approaches to deciding whether a remedy is necessary. Remedy decisions are not always obvious. In many instances, it is necessary to consider multiple lines of evidence before making a decision. Some of those lines of evidence may point in different directions, and balancing those indications to arrive at a reasonable conclusion requires judgment.

Sporadic exceedances

Sometimes large groundwater data sets collected over several quarters or even years at multiple locations include a single exceedance, or a number of exceedances that is small relative to the size of the overall data set. Sometimes there are plausible explanations for occasional exceedances (e.g., change in groundwater elevation, sampling/handling/laboratory issues, etc.). The reasons for occasional minor exceedances become important if the risk from the exceedances is unacceptable and an active remedy is proposed. But in every case, it is important to decide whether such exceedances warrant a remedy. Important lines of evidence to consider in this decision include:

- How large is/are the exceedance(s) relative to the unconditional remediation objective?
- How frequently do they occur?
- Does that frequency appear to be diminishing or increasing?

When deciding whether a remedy is necessary, keep in mind that unconditional groundwater remediation objectives assume many years of exposure, and that minor short term exceedances may be acceptable, even for public water supplies subject to the Safe Drinking Water Act. Another option, when there are at least eight quarters of data available, is to calculate a UCL for the release-related chemical(s) of concern that appear in a given well and compare it against the appropriate unconditional groundwater remediation objective(s).

Persistent exceedance at the edge of a sampling array

This circumstance suggests the need for further investigation. The exceedance may be part of a separate plume, or an indication that delineation of the initial plume is not complete.

Exceedances trending downward

Sometimes observed concentrations show a clear downward trend. However, even if projection of that trend shows that concentrations are likely to quickly drop below unconditional remediation objectives, IDEM will require a remedy unless convincing lines of evidence suggest otherwise. The reason for this is that projections are frequently inaccurate. Concentrations trends may plateau at levels above the unconditional remediation objective, or they may even rebound and move higher. Even if concentrations do eventually fall below the unconditional remediation objective, unacceptable exposure may occur during the intervening period.

Exceedances trending upward

In the absence of compelling lines of evidence to the contrary, this circumstance requires a remedy.

Chemicals that degrade into something more toxic

Several different processes may act on released organic chemicals and transform them into different chemicals. IDEM will require a remedy for degradation products that exceed unconditional remediation objectives, even if those products were not part of the original release. Sometimes the products of degradation processes are more toxic than the original chemicals. The most common instance of this is the generation of vinyl chloride via reductive dechlorination. IDEM's published level for vinyl chloride is lower than that of its common precursor chemicals (e.g., tetrachloroethene and trichloroethene).

<u>Seasonal variation in concentration or variation with depth to groundwater</u>

Depending on circumstances, concentrations of release-related chemicals may vary directly or inversely with groundwater elevation. For example, concentrations may consistently spike during springtime monitoring events when groundwater is often elevated, and be below unconditional remediation objectives during other seasons. The magnitude or duration of any such exceedance is extremely difficult to predict with confidence, and a quarterly groundwater monitoring event may be the only data point collected during a six-month period. For these reasons, IDEM has determined that seasonal exceedances are of greater concern than less frequent, sporadic exceedances, and in the absence of compelling lines of evidence to the contrary, will require a remedy under these circumstances.

<u>Confined to aquifers of limited utility</u>

Dissolved release-related chemicals are sometimes confined to areas or aquifers of limited utility for consumptive purposes. Examples of this include aquifers that are very close to the ground surface, aquifers that yield very little water, and/or groundwater in areas subject to uses that make them unlikely locations (e.g., roadways, cemeteries) for future drinking water wells.[46] Section 3.4.3 describes some lines of evidence that may be relevant to aquifers of potentially limited utility.

However, because groundwater flows, and because every release is *some* finite distance from an existing or potential well, it is important to consider the likely ultimate fate of release-related chemicals dissolved in groundwater. For example, chemicals that degrade readily in conditions that occur in the area of a release are less likely than more persistent chemicals to reach a well at unacceptable concentrations. The density of release-related chemicals, their concentrations, the existence and effectiveness of any aquitards, and the likely attenuation that would occur during transport are all important considerations. In some locations active pumping of groundwater may draw dissolved chemicals laterally or downward.

There is no fixed recipe for making decisions in these situations. Each is inherently project-specific and the final decision will inevitably involve weighing the relative importance of available lines of evidence.

<u>Exceedance in a wellhead protection area</u>

Wellhead protection areas are delineated by a specific groundwater time of travel interval (typically five years) or, in some cases, a fixed 3,000 foot radius originating at one or more public water supply wells. Because wellhead protection areas contain public water supplies, releases within wellhead protection areas pose an increased risk of human exposure. For this reason, it is important to understand how likely it is for release-related chemicals in groundwater to make their way to the wellhead and result in an exceedance.

Potential lines of evidence to consider when deciding whether a release is likely to result in an exceedance of an unconditional groundwater remediation objective at a wellhead include time of travel to the wellhead, the existing extent and behavior of the plume, attenuation rates of release-related chemicals, and the magnitude of exceedance relative to the unconditional groundwater remediation objective. It may be necessary to use groundwater modeling to adequately predict whether an exceedance will occur, and whether a remedy is necessary to control risks from such an exceedance. If modeling cannot adequately predict future exceedances, long-term groundwater monitoring may be

[46] If a drinking water well is already present in such a location, water from that well should be evaluated for groundwater exposure risk.

required. Fortunately, public water supplies are subject to regular testing under the Safe Drinking Water Act, so any exceedance will become apparent should it occur.

3.4.7 Deciding Whether a Remedy is Necessary for Vapor

This subsection concerns remedy decisions for vapors that arise from releases of volatile chemicals[47] to land and groundwater and then enter or have the potential to enter structures via vapor intrusion. Releases directly to the atmosphere may be regulated by IDEM's Office of Air Quality. Risks associated with commercial use of volatile chemicals inside structures may be regulated by either the Indiana Occupational Safety and Health Administration or the U.S. Occupational Safety and Health Administration, or both.

In general, IDEM will require vapor remedies when vapor intrusion currently contributes to exceedances of unconditional remediation objectives in indoor air, or when the results of exterior soil gas or subslab soil gas sampling indicate that vapor intrusion could potentially cause an unacceptable risk in the future. Exterior soil gas and subslab soil gas levels are important because of their existing or potential contribution to vapor intrusion. Soil gas data is particularly important when evaluating the potential for vapor intrusion into structures that do not currently exist (e.g., at a potential building site.)

IDEM has determined that because vapor concentrations, particularly those inside buildings, are highly variable, conservative approaches are appropriate when evaluating risk from vapor intrusion. This is particularly true when making decisions based on small data sets, as is commonly the case in vapor intrusion investigations. For this reason, IDEM does not anticipate approving vapor remediation objectives based on a target cancer risk greater than 10^{-5}, unless the data supporting such proposals is temporally and spatially sufficient to provide assurance that representative concentrations are well understood and accurately reflect potential vapor exposure risk. Possibilities for accomplishing this include frequent sampling (perhaps with a portable analytical system) or with long-term passive sampling approaches.

Vapor remedy decisions must be supported by adequate vapor characterization including, at a minimum, the sampling described in Section 2.3.6.1. Because groundwater flows, the areal distribution of release-related chemicals dissolved in groundwater may change over time, and with it the distribution of soil gas. Even if an area is not currently likely to experience vapor intrusion, it may become susceptible in the future as release-related chemicals in groundwater move toward it. Vapor remedy decisions must take this into account.

3.4.7.1 Standard Vapor Remedy Decision Process

A standardized process for vapor remedy decisions appears below. It begins with indoor air sample results paired with either subslab or exterior soil gas results[48]. Use results from the *first* round of paired samples to identify the response scenario corresponding to the appropriate row and column headings in Table 3-A. Note that this table does not address indoor air impacted by conduit vapors. In the event that indoor air exceeds the URO and conduit vapors are present, further investigation and/or a remedy is necessary.Table 3-B describes next steps for each of the scenarios contained in Table 3-A. *It is acceptable to use commercial remediation objectives instead of unconditional remediation objectives when evaluating existing or potential structures restricted to commercial use via land use controls*.

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[47] Defined for this purpose as a chemical having a vapor pressure greater than one millimeter of mercury at standard conditions.

[48] IDEM has determined that, whenever possible, paired samples should be collected during worst-case conditions.

Neither table is a substitute for critical thinking or best professional judgment. They are only general guides. Structure-specific decisions regarding mitigation options and the urgency and/or timing of action should be based on observed conditions. The conditions at any given structure may lead to different decisions than the simple suggestions provided in the tables. IDEM will evaluate alternate proposals on their merits.

Table 3-A: Matrix for comparison of paired indoor air and subslab/exterior soil gas results

	Indoor Air Concentration			
SGss/SGe Concentration	IA ≤ URO	URO < IA ≤ 2x URO	2x URO < IA ≤ 10x URO	IA > 10x URO
SGss/SGe ≤ URO	**Scenario 1** *Remedy not necessary*	**Scenario 4** *Indoor air source (**4a**) or conduit pathway likely (**4b**)*	**Scenario 4** *Indoor air source (**4a**) or conduit pathway likely (**4b**)*	**Scenario 4** *Indoor air source (**4a**) or conduit pathway likely (**4b**)*
URO < SGss/SGe ≤ 2x URO	**Scenario 2** *Remedy typically not necessary*	**Scenario 5** *Implement remedy or show through additional sampling and lines of evidence that a remedy is not needed*	**Scenario 6** *Implement remedy*	**Scenario 7** *Promptly implement a remedy*
2x URO < SGss/SGe ≤ 10x URO	**Scenario 3** *Implement remedy or indefinite sampling*	**Scenario 6** *Implement remedy*	**Scenario 6** *Implement remedy*	**Scenario 7** *Promptly implement a remedy*
SGss/SGe > 10x URO	**Scenario 3** *Implement remedy or indefinite sampling*	**Scenario 6** *Implement remedy*	**Scenario 6** *Implement remedy*	**Scenario 7** *Promptly implement a remedy*

IA = indoor air SGe = exterior soil gas SGss = subslab soil gas URO = unconditional remediation objective

Examples:

If concentrations of trichloroethene are 2.5 times its unconditional remediation objective in subslab soil gas and 4 times its unconditional remediation objective in indoor air, Scenario 6 applies.

If concentrations of benzene are less than its unconditional remediation objective in indoor air but 20 times its unconditional remediation objective in subslab soil gas, Scenario 3 applies.

Table 3-B: Vapor Remedy Decision Scenarios

Scenario 1	Resample under worst case conditions. If both rounds of paired worst case sampling results show that the SGss/SGe and IA concentrations are below unconditional remediation objectives, neither a vapor remedy nor additional sampling is necessary. If the second round yields a different scenario from the first, implement the most protective scenario or perform additional sampling and/or present lines of evidence that support a different course of action.
Scenario 2	VOC detections in SGss/SGe indicate the potential for vapor intrusion, and additional evaluation is required. If three paired worst case sampling events (winter season, summer season, repeat of winter/summer season) show that SGss/SGe is less than two times its unconditional remediation objective, and indoor air concentrations do not exceed unconditional remediation objectives, vapor intrusion does not pose an unacceptable risk and neither a remedy nor additional sampling is necessary. If any of the sample rounds yield a different scenario, implement the most protective scenario and/or perform additional sampling and present lines of evidence that support a different course of action.
Scenario 3	This scenario has significant potential for future vapor intrusion. Either implement a remedy or monitor SGss/SGe and IA concentrations until a remedy proves either necessary or unnecessary.
Scenario 4	This scenario typically occurs when (a) there is an indoor source of the observed chemical(s) or (b) a preferential pathway (e.g., open conduit) bypasses the soil. To evaluate these scenarios, identify and, if possible, remove any indoor sources, then resample indoor air, SGss, and conduit vapor. Typically two resampling events are the minimum needed to evaluate vapor intrusion. Special circumstances (such as mixed results) may require additional sampling if resampling shows:
	(a) SGss or SGe < URO, IA < URO, and conduit vapor < URO, neither a remedy nor further sampling is necessary. If the indoor air source is known, lines of evidence may allow a single round of resampling. (b) SGss or SGe < URO, IA > URO, and conduit vapor > URO, corrective action and/or additional sampling is necessary.
Scenario 5	In this scenario, vapor intrusion is occurring. Responsible parties should either implement a remedy or demonstrate through additional sampling and lines of evidence that a remedy is not necessary.
Scenario 6	In this scenario, there is strong evidence that vapor intrusion is occurring. Responsible parties should implement a remedy that achieves and maintains acceptable indoor air levels.
Scenario 7	In this scenario, there is very strong evidence that vapor intrusion is occurring. Because observed concentrations in indoor air exceed action levels, responsible parties should promptly implement a remedy that achieves and maintains acceptable indoor air levels.

3.4.8 Deciding Whether a Remedy is Necessary for Other Media

Because releases do not always remain confined to soil, groundwater, and vapor, it is sometimes necessary to decide whether a remedy is required to control risk arising from release-related chemicals in other media, such as surface water or sediments. Closure decisions for these media may need to involve IDEM's Office of Water Quality or other State of Indiana or Federal agencies.

3.4.8.1 Surface Water Remedy Determinations

Per 327 IAC 2-11-5(3), surface water quality standards shall be met in the surface waters of the state at the groundwater – surface water interface. Pore water samples are technically most appropriate for this purpose. Indiana's surface water quality standards appear in 327 IAC 2-1-6. U.S. EPA Region 4 levels (U.S. EPA, 2018) are acceptable for those chemicals for which IDEM does not publish surface water quality standards. Because pore water samples are not as replicable as monitoring well samples, calculation of UCLs from pore water data series is unlikely. Instead, IDEM expects that most remedy decisions for surface water will be made via direct comparison of sample results against surface water quality standards, where an exceedance means a remedy is necessary, unless appropriate lines of evidence show otherwise.

3.4.8.2 Sediment Remedy Determinations

Sediments intended for eventual land application should be evaluated against soil direct contact criteria, with remedy decisions employing the same approach as that applicable to soil direct contact remedy decisions. Some sediments do not require consideration of potential ecological effects. Examples include waste lagoons, storage ponds, and other water features that are/were part of surface water control (not natural features that are intended to support ecological habitat). Where ecological concerns apply, IDEM recommends that remedy decisions for sediments left in place should compare U.S. EPA Region 4 (or equivalent) ecological screening levels for chemicals in sediments against representative concentrations of release-related chemicals in sediments. Calculate the latter using procedures analogous to those for soil direct contact. If representative concentrations exceed appropriate sediment screening levels, a remedy is necessary unless appropriate lines of evidence show otherwise. Additional ecological risk evaluation guidance appears in Appendix D.

3.4.9 Risk Characterization

Also known as forward risk assessment, risk characterization combines exposure assessment with toxicity assessment to provide an estimate of risk, and usually an evaluation of the uncertainty and bias associated with that risk estimate. For example, risk characterizations should, to the extent possible, provide central tendency risk estimates in conjunction with upper bound risk estimates and a clear statement of the uncertainty associated with those estimates. Especially when coupled with realistic exposure assumptions, risk characterization provides a more meaningful evaluation of risks associated with a release than does simple application of published levels. The result should better inform decision making. However, risk characterization is typically far more resource intensive than using screening levels or even site-specific levels. Responsible parties will need to weigh the costs and potential benefits of each approach for themselves. A full description of the risk characterization process is beyond the scope of this document. U.S. EPA (1992c, 2000c) provides detailed guidance.

3.4.10 How IDEM will Evaluate Remedy Necessity Determinations

Soil Direct Contact Remedy Decisions

- Is an interim remedy necessary for any decision unit?
- Has a remedy decision been proposed for each decision unit?
- Are spatially-grouped exceedances evaluated appropriately?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

Leaching Potential Remedy Decisions

- Has a remedy decision been proposed for each decision unit?
- Are spatially-grouped exceedances evaluated appropriately?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

Groundwater Direct Contact Remedy Decisions

- Is an interim remedy necessary?
- Has a remedy decision been proposed for each decision unit?
- Are spatially-grouped exceedances evaluated appropriately?
- Do representative concentrations exhibit trends or seasonal exceedances?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

Vapor Remedy Decisions

- Is an interim remedy necessary?
- Has a remedy decision been proposed for each decision unit?
- If a representative concentration in a decision unit exceeds its unconditional remediation objective and a remedy is not proposed, is that proposal supported by adequate lines of evidence?

4. Remedies

In the context of this guidance, a **remedy** is a means of reducing risk arising from a release-related chemical. A remedy either reduces the concentrations of one or more release-related chemicals, reduces exposure to those chemicals, or both. Remedies need not stand alone, and in many cases adequately controlling risk will require a combination of remedies. For example, adequately controlling risks arising from soil direct contact may require a remedy different than a remedy that adequately controls vapor intrusion risk. A remedy may be implemented for a single decision unit or many decision units.

Remedies that achieve unconditional closure at a decision unit allow that decision unit to be used for any purpose, and do not require ongoing obligations. Achieving an unconditional closure requires showing that any remaining concentrations of release-related chemicals or risks associated with those chemicals are no higher than unconditional remediation objectives, or that convincing lines of evidence demonstrate that a remedy is not necessary.

Remedies that do not achieve unconditional closure at a decision unit require ongoing obligations. Examples of such obligations include one or more activities that must occur (e.g., installation and maintenance of a barrier and/or active remediation system), must not occur (e.g., a land use restriction that prohibits specified activities), or combinations thereof. Those obligations must remain in effect for as long as release-related chemicals are likely to remain in the decision unit at levels that would result in unacceptable risk in the absence of the remedy.

Interim Remedies

The formal remedy selection process is typically undertaken after the release is fully characterized and an evaluation of risks to human health and the environment indicates that a remedy is required. However, it may sometimes be necessary or advisable to implement a remedy before the nature and extent of a release is fully characterized. For example, unacceptable risks (e.g., persons drinking water that exceeds maximum contaminant levels (MCLs) or breathing indoor air that exceeds indoor air action levels) should be prioritized and controlled to protect human health. Other activities, such as removal of source material, may reduce potential risk, overall project cost, and time to closure.

As long as they do not create an unacceptable hazard or worsen risks arising from a release, IDEM does not object to, and may encourage, implementation of one or more interim remedies at any stage of a project. Note, however, that per IC 13-25-5-8.5(c)(1), a *complete* evaluation of risk (and therefore the adequacy of whatever remedy is ultimately proposed) requires adequate characterization of the nature and extent of the release. It is not acceptable to implement a remedy in lieu of adequate characterization.

Section 4 Structure

Section 4.1 provides guidance on the selection of remedies likely to be effective in controlling release-related risk at a decision unit. Section 4.2 provides guidance on implementing remedies and demonstrating that they effectively control risk at a decision unit.

4.1 Task Eight: Select an Adequate Remedy

Task eight corresponds to submission of a proposed remediation work plan or corrective action plan. An **adequate remedy** is one that will reduce risk from release-related chemicals to a level that is acceptable for the intended use of a decision unit. Risks can be controlled by reducing concentrations of release-related chemicals, by reducing receptor exposure to those chemicals, or through some combination of those two general approaches. Many approaches are possible. Rather than prescribing specific approaches, IDEM will evaluate the adequacy of a remedy for both current and future exposures. In some cases, long-term stewardship (Section 4.1.7) will be necessary to ensure remedy adequacy.

4.1.1 Basis for Requirement

IC 13-25-5-8.5(c) describes circumstances under which additional action *is not* necessary to protect human health or the environment. In all other circumstances, additional action *is*, in the absence of convincing lines of evidence to the contrary, necessary to protect human health or the environment. An adequate remedy must be likely to adequately control risk for the likely lifetime of release-related chemicals. An adequate remedy must also meet any additional applicable state or federal requirements.

4.1.2 Remedy Selection: General Considerations

IDEM has determined that many different technologies and tactics are potentially useful for reducing risks arising from release-related chemicals and, except as noted below, the agency does not generally prescribe specific approaches. Instead, responsible parties are generally free to consider the advantages and disadvantages of various remedy options for themselves. Factors to consider include:

- *Effectiveness*. Will the remedy adequately control risk, and do so over the likely lifetime of the release-related chemicals?
- *Timeliness*. Will the remedy control risks quickly enough? A remedy that takes many years to adequately control risk is little better than no remedy.
- *Cost, including cost over time*. Long-term costs associated with the ongoing obligations of a conditional closure may ultimately prove more expensive than achieving an unconditional closure. IDEM will take a special interest in cost when the state acts either in its capacity as Administrator of the Excess Liability Trust Fund or as a party undertaking a response with state funding sources.
- *Acceptability to affected parties*. For example, a remedy that requires placement of an environmental restrictive covenant on a deed must be acceptable to the owner of the relevant property.
- *Potential, if any, to make the original situation worse*. Examples of this include remedies that increase the area affected by the release, or remedies that transform the originally released chemical into a more toxic or otherwise dangerous form or byproduct.
- *Planned use of decision units*. The level of confidence in future planned use is important when assessing potential risk posed by the release.
- *Past experience with the proposed remedy*. All else equal, obtaining IDEM approval of a remedy with an established record of success will likely require less documentation of suitability than would a novel remedy, and may require less time for agency review.

4.1.3 Remedy Selection: Statutory Requirements

IC 13-25-5-7(b) and (c) describe requirements applicable to either proposed or completed remediation work plans. Section 4.2 describes requirements for a completed work plan. Per IC 13-25-5-7(b),

> *A proposed voluntary remediation work plan must include the following:*

(1) Detailed documentation of the investigation conducted by the applicant in preparing the proposed voluntary remediation work plan and a description of the work to be performed by the applicant to determine the nature and extent of the actual or threatened release.

(2) A proposed statement of work to accomplish the remediation in accordance with guidelines established by the department.

(3) Plans concerning the following:

(A) Quality assurance for the implementation of the proposed remediation project.

(B) Descriptions of sampling and analysis.

(C) Health and safety considerations.

(D) Community relations and community comment in planning, cleanup objectives, and implementation processes.

(E) Data management and record keeping.

(F) A proposed schedule concerning the implementation of all tasks set forth in the proposed statement of work.

<u>Detailed documentation of investigative work</u>

IDEM remediation programs may, at their discretion, allow incorporation of previously reported investigative work by reference. However, in instances where remediation work plans must be made available for public review, IDEM may require that those remediation work plans be comprehensive, stand-alone documents.

<u>Statement of work</u>

This is a description of the tasks necessary to implement the remediation work plan. Useful components include a map showing the extent(s) of release-related chemicals superimposed on the extent(s) of the proposed remedies, evidence that plan implementation will adequately control risks, and cost estimates comparing the proposed remedy with other alternatives, particularly when the project is eligible for reimbursement by the Excess Liability Trust Fund.

