




Montana Risk-Based Corrective Action Guidance for Petroleum Releases

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Risk-Based Corrective Action Guidance for Petroleum Releases				

Purpose:	The purpose of this document is to establish a risk-based approach to remediation of releases of petroleum products.
Scope:	This guidance applies to petroleum products, crude oil, and constituents of petroleum products and crude oil released into the environment.

Revision Date	Revision Description
August 2002	Leaching RBSL update
October 2003	Fraction toxicity update
October 2007	Exposure factor, toxicity, and leaching update
September 2009	Fraction toxicity update and removal of soil beneficial use RBSLs
September 2016	Exposure factor, toxicity, leaching, and text update; addition of Tier 2; see Executive Summary
May 2018	January 2017 benzo(a)pyrene toxicity update and May 2017 Montana DEQ-7 update; see Executive Summary

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Definitions and Acronyms

1 x 10⁻⁵ cancer risk – The added risk of one in 100,000 people developing cancer in their lifetime.

ARM – Administrative Rules of Montana

APH – Air phase hydrocarbon. The Massachusetts Method for analysis of the volatile petroleum hydrocarbon fractions in vapor samples.

AST – Aboveground storage tank used to store petroleum. Also see petroleum storage tank definition.

bgs – Below ground surface

BTEX – Benzene, toluene, ethylbenzene, and xylenes.

Carcinogen – A compound that the EPA has determined causes cancer based on the weight of peer-reviewed scientific evidence. Some carcinogens may also have non-carcinogenic effects.

Chemicals of concern (COCs) – Specific petroleum compounds that are identified for evaluation in a RBCA evaluation or a risk assessment.

Circular DEQ-7 – The Montana Numeric Water Quality Standards, applicable to state surface water and groundwater, adopted by rule and published by DEQ.

COC – See chemicals of concern.

Commercial/industrial property - Property used as a place of business with employees present with no one living on the property.

Conceptual site model (CSM) - A representation of the nature, fate and transport of releases that allows assessment of potential and/or actual exposure to contaminants.

Construction scenario - An exposure scenario based on the limited exposure of any individual to surface (0-2 feet below ground surface) and subsurface soils (2-10 feet below ground surface) during excavation.

Corrective action - Actions at a petroleum release that may include, but are not limited to, investigation, site assessment, emergency response, abatement, underground storage tank removal, cleanup, operation and maintenance of equipment, monitoring, reclamation, and termination of the corrective action.

CSM – See conceptual site model.

DAF – See dilution attenuation factor.

DCA 1,2 - See dichloroethane, 1,2.

DEQ - The Montana Department of Environmental Quality.

DEQ-7 - See Circular DEQ-7.

DGE – See down gradient edge.

Dibromoethane, 1,2- (also known as Ethylene dibromide - EDB) - Gasoline additive that was used until leaded gasoline was phased out. EDB may still be found in some leaded aviation gasoline.

Dichloroethane, 1,2- (1,2-DCA) - Leaded gasoline additive that was used until leaded gasoline was phased out. 1,2-DCA is still used as an industrial solvent and it may still be found in some leaded aviation gasoline.

Diesel range organics (DRO) – A lab analysis of petroleum hydrocarbons within the diesel range (C10 to C28). DRO was an accepted analytical method used to determine if a petroleum release was present at a level significant enough to require cleanup. DEQ ceased using DRO with the first RBCA publication in 1998 and uses Montana EPH instead.

Dilution attenuation factor (DAF) –The ratio of soil leachate concentration to the receptor concentration point. The DAF represents the reduction in concentration of a contaminant moving through soil and groundwater.

Down Gradient Edge (DGE) - A term established to describe a hypothetical monitoring well that could be constructed at the down gradient edge of the hypothetical contaminated source zone. This hypothetical well is used in the leaching model to calculate the worst-case groundwater contamination created from the hypothetical contaminant source to calculate RBSLs.

DRO - See diesel range organics.

EDB - See ethylene dibromide or 1,2-dibromoethane.

EPA - The United States Environmental Protection Agency.

EPH - See extractable petroleum hydrocarbons.

Ethylene dibromide (EDB) - See dibromoethane, 1,2.-

Exposure - The contact of a receptor with a chemical of concern.

Exposure pathway - The route a chemical or physical agent takes from a source to an exposed receptor. An exposure pathway describes the mechanism by which an individual or population is exposed to chemicals of concern at or originating from a release. Each exposure pathway includes a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of transfer between media) will also be included. Some examples of complete exposure pathways include:

- ♦ Inhalation of vapors from impacted soils by a person.
- ♦ Impacted soils leaching into potable groundwater and being used by a nearby resident for drinking and bathing.
- ♦ Inhalation of vapors by a neighbor resulting from the migration of contamination.
- ♦ Impacted groundwater discharging to wetlands or other surface water bodies.

Extractable petroleum hydrocarbons (EPH) - A group of petroleum hydrocarbons that includes the petroleum fractions typically found in diesel and other heavier petroleum products that are not analyzed and reported as specific compounds, like naphthalene. EPH is also the analytical method developed by the Massachusetts Department of Environmental Protection to determine the fractional composition of these compounds.

foc –See fraction organic carbon.

Fraction Organic Carbon (foc) – The fraction of organic carbon (%) in the media (soil/water/air) being evaluated.

Gasoline range organics (GRO) - A lab analysis of petroleum hydrocarbons within the gasoline range (C6 to C12). GRO was an accepted analytical method used to determine if a petroleum release was present at a level significant enough to require cleanup. DEQ ceased using GRO with the first RBCA publication in 1998 and uses Montana VPH instead.

GRO - See gasoline range organics.

H₂SO₄ – Sulfuric acid

Hazard index (HI) - The sum of hazard quotients for multiple substances and/or multiple exposure pathways.

Hazard quotient (HQ) - The ratio of the dose of a single substance related to exposure over a specified time period, to a reference dose for that substance derived from a similar exposure period.

HCl – Hydrochloric acid

HDPE – High-density polyethylene.

HHS – See Human Health Standard.

HI – See hazard index.

HQ – See hazard quotient.

Human Health Standard (HHS) – Standards for groundwater and surface water provided in Circular DEQ-7.