<u>Quality assurance</u>

This refers to a description of the measures planned or taken to ensure that data necessary for remedy design and implementation meet data quality objectives (DQOs). Section 2.2 contains additional discussion on DQOs.

<u>Sampling and analysis</u>

This is a description of the methods used to collect, preserve (when necessary), handle, and analyze samples of environmental media.

<u>Health and safety</u>

This is a description of measures planned or taken to ensure both the health and safety of workers implementing remedies and that of persons who may be affected by remedy implementation. Potential topics will vary according to the proposed remedy type, and may include required safety training for project personnel, access controls, monitoring plans, contingency plans for emergencies, etc.

<u>Community relations and comment</u>

This is a description of measures planned or taken to meet community relations requirements. See the Risk-based Program Guide for additional guidance on this topic.

Data management and record keeping

This is a description of measures taken or planned to obtain, use, present, and retain data obtained during implementation of the remediation work plan.

Proposed schedule

This is a timetable that describes when important activities related to implementation of the remediation work plan will occur, and demonstrates that the remedy will control risks in a timely manner.

In some cases, either due to changing circumstances or direction received from IDEM, proposed remediation work plans will need to be modified and resubmitted for IDEM review. Legal requirements, technical considerations, and lines of evidence may vary according to the type of remedy. As detailed below, active remedies, engineered exposure controls and institutional controls each have different considerations; additional discussion of proposed remediation work plan components follows for each of the three remedy categories.

4.1.4 Remedy Selection: Active Remedies

In the context of this guidance, IDEM defines an **active remedy** as a measure that significantly reduces release-related chemical concentrations in a decision unit. Active remedies have many potential benefits. These include possible **unconditional closure**, possible shortened monitoring and/or maintenance periods, a wider variety of future uses and possible reduced future liability. There are many types of active remedies. Examples include:

- Removal and disposal
- Bioremediation
- Groundwater pump and treat systems
- Soil vapor or multiphase extraction systems
- Certain chemical treatments
- Electrical resistance heating

Proposed remediation work plan components applicable to active remedies might include:

- Pilot test results from the project or a similar project, along with a detailed explanation of why conditions are similar at each;
- In some cases, additional characterization (for example correlating release-related chemical concentrations and permeability or a more detailed utility delineation) may provide evidence that an active remedy proposal is likely to work.
- A monitoring proposal to ensure remedies (e.g., injections or fracking) are controlled, don’t mobilize release-related chemicals, or result in plume expansion.
- Pressure monitoring to show an inward gradient and an air sparge interlock with a soil vapor extraction system to ensure that sparging doesn’t mobilize vapors.
- Contingency plans for certain reasonably likely scenarios. For example, a design for an extraction system or treatment wall in case the remedy mobilizes release-related chemicals.

Proposed schedules for active remedies are complicated by the many unknowns associated with implementation. For this reason, it is often necessary to propose performance monitoring criteria that will indicate whether the remedy was implemented as planned and is progressing. Long-term progress is typically shown through periodic monitoring of release-related chemical concentrations and system evaluation (if applicable). Monitoring and evaluation time frames will depend on the relative speed of the technique. Examples of active remedy progress measures include:

- Measurement of oxygen, ozone, tracer gas, etc. to determine air sparge radius of influence
- Vacuum monitoring points to determine soil vapor extraction radius of influence
- Visual/chemical observations in monitoring points to assess injection radius of influence.

Proposed remediation work plans for active remedies must state the long-term remedy goal(s). Examples of acceptable goals include endpoint release-related chemical concentrations, percent reductions, system extraction rate declines, etc.

4.1.5 Remedy Selection: Engineered Exposure Controls

Some remedies, by reducing exposure, may reduce risk to acceptable levels, even without reducing concentrations of release-related chemicals. In the context of this guidance, IDEM defines one subset of such exposure control remedies – those that involve construction or use of some physical structure or apparatus to control exposure – as **engineered exposure controls**. Engineered exposure controls typically work by controlling the movement of chemicals or interrupting exposure pathways. As with other remedies, use of an engineered exposure control does not relieve a responsible party from their statutory obligation to adequately characterize a release. Examples of engineered exposure controls include:

- Engineered caps (e.g., to control soil direct contact exposure or leaching potential concerns)
- Vegetative covers
- Liners
- Slurry walls
- Immobilization or stabilization of release-related chemicals in soils (e.g., to control soil direct contact exposure or leaching potential concerns)
- Drinking water filter systems
- Vapor mitigation systems

IDEM approval of engineered exposure controls requires evidence that exposures will be adequately controlled both now and in the future. The type of evidence will depend on the type of control. Examples include:

- Indoor air testing for a vapor intrusion subslab depressurization system (present) accompanied by an operation and maintenance plan with ongoing indoor air testing (future)
- Potentiometric data indicating capture for a slurry wall (present) and an operation and maintenance plan that includes ongoing gradient monitoring (future)

IDEM publishes many technical guidance documents that indicate what data may be necessary to document the performance of a given exposure control, including vapor mitigation systems, covers, fences, and slurry walls. Links to these documents appear on IDEM's Engineering Controls webpage. IDEM may issue additional guidance on other engineered exposure controls in the future.

Proposed remediation work plans that rely on engineered exposure controls must include operation and maintenance plans to ensure long-term reliability of engineered exposure controls and their ability to adequately control exposure in the future. A remedy that relies on an engineered exposure control must also include an environmental restrictive covenant that requires operation and and maintainance of that control. In some cases, long-term monitoring and entry into a long-term stewardship agreement may be required.

Sometimes it is appropriate to submit operation and maintenance plans following implementation. For example, vapor mitigation systems are sometime installed as part of new construction when soil gas data did not clearly predict whether a system was necessary. If post-construction paired sampling shows that vapor is not a concern, then an operation and maintenance plan is not necessary. Otherwise, confirmatory sampling and an operation and maintenance plan is necessary.

4.1.6 Remedy Selection: Institutional Controls

Effective institutional controls eliminate or reduce exposure via certain exposure pathways by forbidding or restricting certain land uses on a property, or by compelling other activies (e.g., operation and maintenance of an engineered exposure control). There are many kinds of institutional controls, including environmental restrictive covenants, environmental restrictive ordinances, and deed notices. Specific guidance on environmental restrictive covenants and deed notices appears in Appendix E, while Appendix F provides guidance on environmental restrictive ordinances.

Sometimes a release may necessitate a remedy on one or more properties other than the source property. If the approved remedy on such property is an ERC, it is the responsibility of the entity proposing the remedy to obtain the executed document and see that it is recorded. Exposure pathways may be eliminated for certain decision units owned by local governments or state agencies, such as rights-of-way or state-owned roads, by providing adequate notice to those local governments or state agencies. There are occasions when an ERC or ERO is necessary but for a myriad of reasons is not obtainable. IDEM acknowledges that these situations occur and that a solution is often complex. Releases that require notice of impacts to properties other than the source property, including notice to subsequent owners, will be resolved on a project-specific basis.

4.1.7 Long Term Stewardship (LTS)

U.S. EPA (2005c, page 6) states that "Long-term stewardship applies to sites where long-term management of contaminated environmental media is necessary to protect human health and the environment. Long-term stewardship generally includes the establishment and maintenance of physical and legal controls, implementation entities, authorities, accountability mechanisms, information and data management systems, and resources that are necessary to ensure that these sites remain protective of human health and the environment." LTS can:

- Allow responsible parties/property owners to better manage on-going and future risks and liabilities
- Maintain the viability/protectiveness of engineered controls with finite lifespans such as vapor mitigation systems, slurry walls, soil caps, fencing, and other containment systems
- Calculate & "lock-in" cost of current and future liabilities
- Allow long-term oversight of remedy and liability protection after property sale and loss of direct property control
- Support the selection and use of institutional and engineering controls for a risk-based closure

At this time, IDEM has not fully developed a LTS plan, but will consider LTS on a case by case basis. While developing a LTS plan, consider the following components;

- Release setting details
- Controls – institutional & engineering

- Monitoring plan
- Operation and maintenance plan (engineering controls)
- Record Keeping/notices
- Reporting
- Appendices/data collection forms
- Financial assurance

4.1.8 Financial Assurance

Some closure types require financial assurance, either because statute, federal rules, or other regulations require it, or because IDEM determines that financial assurance is required to protect taxpayers. Appendix G provides additional guidance on financial assurance.

4.1.9 How IDEM will Evaluate Remedy Selection

IDEM will evaluate the information described above to determine if a remedy is likely to reduce exposure to acceptable levels within a reasonable timeframe and without unacceptably increasing other risks.

Criteria that IDEM will use to evaluate proposals for active remedies and engineered exposure controls:

Active Remedy Proposals

- Is the proposed remedy likely to be successful? The level of detail required to demonstrate the feasibility and likely success of the system will vary according to the project, but will likely increase if IDEM is paying for the remedy or acting as Administrator of the Excess Liability Trust Fund. See Section 4.1.4 for additional detail.
- Does the proposal include metrics for remediation progress and success? Post-implementation monitoring has two purposes. First, it shows whether or not the system was installed as proposed and is reducing release-related chemical concentrations as expected. Second, it should ultimately show whether or not the system has achieved proposed remediation end points.
- Does the proposal address any likely adverse effects or other issues described in Section 4.1.2?
- Are proposed endoints and confirmatory metrics in various media consistent with acceptable risk levels, given the proposed use of relevant decision units?

Engineered Exposure Control Proposals

- Is the proposed control reasonably likely to adequately control exposure for as long as release-related chemicals are present above unconditional remediation objectives?
- Does the proposal include adequate metrics for confirming that the control adequately controls exposure?
- Do proposed operation and maintenance plans for vapor mitigation systems conform with criteria described in Section 4.2.3.1?

Institutional Controls

- See Appendices E, F, and G as appropriate for guidance on how IDEM will evaluate proposed ERCs, proposed EROs, and financial assurance proposals.

4.2 Task Nine: Remedy Implementation and Confirmation

Because remedy implementation often involves multiple steps with varying levels of uncertainty, IDEM acknowledges that remedy proposals may require modification during or after implementation. If the implemented remedy differs significantly from the proposed remedy, IDEM will require documentation of those differences.

4.2.1 Basis for Requirement

Remedy implementation and confirmation is necessary to demonstrate compliance with IC 13-25-5-8.5(c). IDEM's remediation programs will typically require documentation of compliance with remedy confirmation requirements described in Sections 4.1.2, 4.1.3, 4.2.1, and 4.2.2 to show that the remedy as implemented is effective. Per IC 13-25-5-7(c), a voluntary remediation workplan for a completed remediation project must include the following:

(1) Detailed documentation of the investigation conducted by the applicant in preparing the proposed voluntary remediation work plan and a description of the work performed by the applicant to determine the nature and extent of the actual or threatened release.

(2) A statement of work performed to accomplish the remediation in accordance with rules or guidelines established by the department.

(3) Plans concerning the following:

(A) Quality assurance for the implementation of and, if appropriate, plans for future oversight of the remediation project.

(B) Descriptions of sampling and analysis conducted before and after the remediation is performed.

(C) Health and safety considerations.

(D) Community comment.

(E) Data management and record keeping.

(F) Criteria used to determine remediation levels and remediation methodology.

(4) Other information the department determines is necessary to evaluate the work plan and determine if the remediation objectives have been achieved.

4.2.2 Implementation and Confirmation of Active Remediation

Implementation of active remediation may involve any of a large number of approaches to reduce concentrations of release-related chemicals. Discussion of how to implement those approaches is beyond the scope of this document.

Demonstrating active remediation effectiveness generally requires collection and analysis of samples from relevant media, and submission of those results to IDEM. If groundwater is or was impacted, this will usually include submission of at least four quarters of post-remediation groundwater monitoring data from appropriately located monitoring wells. Most demonstrations will use sample results to determine representative concentrations (Section 3.2) in decision units, and compare those concentrations to appropriate remediation objectives. Confirmation that concentrations of release-related chemicals in a decision unit have been successfully reduced to levels below unconditional remediation objectives will typically result in unconditional closure. Per IC 13-25-5-8.5(c), exceedances of unconditional remediation objectives may require a remedy.

4.2.3 Implementation and Confirmation of Engineered Exposure Controls

There are many types of engineered exposure controls. IDEM publishes technical guidance documents that describe implementation of several types, including vapor mitigation systems, covers, fences, and slurry walls. Links to these documents appear on IDEM's Engineering Controls webpage. Because subslab depressurization systems (SDSS) to control vapor intrusion risk are the most common engineered exposure control proposed to IDEM, Section 4.2.3.1 provides additional guidance on implementation and confirmation of such systems. IDEM may issue additional guidance on other engineered exposure controls in the future.

Demonstrating engineered exposure control effectiveness requires showing that the control adequately controls relevant exposure pathways. It also generally requires submission of documentation that shows that those controls either conform to their proposed design, or describes and justifies any significant changes. Operation, maintenance, and monitoring (OMM) plans tied to an appropriate institutional control or long term stewardship agreement should be submitted to provide reasonable assurance of adequate exposure pathway control in the future.

Engineering controls should usually be supported by institutional controls that ensure those controls stay in place and are maintained. For instance, an environmental restrictive covenant could be used to obligate continued OMM of any engineered exposure control used at a property. Written OMM plans that ensure long-term reliability of engineered exposure controls must be developed and submitted to IDEM for approval.

4.2.3.1 Implementation and Confirmation of an SSDS

Post implementation confirmatory testing must demonstrate that an SSDS is successfully mitigating the vapor intrusion pathway and is likely to continue doing so in the future. The confirmatory testing should consist of both indoor air sampling and documentation of system performance metrics. It takes time for the sub-slab and/or crawl space area to reach steady-state conditions after the installation of a vapor mitigation system. For this reason, an equilibration period (30 days is standard) is necessary before confirmatory indoor air sampling and performance metrics are collected.

Indoor air sampling is a necessary line of evidence to confirm the mitigation system is performing adequately. Verification indoor air sampling is only necessary for previously detected chemicals and their breakdown products. Indoor air samples should be collected in locations biased toward worst case conditions identified during previous sampling events and/or based on professional judgment. Following installation of a vapor mitigation system, IDEM recommends the following:

- One round of indoor air sampling 30 days after system installation
- Documentation of baseline system performance measurements (e.g., manometer, gauge, or other appropriate measurements), and
- Pressure field extension testing to demonstrate that a negative pressure differential exists between the sub-slab and indoor air.

Documentation of a sub-slab vacuum pressure differential in conjunction with visual inspection of the system may be used under certain conditions during the OMM phase of the project to confirm steady-state operational conditions and provide a line of evidence that the mitigation system continues to control vapor intrusion in lieu of continued indoor air testing. In general, this scenario would apply to buildings with minimal and consistent sub-slab exceedances and multiple rounds of indoor air testing to confirm operation.

4.2.3.2 SSDS Operation, Maintenance, and Monitoring (OMM)

Routine long-term OMM of the vapor mitigation system will be necessary for as long as the vapor intrusion pathway requires interruption. A project-specific OMM plan should be developed that specifies the requirements for, and frequency of, indoor air sampling and vapor mitigation system inspection based on building characteristics and the risk level specific to each building. Table 4-A (below) provides general guidance on appropriate inspection and sampling intervals. Conditions at any given building may lead to different decisions than the approaches described below. Generally, an OMM plan should include:

- Routine visual inspections of buildings to ensure that there are no significant changes such as remodeled areas or additions to the buildings;
- Routine visual inspections of vapor mitigation systems, in particular pressure gauges or manometers, to ensure that the system is functioning appropriately; and
- Periodic monitoring of indoor air on the lowest routinely occupied floor to ensure that indoor air concentrations are below remediation objectives and that vapor intrusion does not present a health risk.

Table 4-A: Inspection and Sampling Intervals

	Premitigation Indoor Air Concentration			
SGss or SGe concentration	Indoor air < published level	Published level < indoor air < 2x published level	2x published level < indoor air < 10x published level	Indoor air > 10x published level
SGss or SGe < published level	None anticipated	None anticipated	None anticipated	None anticipated
Published level < SGss or SGe < 2x published level	None anticipated	Schedule 1	Schedule 2	Schedule 2
2x published level < SGss or SGe < 10x published level	Schedule 1 OR conduct on-going sampling	Schedule 1	Schedule 2	Schedule 2
SGss or SGe > 10x published level	Schedule 2	Schedule 2	Schedule 2	Schedule 2

Table 4-B: Mitigation System Monitoring Schedule

Schedule 1	**Schedule 2**
Perform activities specified in Section 4.2.3.2, generally on an annual basis. Annual sampling of indoor air during winter worst case conditions during the first, second, and fifth year, and every fifth year thereafter.	Perform activities specified in Section 4.2.3.2, generally on an annual basis. Annual sampling of indoor air during winter worst case conditions during the first, second, and fourth year, and every other year thereafter.

Remedies may reduce release-related chemical concentrations to levels that no longer require vapor mitigation. If so, it may be possible to terminate operation of vapor intrusion mitigation systems. System termination sampling is based on the results of indoor air and SGss sampling. Prior to sampling for system termination, shut down the mitigation system for a period of at least 30 days to allow re-development of pre-mitigation subsurface conditions. Where possible, collect samples from the same locations initially used to evaluate vapor intrusion. Collect a round of paired samples during worst case conditions and compare the results to Table 3-A. Use the procedures in Table 3-A (typically one to two more rounds of sampling) to determine whether it is appropriate to terminate system operation or pursue some other course of action.

Upon system termination, some building owners may prefer to keep the system in place (e.g., for radon mitigation) instead of removing it. This is acceptable. Otherwise, arrangements should be made with the building owner to remove any equipment and/or monitoring devices associated with the mitigation system or long-term monitoring operations and perform repairs to the building resulting from system removal.

4.2.4 Implementation and Confirmation of Institutional Controls

See Appendices E and F for detailed guidance on this topic.

4.2.5 How IDEM Will Evaluate Remedy Implementation and Confirmation

Active remedies

- Does data show that representative concentrations or risk levels in each decision unit meet remediation objectives specified in the remediation work plan?
- If representative concentrations remain above unconditional remediation objectives, have additional remedies been implemented, and are they likely to adequately control risk?
- Are representative concentrations increasing or likely to increase in the future?

Engineered exposure controls

- Was the control implemented according to the approved plan? If not, were significant deviations from that plan explained and justified where necessary to show adequate control of risk?
- If demonstrating the effectiveness of the engineered exposure control requires sampling data (e.g., for a vapor mitigation system), was data submitted that shows adequate control of risk?
- Will the proposed OMM plan ensure long-term control of risk?
- Appropriate metrics specified?
- Is the control accompanied by an appropriate institutional control that ensures continued OMM of the control?
- Responsible party designated for OMM implementation?

Institutional controls

- See Appendices E and F.

Appendix A: Derivation of Published Levels

IC 13-25-8.5(d)(1) provides that responsible parties may use "levels of hazardous substances and petroleum calculated by the department using standard equations and default values for particular hazardous substances or petroleum" as remediation objectives. The Indiana Department of Environmental Management (IDEM) calculates one or more of such levels for more than 700 chemicals, and refers to those levels as published levels. This appendix describes the derivation of IDEM's published levels, which appear in Table A-5. Table A-5 levels are suitable for use as remediation objectives, and some of them are suitable for use during extent delineation activities. See Section 3.3 for guidance on applying published levels as remediation objectives, and Section 2.3 for guidance on using published levels during extents delineation.

A.1 General Approach

IDEM relies on the values found in the Regional Screening Level (RSL) tables (U.S. EPA, 2019e and subsequent updates) and guidance from the Regional Screening Level User's Guide (U.S. EPA, 2019f and subsequent updates) when deriving published levels. However, for reasons explained in this appendix, IDEM's published levels are not necessarily the same as those that appear in the RSL tables. Among other things, IDEM adjusts the target cancer risk for carcinogens from 10^{-6} to 10^{-5} when deriving published levels from the RSLs. Also, whereas U.S. EPA publishes RSL tables for noncancer hazard quotients of both 0.1 and 1, IDEM uses a target hazard quotient for noncarcinogenic risk of 1.

Although published levels can be used as remediation objectives, they do not necessarily have to be met in order to achieve closure. Published levels are simply one type of remediation objective. However, when adequate characterization of a release shows that representative concentrations in a decision unit are below unconditional remediation objectives (e.g., residential published levels, site-specific residential levels, or naturally occurring background levels), a remedy is not required per IC 13-25-5-8.5(c).

A.2 Revision Schedule

IDEM plans to revise its published levels yearly, using the procedures described herein. IDEM will base the revision for each year on the U.S. EPA Regional Screening Level (RSL) table that was in effect on the last day of the *preceding* year. All versions of IDEM's published levels will be available through links on the IDEM website. IDEM may also, at its discretion, publish one or more abbreviated tables that include a subset of the chemicals appearing in Table A-5, with an emphasis on those chemicals most likely to drive risk and remedy decisions.

A.3 Table Structure

Table A-5 has 17 columns. The first column contains the names of individual chemicals or chemical mixtures. Most chemical names are alphabetized, with numerical prefixes moved to the end of the chemical names. Polychlorinated biphenyls (PCBs) and dioxins are the exceptions; they appear under PCB: or Dioxin: respectively, followed by the chemical name. IDEM follows U.S. EPA nomenclature with respect to chemical names, and the IDEM published levels table makes no special attempt to include or cross-reference any of the myriad synonyms for chemical names. Instead, Chemical Abstract Service Registry Numbers (CASRNs) accompany each chemical name, and provide a unique identifier useful for reconciling chemical synonyms. CASRNs appear in the second column of Table A-5.

Each of the entries in the next 15 columns is a concentration suitable for evaluating risk or potential risk under a specific exposure scenario. There are six columns for soil direct contact exposure scenarios, one for groundwater direct contact exposure, two for indoor air direct contact exposure scenarios, and six for potential exposures arising from soil gas.

A.4 Derivation of Published Levels

The following subsections describe the procedures that IDEM uses to derive its published levels. All of the levels described below are published using a single significant digit and scientific notation.

A.4.1 Soil Direct Contact Levels

IDEM's published levels for soil direct contact assume exposure via ingestion, dermal contact, and inhalation of volatiles and particulates. Table A-5 contains soil direct contact levels for six different exposure scenarios. All of the soil direct contact levels described below are published in units of milligrams per kilogram (mg/kg). Note that IDEM caps some of its published levels for soil direct contact at either the soil saturation limit or the maximum cap, as described below. Except for excavation worker levels, IDEM does not publish soil direct contact levels for volatile chemicals, defined for this purpose as chemicals with a vapor pressure equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

The soil saturation limit (C_{sat}) is the concentration in soil at which a chemical exceeds the absorptive limits of the soil particles. Chemicals at concentrations above C_{sat} may be present as free phase product, and U.S. EPA (2019f) notes that the presence of free phase chemicals may violate assumptions underlying the RSL equations. IDEM intends exceedance of the soil saturation cap to prompt further evaluation of decision units that may contain free phase chemicals. IDEM uses C_{sat} values, when available from the RSL Summary Table, to cap published levels for soil direct contact.