Lead scavengers - Compounds such as 1,2-DCA and EDB added to leaded gasoline to help volatilize or scavenge tetraethyl lead so it would not accumulate in the engine.

MBTEXN - Methyl tertiary-butyl ether, benzene, toluene, ethylbenzene, xylenes, and naphthalene. A set of compounds commonly found in gasoline.

MCA - Montana Code Annotated.

Methyl tertiary-butyl ether (MTBE) - A synthetic chemical formerly (1979 to 2005) added to commercial gasolines as an anti-knock additive or oxygenate.

MTBE - See methyl tertiary-butyl ether.

Non-carcinogen - A compound that the EPA has determined to have toxic effects, but has not determined to be a carcinogen. Some carcinogens may also have non-carcinogenic effects.

PAHs - See polycyclic aromatic hydrocarbons.

Petroleum or petroleum product - Crude oil or any fraction of crude oil that is liquid at standard conditions of temperature and pressure (60 degrees Fahrenheit and 14.7 pounds per square inch absolute) such as gasoline, fuel oil, diesel oil, lubricating oil, hydraulic fluids, oil sludge, or refuse, and any other petroleum related product or waste or fraction of the product or waste. The definition also includes additives that may be blended with the product to enhance its properties as a fuel or lubricant. Specific legal definitions relevant to the investigation of petroleum products may be found at § 75-10-302, MCA and § 75-10-701, MCA.

Petroleum release - A release of petroleum product into the environment, with “release” defined below.

Petroleum storage tank (PST) - A tank that contains or contained petroleum or petroleum products and that is: an underground storage tank defined in 75-11-503, MCA; a storage tank that is situated in an underground area, such as a basement, cellar, mine, drift, shaft, or tunnel; an aboveground storage tank (AST) with a capacity less than 30,000 gallons; including aboveground or underground pipes associated with these tanks. The definition of PST excludes pipelines regulated by the Natural Gas Pipeline Safety Act of 1968 (49 U.S.C. 1671, et seq.), the Hazardous Liquid Pipeline Safety Act of 1979 (49 U.S.C. 2001, et seq.), and comparable state laws, if the facility is intrastate (see § 75-11-302(21), MCA).

Polycyclic aromatic hydrocarbons (PAHs) - A group of petroleum hydrocarbons that includes several semivolatile compounds typically found in petroleum products, especially petroleum products that are heavier than diesel (Also referred to as polynuclear aromatic hydrocarbons).

ppb – Parts per billion.

ppm – Parts per million.

PPRTV – EPA Provisional Peer-Reviewed Toxicity Values

PST – See petroleum storage tank.

RBCA - See risk-based corrective action.

RBSL - See risk-based screening level.

RCRA – See Resource Conservation and Recovery Act.

RCRA metals - A group of eight heavy metals that are listed and monitored by RCRA because they are considered toxic even at low concentrations. These metals include arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se), and silver (Ag).

Resource Conservation and Recovery Act – The federal law that creates the framework for the proper management of hazardous and non-hazardous solid waste. The law describes the waste management program mandated by Congress that gave EPA authority to develop the RCRA program. RCRA includes regulations associated with underground storage tanks.

Reasonably anticipated future uses - Likely future land or resource uses that take into consideration:

- ♦ local land and resource use regulations, ordinances, restrictions, or covenants;
- ♦ historical and anticipated uses of the site;
- ♦ patterns of development in the immediate area; and
- ♦ relevant indications of anticipated land use from the owner of the site and local planning officials.

Receptor - Any person, plant, or animal that is or could potentially be adversely affected by a petroleum release.

Regional Screening Levels (RSL) – Risk-based screening levels published by the EPA to screen chemicals at contaminated sites. RSLs are calculated using the latest toxicity values, default exposure assumptions and physical and chemical properties and are updated semi-annually.

Release - Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of petroleum or a petroleum product into the environment.

Residential property - Any property used as a temporary or permanent place of residence. Residential properties also used for businesses are considered residential (e.g., a farm or ranch or a gas station with an on-site residence). Residential properties that include other uses not defined here are evaluated on a case-by-case basis.

Resolved petroleum release – A categorization status used for petroleum releases meaning that DEQ has determined all cleanup requirements have been met and the conditions at the site ensure present and long-term protection of human health, safety and the environment as defined in §75-11-521(5), MCA (also called “closed”). For the purposes of this document, “resolved” can also refer to a suspected petroleum release that DEQ has determined did not release petroleum into the environment exceeding applicable RBSLs.

Risk-based corrective action (RBCA) - A decision-making process based on the protection of public health, safety, and welfare, and the environment, which results in the consistent assessment, remediation and/or resolving (closure) of petroleum releases.

Risk-based screening level (RBSL) - A chemical concentration considered acceptable for a given exposure scenario based on estimated risk to potential receptors.

RSL – See regional screening levels.

Soil Screening Levels (SSLs) – A risk-based concentration used for initial comparison of site soil data to identify contaminants of concern for leaching to groundwater.

SPLP – See Synthetic Precipitation Leaching Procedure.

SSL – See soil screening level.

Synthetic Precipitation Leaching Procedure (SPLP) – A sample preparation method developed to model an acid rain leaching environment. It is used for quantifying contaminant partitioning and mobility in site soils.

TEH – Total extractable hydrocarbons. The total amount of hydrocarbon compounds calculated in a petroleum mixture or product using the EPH Method (Montana Method) that falls within the molecular carbon molecule range of C-9 and C-36.

TPH – Total petroleum hydrocarbons. TPH may also refer to total purgeable hydrocarbons but that term is not used in this guidance.

Total Petroleum Hydrocarbons - This term is generally applied to analytical methods that report one concentration for the petroleum hydrocarbons present and that are no longer approved by DEQ to assess risks posed by petroleum contamination.

Tier 1 – The simplest level of RBCA for petroleum releases in Montana. In Tier 1 RBCA, petroleum contaminant levels are compared to pre-determined RBSLs for COCs to determine whether additional evaluation and/or cleanup is necessary. It involves situations where the petroleum contaminant is confined to soil and/or is present in the groundwater at concentrations below DEQ-7 human health standards or groundwater RBSLs. The Tier 1 process may not be applicable to sites where site-specific cleanup levels have already been chosen or will be identified through an appropriate authority.

Tier 2 – A potential site-specific alternative risk-based approach for sites where Tier 1 RBSLs have been exceeded. Tier 2 involves adjusting Tier 1 RBSLs based upon site-specific information such as the number of COCs or the characteristics of the vadose zone.

Tier 3 – A potential site-specific alternative risk-based approach for sites where Tier 1 RBSL and Tier 2 site-specific screening levels have been exceeded. Tier 3 involves conducting site-specific human health and/or ecological risk assessments and fate and transport analyses and calculating site-specific cleanup levels.

TSP – Trisodium phosphate.

Vadose zone – The part of the soil column extending down from the Earth surface to the depth where the subsurface materials are saturated with groundwater. It is also known as the unsaturated zone.

Vapor Intrusion (VI) - Vapor intrusion is the migration of volatile chemicals from the subsurface into overlying or subterranean structures. Volatile chemicals in contaminated soil or groundwater can emit vapors that may migrate through subsurface soils and into air spaces of adjacent or overlying structures. Depending upon the chemicals, some vapors inhaled by occupants can cause adverse health effects, including an increased lifetime cancer risk. In some cases, the vapors may accumulate in buildings to levels that may pose near-term safety hazards, acute health effects or aesthetic problems.

VI – See vapor intrusion.

VOC – See volatile organic compounds.

Volatile organic compounds (VOCs) - Organic chemicals that have a high vapor pressure at ordinary room temperature (60° Fahrenheit), some of which may have short- and long-term adverse health effects.

Volatile petroleum hydrocarbons (VPH) - A group of petroleum hydrocarbons that includes the petroleum fractions typically found in gasoline and other lighter petroleum products that are not analyzed and reported as

specific compounds, like benzene. VPH is also the analytical method developed by the Massachusetts Department of Environmental Protection to determine the fractional composition of these compounds.

VPH - See volatile petroleum hydrocarbons.

Executive Summary of 2018 Changes

The Montana Department of Environmental Quality (DEQ) conducts periodic reviews of its Montana Risk-Based Corrective Action (RBCA) Guidance for Petroleum Releases to determine if changes to methods and toxicity information warrant updating the guidance. Following is a bulleted list of substantive changes made to the September 2016 version of the RBCA. The changes in RBSL calculation parameters are documented in the RBCA Appendices. Additional minor editorial changes and updates were also made.

- Updated toxicity values for benzo(a)pyrene and the other carcinogenic polycyclic aromatic hydrocarbons (PAHs) with toxicity relative to benzo(a) pyrene used to calculate direct contact risk-based screening levels (RBSLs) (EPA 2017).
- Updated the groundwater RBSLs to reflect updated Montana Circular DEQ-7 human health standards (HHSs; DEQ 2017).
- Updated the RBSL based upon leaching to groundwater to be protective of the 2017 DEQ-7 HHSs.
- Various clarifying language regarding Tier 2 procedures.
- One final thing to note regarding the 2018 changes to the RBCA is that the 2018 RBSLs for soil and water are still not designed to be protective of risks posed by the vapor intrusion (VI) pathway. In 2016, DEQ added some discussion related to VI and included a description of its Air Phase Hydrocarbon (APH) Calculator; however, if volatile compounds are present in the vicinity of habitable structures, then the VI pathway should be evaluated either qualitatively or quantitatively using the Montana Vapor Intrusion Guide (DEQ, 2011). In addition, DEQ completed a study and published a report called Typical Indoor Air Concentrations of Volatile Organic Compounds in Non-Smoking Montana Residences Not Impacted by VI (DEQ, 2012). These VI documents are guidance and are not considered regulation. At this time, DEQ has not adopted the EPA Petroleum Vapor Intrusion Guidance or the EPA Vapor Intrusion Screening Level (VISLs) Calculator.

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RISK-BASED CORRECTIVE ACTION EVALUATION PROCESS

1.0 INTRODUCTION

1.1 Overview of Risk-Based Corrective Action

DEQ created this document to describe the risk-based corrective action (RBCA) evaluation process. This document provides a description of the concepts and terms used in RBCA for petroleum releases in Montana and is not intended to address other chemical (non-petroleum) releases. This document is applicable to petroleum releases, suspect releases, and permits regulated by DEQ's Waste Management and Remediation Division and Enforcement Division. In addition, this guidance may be used as a screening tool for new releases at hazardous waste sites that are covered by Resource Conservation and Recovery Act (RCRA) permits or orders. For hydrocarbon compounds not specifically addressed in this document, a site-specific approach may be developed in consultation with DEQ. The appropriate regulating agency or bureau should be contacted to determine whether the RBCA evaluation process is appropriate.

1.2 RBCA Risk Evaluation

The goal of RBCA is to identify and reduce risks to public health, safety, and welfare, and the environment. RBCA uses environmental risk analysis, which incorporates elements of toxicology, hydrogeology, chemistry, and engineering to assess the existing and potential risks from a petroleum release. This information is used to develop contaminant concentration levels determined to be acceptable in the State of Montana. The risk-based screening levels (RBSLs) developed within RBCA can be used as cleanup levels at sites in Montana without the need to perform site-specific leaching evaluations or risk analysis for each release and exposure scenario.

DEQ's Tier 1 (the lowest level of complexity in the RBCA evaluation process) site evaluation process consists of assessing site conditions and maximum contaminant concentrations, and choosing the appropriate Tier 1 RBSLs to determine whether further evaluation or corrective action is needed to confirm a suspected release or address a release. Tier I RBSLs may be used in an environmental assessment or permitting process to determine whether a release has occurred or to set permit limits. The Tier 1 process involves comparing contaminant concentrations to Tier 1 RBSLs tables containing generic contaminant concentrations that represent acceptable risks to human health and the environment with very limited site-specific information (current and future land uses and depth to the water table). Sites with potential impacts to soil and groundwater from petroleum releases are initially evaluated through the RBCA Tier 1 evaluation process. Tier 1 allows sites to be screened, evaluated, and cleaned up to generic screening levels. Generic screening levels for petroleum-related compounds are the RBSLs found in Tables 1, 2 and 3. When petroleum contamination is demonstrated to be less than RBSLs, the release or suspected release might be resolved without the need to perform site-specific risk analysis or additional remediation.