U.S. EPA (2019f) notes that chemical concentrations greater than ten percent (100,000 mg/kg) may violate some RSL equation assumptions related to soil adherence and wind-borne dispersion. For this reason, IDEM caps published levels for soil direct contact at 100,000 mg/kg. Qualifiers next to published levels for soil direct contact indicate the following: C = carcinogenic endpoint; L = level capped at 100,000 milligrams per kilogram (mg/kg); N = noncarcinogenic endpoint; S = level capped at soil saturation limit.

A.4.1.1 Residential Soil Direct Contact Levels

The third column of Table A-5 contains levels for the residential soil direct contact exposure scenario. IDEM derives the levels from values appearing in the U.S. EPA RSL resident soil table as follows:

1. Multiply the carcinogenic screening level (if any) appearing in the RSL resident soil table by ten to produce a carcinogenic level at a target cancer risk of 10^{-5}. Multiply the resulting number by a factor of 1.4 to account for IDEM's exposure frequency assumption (250 days/year) versus the U.S. EPA default exposure frequency (350 days/year).
2. Select the lower of the following as the IDEM published level for residential soil direct contact:
   - The 10^{-5} carcinogenic level (if any) as derived in Step 1, above
   - The noncarcinogenic screening level (if any) appearing in the RSL resident soil table, multiplied by 1.4
   - The Csat value (if any) appearing in the RSL resident soil table
   - 100,000 mg/kg
3. Delete any residential soil direct contact levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

For the residential soil direct contact scenario, IDEM adopted U.S. EPA's residential screening level for lead. U.S. EPA considers this level protective of young children in a residential setting (U.S. EPA, 1994b). If U.S. EPA changes their residential screening level for lead, IDEM will adopt the new U.S. EPA level.

A.4.1.2 Commercial Soil Direct Contact Levels

The fourth column of Table A-5 contains levels for the commercial soil direct contact exposure scenario. IDEM derives the levels from values appearing in the U.S. EPA RSL Composite Worker Soil table as follows:

1. Multiply the carcinogenic screening level (if any) appearing in the RSL Composite Worker Soil table by ten to produce a carcinogenic level at a target cancer risk of 10^{-5}.
2. Select the lower of the following as the IDEM published level for commercial soil direct contact:
    - The 10^{-5} carcinogenic level (if any) as derived in Step 1, above.
    - The noncarcinogenic screening level (if any) appearing in the RSL Composite Worker Soil table (Hazard Quotient = 1)
    - The Csat value (if any) appearing in the RSL Composite Worker Soil table
    - 100,000 mg/kg
3. Delete any commercial soil direct contact levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

IDEM calculates lead screening levels for the commercial soil direct contact scenario using U.S. EPA's Adult Lead Model (U.S. EPA, 2003).

A.4.1.3 Excavation Worker Soil Direct Contact Levels

The fifth column of Table A-5 contains levels, expressed in mg/kg, for the excavation worker soil direct contact scenario. IDEM derives excavation worker soil direct contact levels using the industrial soil direct contact screening levels published in U.S. EPA's RSLs, adjusted for somewhat different exposure assumptions than those used by U.S. EPA. Table A-1 compares the different exposure assumptions that IDEM uses to derive excavation soil direct contact levels from commercial soil direct contact levels.

Table A-1: Exposure Assumptions

	Commercial	Excavation
Averaging time (years)	25 (non-cancer) 70 (carcinogen)	1 (non-cancer) 70 (carcinogen)
Exposure frequency (days/year)	250	45
Exposure duration (years)	25	1
Ingestion rate (milligrams/day)	100	330

Application of these parameter assumptions and the equations in Section 4.2 of U.S. EPA (2019f) yields the following relationships between levels for the excavation worker and commercial exposure scenarios.

Equation A-1: Ingestion of Noncarcinogens for the Excavation Worker Scenario

$$IL_{Exc-Ing-NC} = \left(\frac{500}{297}\right) IRSL_{CI-Ing-NC}$$

Where $IL_{Exc\text{-}Ing\text{-}NC}$ is an intermediate excavation worker level (used in Equation A-7, below) for the noncarcinogenic ingestion exposure pathway, and $IRSL_{CI\text{-}Ing\text{-}NC}$ is IDEM's intermediate level for commercial noncarcinogenic ingestion, which is the same as U.S. EPA's noncancer ingestion screening level from their Composite Worker Soil Table.

Equation A-2: Dermal Contact with Noncarcinogens for the Excavation Worker Scenario

$$IL_{Exc-Der-NC} = \left(\frac{50}{9}\right) IRSL_{CI-Der-NC}$$

Where $IL_{Exc\text{-}Der\text{-}NC}$ is an intermediate excavation worker level (used in Equation A-7, below) for the noncarcinogenic dermal exposure pathway, and $IRSL_{CI\text{-}Der\text{-}NC}$ is IDEM's intermediate level for commercial noncarcinogenic dermal contact, which is the same as U.S. EPA's noncancer dermal screening level from their Composite Worker Soil Table.

Equation A-3: Inhalation of Noncarcinogens for the Excavation Worker Scenario

$$IL_{Exc-Inh-NC} = \left(\frac{50}{9}\right) IRSL_{CI-Inh-NC}$$

Where $IL_{Exc\text{-}Inh\text{-}NC}$ is an intermediate excavation worker level (used in Equation A-7, below) for the noncarcinogenic inhalation exposure pathway, and $IRSL_{CI\text{-}Inh\text{-}NC}$ is IDEM's intermediate level for commercial noncarcinogenic inhalation, which is the same as U.S. EPA's noncancer inhalation screening level from their Composite Worker Soil Table.

Equation A-4: Ingestion of Carcinogens for the Excavation Worker Scenario

$$IL_{Exc-Ing-Carc} = \left(\frac{12{,}500}{297}\right) IRSL_{CI-Ing-Carc}$$

Where $IL_{Exc\text{-}Ing\text{-}Carc}$ is an intermediate excavation worker level (used in Equation A-8, below) for the carcinogenic ingestion exposure pathway, and $IRSL_{CI\text{-}Ing\text{-}Carc}$ is IDEM's intermediate level for commercial carcinogenic ingestion, which is ten times U.S. EPA's carcinogenic ingestion screening level from their Composite Worker Soil Table.

Equation A-5: Dermal Contact with Carcinogens for the Excavation Worker Scenario

$$IL_{Exc-Der-Carc} = \left(\frac{1{,}250}{9}\right) IRSL_{CI-Der-Carc}$$

Where $IL_{Exc\text{-}Der\text{-}Carc}$ is an intermediate excavation worker level (used in Equation A-8, below) for the carcinogenic dermal contact exposure pathway, and $IRSL_{CI\text{-}Der\text{-}Carc}$ is IDEM's intermediate level for commercial carcinogenic dermal exposure, which is ten times U.S. EPA's carcinogenic dermal screening level from their Composite Worker Soil Table.

Equation A-6: Inhalation of Carcinogens for the Excavation Worker Scenario

$$IL_{Exc-Inh-Carc} = \left(\frac{1{,}250}{9}\right) IRSL_{CI-Inh-Carc}$$

Where $IL_{Exc\text{-}Inh\text{-}Carc}$ is an intermediate excavation worker level (used in Equation A-8, below) for the carcinogenic inhalation exposure pathway, and $IRSL_{CI\text{-}Inh\text{-}Carc}$ is IDEM's intermediate level for commercial carcinogenic inhalation exposure, which is ten times U.S. EPA's carcinogenic inhalation screening level from their Composite Worker Soil Table.

Equation A-7: Noncarcinogenic Level for the Excavation Worker Scenario

$$IL_{Exc-NC} = \frac{1}{\left(\frac{1}{IL_{Exc-Ing-NC}}\right) + \left(\frac{1}{IL_{Exc-Der-NC}}\right) + \left(\frac{1}{IL_{Exc-Inh-NC}}\right)}$$

Where the value of any quotient in parentheses is set to zero when its denominator is zero.

Equation A-8: Carcinogenic Level for the Excavation Worker Scenario

$$IL_{Exc-Carc} = \frac{1}{\left(\frac{1}{IL_{Exc-Ing-Carc}}\right) + \left(\frac{1}{IL_{Exc-Der-Carc}}\right) + \left(\frac{1}{IL_{Exc-Inh-Carc}}\right)}$$

Where the value of any quotient in parentheses is set to zero when its denominator is zero.

IDEM selects the lower of the noncarcinogenic level (Equation A-7), carcinogenic level (Equation A-8), Csat, and 100,000 mg/kg as the IDEM published level for the excavation worker scenario. IDEM calculates lead screening levels for the excavation worker scenario using U.S. EPA's Adult Lead Model (U.S. EPA, 2003).

Note that this approach uses the chronic toxicity parameter values employed in the derivation of IDEM's published levels for commercial soil direct contact. Where available, subchronic toxicity parameter values may be more appropriate when deriving levels for the excavation worker soil direct contact scenario.

A.4.1.4 Recreational Soil Direct Contact Levels – Community Park

The sixth column of Table A-5 contains levels for the recreational soil direct contact (community park) exposure scenario. IDEM calculates published levels for the recreational soil direct contact (community park) exposure scenario using the Recreator scenario module found in U.S. EPA's RSL Calculator, and the user-specified parameter values found in Table A-2 below. IDEM does not publish recreational soil direct contact (community park) levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

Table A-2: Recommended Exposure Parameter Inputs for the Community Park Scenario

Age Segment (yr)	Adherence Factor[a] (AF) (mg/cm^2)	Body Weight[b] (BW) (kg)	Exposure Duration (ED) (yr)	Exposure Frequency[c] (EF) (day/yr)	Exposure Time[d] (ET) (hr/event)	Intake Rate[c] (IRS) (mg/day)	Skin Surface Area[c] (SA) (cm^2/day)
0 thru 2	0.2	15	2	75	2	100	2,600
2 thru 6	0.2	15	4	75	2	100	2,900
6-16	0.2[c]	80	10	104	2	100	5,000
16-26	0.07	80	10	75	2	50	5,700

Hazard Quotient	1
Target Cancer Risk	10^{-5}
Climatic Zone	Chicago
Fraction of vegetative cover	0.8

Parameter value sources:

[a]U.S. EPA (2004, Exhibit 3-3)

[b]U.S. EPA (2011, Table 8-1)

[c]IDEM (2011, Best professional judgment)

[d]U.S. EPA (2011, Table 5-1)

[e]U.S. EPA (2004, Exhibit C-1)

A.4.1.5 Recreational Soil Direct Contact Levels – Playing Field

The seventh column of Table A-5 contains levels for the recreational soil direct contact (playing field) exposure scenario. IDEM calculates published levels for the recreational soil direct contact (playing field) exposure scenario using the Recreator scenario module found in U.S. EPA's RSL Calculator, and the user-specified parameter values found in Table A-3 below. IDEM does not publish recreational soil direct contact (playing field) levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table. Note that this scenario assumes an exposure frequency of thirty days. At some high-use sports fields it may be necessary to evaluate whether this assumption is reasonable. If a higher frequency is appropriate, then adjust the exposure frequency values in the table below accordingly.

Table A-3: Recommended Exposure Parameter Inputs for the Playing Field Scenario

Age Segment (yr)	Adherence Factor[a,c] (AF) (mg/cm^2)	Body Weight[b] (BW) (kg)	Exposure Duration (ED) (yr)	Exposure Frequency[c] (EF) (day/yr)	Exposure Time[d] (ET) (hr/event)	Intake Rate[c] (IRS) (mg/day)	Skin Surface Area[c] (SA) (cm^2/day)
0 thru 2	0.12	15	2	30	2	100	2,600
2 thru 6	0.12	15	4	30	2	100	2,900
6-16	0.12	80	10	30	3	100	5,000
16-26	0.07	80	10	30	2	50	5,700

Hazard Quotient	1
Target Cancer Risk	10^{-5}
Climatic Zone	Chicago
Fraction of vegetative cover	0.8

Parameter value sources:

[a]U.S. EPA (2004, Exhibit 3-3)

[b]U.S. EPA (2011, Table 8-1)

[c]IDEM (2011, Best professional judgment)

[d]U.S. EPA (2011, Table 5-1)

[e]U.S. EPA (2004, Exhibit C-1)

A.4.1.6 Recreational Soil Direct Contact Levels - Trail

The eighth column of Table A-5 contains levels for the recreational soil direct contact (trail) exposure scenario. IDEM calculates published levels for the recreational soil direct contact (trail) exposure scenario using the recreator scenario module found in U.S. EPA's RSL Calculator, and the user-specified parameter values found in Table A-4 below. IDEM does not publish recreational soil direct contact (trail) levels for chemicals with a vapor pressure listed as equal to or greater than one millimeter of mercury in the RSL Chemical-specific Parameters Supporting Table.

Table A-4: Recommended Exposure Parameter Inputs for the Trail Scenario

Age Segment (yr)	Adherence Factor[a] (AF) (mg/cm^2)	Body Weight[b] (BW) (kg)	Exposure Duration (ED) (yr)	Exposure Frequency[c] (EF) (day/yr)	Exposure Time[d] (ET) (hr/event)	Intake Rate[c] (IRS) (mg/day)	Skin Surface Area[c,e] (SA) (cm^2/day)
0 thru 2	0.04	15	2	75	1	6	2,600
2 thru 6	0.04	15	4	75	1	6	2,900
6-16	0.04	80	10	104	1	6	5,000
16-26	0.04	80	10	75	1	3	5,700

Hazard Quotient	1
Target Cancer Risk	10^{-5}
Climatic Zone	Chicago
Fraction of vegetative cover	0.99

Parameter value sources:

[a]U.S. EPA (2004, Exhibit 3-3)

[b]U.S. EPA (2011, Table 8-1)

[c]IDEM (2011, Best professional judgment)

[d]Wolter, *et. al.* (2001).

[e]U.S. EPA (2004, Exhibit C-1)

A.4.2 Groundwater Direct Contact Levels

Column nine of Table A-5 contains levels for the residential groundwater direct contact exposure scenario, expressed in micrograms per liter (µg/l). Residential groundwater direct contact levels account for exposures through ingestion of water, dermal contact with water, and inhalation of volatile chemicals arising from groundwater, as reasonably likely to occur in a home. Consistent with U.S. EPA, IDEM does not publish levels for any of the many possible commercial groundwater direct contact exposure scenarios.

For chemicals that have a maximum contaminant level (MCL) established under the Safe Drinking Water Act, IDEM uses the MCL as the published level for residential groundwater direct contact. For chemicals without MCLs, IDEM derives published levels for residential groundwater direct contact from values that appear in the U.S. EPA RSL Resident Tapwater Table as follows:

1. Multiply the value (if any) appearing in the carcinogenic screening level column of the RSL Resident Tapwater Table by ten to produce a carcinogenic screening level at a target cancer risk of 10^{-5}.
2. Select the lower of the 10^{-5} carcinogenic screening level derived above (if any) and the value (if any) appearing in the noncarcinogenic screening level column of the RSL Resident Tapwater Table as the IDEM published level for residential groundwater direct contact.

Qualifiers next to published levels for groundwater indicate the following: C = carcinogenic endpoint; M = level set to maximum contaminant level established under the Safe Drinking Water Act; N = noncarcinogenic endpoint.

A.4.3 Indoor Air Direct Contact Levels

IDEM calculates and publishes levels for two different indoor air direct contact scenarios - residential indoor air and commercial indoor air, expressed in micrograms per cubic meter (µg/m^3). IDEM's published levels for indoor air direct contact assume exposure via inhalation of volatile chemicals. IDEM does not publish indoor air direct contact levels for nonvolatile chemicals. Qualifiers next to published levels for indoor air indicate the following: C = carcinogenic endpoint; N = noncarcinogenic endpoint.

A.4.3.1 Residential Indoor Air Direct Contact Levels

Column ten of Table A-5 contains levels for the residential indoor air direct contact exposure scenario. IDEM derives these levels from values appearing in the U.S. EPA RSL Resident Air Table as follows:

1. Multiply the value (if any) appearing in the carcinogenic screening level column of the RSL Resident Air Table by ten to produce a residential indoor air carcinogenic screening level at a target cancer risk of 10^{-5}.
2. Select the lower of the 10^{-5} carcinogenic screening level (if any) as calculated above and the value (if any) appearing in the noncarcinogenic screening level column of the RSL Resident Air Table as the IDEM published level for residential indoor air direct contact.
3. Delete residential indoor air direct contact levels for chemicals with vapor pressures listed as less than 1 millimeter of mercury in the U.S. EPA RSL Chemical-specific Parameters Supporting Table.

IDEM does not include residential indoor air action levels in the published levels table. However, they may be calculated by multiplying the published level for residential indoor air direct contact by ten.

A.4.3.2 Commercial Indoor Air Direct Contact Levels

Column eleven of Table A-5 contains levels for the commercial indoor air direct contact exposure scenario. IDEM derives these levels from values appearing in the U.S. EPA RSL Composite Worker Air Table as follows:

1. Multiply the value (if any) appearing in the carcinogenic screening level column of the RSL Composite Worker Air Table by ten to produce a commercial indoor air carcinogenic screening level at a target cancer risk of 10^{-5}.
2. Select the lower of the 10^{-5} carcinogenic screening level (if any) as calculated above and the value (if any) appearing in the noncarcinogenic screening level column of the RSL Composite Worker Air Table as the IDEM published level for commercial indoor air direct contact.
3. Delete commercial indoor air direct contact levels for chemicals with vapor pressures listed as less than 1 millimeter of mercury in the U.S. EPA RSL Chemical-specific Parameters Supporting Table.

IDEM does not include commercial indoor air action levels in the published levels table. However, they are easily calculated by multiplying the published level for commercial indoor air direct contact by ten.

A.4.4 Soil Gas Levels

IDEM publishes six different types of soil gas levels, all expressed in micrograms per cubic meter (μg/m^3). IDEM derives these levels by dividing an indoor air level by an appropriate attenuation factor, as described below. Qualifiers next to published levels for soil gas indicate the following: C = carcinogenic endpoint; N = noncarcinogenic endpoint.

A.4.4.1 Residential: Subslab/Deep Exterior Soil Gas/Conduit Vapor

Column twelve of Table A-5 contains levels for residential subslab, deep exterior soil gas, and/or residential conduit vapor. IDEM derives these levels by dividing the published level for residential indoor air by an attenuation factor of 0.03.

A.4.4.2 Commercial: Subslab/Deep Exterior Soil Gas/Conduit Vapor

Column thirteen of Table A-5 contains levels for commercial subslab, deep exterior soil gas, and/or commercial conduit vapor. IDEM derives these levels by dividing the published level for commercial indoor air by an attenuation factor of 0.03.

A.4.4.3 Large Commercial: Subslab/Deep Exterior Soil Gas/Conduit Vapor

Column fourteen of Table A-5 contains levels suitable for use with large commercial subslab, deep exterior soil gas, and/or conduit vapor results. IDEM derives them by dividing the published levels for commercial indoor air by an attenuation factor of 0.003. See Section 3.3.4 for lines of evidence that support a large commercial structure designation.

A.4.4.4 Residential: Shallow Exterior/Utility Corridor Soil Gas

Column fifteen of Table A-5 contains levels for residential shallow exterior and/or utility corridor soil gas. IDEM derives these levels by dividing the published level for residential indoor air by an attenuation factor of 0.1.

A.4.4.5 Commercial: Shallow Exterior/Utility Corridor Soil Gas

Column sixteen of Table A-5 contains levels for commercial shallow exterior and/or utility corridor soil gas. IDEM derives these levels by dividing the published level for commercial indoor air by an attenuation factor of 0.1.

A.4.4.6 Large Commercial: Shallow Exterior/Utility Corridor Soil Gas

Column seventeen of Table A-5 contains levels suitable for use with shallow exterior and/or utility corridor soil gas results obtained beneath or near commercial structures that qualify as large. IDEM derives them by dividing the published levels for commercial indoor air by an attenuation factor of 0.01. See Section 3.3.4 for lines of evidence that support a large commercial structure designation.

NOTE: The table on the following page is for illustrative purposes only. IDEM does not intend to reduce the number of chemicals for which it publishes levels.