A petroleum release from a petroleum storage tank (PST) is confirmed when any soil analytical data exceed levels published in this document (see Administrative Rules of Montana 17.56.506).

The administrative rule also requires any person conducting subsurface investigations, as well as any other parties, to report a suspected petroleum release to DEQ. Failure to report a suspected or confirmed release may result in enforcement actions.

For sites where chemicals exceed Tier 1 RBSLs, a Tier 2 evaluation allows screening levels to be adjusted based upon site-specific information and cleanup to site-specific screening levels for direct contact and leaching to groundwater exposure scenarios. Tier 2 involves adjusting Tier 1 RBSLs based upon site-specific information such as the number of chemicals of concern (COCs) or the characteristics of the vadose zone. Additional site-specific data or information may be necessary for a Tier 2 evaluation. Direct contact adjustments for carcinogenic compounds are based on a 1×10^{-5} excess lifetime cancer risk and non-carcinogenic compounds are based on a hazard index of 1. Leaching to groundwater adjustments may be based upon site-specific dilution and attenuation, an analysis of time for transport, or the evaluation of site-specific chemical partitioning behavior.

More complicated releases require a more extensive investigation, data collection, and analysis to fully assess the risk and address the contamination. These will typically include releases where surface water or groundwater are contaminated at concentrations above groundwater RBSLs or Circular DEQ-7 human health standards, or releases with extensive soil contamination that cannot practically be dealt with under Tier 1 or Tier 2. An example of the latter situation would be a release with gasoline-contaminated surface water or sediment. A Tier 3 analysis is appropriate for these types of sites. Tier 3 involves a full risk assessment, calculation of site-specific cleanup levels, or a site-specific modeling of contaminants leaching to groundwater, and is intended for use at more complex releases.

Vapor Intrusion (VI) cleanup levels are developed using a Tier 2 type of approach. Please refer to DEQ's Vapor Intrusion Guidance for additional information. In addition, Tier 1 or Tier 2 may not be appropriate for releases where site-specific cleanup levels have already been established (e.g., there is already a Record of Decision for the site). The appropriate regulating agency or bureau should be consulted to determine whether Tier 1 or 2 may be applied at these releases.

2.0 CORRECTIVE ACTIONS UNDER RBCA

The nature and extent of contamination at petroleum releases are generally characterized through remedial investigations. During these investigations, responsible parties and their environmental professionals identify which contaminants are present at a release, determine concentrations, and horizontal and vertical distribution of the contaminants. Other site conditions, such as geology, hydrogeology (including determination of site-specific depth to groundwater), local land use, and potential receptors are also documented. This information is evaluated and analytical data are compared to RBSLs to determine RBCA site-specific screening levels for each release (described in more detail below). These site-specific screening levels are set to ensure that any COC concentrations that might remain will not pose unacceptable risks to public health, safety, and welfare, and the environment.

RBCA screening levels can be achieved by removing contaminated material from the release until remaining COC concentrations are below Tier 1 RBSLs. However, RBCA screening levels may also be reached by using combinations of other methods that reduce the potential for exposure. Acceptable methods might include excavation, in situ treatment technologies, source

control or treatment, engineered controls that reduce or restrict migration, or enhancement technologies that promote biodegradation.

Removing or reducing contamination to levels below the RBSLs does not always ensure that contamination has not already leached or migrated downward to the water table. The RBSLs listed in this document that address protection of groundwater are based on protective assumptions to minimize leaching of contaminants to groundwater. If soil contamination concentrations are reduced below RBSLs, then leaching at levels of concern should not occur in the future. However, if contamination exceeded RBSLs in the past, then the leaching process may have already taken place. This has been particularly evidenced in permeable soils and at locations where releases have been present for long periods of time. Therefore, achieving soil RBSLs does not preclude the need to investigate groundwater to determine whether groundwater has been contaminated. In some cases, contamination may have leached downward and formed a smear zone of contamination within the soil between the seasonal high and low water levels of an aquifer. A smear zone can be a secondary source of groundwater contamination. Many factors should be evaluated to determine if a groundwater investigation is necessary. These factors should include the volume and age of the release, permeability of the soil, the depth to groundwater, maximum soil contaminant concentrations originally present, and estimated mass of contamination removed or destroyed, as well as other site-specific parameters.

Risk-based evaluation and cleanup may also be conducted through a Tier 2 evaluation. Some spills can be mitigated easily and remediated to meet Tier 1 generic screening levels (Tier 1 RBSLs), but for sites with more complex issues, a Tier 2 evaluation may be warranted. The Tier 2 evaluation allows Tier 1 RBSLs to be adjusted to site-specific screening levels for direct contact exceedances and leaching to groundwater. If VI is found to be an issue at a site, a separate evaluation will be done using site-specific adjustments when appropriate. Section 4.0 discusses the VI evaluation process.

3.0 TIER 1 RBCA EVALUATION PROCESS

The Tier 1 evaluation is the lowest level of complexity of RBCA. It can be applied for initial evaluation of contaminated soil or simple releases that can be cleaned up using routine methods with limited site characterization. A Tier 1 evaluation generally includes: conducting a field investigation to determine the maximum concentrations of COCs in soil and groundwater associated with the release, developing a conceptual site model (CSM) to identify potentially complete exposure pathways and receptors, and comparing the maximum COC concentrations to the Tier 1 RBSL Tables to determine which pathways are considered complete. The Tier 1 evaluation provides information regarding the “worse-case” scenario and allows responsible parties to decide whether a release will require additional evaluation or remedial actions.

For petroleum releases from a PST system, responsible parties and their environmental professionals follow guidelines to complete forms such as a 30-Day Release Report. This provides DEQ with the information necessary to determine what corrective action is necessary, and whether a release can be resolved without further action.

3.1 Documenting Site Conditions

For releases from PSTs, initial conditions related to the release site are typically documented on the 30-Day Release Report submitted to DEQ. The DEQ Enforcement Division uses the Complaint/Spill Report to document initial information about a release. Other regulating agencies or bureaus may have their own reporting requirements.

DEQ uses information and laboratory analytical data provided by the responsible party to determine whether a release can be resolved using Tier 1, or if a more complex evaluation is needed under Tiers 2 or 3. Some site conditions, such as surface water or sediment contamination, or vapor intrusion prevent resolving a release under Tier 1. In such cases, DEQ may require a Tier 2 or a Tier 3 evaluation to gather more information and develop release cleanup and management strategies, and site-specific screening or cleanup levels.