Table A-5: 20XX IDEM OLQ Human Health Levels	Medium >	SOIL						GROUNDWATER	INDOOR AIR		SOIL GAS OR CONDUIT VAPOR					
	Type >	Direct Contact - Long Term		Direct Contact - Short Term				Direct Contact	Direct Contact - Long Term		Subslab/Deep Exterior/Conduit			Shallow Exterior		
	Land Use >	Res	Com	Exc	Rec-CP	Rec-PF	Rec-Trail	Res	Res	Com	Res	Com	Large Com	Res	Com	Large Com
	Units/Q >	mg/kg Q	mg/kg Q	mg/kg Q	mg/kg Q	mg/kg Q	mg/kg Q	ug/L Q	ug/m3 Q	ug/m3 Q	ug/m3 Q	ug/m3 Q	ug/m3 Q	ug/m3 Q	ug/m3 Q	ug/m3 Q
Anthracene	120-12-7	3.E+04 N	1.E+05 L	1.E+05 L	TBD	TBD	TBD	2.E+03 N								
Arsenic, Inorganic	7440-38-2	1.E+01 C	3.E+01 C	9.E+02 N	TBD	TBD	TBD	1.E+01 M								
Barium	7440-39-3	2.E+04 N	1.E+05 L	1.E+05 L	TBD	TBD	TBD	2.E+03 M								
Benzene	71-43-2			2.E+03 S				5.E+00 M	4.E+00 C	2.E+01 C	1.E+02 C	5.E+02 C	5.E+03 C	4.E+01 C	2.E+02 C	2.E+03 C
Benzo[a]pyrene	50-32-8	2.E+00 C	2.E+01 C	5.E+02 N	TBD	TBD	TBD	2.E-01 M								
Beryllium and compounds	7440-41-7	2.E+02 N	2.E+03 N	4.E+03 N	TBD	TBD	TBD	4.E+00 M								
Carbon Tetrachloride	56-23-5			5.E+02 S				5.E+00 M	5.E+00 C	2.E+01 C	2.E+02 C	7.E+02 C	7.E+03 C	5.E+01 C	2.E+02 C	2.E+03 C
Chloroform	67-66-3			2.E+03 C				8.E+01 M	1.E+00 C	5.E+00 C	4.E+01 C	2.E+02 C	2.E+03 C	1.E+01 C	5.E+01 C	5.E+02 C
Chromium(VI)	18540-29-9	4.E+00 C	6.E+01 C	3.E+03 C	TBD	TBD	TBD	4.E-01 C								
Cyanide (CN-)	57-12-5			6.E+02 N				2.E+02 M	8.E-01 N	4.E+00 N	3.E+01 N	1.E+02 N	1.E+03 N	8.E+00 N	4.E+01 N	4.E+02 N
DDT	50-29-3	3.E+01 C	9.E+01 C	9.E+02 N	TBD	TBD	TBD	2.E+00 C								
Dibromoethane, 1,2-	106-93-4			2.E+02 C				5.E-02 M	5.E-02 C	2.E-01 C	2.E+00 C	7.E+00 C	7.E+01 C	5.E-01 C	2.E+00 C	2.E+01 C
Dichlorobenzene, 1,4-	106-46-7			2.E+04 C				8.E+01 M	3.E+00 C	1.E+01 C	9.E+01 C	4.E+02 C	4.E+03 C	3.E+01 C	1.E+02 C	1.E+03 C
Dichloroethane, 1,1-	75-34-3			2.E+03 S				3.E+01 C	2.E+01 C	8.E+01 C	6.E+02 C	3.E+03 C	3.E+04 C	2.E+02 C	8.E+02 C	8.E+03 C
Dichloroethane, 1,2-	107-06-2			7.E+02 N				5.E+00 M	1.E+00 C	5.E+00 C	4.E+01 C	2.E+02 C	2.E+03 C	1.E+01 C	5.E+01 C	5.E+02 C
Dichloroethylene, 1,1-	75-35-4			1.E+03 S				7.E+00 M	2.E+02 N	9.E+02 N	7.E+03 N	3.E+04 N	3.E+05 N	2.E+03 N	9.E+03 N	9.E+04 N
Dichloroethylene, 1,2-cis-	156-59-2			2.E+03 S				7.E+01 M								
Dichloroethylene, 1,2-trans-	156-60-5			2.E+03 S				1.E+02 M								
Dioxane, 1,4-	123-91-1			1.E+04 C				5.E+00 C	6.E+00 C	3.E+01 C	2.E+02 C	8.E+02 C	8.E+03 C	6.E+01 C	3.E+02 C	3.E+03 C
Dioxins: TCDD, 2,3,7,8-	1746-01-6	7.E-05 C	2.E-04 C	1.E-03 N	TBD	TBD	TBD	3.E-05 M								
Ethylbenzene	100-41-4			5.E+02 S				7.E+02 M	1.E+01 C	5.E+01 C	4.E+02 C	2.E+03 C	2.E+04 C	1.E+02 C	5.E+02 C	5.E+03 C
Fluoranthene	206-44-0	3.E+03 N	3.E+04 N	7.E+04 N	TBD	TBD	TBD	8.E+02 N								
Formaldehyde	50-00-0			2.E+04 N				4.E+00 C	2.E+00 C	9.E+00 C	7.E+01 C	3.E+02 C	3.E+03 C	2.E+01 C	9.E+01 C	9.E+02 C
Lead and Compounds	7439-92-1	4.E+02	8.E+02	1.E+03	TBD	TBD	TBD	2.E+01 M								
Mercury (elemental)	7439-97-6	3.E+00 S	3.E+00 S	3.E+00 S	TBD	TBD	TBD	2.E+00 M								
Methyl Ethyl Ketone (2-Butanone)	78-93-3			3.E+04 S				6.E+03 N	5.E+03 N	2.E+04 N	2.E+05 N	7.E+05 N	7.E+06 N	5.E+04 N	2.E+05 N	2.E+06 N
Methyl tert-Butyl Ether (MTBE)	1634-04-4			9.E+03 S				1.E+02 C	1.E+02 C	5.E+02 C	4.E+03 C	2.E+04 C	2.E+05 C	1.E+03 C	5.E+03 C	5.E+04 C
Methylene Chloride	75-09-2			3.E+03 S				5.E+00 M	6.E+02 N	3.E+03 N	2.E+04 N	9.E+04 N	9.E+05 N	6.E+03 N	3.E+04 N	3.E+05 N
Methylnaphthalene, 1-	90-12-0	3.E+02 C	4.E+02 S	4.E+02 S	TBD	TBD	TBD	1.E+01 C								
Naphthalene	91-20-3	5.E+01 C	2.E+02 C	3.E+03 N	TBD	TBD	TBD	2.E+00 C								
PCBs: High risk	1336-36-3	3.E+00 C	9.E+00 C	6.E+02 C	TBD	TBD	TBD	5.E-01 M								
PCBs: Low risk	1336-36-3							5.E-01 M								
PCBs: Lowest risk	1336-36-3							5.E-01 M								
Pentachlorophenol	87-86-5	1.E+01 C	4.E+01 C	3.E+03 C	TBD	TBD	TBD	1.E+00 M								
Tetrachloroethylene	127-18-4			2.E+02 S				5.E+00 M	4.E+01 N	2.E+02 N	1.E+03 N	6.E+03 N	6.E+04 N	4.E+02 N	2.E+03 N	2.E+04 N
Toluene	108-88-3			8.E+02 S				1.E+03 M	5.E+03 N	2.E+04 N	2.E+05 N	7.E+05 N	7.E+06 N	5.E+04 N	2.E+05 N	2.E+06 N
Trichloroethane, 1,1,1-	71-55-6			6.E+02 S				2.E+02 M	5.E+03 N	2.E+04 N	2.E+05 N	7.E+05 N	7.E+06 N	5.E+04 N	2.E+05 N	2.E+06 N
Trichloroethane, 1,1,2-	79-00-5			4.E+01 N				5.E+00 M	2.E-01 N	9.E-01 N	7.E+00 N	3.E+01 N	3.E+02 N	2.E+00 N	9.E+00 N	9.E+01 N
Trichloroethylene	79-01-6			1.E+02 N				5.E+00 M	2.E+00 N	9.E+00 N	7.E+01 N	3.E+02 N	3.E+03 N	2.E+01 N	9.E+01 N	9.E+02 N
Trimethylbenzene, 1,2,3-	526-73-8			3.E+02 S				6.E+01 N	6.E+01 N	3.E+02 N	2.E+03 N	9.E+03 N	9.E+04 N	6.E+02 N	3.E+03 N	3.E+04 N
Trimethylbenzene, 1,2,4-	95-63-6			2.E+02 S				6.E+01 N	6.E+01 N	3.E+02 N	2.E+03 N	9.E+03 N	9.E+04 N	6.E+02 N	3.E+03 N	3.E+04 N
Trimethylbenzene, 1,3,5-	108-67-8			2.E+02 S				6.E+01 N	6.E+01 N	3.E+02 N	2.E+03 N	9.E+03 N	9.E+04 N	6.E+02 N	3.E+03 N	3.E+04 N
Vinyl Chloride	75-01-4			1.E+03 C				2.E+00 M	2.E+00 C	3.E+01 C	6.E+01 C	9.E+02 C	9.E+03 C	2.E+01 C	3.E+02 C	3.E+03 C
Xylenes	1330-20-7			3.E+02 S				1.E+04 M	1.E+02 N	4.E+02 N	3.E+03 N	1.E+04 N	1.E+05 N	1.E+03 N	4.E+03 N	4.E+04 N
Zinc and Compounds	7440-66-6	3.E+04 N	1.E+05 L	1.E+05 L	TBD	TBD	TBD	6.E+03 N								

Abbreviations: C = cancer; Com = commercial; CP = community park; DC = direct contact; Exc = excavation; L = Capped at 100,000 mg/kg; M = MCL; mg/kg = milligrams/kilogram; N = noncancer; PF = playing field; Q = qualifier; Rec = recreational; Res = residential; S = soil saturation limit

Appendix B: Background

IC 13-25-5-8.5 defines "background levels of hazardous substances and petroleum that occur naturally on the site" as acceptable remediation objectives. For this reason, IDEM does not anticipate requiring a responsible party to implement a remedy to address risks arising from naturally occurring concentrations of chemicals, even if those concentrations exceed IDEM's published levels.

This appendix provides examples of procedures for deciding whether observed concentrations of chemicals in soil, groundwater, or vapor are attributable to naturally occurring background. Essentially, the procedures described herein compare chemical concentrations found within an area potentially affected by a release to those found in a similar area that is not affected by a release. Comparison of observed concentrations between the areas usually indicates whether or not a release has occurred.

There are many possible approaches to naturally-occurring background evaluations. All of them rely critically on an adequate understanding of the area under evaluation, as reflected in a CSM. IDEM will evaluate each background demonstration on its merits, and for consistency with U.S. EPA guidance (U.S. EPA, 2002e). However, most projects will not require a background or off-site source demonstration. In other cases, it may be possible to rely, at least in part, on pre-existing studies. IDEM recognizes and will give consideration to regional (IDEM 2014, 2017d) or state-wide background studies (Smith et al., 2014). IDEM will evaluate proposals to use data from such studies on a project-specific basis.

B.1 General Approach

The remainder of this appendix is broken into several subsections:

- Soil background, including terminology, sampling considerations, and outlier testing
- Evaluating soil background using judgmentally-collected samples
- Evaluating soil background using systematically-collected samples
- Evaluating soil background using small sample sets
- Evaluating groundwater background
- Evaluating vapor background
- What IDEM will look for when evaluating background demonstrations

B.2 Background Levels in Soil

The basic procedure for background evaluation in soils involves collecting samples from each of two different separate areas and comparing the sample results to see if they differ significantly. The first sample set should come from a background reference area. The second sample set should come from a decision unit (Section 3.1).

B.2.1 Soil Background Reference Areas

Soil background reference areas should have physical, chemical, and geological characteristics similar to the decision unit, but have virtually no impacts from the decision unit. IDEM recommends using background reference areas as close as practicable to the decision unit. However, it may be difficult to find a suitable background reference area near some decision units. In some cases a non-impacted area within a decision unit may be suitable as a background reference area. Because selection of a background reference area is a matter of professional judgment, responsible parties may wish to obtain concurrence on appropriate sampling locations from IDEM staff before collecting background samples.

It is not appropriate to bias the background data by sampling locations suspected to have high concentrations of release-related chemicals. The following may not be suitable as background reference areas:

- Areas where hazardous substances, petroleum, solid or hazardous waste or waste waters are known or suspected to have been managed, treated, handled, stored, or disposed.
- Areas affected by roadways or parking lot runoff or road spray when evaluating chemicals associated with motor vehicles.
- Railroad tracks, right-of-ways, or other areas affected by their runoff when evaluating chemicals associated with railroads and right-of-way maintenance.
- Storm drains or ditches presently or historically receiving industrial or urban runoff.
- Fill areas, unless the decision unit under investigation is on similar fill, or IDEM agrees that the fill area is a valid background reference area.[49]

B.2.2 Soil Background Threshold Values

Sample results from background reference areas are used to calculate a background threshold value (BTV). The BTV is in turn compared against sample data from the decision unit. Appropriate approaches vary depending on soil sampling methodology and the number of samples collected. IDEM also recognizes that other approaches may be acceptable or even preferable, and will evaluate alternative approaches on their merits.

Singh and Maichle (2015) and IDEM recommend a minimum of ten background samples when determining a BTV. More than ten samples may be necessary to calculate a BTV when the laboratory reporting limit is equal to the remediation objective. Investigators should document that the number of samples is adequate to support the selected method in these cases by evaluating the ratio of the minimum detectable difference to an estimate of the standard deviation of the distribution of the concentrations at the decision unit (U.S.EPA 2002). Because the data evaluation process sometimes reduces the size of the set of background samples, it may be prudent to collect extra samples during the initial sampling effort.[50] Conversely, IDEM recognizes that there are instances in which it is impracticable to collect ten or more samples. Section B.2.6 provides guidance for those circumstances.

B.2.3 Soil Outliers

U.S. EPA (2006b) contains guidance on identifying potential outliers, including selection and application of specific statistical tests for that purpose. The details of those procedures are beyond the scope of this document. Instead an abbreviated outline of appropriate procedures follows, illustrated in Figure B-1.

Attempts to identify outliers should always bear in mind that sample results that appear to be outliers may actually represent extreme values of a distribution. For this reason, it is not appropriate to rely solely on graphical and statistical tests to identify outliers. Any decision to drop sample results from a data set "…should be based on judgmental or scientific grounds" (U.S. EPA, 2006b, page 115), such as transcription errors or measurement system errors.

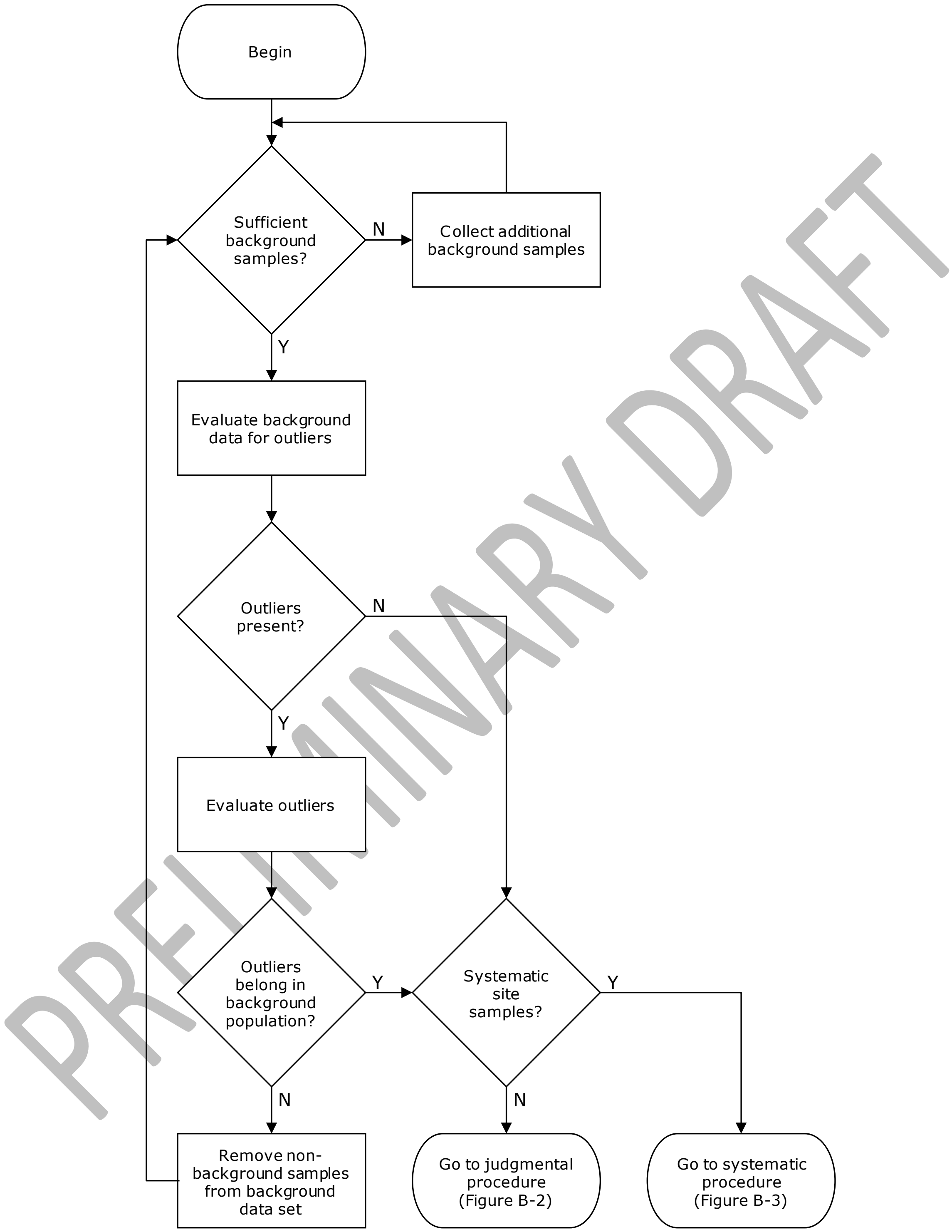
Abbreviated Procedure

[49] Fill in this context refers only to clean fill or fill that is excluded from the requirements of the solid or hazardous waste management regulations. Waste fill is subject to rule and is beyond the scope of this guidance.

[50] Sometimes it is possible for the laboratory to hold samples for future analysis, subject to need and method holding times.

1. *Collect a sufficient number of samples from an appropriate background reference area.* Most of the procedures in this guidance call for at least ten samples, though Section B.2.6 describes a procedure for smaller sample sets. Potential issues that could reduce the number of data points include sample collection, handling, and analysis issues; the presence of outliers, or an excessive number of non-detect samples. If the number of data points is insufficient, collect additional samples. Note that in some cases it may be possible to submit more than the needed number of samples to the laboratory and ask that some of them be held pending evaluation of the first set of results.
2. *Screen background sample results for potential outliers.* IDEM recommends using graphical methods for this purpose. Q-Q plots or box-and-whisker plots are often suitable. See U.S. EPA (2006b) for specifics on the construction and interpretation of these plots.
3. *Perform formal outlier tests on any identified potential outliers.* If the background reference area data set contains potential outliers, perform the Dixon Test (U.S. EPA, 2006b) for data sets containing 25 or fewer samples, and Rosner's Test for data sets containing more than 25 samples.
4. *Decide whether outliers identified in step three above belong in the background population.* As noted in the second paragraph of this section, any decision to drop an identified outlier should be based on judgmental and scientific grounds, not merely because of the result of a statistical test.
5. If identified outliers are dropped from the background data set, return to step one above. If identified outliers belong in the background data set, or if there are no outliers present, go to the procedure described in Section B.2.4 for judgmentally collected background reference area samples, and Section B.2.5 for systematically collected background reference area samples.

Figure B-1: Outlier Evaluation



B.2.4 Background Threshold Values Using Judgmental Soil Samples

Figure B-2 illustrates an example procedure for comparing a judgmentally-collected background data set to decision unit sample results. Under this approach, the BTV is the 90th percentile value, calculated from a set of at least ten background data points, *after addressing outliers* (Section B.2.3). Comparison of the BTV with decision unit data will lead to different conclusions, depending primarily on which concentrations are greater.

<u>Procedure</u>

1. *Calculate the 90th percentile BTV of the background data set.*
   a. Multiply the number of data points by 0.9 to find the position of the 90th percentile.

      Example: 12 data points X 0.9 = 10.8 (position of the 90th percentile)

   b. Arrange the individual data points in ascending order of their concentration values

      Example: 2, 5, 7, 12, 14, 16, 20, 23, 25, 27, 29, 32

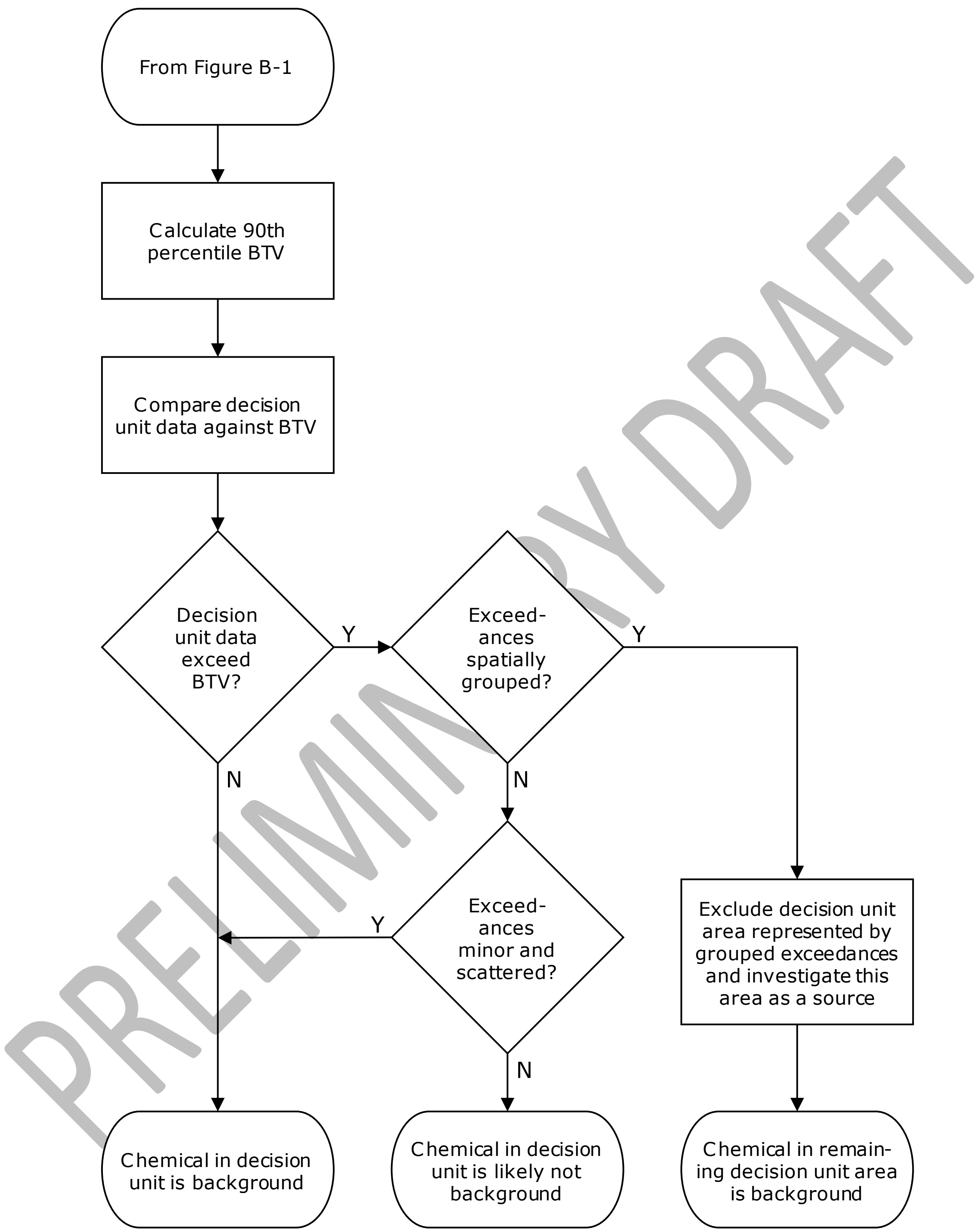
   c. Calculate the concentration corresponding to the 10.8th position as the value of the 10th position plus 80% of the difference between the 10th and 11th values.

      Example: 27 + 0.8 X (29-27) = 27 + 0.8 X (2) = 27 + 1.6 = 28.6 ~ 29

2. *Compare the BTV to each decision unit sample concentration.*
   a. If decision unit sample concentrations are no greater than the BTV, the decision unit concentrations are background.
   b. If decision unit sample concentrations include only scattered, minor, and non-spatially grouped exceedances of the BTV, then the decision unit concentrations may be background.
   c. If decision unit sample concentrations include spatially grouped exceedances, treat the area defined by those exceedances as a potential source area, and characterize it accordingly. That portion of the decision unit that does not exceed the BTV can be regarded as background.
   d. If decision unit sample concentrations exceed the BTV, concentrations in the decision unit are likely not background.

IDEM will evaluate alternative approaches consistent with U.S. EPA (2002e) and Singh and Maichle (2015).

Figure B-2: Background Threshold Values Using Judgmental Sampling



B.2.5 Background Threshold Values Using Systematic Soil Samples

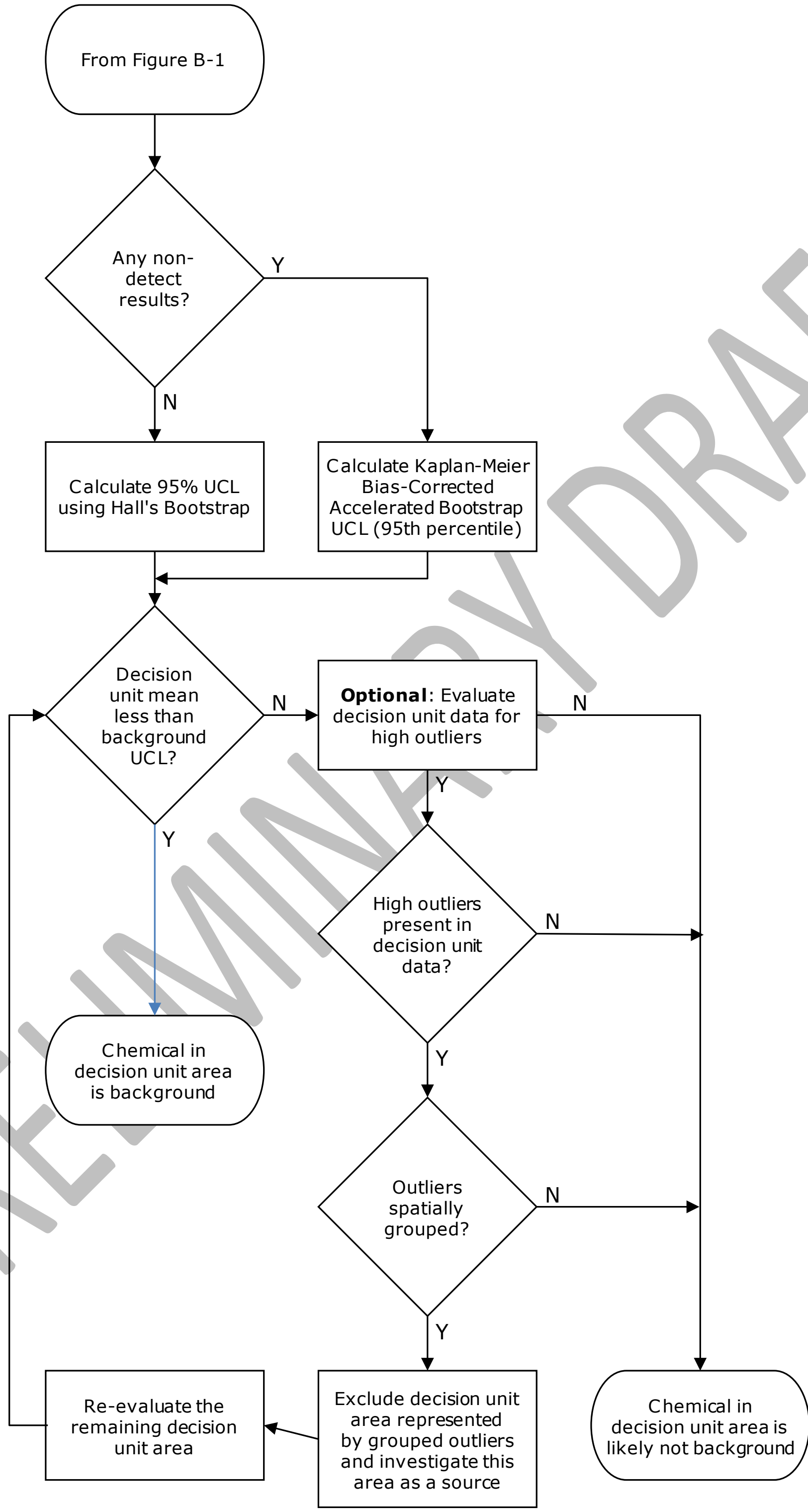
U.S. EPA's ProUCL software includes background comparison tools that are useful for comparing decision unit samples to systematically-collected background samples. ProUCL applies several methodologies to each analysis and then recommends an appropriate statistic depending on the characteristics of the data. Alternatively, the rest of Subsection B.2.5 describes an example procedure for comparing a systematically-collected background data set to decision unit samples. Figure B-3 illustrates the procedure, which follows the outlier procedures described in Section B.2.3.

Procedure

1. For background data sets with non-detect values, calculate the 95th percentile Kaplan-Meier Bias-Corrected Accelerated Bootstrap UCL using 10,000 bootstrap operations, and use the resulting UCL as the BTV. For background data sets without non-detect values, calculate the 95% UCL using Hall's Bootstrap, and use the resulting UCL as the BTV.
2. Compare the BTV calculated in step one above to the arithmetic mean of the decision unit sample results.
    a. If the arithmetic mean of the decision unit samples is less than the BTV, then the chemical in the decision unit is background.
    b. If the arithmetic mean of the decision unit samples is greater than the BTV, either
        i. Conclude that the chemical in the decision unit is not background, or
        ii. Evaluate the decision unit sample results for high outliers.
            A. If there are no high outliers in the decision unit sample results, the chemical in the decision unit is not background.
            B. If there *are* high outliers in the decision unit data, determine whether those outliers are spatially grouped.
                α. If the high outliers are not spatially grouped, the chemical in the decision unit is not background.
                β. If the high outliers are spatially grouped, carve out the area defined by those outliers and investigate it as a source. Then re-evaluate the remainder of the decision unit, beginning with Step 2, above.

IDEM will evaluate other approaches consistent with U.S. EPA (2002e) and Singh and Maichle (2015).

Figure B-3: Background Threshold Values Using Systematic Sampling



B.2.6 Background Evaluations Using Small Soil Sample Sets

Some remediation projects have trouble getting enough background samples to calculate a statistically-based BTV. This is often due to a scarcity of suitable background reference areas. This subsection describes an example procedure for obtaining BTVs from small background sample sets. Figure B-4 illustrates the procedure in decision tree format.

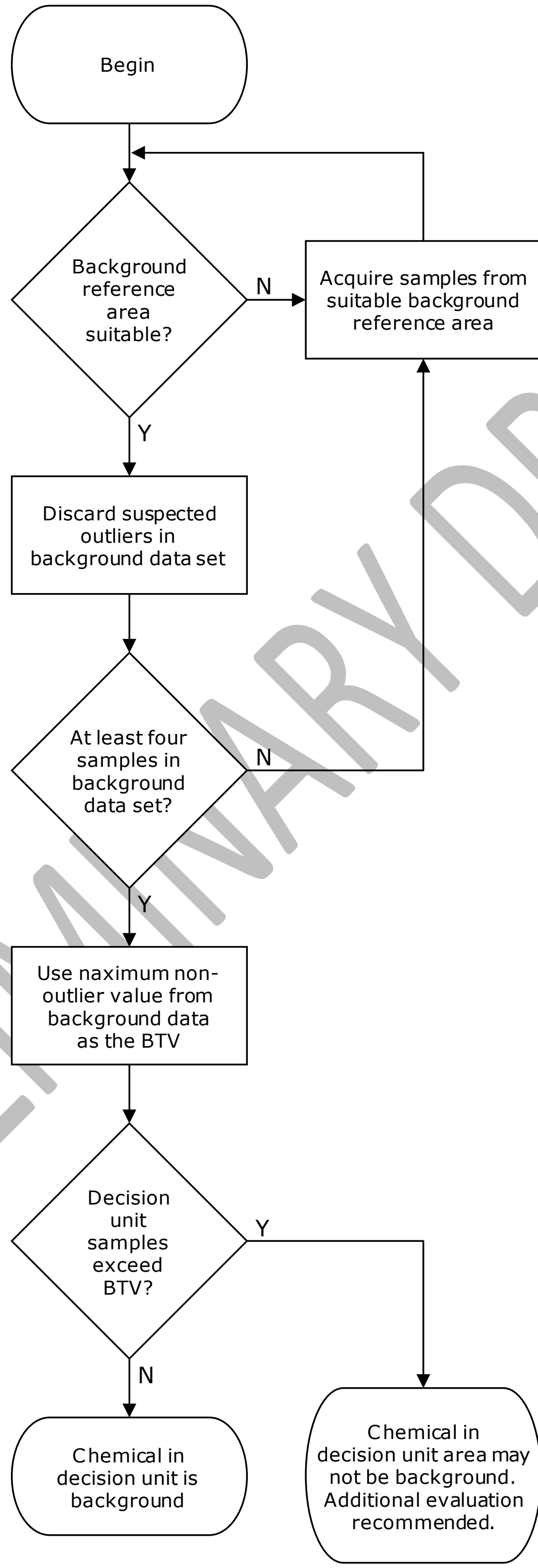
Procedure

1. Use criteria described in Section B.2.1 to decide whether the proposed background reference area is appropriate. If it is not, select an appropriate background reference area and collect sufficient samples from that area. Otherwise, continue to Step 2.
2. Use a Q-Q plot to screen background reference area samples for outliers. If the Q-Q plot reveals one or more potential outliers, use Dixon's test on those outliers. Discard identified outliers that meet the criteria described in Section B.2.3.
3. If fewer than four background reference area sample results remain, collect additional background reference area samples, and return to Step 2. Otherwise, designate the maximum non-outlier value from the background reference area samples as the BTV.
4. Compare the BTV against each decision unit sample result for the same chemical. If decision unit sample concentrations do not exceed the BTV, then the decision unit is background. Otherwise, the decision unit may not be background, and further characterization of the decision unit may be necessary.

B.2.7 Background in Soils: Other Approaches

Singh and Maichle (2015) identify additional procedures for the BTV comparison to decision unit samples, including use of two-sample hypothesis testing and graphical methods to compare two or more populations. IDEM will evaluate alternative proposals consistent with U.S. EPA (2002e) and Singh and Maichle (2015).

Figure B-4: Background Evaluation using Small Background Sample Sets



B.3 Background Levels in Groundwater

As with soils, the basic procedure for background evaluation in groundwater involves collecting samples from each of two different areas and comparing the sample results to see if they differ significantly The first sample set should come from a groundwater background reference area. The second sample set should come from a decision unit (Section 3.1). What follows is an example procedure (illustrated in decision tree form in Figure B-5) for evaluating background levels in groundwater. IDEM will evaluate alternative procedures on their merits.

<u>Procedure</u>

1. Collect eight or more quarters of data from appropriate groundwater locations, as described in Section B.3.1.
2. If there is more than one groundwater sampling location in the background reference area, it may be advantageous to pool the background data to minimize the number of necessary comparisons with decision unit groundwater sample results. To do this, calculate the root mean square deviation (RMSD) of the data from each background well (Equation B-1, below) and check to see if the RMSD is no greater than 1.3. If so, data pooling is appropriate. If not, either consult with IDEM regarding next steps, or proceed without pooling the data.
3. If there are non-detect values in the background data set (pooled or not), calculate the 95% UCL using the Kaplan-Meier Bias-corrected Accelerated Bootstrap and use that as the groundwater BTV. If there are no non-detect values in the background data set (pooled or not), calculate the 95% UCL using Hall’s Bootstrap, and use that as the groundwater BTV.
4. Compare the BTV determined above with the arithmetic mean of groundwater data from the decision unit. If the arithmetic means of groundwater data from all the monitoring wells within the decision unit are less than the BTV, the decision unit is not a source. Otherwise, the decision unit may be a source, and further characterization or a remedy is necessary.

Equation B-1: Root Mean Squared Deviation

RMSD = $\sqrt{\frac{\sum_{i=1}^{n}(C_{ai}-C_{wi})^2}{N}}$

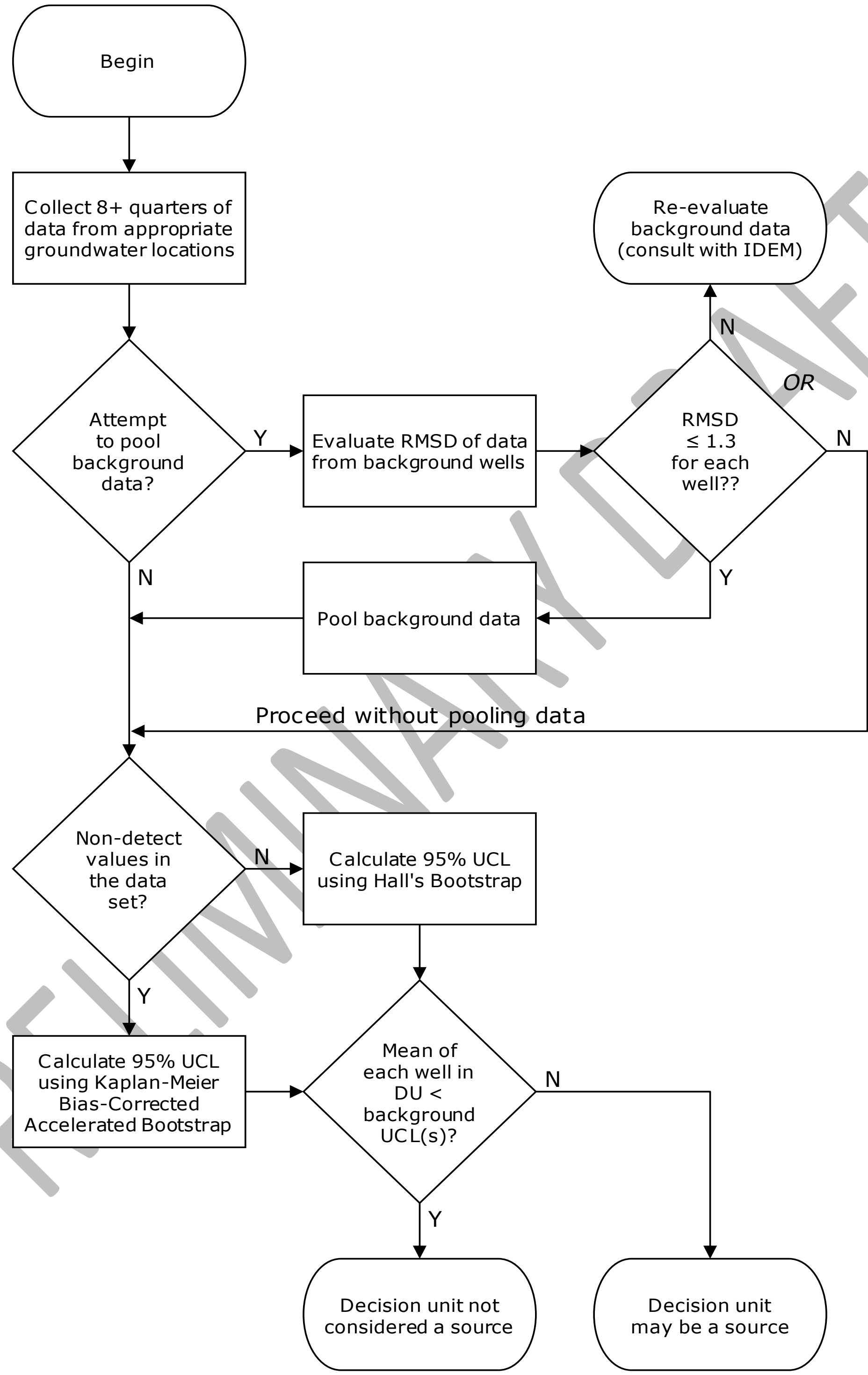
Where:

C_{wi}= the concentration of a chemical for a given sampling event in the well currently under evaluation

C_{ai}= the average concentration of that chemical in those background wells not currently under evaluation. For example: if there are four background wells and well 2 is currently under evaluation, this value is the average of that chemical’s concentrations in wells 1, 3, and 4; and

N = the total number of background wells.

Figure B-5: Groundwater Background Evaluation



DU	=	Decision unit
RMSD	=	Root mean square deviation
UCL	=	Upper confidence limit of the mean

B.3.1 Appropriate Groundwater Sampling Locations

Appropriate groundwater background sampling points are typically upgradient of, and hydraulically connected to, the decision unit. Background sampling placement should consider the following hydrogeologic assumptions:

- The groundwater background samples are from areas unaffected by any release(s) that affect(s) the decision unit.
- The upgradient and downgradient well samples are drawn from the same aquifer and the wells are screened at approximately the same hydrostratigraphic position. The fate and transport characteristics of chemicals dissolved in groundwater likely will differ in each aquifer, resulting in unique concentration patterns.
- The groundwater flows in a definable path from upgradient to downgradient wells beneath the area under investigation. Undefined or incorrectly defined flow paths may invalidate statistical comparisons.
- The groundwater flow moves at a sufficient velocity beneath the decision unit, so that the same groundwater observed at upgradient well locations is subsequently monitored at downgradient wells over the course of the evaluation.
- The time between sampling events and velocity of the groundwater flow is sufficient to ensure collection of independent samples.

To minimize sampling variability, collect all groundwater samples using the same or similar sampling equipment and methods. Because groundwater moves, background evaluations in groundwater take more time than soil evaluations. Sampling over time also allows for evaluation of fluctuations in observed concentrations caused by climate and rainfall. Collect a minimum of eight quarterly samples from each well used in the evaluation.

Clustered or spatially correlated sampling results can skew background statistics. Geospatial methods address this problem by better representing background concentrations that vary spatially. The products of the analysis can be measurements of spatial correlations of existing data, as well as an estimate of the true background population statistical distribution when working with spatially correlated data. For more information, see ITRC (2016) for discussion on using geospatial results in background estimation.

B.4 Background Levels in Vapor

IDEM is not aware of any naturally occurring sources of significant ambient air concentrations of the chemicals (chlorinated solvents and benzene) that typically drive *release-related* indoor air risk. For this reasons, IDEM does not provide detailed guidance on demonstrating the existence of naturally occurring ambient background in vapor. Any such demonstrations will have to be project-specific, and IDEM will evaluate them based on the characteristics of the demonstrations.

B.5 How IDEM Will Evaluate Background Level Demonstrations

Soils

- Does the soil background reference area have physical, chemical, and geological characteristics similar to the decision unit under evaluation?
- Is the background reference area free of impacts from chemical releases?
- Have the background reference data been screened appropriately for outliers?
- Were there sufficient number of background data points collected to meet the DQO?
- Is a reasonable rationale provided for dropping any outliers from the background threshold data set?
- Have spatially grouped outliers been identified for further investigation as a potential source area?
- Are there sufficient sample results to perform relevant statistical tests?
- Were background threshold values calculated appropriately?
- Were appropriate conclusions drawn from comparison of the background threshold value and data from the decision unit(s)?

Groundwater

- Is the groundwater background reference area unaffected by releases?
- Are groundwater background reference area and decision unit wells drawn from the same aquifer and screened at approximately the same hydrostratigraphic position?
- Does groundwater flow in a definable path from upgradient to downgradient wells?
- Is groundwater flow velocity sufficient so that the same groundwater observed at upgradient well locations is subsequently observed at downgradient wells during the course of the evaluation?
- Is groundwater flow velocity sufficient to ensure collection of independent quarterly samples from any given well?
- Are there sufficient sample results to perform the relevant tests?
- Were there sufficient number of background data points collected to meet the DQO?
- Were the groundwater background data shown to be independent, and identically-distributed data?
- If groundwater background data pooling is proposed, is the root mean squared deviation of the background well data no greater than 1.3?
- Is the groundwater background threshold value based on an appropriate upper confidence limit, taking into account whether the background data set contains nondetect values?
- Were appropriate conclusions drawn from comparison of the background threshold value and data from each monitoring well in the decision unit?

Vapor

- IDEM evaluation of vapor background demonstrations will be highly dependent on the characteristics of the demonstration.

Appendix C: Quantitative Plume Trend Analysis

Quantitative plume trend analysis can be a strong line of evidence that a plume of release-related chemicals in groundwater behaves consistently, both temporally and spatially. These analyses require a minimum of eight quarters of data from wells that are placed in the same flow zone, within the release-related chemical plume, and in locations that allow an understanding of plume behavior (Section 2.3.5.3). Quantitative plume trend analysis is generally not necessary at well-understood releases, and should be considered only if qualitative lines of evidence fail to show adequately predictable plume behavior. Several possible analysis methods appear below. IDEM will evaluate other methods on a case by case basis.

C.1 General Approach

If release-related chemicals are present in groundwater at concentrations that exceed unconditional remediation objectives, it is necessary to understand the likely behavior of the plume behavior over time. However, evaluation of plume behavior may be premature or even unnecessary if:

- The nature and/or extents of the plume are still under investigation.
- Active remediation is occurring.
- The intent is to quickly drive plume concentrations below an unconditional remediation objective.
- Release-related chemicals are moving onto the facility from another source.

<u>Statistical Analysis</u>

Statistical plume trend analysis is a powerful line of evidence that combines groundwater monitoring data with regression analysis, time-trend analysis, and other statistical tests from a representative groundwater monitoring well network to demonstrate an increasing, decreasing, or consistent plume. However, appropriate application of statistical plume trend analysis requires a comprehensive well network (as described in Section 2.3.3.2), *at least* two years of consistent data collection, and periodic reassessment of plume conditions. Consistent behavior across the plume, normally a sign of a mature plume, is a stronger line of evidence than individual well results. Independent statistical analysis of individual wells does not normally not provide sufficient evidence of plume behavior – a statistical analysis of data from a well network is required.

When considering statistical analysis of plume behavior, consider the following:

- There are multiple trend test methods. The appropriate test depends on several factors, most notably the statistical distribution of the underlying data. If the data appear to fit a predictable distribution, such as normal or lognormal, then a more powerful trend test, such as ordinary least squares regression, can be used. Non-parametric tests like Mann-Kendall or Theil-Sen are appropriate for data that do not fit a known distribution.
- Parametric tests are often more powerful than nonparametric tests. However, as noted above, parametric tests require normal or transformed normal data.
- A statistical test may not be representative if the CSM is incomplete. If wells are not in locations that allow an understanding of the plume (same flow zone, in the plume, and in locations as described in Section 2.3.5.2), data from those wells could provide misleading statistical results.

C.2 Time-Trend Analysis

All else equal, the past behavior of a mature plume is a good indicator of future behavior. This explains the emphasis U.S. EPA (2009) places on monotonic long-term trends (over at least eight quarters) in plume behavior. Monitoring well network design is critical, and consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration.