3.2 Conceptual Site Model

Once a petroleum release has been confirmed, CSM should be developed. A complete exposure assessment is necessary to characterize a site's exposure setting, which includes the physical environment, potentially exposed populations, and current and reasonably anticipated future land uses. This allows the potential exposure pathways, points of exposure, and exposure routes to be identified to ensure that adequate data are collected for all impacted media.

The CSM begins with the source. Sources of petroleum contamination include storage tanks, piping and dispensers, and surface spills or overfills, such as from a refueling truck or other activities. A leak or release from any source can potentially contaminate the surrounding media and create an exposure pathway to a receptor. For example, petroleum leaking beneath a dispenser can enter and contaminate the soil. The petroleum can then leach through the soil to the groundwater where a nearby domestic well may pump the contaminated groundwater into a house creating a potential pathway between the petroleum contamination released from the dispenser and a resident user of the well. COCs from a leak or release can spread through various environmental media such as soil, groundwater, surface water, and air, and can accumulate in vegetation, animals, and other organisms. They are transported by many processes, including gravity, advection, dispersion, diffusion and volatilization. The spread and migration of COCs help complete the exposure pathway which can include natural or man-made processes and media, and can be direct or indirect.

Figure 1 is an example of common exposure pathways for gasoline leaking from an underground storage tank system. Vapors can migrate through the soil vertically or laterally to contribute to VI, which can cause human health impacts. Soluble fractions of gasoline dissolve into and move through groundwater and impact wells. Vapors can penetrate concrete subfloors in basements creating an explosive hazard in nearby houses or other enclosed structures.

Figure 2 provides a flowchart example of a CSM for the same type of release. Table 5 provides a template for a tabular version of a typical petroleum tank release CSM. Additional information regarding the components of a CSM is provided below. The initial CSM is developed based upon the information available for the site at the time. As the site is characterized and risks are evaluated, the CSM is adjusted and refined based upon new information. For example, if the groundwater is not known to be contaminated but COCs are later found in groundwater, additional exposure pathways and receptors may be added. The CSM provides the basis for

determining what data and analyses are necessary to assess risks and determine remediation requirements.

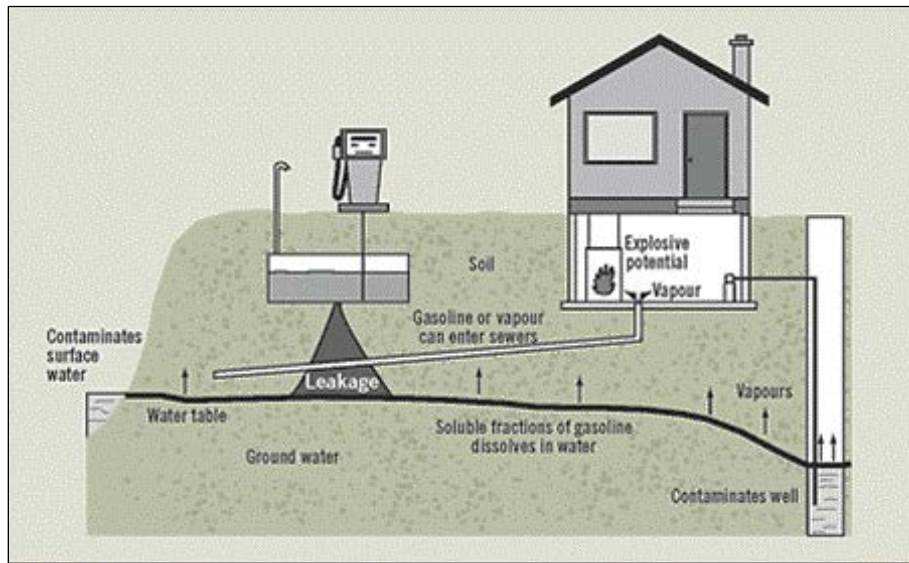


Figure 1 - Graphical depiction of conceptual site model

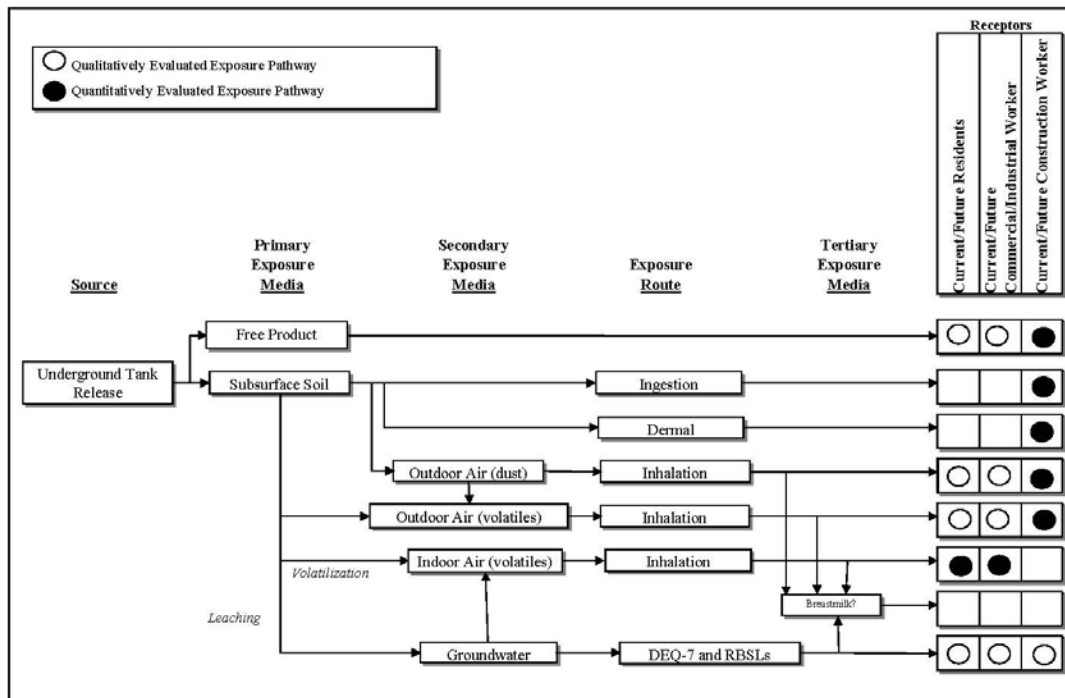


Figure 2 - Conceptual Site Model Flowchart

3.2.1 Receptors

Receptors are humans or organisms that are or may be exposed to COCs in environmental media (surface soil, groundwater, outdoor air, etc.) which can be divided into primary, secondary, and even tertiary points of exposure, each using a different route of exposure (ingestion, inhalation, etc.). Typical receptors include:

- Adults and children in a residential scenario;
- Adult workers in a commercial scenario; and
- Adults in a construction scenario (which includes residential excavations).