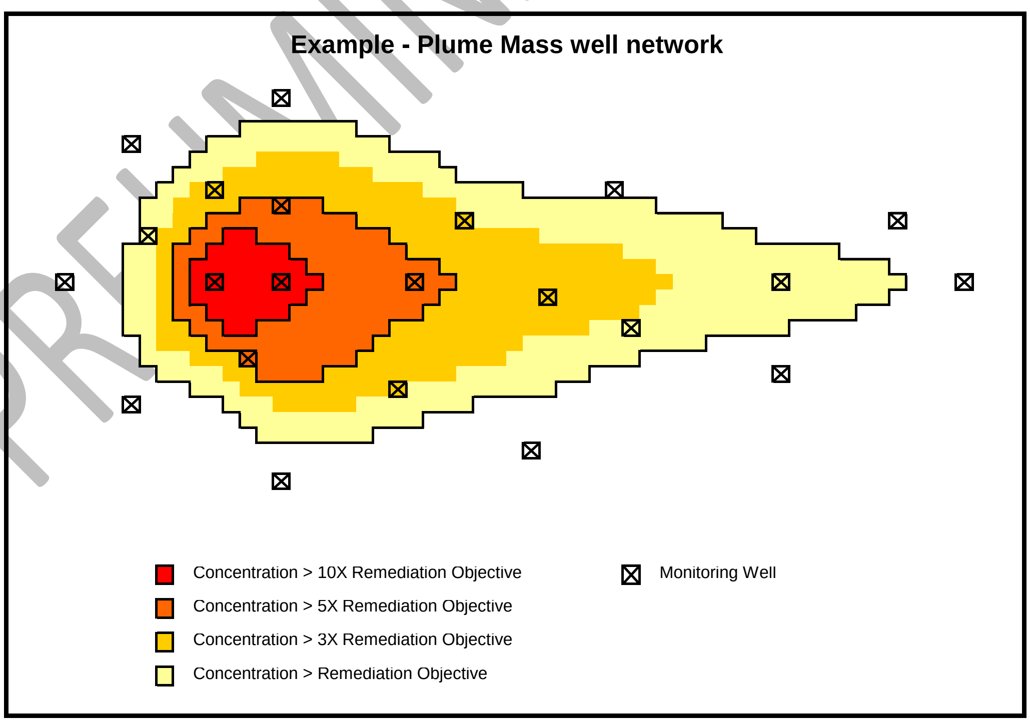
Plume Trend Analysis: Plume Mass

Estimating plume mass requires a three-dimensional understanding of dissolved chemical concentrations at a resolution that allows observation of changes in the overall plume mass. This demonstration may require an extensive groundwater monitoring network, including sampling points at multiple depths so that it is possible to understand how dissolved concentrations vary vertically. In some cases it may be possible to use knowledge of the subsurface to interpolate between sampling points. A Mann-Kendall evaluation that uses at least eight quarters of calculated relative mass data can provide a high level of confidence in the expected behavior of the plume. In general, more data will increase the value of this line of evidence.

The extent of the necessary monitoring well network will vary by project. Consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration. IDEM recommends beginning with a regression analysis and concluding with a Mann-Kendall analysis of the change in mass over time. However, IDEM will evaluate alternative statistical demonstrations on a project-specific basis.

After eight independent samples are collected at each monitoring well in a network that adequately covers the extents of the plume, a successful demonstration of decreasing plume mass will show that the relative mass over time has a negative slope or S-value (depending on the statistical method used).

Figure C-1: Illustration of Plume Mass Well Network



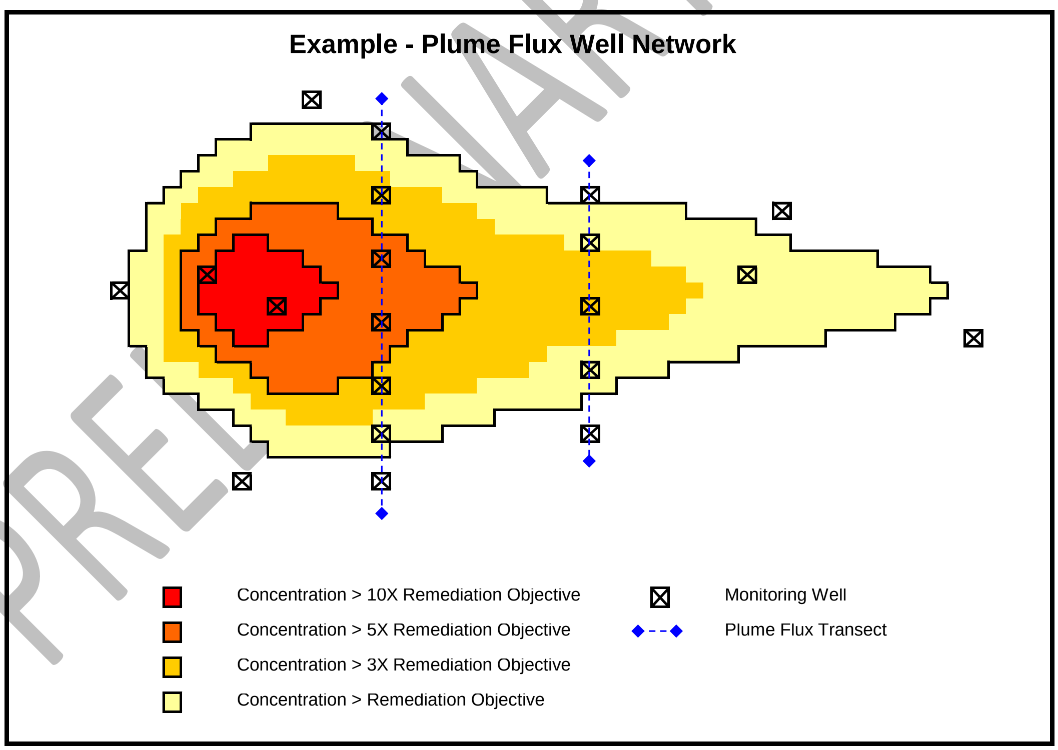
Plume Trend Analysis: Plume Flux

Plume flux is a measurement of change in dissolved chemical concentrations across a plane. Examining the trend in plume flux across one or more projected planes is a useful way to evaluate release-related chemical movement (Figure C-2). However, as with plume mass, complete and accurate characterization of flux may require a substantial monitoring well network that includes multiple transects across the plume at multiple sampling depths. In some cases it may be possible to use knowledge of the subsurface to interpolate between sampling points. A Mann-Kendall evaluation of the calculated relative mass at each transect based on at least eight quarters of data can provide a high level of confidence in the expected behavior of the plume. Plume flux measurements using more sampling data will increase the weight of this line of evidence.

Consultation with IDEM technical staff is recommended to ensure that the monitoring well network is appropriate for the demonstration. Plume flux analysis supplements the plume mass line of evidence with additional statistical evaluations. IDEM recommends beginning with regression analysis for each transect, and concluding with Mann-Kendall analysis for each transect. However, IDEM will evaluate alternative statistical demonstrations on a project-specific basis.

After eight independent samples are collected at each monitoring well in at least two transects across the plume, a successful demonstration of decreasing plume flux will show that the relative flux over time has a negative slope or S-value (depending on the statistical method used).

Figure C-2: Plume Flux Well Network



Multiple Sample Location Statistical Analysis

This analysis evaluates trends at multiple sampling locations. All else equal, more data will increase the weight of this line of evidence. A Mann-Kendall evaluation of the concentrations at each monitoring well for at least eight quarters provides a pattern for the individual wells. A high level of confidence in the expected behavior of the plume can be demonstrated when characteristics are consistent across relevant monitoring wells.

Plume Trend Analysis: Multiple Sample Location Statistical Analysis

This powerful line of evidence combines monitoring data with regression analysis, time-trend analysis, and other statistical tests from a representative groundwater monitoring well network to demonstrate an increasing, decreasing, or constant plume. However, it requires a comprehensive well network, multiple years of consistent data collection, and periodic reassessment to be applied appropriately. The independent statistical analysis of each well will not normally provide the necessary evidence of any plume behavior. Other lines of evidence are often more directly applicable to well-characterized sources (e.g., age of the plume). By analyzing these other lines of evidence first, it may be possible to evaluate the plume behavior without using statistics. The process of assessing ambient plume trends should be postponed until all active remediation is completed.

Once a trend is identified (at least eight independent rounds of sampling data is needed) additional sampling may be needed to verify the identified trend (this is usually the case if the eight initial quarters are the only sampling data).

A demonstration via this method that a plume is decreasing provides a high level of confidence that risks are decreasing. Conversely, an increasing plume warrants additional investigation and/or monitoring. Consistent characteristics across the extent of the plume provide a higher level of confidence that the potential future behavior of the plume is understood (U.S. EPA, 2006b). This involves evaluating the trend of multiple sampling locations with multiple observations; all else equal more data will increase the weight of this line of evidence. Demonstrating plume behavior is unlikely when at least two of the plume monitoring wells exhibit statistically significant different trends (increasing and decreasing), or when other characteristics are not consistent across relevant monitoring wells.

Characterization of hydrogeologic conditions may require additional wells. If the wells do not meet appropriate criteria, or if conditions change, previously installed wells may no longer produce samples that adequately represent the plume. In such cases, new wells may be necessary, or existing wells may be re-designated to serve a different monitoring function than originally intended.

Some wells must be located within specific groundwater time-of-travel distances from the source and show some form of correlation. Before installing wells, estimate the advective flow velocity of groundwater at the decision unit to ensure that the new wells will meet groundwater time-of-travel requirements. This approach will allow sufficient time during monitoring to ensure that groundwater from the closure area reaches key monitoring wells.

Statistical analysis methods may be acceptable when IDEM accepts the characterization and agrees that the CSM is adequately developed. In addition, information from the statistical plume trend analysis can also be used to further refine the CSM.

Standards for such tests (e.g., Mann-Kendall or Theil-Sen) should include the following:

- No well described in the monitoring well network (Section 2.3.3.2) can have an increasing trend at a significance level greater than five percent
- After eight independent samples are collected at each monitoring well in the network, only one source well can have a positive slope or S-value.

If the analysis cannot meet both standards, additional lines of evidence are needed to establish stable plume behavior. Additional lines of evidence can include further quarterly groundwater monitoring unless any messenger or perimeter of compliance well shows an increasing trend at a 5% level of significance.

If there is widespread variation within the plume, IDEM may request the statistical analysis depicted in Figure C-3, which includes an evaluation of the homogeneity of the plume trend.

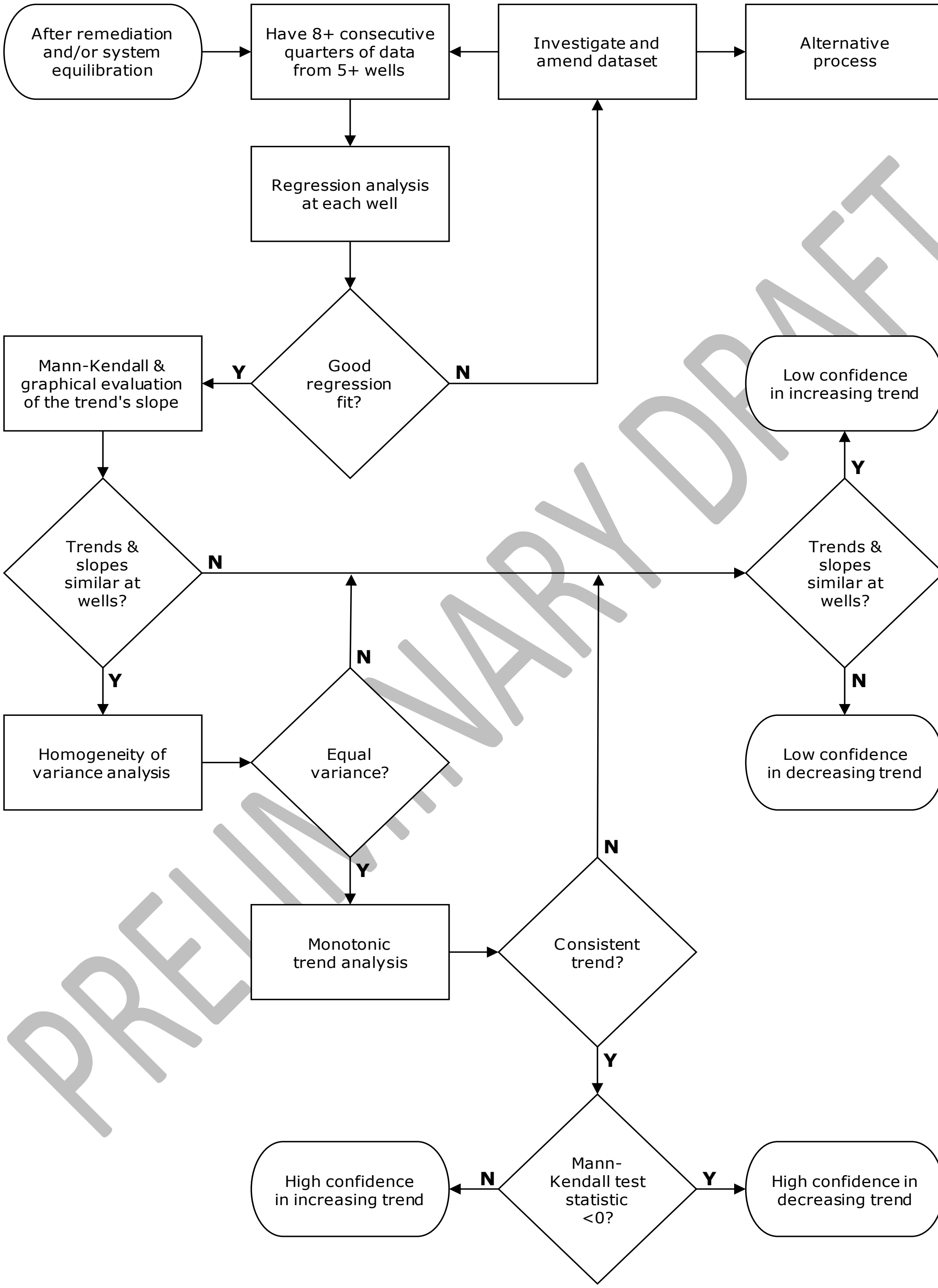
- Step 1: Regression analysis of data from each well
- Step 2: Mann-Kendall trend analysis of data from each well
- Step 3: Graphical demonstration that data from each well exhibit similar trends and slopes
- Step 4: Homogeneity of variance analysis
- Step 5: Monotonic trend analysis

U.S. EPA (2006b) describes various methods for evaluating trends of different combinations of spatial and temporal data. The ProUCL (Singh and Maichle, 2015) statistical package (or similar software) can evaluate the data used for trend analysis, as well as evaluate the trends in the data. The minimum sample size recommendation is at least eight observations. IDEM will evaluate other plume trend analysis methods on their merits. For example, Fox and Weisberg (2011) describe an approach using multivariate statistical analysis.

C.3 Modeling Plume Behavior

Groundwater modeling may be helpful when attempting to predict the future extents of release-related chemical plumes. Groundwater modeling is inherently project-specific and will typically require geologic and hydrologic parameter values in addition to knowledge of release-related chemical behavior. IDEM review of groundwater modeling results will require that submissions include information on the model used (including any version number), all model inputs, assumptions, calibration results, validation results, and the results of sensitivity testing.

Figure C-3: Example of Plume Trend Analysis



Appendix D: Ecological Risk Evaluation

Ecological risk evaluation is a potentially complex process, and a full treatment of the topic is beyond the scope of this document. This appendix sketches the outline of an ecological risk evaluation process and lists references that provide additional guidance on ecological risk evaluation. The process begins with the simplest and least resource-intensive type of evaluation and progresses, when appropriate, into progressively more complex and resource-intensive procedures:

Step 1 Determine if ecologically significant areas are present near the release (Section D.3.1). Use existing information to determine whether release-related chemicals have reached, or are reasonably likely to reach, ecologically important areas (Section D.3.1). If not, there is no need for further ecological risk evaluation. If yes, proceed to Step 2.

Step 2 Use relatively limited sampling data and generic ecological screening levels to determine whether further ecological risk evaluation is necessary (Section D.3.2). If not, there is no need for further ecological risk evaluation. If yes, proceed to Step 3.

Step 3 Refine the screening levels based on project-specific conditions. This usually involves estimating doses received by species that represent specific ecosystem guilds and comparison of those doses against specific criteria. Decide whether an ecological remedy is necessary. This is a potentially iterative process (Section D.3.3).

IDEM anticipates that the first step listed above will be adequate for the vast majority of releases, and that the percentage of releases proceeding through the process will diminish with each successive step. In some cases, it may be obvious that an ecological remedy is necessary. When that is true, it is acceptable to proceed directly to implementation of an appropriate interim ecological remedy.

D.1 Basis for Requiring Ecological Risk Evaluation

Ecological risk evaluation is necessary to determine per IC 13-25-5-8.5(c) whether additional action is necessary to protect the environment. IDEM has determined that Step 1 above (Section D.3.1) is likely to suffice for the large majority of releases. Sections D.3.2 through D.3.4 provide additional guidance for those releases where additional ecological evaluation proves necessary.

D.2 Preliminary Ecological Risk Evaluation

Current and historic facility operations and environmental setting are important to consider when evaluating potential ecological risk. Every CSM should set the stage for a preliminary evaluation of the potential for ecological risk. IDEM anticipates that in most cases, an adequate discussion of potential ecological risk will be relatively brief – generally a few paragraphs or less – and that information collected during routine CSM development will usually suffice to decide whether release-related chemicals are reasonably likely to reach ecological receptors.

A process diagram (Figure D-1) illustrates an approach to answering this question. It starts by asking whether the extents of release-related chemicals are restricted to areas *not* subject to ecological risk evaluation (**exempt areas**). Such areas might include the following:

- Paved areas, including paved drainage ditches
- Buildings and associated landscaping
- Other areas characterized by intensive development
- Tilled land

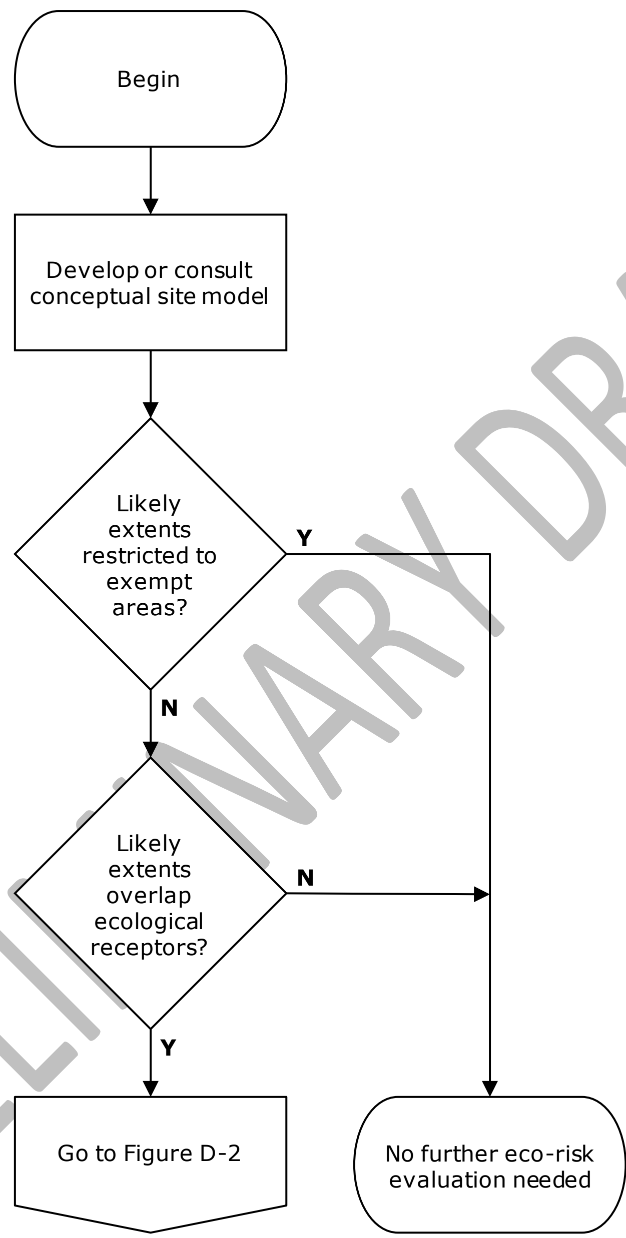
It then asks whether chemicals from the release are reasonably likely to reach an area of potential ecological significance. Examples of such areas include:

- Waters of the state, including but not limited to streams, ponds, wetlands, and associated sediments
- Parks, nature preserves, fish and wildlife areas, or legally protected areas such as conservation easements and mitigation banks
- Sinkholes or karst recharging areas
- Any other area important to the reproduction and/or survival of endangered, threatened, or sensitive species, or species of concern.

Answering this question may be as simple as demonstrating that a plume of release-related chemicals in groundwater is stable and does not extend as far as the nearest potential ecological receptor (e.g., the nearest downgradient wetland). As stated earlier, information collected in conjunction with CSM development (nature, extent, and stability of release determinations, wetland inventory maps, land use information for surrounding properties, areas with endangered species, etc.) will often suffice.

If further ecological assessment is necessary, responsible parties should proceed to Section D.3.2.

Figure D-1: Are Release-related Chemicals Reasonably Likely to Reach Ecological Receptors?



D.3 Screening Level Ecological Risk Evaluation

This step uses sample results to derive representative concentrations of release-related chemicals found in media in one or more decision units that contain ecologically significant areas. Examples include sediment or surface water samples from a potentially impacted wetland, or surficial soil samples from an area potentially impacted by aerial deposition that is home to endangered plants. If suitable analytical data is not already available, completion of this step will require additional sampling and analysis.