Both current and potential future receptors and both on-site and off-site receptors should be evaluated. Therefore, current and reasonably anticipated future land uses for a site and surrounding properties will need to be determined.

3.2.2 Exposure Pathways

Exposure pathways are ways a receptor can come into contact with a COC. Specific pathways include direct contact, leaching from soil to groundwater, runoff to surface water, dispersion of dust through the air, volatilization of COCs to indoor or outdoor air, and uptake of COCs by plants.

3.2.3 Exposure Routes

Exposure routes are the way COCs in contaminated media may come into contact with potential receptors and include:

- Ingestion;
- Dermal Contact; and
- Inhalation.

Exposure routes should be evaluated for current and future exposures. Exposure at petroleum contaminated sites occurs at an exposure point (e.g., contaminated soil or water) through an exposure route (e.g., incidental ingestion of soil, ingestion of water, inhalation of vapors or soil particles).

3.3 Chemicals of Concern

Typical petroleum products such as fuels and lubricants contain a large number of chemical constituents that may be harmful to the public health, safety, and welfare, and to the environment. DEQ has identified several common petroleum constituents as COCs generally detected in petroleum releases. Soil and water samples from petroleum release sites are analyzed for these COCs during a Tier 1 evaluation. Other COCs may be included based on site-specific activities. Any additional COCs will be identified by the appropriate regulating agency or bureau and evaluated outside the Tier 1 process.

COCs include specific compounds (such as methyl tertiary-butyl ether (MTBE), benzene, toluene, ethylbenzene, xylenes, naphthalene, lead scavengers (1,2-DCA and EDB), and PAHs) as well as groupings of compounds contained in VPH and EPH. VPH and EPH laboratory analyses are critical to evaluating risks posed by many chemicals present in typical petroleum products under the RBCA process. These analyses report groupings of chemicals, or “fractions” of the total sum of petroleum chemical present in a sample. The toxicity and behavior of a surrogate chemical have been assigned to represent each fraction in risk and fate and transport analyses. See Section 3.4.1 for further discussion of the VPH and EPH in the RBSL development process.

Data collected at each site are compared to the Tier 1 RBSL tables in order to determine site COCs. Any compounds with concentrations above Tier 1 RBSLs are considered COCs for the site. The Tier 1 process consists of three different tables located in the Tables Section of this document:

- **Table 1** applies to residential and commercial sites with contaminated surface soils from 0-2 feet below ground surface (bgs). The distance from the sample depth to groundwater is also taken into consideration. Select the screening level corresponding to the appropriate site use (residential or commercial) and select the appropriate distance to groundwater (less than 10 feet to groundwater, 10-20 feet to groundwater, or greater than 20 feet to groundwater). For VPH and EPH compounds at PST sites, the RBSLs in bold in the first column (residential, less than 10 feet to groundwater) of Table 1 are used to determine if a release has occurred at a site.
- **Table 2** applies to contaminated subsurface soil (greater than 2 feet bgs). RBSLs in this table are not differentiated for commercial and residential sites as they are for Table 1 because the exposures potentially experienced by construction workers and residents conducting excavation activities such as building structures, planting trees or shrubs, or other construction activities would be the same. The depth to groundwater is crucial when choosing the appropriate screening level. The depth used represents the distance between where the sample was collected and the shallowest water table.
- **Table 3** applies to groundwater COCs that have been derived from DEQ-7 human health standards (HHSs; DEQ 2017), where available, DEQ RBSLs for compounds without DEQ-7 HHSs, and EPA tapwater RSLs (EPA 2017).

3.4 Sampling Protocols

Table A provides useful information that should be reviewed and addressed when collecting soil samples for analysis including: holding time, preservation method, and type and number of sample containers that should be used. Sampling for volatile organic compounds (VOCs), PAHs, RCRA metals, oxygenates, and lead scavengers also have specific sampling requirements. During the initial site characterization DEQ recommends collecting additional field data, including soil characteristics (bulk density, soil moisture, pH, total organic carbon (TOC), and texture), hydrological characteristics, source characteristics, and chemical biodegradation data. Collection of this data will assist with understanding the behavior of the COCs and will save money and time if the release requires a Tier 2 or 3 evaluation.

Table A - Soil Sampling and Preservation Protocol

Parameter	Analytical Method	Sample Container/ Preservation	Holding Time
Soil Samples			
VPH	Montana Method VPH	For samples not methanol preserved: One 4 oz glass jar, cool to (4 ± 2) °C. For samples preserved with methanol: One pre-weighed jar or 2 vials with methanol , plus one 4 oz glass jar without methanol for moisture analysis, cool to (4 ± 2) °C	Without methanol preservation: 7 days to extraction and 28 days to laboratory analysis. With methanol preservation: 28 days to laboratory extraction and analysis.
EPH Screen	Montana Method EPH	One 4 oz glass jar, cool to (4 ± 2) °C	14 days to laboratory extraction and 40 days to analysis.
EPH Fractionation with or without PAH's	Montana Method EPH (PAHs: 8270C or 8270D)	One 4 oz glass jar, cool to (4 ± 2) °C	Following EPH Screen 14 day extraction, 40 days to analysis.
VOCs	EPA Method 8260B	One 4 oz. glass jar, cool to (4 ± 2) °C	14 days to extraction and analysis
RCRA Metals plus zinc (Except Hg)	EPA Method 6010 or 6020	One 4 oz. plastic or glass jar, no preservation	6 months
Mercury (Hg)	EPA Method 7471	One 4 oz. plastic or glass jar, no preservation	28 days
Oxygenates	EPA Method 8260B	125 ml glass jar, cool to (4 ± 2) °C	14 days to extraction and analysis
Lead Scavengers: EDB	EPA Method 8011	125 ml glass jar, cool to (4 ± 2) °C	14 days to extraction and analysis
1,2-DCA	EPA Method 8260B	125 ml glass jar, cool to (4 ± 2) °C	14 days to extraction and analysis

3.4.1 Soil Sampling and Reporting Procedures

The number of soil samples collected and analyzed should delineate the extent and magnitude of the area of confirmed or suspected contamination. For RBCA analysis, soil samples should be collected from worst-case areas, surface spills or other likely sources of petroleum contamination. Samples associated with PST sites should be submitted to a laboratory capable of implementing DEQ's analytical protocol. The laboratory reporting limit should be less than DEQ screening criteria. Table B shows analyses based on product type and testing procedure. The Montana EPH and VPH analytical methods, developed by the Massachusetts Department of Environmental Protection and modified by DEQ, should be used for all RBCA evaluations in Montana.

When sample results are reported to DEQ as part of a standard reporting process for any phase of site assessment or remediation, the report should include all associated laboratory documentation including chromatograms, quality control/quality assurance data and chain of custody forms, as well as soil sample locations, sample depths, and other pertinent site history data.

Table B outlines the analytical methods necessary to apply RBCA analysis for various petroleum products in soil. VPH analysis is necessary for petroleum products that typically contain light range hydrocarbons to determine the concentrations of MTBE, benzene, toluene, ethylbenzene,

xylenes, naphthalene (collectively referred to as MBTEXN) and light end aliphatic and aromatic hydrocarbon fractions in the soil. EPH analysis is necessary in conjunction with VPH for most of the petroleum product types excluding gasoline, aviation gas, and mineral/dielectric oils. DEQ uses a two-step screening technique to evaluate soils at sites where the EPH analysis is necessary to reduce the analytical costs for the EPH analysis. The first step in the screening technique is similar to the diesel range organics (DRO) analysis and generates a total extractable hydrocarbon (TEH) concentration. If the initial screening result is 200 mg/kg or less, no additional EPH analysis is necessary. However, if the TEH concentration is greater than 200 mg/kg, then the EPH fractionation step is necessary. PAH analysis is needed on a site-specific basis if heavy hydrocarbons, refinery wastes or unknown oils/sources are present.

Table B - Testing Procedures for Soils

Petroleum Product	VPH	EPH Screen	EPH Fractionation	EPH for PAHs 8270C or 8270D	RCRA Metals + Zinc	EPA Method 8260B	Lead Scavengers
Gasoline/Aviation Gasoline	R						SS
Diesel (#1 & #2)	R	R	X	SS			
#1 - #2 Heating Oils	R	R	X	SS			
#3 - #6 Fuel Oils		R	X	X			
Used/Waste Oil	R	R	X	X	R	R	SS
Kerosene, Jet Fuel (Jet-A, JP-4, JP-5, JP-8, etc.)	R	R	X	SS			
Mineral/Dielectric Oils		R	X				
Heavier Wastes		R	X	X			
Crude Oil	R	R	X	X			
Unknown Oils/Sources	R	R	X	X	R	R	SS

R - required for RBCA analysis (DEQ technical lead will determine site-specific sampling requirements)

X - analysis to be run if the EPH screen concentration is >200 ppm TEH

SS - Site-specific determination.

3.4.1.2 Dry-Weight Reporting for Soil and Sediment Samples

Soil and sediment sample values are reported on a dry-weight basis. The initial contaminant concentration measured by a laboratory is the “as-is” or “wet weight” result. Calculations are made to wet weight contaminant concentrations to account for the moisture content of the soil (as determined by the lab) and the corrected concentrations are reported as dry weight. This eliminates the variability of contaminant concentrations as a function of moisture content.

3.4.1.3 Moisture Data Reporting for Soil and Sediment Samples

Since all soil and sediment data are reported on a dry-weight basis, moisture percentage is also determined so an adjustment can be made to the “as-is” or wet weight result. The moisture percentage should be included on the laboratory data reports so that fate and transport of COCs may be evaluated.

3.4.2 Groundwater Sampling Procedures

At some sites, it may be necessary to investigate groundwater quality to verify that contaminant concentrations are below RBSLs and DEQ-7 HHSs. MBTEXN and other lighter range hydrocarbons are commonly detected at gasoline and diesel release sites at concentrations that

exceed human health standards. The VPH method includes MBTEXN compounds but the EPH method does not. MBTEXN compounds are present in the heavier petroleum products and VPH analysis is needed in addition to the EPH method at all diesel #1, diesel #2, kerosene, jet fuel, and waste oil release sites to determine MBTEXN concentrations.

EPA Method 8270C or 8270D for PAH analysis is typically appropriate for refinery wastes and other heavy hydrocarbons regardless of the screening concentration. VPH analysis may also be necessary for some contaminants.

At sites that have used or currently use aviation fuel and those that may have had releases of leaded gasoline, analyses for the lead scavengers 1,2-DCA (1,2-dichloroethane) and EDB (also known as 1,2-dibromoethane) should be performed. Lead scavengers were added to leaded gasoline from the 1920's through the 1980's to reduce engine fouling caused by the tetra ethyl lead that was added to gasoline as an anti-knocking compound. Lead scavengers may still be present in off-road fuels such as racing gasoline and leaded aviation gasoline. Table C outlines the analytical methods for individual petroleum products in groundwater.

Table C - Testing Procedures for Groundwater

Petroleum Product	VPH	EPH Screen	EPH Fractionation	EPA Method 8270C or 8270D for PAHs	RCRA Metals + Zinc	EPA Method 8260B	Oxygenates & Lead Scavengers
Gasoline/Aviation Gasoline	R						SS
Diesel (#1 & #2)	R	R	SS	SS			
#1 - #2 Heating Oils	R	R	SS	SS			
#3 - #6 Fuel Oils		R	SS	R			
Used/Waste Oil	R	R	SS	R	SS	R	SS
Kerosene, Jet Fuels (Jet-A, JP-4, JP-5, JP-8, etc.)	R	R	SS	SS			
Mineral/Dielectric Oils		R	SS	SS			
Heavier Wastes		R	SS	R			
Crude Oil	R	R	SS	R			
Unknown Oils/Sources	R	R	SS	R	SS	R	SS

R – Analysis required for RBCA evaluation

SS – Site-Specific determination.