This step begins with development of an ecological CSM, which may draw heavily on information already collected during development of a standard CSM. While the process diagram shown in Figure D-2 provides a basic overview of general ecological risk evaluation steps, a more detailed account is provided in U.S. EPA (2018). Important components of the ecological CSM include:

- Release-related chemicals of potential ecological concern
- Potentially affected decision units with ecologically-sensitive areas
- Potentially affected media in decision units with ecologically-sensitive areas

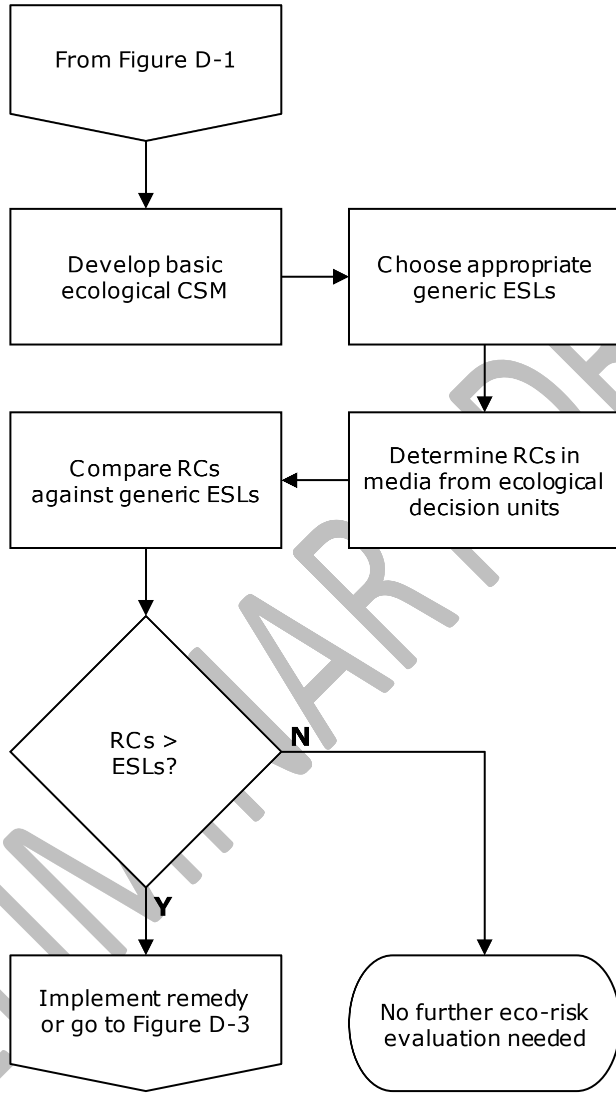
Note that chemicals that might pose an ecological risk can be different from those that might pose a human health risk. Possible reasons include differing exposure pathways, sensitivities, and responses to chemicals. Use of some generic ecological screening levels (ESLs) may also require identification of potentially affected taxa (e.g., birds, mammals, invertebrates).

Where applicable, Indiana Water Quality Standards (327 IAC 2) exist by rule and take precedence over guidance. After Indiana Water Quality Standards are considered, IDEM recommends starting with U.S. EPA Region 4 Ecological Screening Levels (U.S. EPA, 2018). Other ESL sources may be appropriate when Indiana Water Quality Standards or U.S. EPA ESLs are not available for a chemical; see especially NOAA (2008) and U.S. EPA (2006c). Following sampling and analysis of media from decision units with ecological receptors, responsible parties should calculate representative concentrations and compare those concentrations to the selected generic ESLs. Factors such as surface water hardness, temperature, and total organic carbon should be considered when collecting and using data (U.S. EPA, 2018).

Significant exceedances warrant an ecological remedy or further evaluation unless appropriate lines of evidence demonstrate otherwise. Potentially relevant lines of evidence include:

- Background concentrations
- Contributions of other sources, such as outfalls
- Existing ecological studies applicable to the decision unit
- Determination whether discharges of release-related chemicals were permitted.

Figure D-2: Do Representative Concentrations of Release-related Chemicals Exceed Generic Ecological Screening Levels?



CSM = Conceptual site model
ESL = Ecological screening level
RC = Representative concentration

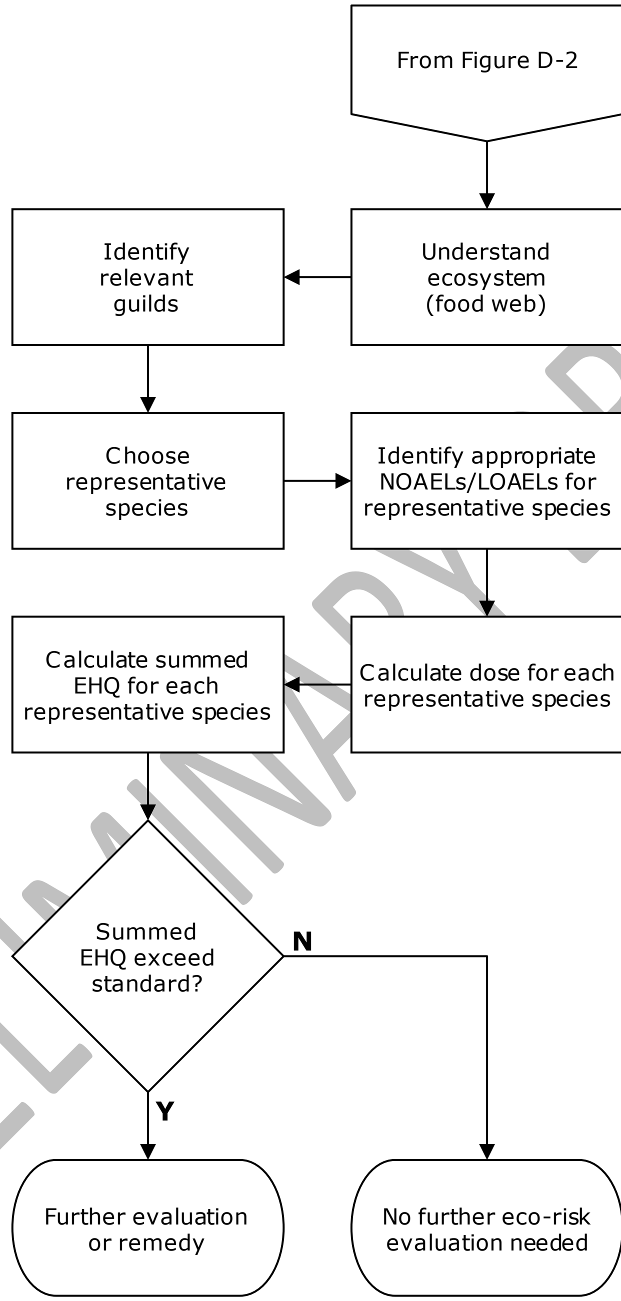
D.4 Ecological Risk Evaluation: Refinement

Whereas Section D.3.2 uses generic, media-specific screening levels for comparison against representative concentrations, a refined ecological risk assessment uses levels experimentally derived for species representative of various groups in the food web that are, or should be, present in the release area. An adequate ecological risk assessment may require several iterations, depending on what each step of the process reveals. Figure D-3 is a decision tree that illustrates the process. Basic steps may include:

- Develop an understanding of the ecosystem (i.e., the food web) in the release area;
- Identify relevant guilds (groups of organisms occupying a similar ecological niche – e.g., insectivorous birds, benthic organisms, predatory mammals, etc.);
- Choose representative species for each of those guilds (e.g., American Robin, Raccoon, Eastern Newt, etc.);
- Identify, from the literature, appropriate no observed adverse effect levels (NOAELs) or lowest observed adverse effect levels (LOAELs) for each representative species;
- Calculate an estimated dose for each release-related chemical of potential ecological concern (COPEC) x representative species combination;
- Compare data to Refinement Screening Values (from tables appearing in U.S. EPA, 2018)
- Calculate an ecological hazard quotient (EHQ) for each COPEC x representative species combination, where EHQ = Dose/NOAEL or EHQ = Dose/LOAEL, and sum EHQs for different chemicals for a given representative species;
- Compare EHQs to appropriate factors, discussed below;
- Perform an analysis of uncertainty, and how it affects the conclusions of the assessment.

If the EHQ does not exceed an appropriate factor (derived by refining ecological hazard quotients using project-specific data and exposure assumptions when generic data and assumptions result in an ecological hazard quotient exceeding one), no further ecological risk evaluation is necessary. Otherwise, additional evaluation or an ecological remedy is necessary.

Figure D-3: Do Representative Concentrations of Release-related Chemicals Exceed Project-specific Ecological Screening Levels?



EHQ = Ecological hazard quotient
LOAEL = Lowest observed adverse effect level
NOAEL = No observed adverse effect level

D.5 How IDEM will Evaluate Ecological Risk Evaluations

Step 1

- IDEM will decide whether it agrees with the responsible party's determination that the present and likely future extents of the release either do or do not overlap ecologically significant areas. IDEM will typically use extents maps or diagrams provided by the responsible party to make this determination, but may also choose to use aerial photographs, National Wetland Inventory maps, appropriate layers in the Indiana State Map, or other resources as appropriate when making this decision. Note that extents maps and diagrams will require the concurrence of IDEM technical staff.

Step 2

- Were ecological decision units appropriately defined?
- Were appropriate ecological screening levels proposed?
- Were there sufficient sample data from each ecological decision unit?
- Were representative concentrations of each COPEC calculated appropriately?

Step 3

- In addition to factors described under Step 2, above:
- Were relevant guilds identified?
- Were appropriate representative species chosen?
- Were appropriate NOAELs/LOAELs chosen?
- Were appropriate doses calculated for each representative species?
- Were summed EHQs calculated for each representative species?
- Were appropriate ecological remediation objectives specified?
- Do summed EHQs exceed ecological remediation objectives?

Appendix E: Environmental Restrictive Covenants

An environmental restrictive covenant (ERC) is a legal measure designed to protect human health by limiting exposure to release-related chemicals. ERCs limit human exposure by restricting activity on, use of, and/or access to properties, or by requiring the operation and maintenance of an engineering control. IC 13-25-5-8.5(e) directs IDEM to consider and give effect to ERCs in evaluating risk-based remediation proposals.

When an ERC is proposed as a remedy or component of a remedy, IDEM will evaluate it to determine (a) whether the activities, land use restrictions, and obligations proposed are sufficient to protect human health and the environment, and (b) whether it attaches to the correct real estate (i.e. references the correct legal description, deed number, and state parcel identification number(s)) and (c) includes all the necessary elements of a restrictive covenant as defined in IC 13-11-2-193.5 and IC 13-14-2-6(5) and (6).

A proposed ERCs must be submitted to IDEM for review prior to recording. IDEM must determine whether the proposed restrictions and obligations are adequate to prevent unacceptable risk to human health to the environment, now and in the future. IDEM will also review the proposed ERC to ensure that it contains all the elements necessary to make it enforceable by IDEM. After the ERC is approved by IDEM, it must be recorded in the recorder's office in the county where the property is located.

E.1 Legal Requirements for ERCs

Per IC 13-11-2-193.5, an ERC executed after June 30, 2009:

(A) limits the use of the land or the activities that may be performed on or at the land or requires the maintenance of any engineering control on the land designed to protect human health or the environment;
(B) by its terms is intended to run with the land and be binding on successors;
(C) is recorded with the county recorder's office in the county in which the land is located;
(D) explains how it can be modified or terminated;
(E) grants the department access to the land;
(F) requires notice to a transferee of:
  (i) the land; or
  (ii) an interest in the land;
  of the existence of the restrictive covenant; and
(G) identifies the means by which the environmental files at the department that apply to the land can be located.

Per IC 13-14-2-6(5) and (6), the terms of an ERC may be enforced by IDEM in court if the ERC:

Was approved by IDEM and created in connection with any

(i) remediation;
(ii) closure;
(iii) cleanup;
(iv) corrective action; or
(v) *determination exercising enforcement discretion or of no further action being required.*

IDEM's Institutional Controls webpage[51] provides program specific ERC templates that both fulfill the legal definition of an ERC and have been vetted by IDEM's Office of Legal Counsel. The provided templates are fill-in-the-blank Word® documents. Should the property owner decide to modify the provided language in these templates, IDEM's Office of Legal Counsel must review those modifications to ensure that the revised ERC satisfies the legal definition of an ERC. This legal review will require additional time and should be taken into consideration for the project's timeline.

E.2 Selection of Land Use Restrictions and Obligations

When determining the appropriate restriction or obligation required for a property, consider the following:

- Affected media
- Current and reasonably expected future groundwater use
- Current and reasonably expected future use of each decision unit and neighboring properties
- Properties of the release-related chemicals (e.g., mobility, naturally attenuating, etc.)
- Current and potential receptors
- Availability of public water supply systems

Table E-1 lists some factors to consider when selecting appropriate land use restrictions for a property. Table E-1 is not comprehensive - other restrictions may be necessary. In accordance with IC 13-14-2-8, IDEM shall make the final determination on the land use restrictions that are protective of human health.

[51] https://www.in.gov/idem/cleanups/2358.htm

Table E-1: Restrictions and Remedies

Direct Contact Exposure	Remediation Objective Exceeded	Possible Land Use Restrictions
Soil	Unconditional	• Residential restriction; or • Soil cap with O&M plan • Proper soil handling & disposal • Agricultural restriction[52]
	IDEM Published Commercial Level, or equivalent	• Residential restriction • Soil cap with O&M plan • Proper soil handling & disposal • Soil management plan
	IDEM Published Excavation Worker, or equivalent	• Excavation restriction • Soil cap with O&M plan • Proper soil handling & disposal • Soil management plan
Groundwater	Unconditional	• Groundwater use restriction • Agricultural restriction[53]
Vapor	Unconditional	• Residential restriction • Test before residential use • Vapor mitigation system with O&M plan • Vapor barrier • Basement restriction[54]
	IDEM Published Commercial Level, or equivalent	• Test before residential use • Vapor mitigation system with O&M plan • Vapor barrier • Basement restriction (if groundwater is shallower than eight feet below ground surface)

[52] Generally, an agricultural restriction is considered when impacts and groundwater are shallow, release-related chemicals are bioaccumulative (i.e. PCBs or metals) and/or an engineered cap is in place.

[53] For groundwater shallower than five feet below ground surface

[54] If groundwater acting as a vapor source did not previously prompt a vapor investigation (See Section 2.3.6.1) based on the current structure configuration but the addition of a basement would prompt a vapor investigation, a future use basement restriction may be acceptable to prevent exposure.

E.3 Property Description

ERCs must be recorded in the county recorder's office in which the real property is located, and the ERC must cross-reference the most recent deed of the record in the recorder's office. To ensure that the ERC is attached to the correct property, provide a copy of the current deed along with the draft ERC to IDEM. IDEM's GIS Services will plot the legal description to create a geographic information system (GIS) polygon of the restricted property. The ERC should also include the correct address, 18-digit State Parcel Identification Number (PIN), and legal description provided on the current deed. An ERC is recorded on the property deed. If an ERC is proposed as a remedy, the ERC must be agreed to and executed by each person owning an interest in the property. If one deed contains descriptions of several parcels, or several deeds are included in a single ERC, it should be made clear which obligations and restrictions are applicable to each parcel, and/or which parcels are not involved at all.

E.4 Affected Area

An **affected area** is a portion of real property impacted by concentrations of release-related chemicals that requires a remedy that may not be necessary for the rest of the property. The driver for the restriction, or the obligation, may be either the specific chemical or the media in which it is found. When an affected area is involved, it is crucial to accurately delineate the boundaries of the affected area based on data for each impact and to accurately depict it on a map. This may be accomplished by the use of GPS points to clearly delineate the boundaries or by conducting a survey of the area.

Define affected area boundaries using sampling data for the chemicals and media involved. Affected areas may differ by media. For example, soil sampling data immediately surrounding a drum storage pad may define an affected area for soils that requires restrictions or obligations specific to controlling risk from exposure to those soils. However, if the same release has created a much larger affected area in groundwater, that larger area will require restrictions or obligations specific to controlling risk from exposure to that groundwater. The overall affected area must ecompass all chemical-specific and media-specific affected areas related to the release.

In other instances, off-site properties may be affected and also require a remedy. If the approved remedy on such property is an ERC, it is the responsibility of the entity proposing the remedy to obtain the executed document and see that it is recorded.

E.5 Finalized ERCs

Once a draft ERC has been reviewed by IDEM and finalized, it must be signed and notarized by the current property owner. If there is more than one person who owns the property, each person must sign the ERC. Either the property owner, or an authorized representative[55] of the property owner, can record the ERC on the property deed in the recorder's office in the county where the property is located. Provide a copy of the recorded ERC to IDEM. IDEM provides a copy of the recorded ERC to the county health department and/or county well permitting authority in which the property is located. IDEM will visually depict the property location on IDEM's GIS map as well as IndianaMap to ensure that future property owners and neighboring properties' owners are aware of release-related chemicals remaining on the affected properties in their communities.

ERCs are typically recorded at the end of the remedy implementation process as part of a closure. However, there are instances (e.g., when the property is going to be transferred, when full

[55] An authorized representative is someone who has power of attorney for the property owner, or has authority to sign on behalf of an entity such as a municipality, corporation, or LLC.

implementation of a remedy may take a long time, or when the property may be eligible for a tax sale) in which it may be appropriate to record an ERC prior to the end of the remedial process. Modification of a previously recorded ERC may be required if the restrictions and obligations are no longer adequate to protect human health and the environment. Any such modification must be approved and recorded before IDEM will approve closure.

IDEM has the authority to require the owner of the source property to place necessary restrictions on that property. In some limited circumstances, property owners meeting the criteria in IC 13-25-4-24 may be required to execute an ERC if the commissioner determines an ERC is necessary to protect human health or the environment. If the owner refuses to execute an ERC voluntarily, IDEM may file an action in court requesting an order from the court requiring an ERC be executed.

E.6 ERC Modification or Termination and Cost Recovery

The law provides a procedure under IC 13-14-2-9, and regulations promulgated thereunder, for making changes to the restrictions and obligations or for terminating the restrictions in an ERC. An owner desiring approval to change the use of a property, to modify a restriction or obligation due to a transaction, or to terminate a restriction entirely can submit a proposal to IDEM indicating the modification desired along with the supporting data and information necessary to justify the modification or termination.

Unless an ERC is modified or terminated, it applies to a property in perpetuity. Submittals requesting to modfiy or terminate restrictions or obligations may be submitted to IDEM with sufficient data to support a determination that a modification or termination is justified. IDEM will approve the proposed change or termination, or it will deny the request. Any modification or termination of an IDEM-approved ERC also requires IDEM approval.

OLQ requires reimbursement for the administrative and personnel expenses associated with the development of the written determination under 329 IAC 1-2-7 [PDF]. IDEM will bill OLQ personnel expenses at $75.00 per hour (subject to change) for the review. Once the review is completed, IDEM will issue an invoice reflecting the actual number of hours spent on the review. OLQ will not issue the written determination until payment for invoiced costs is received.

Individuals who propose modification or termination of an ERC must provide written justification and all supporting documentation necessary for review, including the following completed forms.

- ERC/Deed Notice Modification or Termination Request - 56082 (available on the IDEM Forms page), and either
- ERC Modification Template, May 2018 [DOC] or ERC Termination Template, May 2018 [DOC]

If IDEM concurs, a modification or termination document stating the reasons for the change, and IDEM's approval of the change, will need to be recorded in the same manner as the original ERC. A copy of the recorded modification or termination must be provided to IDEM.

E.7 Institutional Controls Registries

IDEM staff will enter information from recorded ICs into an Institutional Control Registry. IDEM maintains two registries; a Remediation Sites registry that is a listing of properties with recorded ERCs, and a Solid Waste Registry that is a listing of solid waste landfills with recorded deed notices or ERCs. The registries allow IDEM to track properties with ICs and provide external stakeholders (local government units, water utilities, real estate developers, concerned citizens, etc.) notice of properties subject to restricted use or obligations.

IDEM updates the IC Registries every month. The reports contain project-specific information on each property with an institutional control, such as the address, city, county, remediation program, and a listing of land use restrictions and/or engineered controls. There are two active links on the registries. The first active link is to IDEM's Virtual File Cabinet to provide direct access to the institutional control document. The second active link is to a GIS map that depicts the restricted properties and provides information on those properties.

E.8 How IDEM Will Evaluate Environmental Restrictive Covenants

IDEM will consider the following when reviewing environmental restrictive covenants:

ERC Format

- Was a program-specific ERC template used?
- If a program-specific template was used, has the standard language been significantly modified?
- IDEM does not require use of a program-specific template. However, if a template is not used, the proposed ERC will require additional scrutiny, including by IDEM's Office of Legal Counsel. This will result in a longer review time for the proposed ERC.

ERC Recitals

- Is the name and full address of the owner listed, correct, and used throughout?
- If the deed is in the name of a different person or entity than the person who is signing the ERC, are there recitals to connect the two parties? (e.g., the names are different because of death/inheritance, corporate mergers, or bankruptcy).
- Is the full address of the property listed and correct?
- Have the correct parcel identification numbers been provided?
- Is the total acreage correct?
- If provided, is the summary of remedial activities accurate?
- If provided, are the factual statements made in the recitals correct?

ERC Restrictions

- Are the restrictions appropriate based on the remaining chemicals and concentrations?
- Are any groundwater restrictions property-wide, unless an acceptable explanation is provided to justify restricting groundwater usage to only a portion of the property?
- Are any of the restrictions to be applied only in an "affected area" instead of the entire property?
- If restrictions are applied to an "affected area", is it clearly described in the text and depicted on an attached map?
- If any of the restrictions are to be applied only to an affected area or if an engineering control such as a cap or cover is present, have GPS coordinates or a legal survey of the affected area been provided?
- If a program-specific template was used, has any of the default restriction language contained in the template ERC been modified? If so, is the language acceptable?

ERC Exhibits

- Was a copy of the warranty deed provided?

- Does the owner name listed in the ERC match the owner shown on the deed?
- Is the legal description from the warranty deed included as an exhibit to the ERC?
- If a map was provided, is it legible?
- If a restriction or obligation covers only a portion of the property, is a map of that portion provided?
- Does the ERC and its narrative, in conjunction with the map, contain information that would enable an inspector, unfamiliar with the property, to determine the location of the affected or restricted area?
- If one or more tables are included, have they been edited to remove sample points where concentrations of release-related chemicals are non-detect or below unconditional remediation objectives?
- Is the font size used in the exhibits at least 10 point?
- Are the exhibits without color, hatching, or shading so that they can be scanned in black and white?
- Do the exhibits in the ERC match the title pages?

<u>Other Considerations</u>

- Is the property in a wellhead protection area?
- Are county references consistent throughout?

Appendix F: Environmental Restrictive Ordinances

IC 13-11-2-71.2 defines an environmental restrictive ordinance (ERO) as an ordinance adopted by a municipal corporation[56] that seeks to control the use of groundwater in a manner and to a degree that protects human health and the environment against unacceptable exposure to a release of hazardous substances or petroleum, or both.

Per IC 13-25-5-8.5(e), IDEM must consider and give effect to EROs in evaluating risk-based remediation proposals. IDEM will not consider an ERO as a remedy for a source property under the control of a current owner. Because EROs are defined to eliminate access to groundwater, vapor intrusion issues, if those conditions exist, must be addressed through a different remedy.

Because IDEM has the responsibility to ensure that remedies protect human health, it will review EROs for effectiveness. Effective EROs *prohibit* use of groundwater that exceeds unconditional remediation objectives for potable use and, depending on the release-related chemical(s), remaining concentrations, and plume dynamics, *may* prohibit use of groundwater for other purposes (e.g., irrigation, cooling water, etc.). EROs may not be acceptable where plumes encroach on, or fall within, a wellhead protection area (WHPA).[57] ERO effectiveness depends in part on understanding the present and future extents of release-related chemicals in groundwater, and ensuring that the ERO area fully encompasses those extents and a recommended additional buffer zone area. The CSM will inform design of the ERO area, and the design may also employ lines of evidence from a plume behavior evaluation.

EROs that allow for special use exceptions or variances may unintentionally permit future unacceptable exposure to release-related chemicals in groundwater. Therefore, before granting a variance or exception, local government units should ensure that the proposed changes will not result in unacceptable exposure.

Depending on release-specific factors (unusually toxic or persistent chemicals, large and/or unstable plumes, etc.) IDEM may condition its approval of a remedy that relies on an ERO on the responsible person's compliance with continuing obligations. For example, IDEM may condition closure approval on the responsible person's continued groundwater monitoring to ensure that the plume does not extend beyond the established boundaries of the ERO. In addition, the responsible person may need to take other remedial measures to control exposure via pathways (such as vapor intrusion) not addressed by the ERO.

F.1 ERO Notification Provisions

In accordance with IC 36-1-6-11(c) and IC 36-2-4-8(4), EROs enacted after 2009 must provide notice to IDEM under certain situations. Failure to include such language regarding notice in the ordinance *does not*, however, void the ordinance. Such an ordinance may also require that the entity requesting the use of the ordinance propose additional measures to ensure that notice is provided to IDEM. Notice to IDEM is required as follows:

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[56] As defined in IC 36-1-2-10. For purposes of this guidance, a municipal corporation may include counties, municipalities, townships, local hospital corporations, or any entity that may enact an ordinance.

[57] Either the five-year time of travel of a delineated WHPA or a 3,000-foot fixed radius WHPA for a community water system. In accordance with IC 5-14-3-4(b)(19)(H), locations of approved WHPAs are not available online. For general information regarding WHPAs consult the IDEM Wellhead Protection Program web page; to determine whether a specific release is within a WHPA, contact IDEM's Ground Water Section via phone at 317-232-8603.

- Giving written notice to IDEM not later than 60 days *before* amendment or repeal of the ERO;
- Giving written notice to IDEM not later than 30 days *after* passage, amendment, or repeal of an ERO.

Local government units should send these notices to IDEM at the following address:

IDEM, Office of Land Quality
Remediation Services Branch
Attn: Institutional Controls Group
IGCN-Suite 1101
100 N Senate Ave
Indianapolis, IN 46204-2251

F.2 How IDEM Will Evaluate Environmental Restrictive Ordinances

IDEM will thoroughly evaluate EROs proposed as a component of a remedy. Approval of an ERO for one release does not ensure that other releases within the boundaries of the ERO will automatically be granted closure based on that same ERO. Use of an ERO as a proposed remedy will be evaluated on a case-by-case basis and evaluated according to the facts applicable to each release. ERO evaluations will include at a minimum:

1. An assessment of plume extent and stability of the plume. There should be sufficient understanding of the plume mass flux to demonstrate that the plume will not migrate beyond the boundaries established in the ERO at levels that would not be considered protective of human health. This may be accomplished by:
    a. Identifying characteristics of the release setting and the plume that provide a level of confidence that the plume is near its maximum extent and concentration;
    b. Demonstrating that the plume is stable or shrinking, prior to acceptance of an ERO as an IC for a particular release; or
    c. Long-term monitoring that demonstrates that the plume does not extend beyond the boundaries established in the ERO.
2. Location of the release with respect to the ERO coverage area. The ERO coverage area should include the plume, predicted future plume extents, and usually should include a buffer zone.
3. Evaluation of the receptor survey. The receptor survey should thoroughly document all water use within and near the ERO boundaries including:
    a. Potable well users within ERO extent (noting that some commercial/industrial wells are also used for potable water);
    b. Commercial/industrial, dewatering, and irrigation wells;
    c. Nearby water withdrawals (such as high-capacity wells near the ERO coverage area that may impact the plume);
    d. Food or drug manufacturing facilities that use groundwater wells.
4. Input from the local government unit that has enacted or that has proposed adoption of the ERO. Responsible parties and their consultants are encouraged to work directly with the local government unit. Because IDEM must rely on local governments to enforce EROs, municipal involvement throughout the review process will help IDEM evaluate the effectiveness of proposed EROs. IDEM project managers will contact local governments for information including:

a. Current and future local water resource planning;

b. Procedures for granting exceptions and variances to the ERO;

c. Local point of contact for ERO monitoring and compliance;

d. Notification provisions for EROs.

IDEM will notify local government units, including public water supply systems, in writing of any formal proposal to use an ERO at a particular location; and will request input on the items listed above if the information has not already been provided in the work plan.

5. Future effectiveness of the ERO (notice to interested parties). IDEM has the responsibility to ensure that remedial decisions are protective of human health. One of the documented limitations with the use of local groundwater ordinances as an IC is that their continued effectiveness hinges on public acceptance and awareness of the ordinance. In Indiana, this is particularly important given the lack of comprehensive state-wide well permitting requirements. Continued compliance with an ERO is necessary for the ERO to remain effective at managing risk and controlling unacceptable exposure. Therefore, a plan or mechanism that ensures continuing public awareness of, and compliance with, the ERO can help to ensure that the ERO remains effective at managing risk. Some examples of such plans may include but are not limited to:

    a. If there is an existing local well permitting authority, notification to that entity of the existence of the ERO so that no potable wells, or wells that may exacerbate the risk, are permitted.

    b. Active monitoring and outreach by the local government unit so there is an ongoing public awareness of the ERO.

6. Evaluation of the ERO language. IDEM will evaluate each ERO on its own merits, and there is no requirement to follow a particular template. However, clear, unambiguous ERO language is recommended, such as:

    a. A statement indicating that the purpose of the ERO is to protect public health, and that the ordinance has been enacted as a response to unacceptable groundwater risk.

    b. Language that specifically excludes all use of groundwater as a potable drinking water source for human and domestic purposes and prohibits the installation of new wells. An ordinance that just requires hookup to an existing water supply only if supply lines are available, or one that allows existing wells to remain in use, may not be sufficiently protective of human health.

    c. A clause that states that the ERO shall not in any way restrict or limit the ability of parties to perform remediation or to monitor the release.

    d. Language that limits the variances or exceptions allowed by the ERO[58], and requires the proper handling and disposal of water that is withdrawn.

    e. If the ERO does not apply everywhere within the boundaries of the local government unit, the extent of the ERO should be easily identifiable and clearly defined within the ERO (e.g., map or illustration showing ERO boundaries, legal description of ordinance boundaries, or common reference points such as street names). A buffer zone outside of the modeled/measured plume

[58] Examples include irrigation wells, heat pump wells, cooling water wells, fire protection wells, construction dewatering wells.

area is recommended to compensate for the potential influence on the plume by nearby water withdrawals. ERO boundaries should be fixed and should not be subject to change without amending the ERO (e.g., no boundaries defined by zoning districts or the availability of public water).

f. Language that specifies that the ERO applies at all depths and is not limited to specific aquifers.

Final acceptance by IDEM will depend on ERO content, effectiveness, and adoption by the local unit of government. IDEM will not issue closure documentation prior to receiving certification from an authorized official that the approved ERO meets the requirements of the governing statute and has been lawfully adopted by the local unit of government.[59] IDEM will draft closure documents so that closure decisions may be revisited if IDEM receives or becomes aware of new information. Examples of circumstances where this is likely to happen include: 1) the ERO is subsequently amended in a manner that allows plume movement beyond the established ERO control area or would allow exposure to release-related chemicals in groundwater, 2) the ERO is repealed, 3) variances/exceptions are granted that could allow for exposure to groundwater that exceeds unconditional remediation objectives, or 4) there is evidence that exposure to groundwater that exceeds unconditional remediation objectives is occurring within an ERO approved as an IC. IDEM will enter all EROs used as a component of a remedy in IDEM's Institutional Controls Registry (Section 12.11).

[59] The ERO copy should be certified [signed by the local authority and attested by the town clerk-treasurer (IC 36-52-10.2) or city clerk (IC 36-4-6-17).

Appendix G: Financial Assurance

Certain conditional closures may include the incurrence of continuing expenses. Examples include remedies with ongoing operational, maintenance, and/or sampling costs, or remedies that require periodic replacement of limited-life components. Financial assurance (FA) is a guarantee that funds will be available for such expenses in the event that the responsible party becomes insolvent. In this context, the term responsible party refers to the property owner, operator, or program participant who is providing the financial assurance. When there is a substantial potential exposure risk from failure or need for eventual replacement of a costly remedy, IDEM may request that responsible parties establish and maintain FA to operate and maintain the remedy as a condition of closure.

When FA is considered necessary, it will be established under an agreement such as an Agreed Order, Voluntary Remediation Agreement, or Long Term Stewardship Agreement. This guidance does not address specific rules and regulations related to financial assurance required as part of a Resource Conservation and Recovery Act (RCRA) treatment, storage, and disposal facility permit for operation or corrective action under 329 IAC Article 3.1 or 40 CFR Parts 260-270; or financial assurance required as part of a solid waste permit or registration required under 329 IAC Article 10 (relating to solid waste disposal facilities); 329 IAC Article 11 (relating to solid waste processing facilities); 329 IAC Article 11.5, 11.6, or 11.7 (relating to biomass anaerobic digestion facilities and biomass gasification facilities, mobile home salvaging facilities, and alternative fuel source facilities, respectively); 329 IAC Article 15 (relating to waste tire management facilities); and 329 IAC Article 16 (relating to electronics waste management facilities). For the specific financial assurance requirements relating to these types of facilities, see these rules and regulations.

G.1 Financial Assurance: Determining Amount

The FA amount requested of the responsible party will be no less than the cost estimate to operate, maintain, and inspect engineered controls (ECs) for which FA is required for the duration of the risk. If the duration of the risk is expected to last for an extended time period, FA will need to be structured for an appropriate rolling time period.

Cost estimates to operate and maintain the remedy are based on the costs to the responsible party of hiring a third party to conduct the necessary activities. Generally the cost estimate is calculated by multiplying the annual cost estimate by the number of years necessary to operate and maintain the remedy. In cases where a remedy will require the eventual replacement of an engineered system or control, the cost estimate includes the cost of such replacement.

When a remedy involves FA, the closure mechanism will obligate the responsible party to review and update cost estimates at least once every five years, or more often if necessary to reflect changing circumstances, either by completing a new cost estimate in current dollars, or by multiplying the previous year's cost estimate by a specified inflation factor. The financial instruments will then need to be updated to cover the new cost estimates, and both the cost estimate and adjusted instruments submitted to IDEM.

Some costs, such as erosion control and groundwater sampling, might be reduced over time as the cover vegetation matures and a meaningful amount of monitoring data is accumulated. Due to project-specific conditions, a shorter or longer remedy operation and maintenance period might be determined to be appropriate; however, FA will need to be maintained until the threat of harmful exposure is demonstrated to no longer exist.

When evaluating the amount of FA needed to ensure the effectiveness of the remedy, IDEM will apply the following guidelines:

- Activities are described in an operation and maintenance plan in sufficient detail to facilitate review of the cost estimates.
- Cost estimates are itemized in detail.
- Cost estimates reflect the costs to hire a third party to conduct the remedy operation and maintenance activities.

G.2 Financial Assurance: Timeframe for Establishing

After the nature and extents of release-related chemicals have been adequately determined, any interim remedial/clean-up activities have been completed, and a long-term remediation and/or exposure control method has been approved by IDEM, the responsible party should then proceed to obtain FA via one of the mechanisms listed below. IDEM will not issue a closure certification, covenant not to sue, or other closure documentation until after review and acceptance of the financial mechanism by IDEM staff. When closure is based on the provision and maintenance of FA and a responsible party fails to maintain adequate FA, the conditions for closure will no longer be met and IDEM may require the responsible party to take further action.

G.3 Financial Assurance: Instruments

The following five types of financial instruments are allowed under current RCRA rules. The responsible party may propose to use any of these instruments, and IDEM will evaluate the appropriateness of the requests. Each instrument is briefly described below.

1. Trust Fund. A trust fund is an agreement between two parties wherein the responsible party (Grantor) sets aside a specific amount of cash or funds, which is held in trust by a second party (the Trustee) for the purpose of paying for operation and maintenance of the remedy. IDEM is named as the beneficiary of the trust. In the event of bankruptcy, IDEM uses the funds in the trust to hire a third party contractor to operate and maintain the remedy.
2. Letter of Credit (LOC). An irrevocable standby LOC is a document issued by a bank or other financial institution that guarantees the payment of a responsible party's obligation for up to a stated dollar amount for a specified time. The responsible party arranges with a financial institution to issue an LOC payable to IDEM, assuring that the responsible party will pay for operation and maintenance costs when necessary. Essentially, an LOC substitutes the bank's credit for that of the responsible party, eliminating the financial risk to the state. An LOC is always accompanied by a stand-by trust agreement, which creates a trust into which IDEM will deposit the funds from the LOC in the event that it must cash in the LOC in order to continue operation and maintenance of the remedy should the responsible party be unable to do so.
3. Surety Bond. Like an LOC, a surety bond is an agreement between two parties. One party (the Surety) guarantees that the financial obligations of the second party (the Principal) will be met. For purposes of FA, the responsible party is the Principal. By means of the bond, the Surety guarantees to IDEM that it will meet the responsible party's obligations if the responsible party is unable to do so. A surety bond is always accompanied by a stand-by trust agreement, which creates a trust into which IDEM will deposit the face value of the surety bond in the event that the responsible party has failed to meet its obligations under the terms of the bond.
4. Insurance. A responsible party may obtain an insurance policy for a face value amount at least equal to the cost estimate for the operation and maintenance of the remedy. Through a policy, the insurer agrees to reimburse the party that incurred the cost of the operation and maintenance

upon direction from IDEM, for costs incurred to operate and maintain the remedy. The insurer must be licensed by a state (use of offshore insurers is not allowed) and may not cancel, terminate, or fail to renew the policy unless the responsible party fails to pay the premiums.

5. Financial Test. A responsible party may demonstrate the ability to cover the costs of operation and maintenance of the remedy without a third-party guarantee by passing a financial test. With this form of FA, the company is responsible for paying costs associated with operation and maintenance of the remedy. These tests document that the responsible party has sufficient assets located within the United States to cover operation and maintenance costs. Only companies with large net worth relative to the total estimated costs of remedy operation and maintenance are likely to pass a financial test. The responsible party demonstrates that they continue to pass the financial test by submitting updated information to IDEM within 90 days after the close of each fiscal year.

A responsible party may obtain a Corporate Guarantee from a separate but related company to cover remedy operation and maintenance costs in the event the responsible party is unable to meet the Financial Test. The related company demonstrates the ability to serve as a guarantor for the responsible party by passing the financial test.

G.4 How IDEM Will Evaluate Financial Assurance

A draft version of the FA instrument must be submitted for review and evaluation. The FA instrument must be funded to the approved cost estimate and must use IDEM's non-negotiable language for Financial Assurance Instruments. IDEM staff will review and either comment or approve the FA instrument. Once approved, the FA instrument must be implemented and submitted to IDEM. FA is required to be updated annually. Additional details on FA are provided in the Financial Assurance Implementation for Remediation Projects Standard Operating Procedure.

Acronyms, Initialisms, and Abbreviations

µg	microgram
AA	ambient air
AF	adherence factor
ALM	Adult Lead Model
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials (formerly; now ASTM International)
BGS	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
BTV	background threshold value
BW	body weight
CASRN	Chemical Abstracts Service Registry Number
CD	consent decree
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
cm	centimeter
COPEC	chemical of potential ecological concern
CSA	crawl space air
Csat	soil saturation limit

CSM	conceptual site model
DNAPL	dense nonaqueous phase liquid
DQO	data quality objective
DQOP	Data Quality Objectives Process
EC	engineering control
ED	exposure duration
EF	exposure frequency
EHQ	ecological hazard quotient
ERC	environmental restrictive covenant
ERO	environmental restrictive ordinance
ESL	ecological screening level
ET	exposure time
FID	flame ionization detector
ft	feet
GC	gas chromatography
GC/MS	gas chromatography/mass spectroscopy
GIS	geographic information system
GW	groundwater
HI	hazard index
HQ	hazard quotient

hr	hour
HVAC	heating, ventilation, and air conditioning
IA	indoor air
IAb	indoor air background
IAC	Indiana Administrative Code
IBP	Indiana Brownfields Program
IC	Indiana Code *or* institutional control
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IDW	investigation derived waste
IEUBK	integrated exposure uptake biokinetic (model)
IRIS	Integrated Risk Information System
IRS	intake rate
ITRC	Interstate Technology and Regulatory Council
kg	kilogram
l	liter
LCS	laboratory control sample
LNAPL	light nonaqueous phase liquid
LOAEL	lowest observed advese effect level

LUST	leaking underground storage tank
m	meter
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDDR	minimum data documentation recommendation
mg	milligram
mg/kg	milligrams per kilogram
MS	matrix spike
MSD	matrix spike duplicate
NAPL	nonaqueous phase liquid
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observed adverse effect level
NPD	Nonrule Policy Document
NPDES	National Pollution Discharge Elimination System
OLQ	Office of Land Quality
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
P2	*Risk-based Program Guide*
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl

PID	photoionization detector
PIN	parcel identification number
POC	perimeter of compliance
ppb	parts per billion
PRP	potentially responsible party
PVI	petroleum vapor intrusion
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
R2	*Risk-based Closure Guide*
RC	representative concentration
RCG	*Remediation Closure Guide*
RCRA	Resource Conservation and Recovery Act
RMSD	root mean squared deviation
RO	remediation objective
RP	responsible party
RPD	relative percent difference
RRC	release-related chemical
RSL	Regional screening level
SA	skin surface area
SAP	sampling and analysis plan

SCP	State Cleanup Program
SGe	soil gas, exterior
SGss	soil gas, subslab
SPLP	synthetic precipitation leaching procedure
TSD	treatment storage and disposal
TSDF	treatment storage and disposal facility
UCL	upper confidence limit of the mean
URO	unconditional remediation objective
USCS	United Soil Classification System
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank
VI	vapor intrusion
VIGWSL	vapor intrusion groundwater screening level
VOC	volatile organic chemical
VRP	Voluntary Remediation Program
WHPA	wellhead protection area
yr	year

Glossary

Active remedy	A measure that significantly reduces release-related chemical concentrations in a decision unit.
Adequate remedy	A measure that either by itself or in concert with one or more other measures reduces risk from release-related chemicals to an acceptable level for the intended use of a decision unit.
Aquifer	An underground geological formation as defined in IC 14-25-7-1.
Characterization	A determination of the source, nature, and extents of release-related chemicals.
Closure	IDEM's written recognition that a party has demonstrated attainment of remediation objectives for a chemical release.
Commercial indoor air action level	Ten times a chemical's published level for commercial indoor air, which corresponds to a carcinogenic risk of 10^{-4} or a hazard quotient of ten, whichever results in a lower concentration.
Conceptual site model	A comprehensive description of the release, including its setting, characterization, an evaluation of risks associated with the release, and any remedy proposed and implemented to address those risks.
Conditional closure	A closure that requires an ongoing remedy.
Conditional remediation objective	A remediation objective that does not permit unrestricted use of a property. For example, IDEM's published levels for commercial soil direct contact are conditional remediation objectives because they are calculated assuming no residential use.
Decision unit	A geographic location in which humans (or organisms) may be exposed to release-related chemicals, that requires a decision about whether or not a remedy for that exposure at that location is necessary.
Deep soil gas	Soil gas from more than five feet below ground surface.
Delineation	The act of determining the extents of a chemical release.
Engineered exposure control	A physical structure or apparatus that reduces or controls exposure.
Exempt area	An area that is *not* subject to ecological risk evaluation.
Extent	The volume or two-dimensional projection in horizontal space of a volume of media that contains release-related chemicals at concentrations or risk levels that exceed unconditional remediation objectives.
Line of evidence	A fact or set of facts relevant to a decision.

Naturally occurring background	Substances present in the environment in forms that have not been influenced by human activity (e.g., arsenic in New Albany shale).
Nature	The identity and concentrations of release-related chemicals in various media.
Off-site source	An identifiable, localized source outside the site of interest that contributed release-related chemicals to the site (e.g., chlorinated solvents from a dry cleaner impacting a neighboring business that has no history of using those solvents).
Plume behavior	How release-related chemical concentrations change spatially and over time, and interact with potential receptors.
Published level	A concentration published by IDEM for a particular chemical in a particular medium which is acceptable for a specified exposure scenario.
Release-related chemical	A substance placed on the land or in the subsurface that is, by virtue of its nature or quantity, subject to regulation by IDEM's Office of Land Quality. The term also includes regulated breakdown products of the above.
Remediation objective	Per IC 13-25-5-8.5(b), either (1) a concentration of a substance equal to the naturally occurring concentration of that substance on the site, or (2) an environmental concentration of a substance that is, given the conditions, uses, and restrictions prevailing on the site, protective of human health and the environment. For purposes of this document, a remediation objective may be a conditional remediation objective or an unconditional remediation objective.
Remedy	A means of reducing risk arising from a release-related chemical. Remedies either reduce the concentration of a release-related chemical, reduce exposure to that chemical, or both. An adequate remedy will, either by itself or in concert with one or more other remedies, reduce risk from release-related chemicals to an acceptable level.
Representative concentration	An estimate of the concentration of a release-related chemical in a particular medium within a decision unit.
Residential indoor air action level	Ten times a chemical's published level for residential indoor air, which corresponds to a carcinogenic risk of 10^{-4} or a hazard quotient of ten, whichever results in a lower concentration.
Shallow soil gas	Soil gas from no more than five feet below gound surface.
Source area	Where release-related chemicals are present in one phase at concentrations high enough to enable them to readily transfer to a different phase at concentrations that require a remedy.
Source facility	The building, land, or enterprise used for one or more purposes (e.g., gasoline sales and storage, dry cleaning, manufacturing, etc.), where the release occurred.
Source mass	The mass of release-related chemicals in source areas.

Source point	The physical location where release-related chemicals first entered the environment.
Unconditional closure	A closure that does not require an ongoing remedy.
Unconditional remediation objective	A remediation objective that permits unrestricted use of a property. Examples include IDEM's published levels for residential exposure scenarios, naturally occurring background levels, or site-specific residential levels.
Volatile organic chemical	A chemical having a vapor pressure greater than one millimeter of mercury at standard conditions.

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