EPH fractionation may be necessary if the EPH screen concentration is >1000 µg/L TEH.

Table D provides useful information that should be reviewed and addressed when collecting aqueous samples for analysis including: holding time, preservation method, and type and number of sample containers that should be used. Sampling for VOCs, PAHs, RCRA metals, oxygenates, and lead scavengers also have specific sampling requirements.

Table D - Aqueous Sampling and Preservation Protocol

Parameter	Analytical Method	Sample Container/ Preservation	Holding Time
VPH	Montana Method VPH	Three 40 ml vials with zero headspace, acidify with HCl to pH <2, cool to (4 ± 2) °C	14 days to analysis
EPH Screen	Montana Method EPH	Two 1 liter amber glass bottles, acidify with HCl or H ₂ SO ₄ to pH <2, cool to (4 ± 2) °C	14 days to extraction, 40 days to analysis
EPH	Montana Method EPH	Two 1 liter amber glass bottles, acidify with HCl or H ₂ SO ₄ to pH <2, cool to (4 ± 2) °C	14 days to EPH Screen extraction, 40 days to analysis
VOCs (Drinking Water)	EPA Method 524.2	Three 40 ml vials with zero headspace, acidify with HCl to pH <2, cool to (4 ± 2) °C. Remove chlorine with Ascorbic Acid.	14 days to analysis
VOCs	EPA Method 8260B	Two 40 ml vials with zero headspace, acidify with HCl to pH <2, cool to (4 ± 2) °C	14 days to analysis
PAHs (Semivolatile Organics)	EPA Method 8270C or 8270D	Two 1 liter amber glass bottles, do not acidify , cool to (4 ± 2) °C. Remove chlorine with ~4 drops of 10% Sodium Thiosulfate (Na ₂ S ₂ O ₃)	7 days to extraction, 40 days to analysis
Lead Scavengers EDB 1,2-DCA	EPA Method 8011 EPA Method 8260B	Six 40 ml vials, acidify with HCl to pH <2, cool to (4 ± 2) °C. Remove chlorine with ~4 drops of 10% Sodium Thiosulfate (Na ₂ S ₂ O ₃)	14 days to analysis
RCRA Metals plus zinc (except Hg)	EPA Method 6010/200.7 or 6020/200.8	One 250 ml HDPE bottle, acidify with nitric acid (HNO ₃) to pH <2, cool to (4 ± 2) °C	6 months
Mercury (Hg)	EPA Method 245.1 or 7470	One 250 ml HDPE bottle, acidify with HNO ₃ to pH <2, cool to (4 ± 2) °C	28 days

To reduce analytical costs, DEQ uses the EPH screening technique. The EPH screen approach is similar to that previously described for soils and generates a TEH concentration. If the initial screening result is 1,000 µg/L TEH or less, EPH fractionation is not necessary. If the TEH concentration exceeds 1,000 µg/L, fractionation is necessary to determine the fraction concentrations.

At least one high and one low seasonal groundwater sampling event may be needed to evaluate seasonal COC variability.

3.4.2.1 EPH Screen vs TEH

Initial groundwater samples should be submitted for the EPH screen and fractionated if the EPH screen concentration is greater than 1,000 µg/L. The EPH screen and the post-fractionation TEH concentration can have significant differences for the same sample because they are derived by two distinct analytical methods.

The EPH screen concentration is a summation of all of the compounds that are extracted from the sample and show up on the chromatogram regardless of elution time. In addition to petroleum hydrocarbons, these compounds may include naturally occurring organics and intermediate metabolites (hydrocarbon breakdown products).

The post-fractionation TEH concentration is a summation of the compounds that show up on the chromatograms after the sample has been run through a silica gel cartridge and rinsed with

hexane and methylene chloride. The silica gel removes polar petroleum hydrocarbons, such as intermediate metabolites and naturally occurring organics, so the compounds that pass through the cartridge should be the regulated petroleum hydrocarbons.

3.4.2.2 Aqueous Sample Preservation

The VPH method recommends the use of three 40 milliliter (ml) vials. The samples are to be preserved by adding hydrochloric acid (HCl) to reduce the pH to 2 or less. The vial should be checked to ensure no air bubbles are present in the vial before placing on ice. Please refer to Table D for additional sampling procedures.

Trisodium phosphate (TSP) is used as an alternative to acid preservation for fuel oxygenates. It prevents the biological degradation of the target analytes and does not cause hydrolysis of ethers to alcohols.

At sites where drinking water supplies, either water supply lines or domestic or public water supply wells, are threatened by petroleum contamination, VOC analysis by EPA Method 524.2 of the water inside the well or pipelines may be necessary. HCl is used as a preservative. If the water system is chlorinated, ascorbic acid needs to be added to prevent the formation of chlorination by-products. If the supply is not chlorinated, then only HCl is used for preserving the sample.

3.4.3 Use of Old and New Total Petroleum Hydrocarbon Data

While the use of the Montana VPH/EPH approach is a preferred means to characterize risks from petroleum products released to the environment, there are significant amounts of historical total petroleum hydrocarbon (TPH) data that have been obtained in the past for contaminated sites. For a Tier 1 evaluation, old TPH data may be converted to EPH fractional data using the guidelines discussed below. If the historical data exceeds current RBSLs, indicating that additional evaluation of a release is necessary, then the Montana VPH/EPH approach should be used.

Conservative assumptions can be made to “convert” old TPH data into EPH fractional data. Since TPH is essentially a summation of the three EPH fractions (i.e., C9-C18 aliphatics, C19-C36 aliphatics, and C11-C22 aromatics), it is possible to “convert” TPH data into the EPH fractional ranges, by making informed and reasonably conservative judgements on the chemistry of the TPH data. Compositional assumptions for soil data that are considered to be protective at most sites are provided in Table E.

Table E - Recommended TPH Compositional Assumptions in Soil

Petroleum Product	C11-C22 Aromatics	C9-C18 Aliphatics	C19-C36 Aliphatics
Diesel/#2/Crankcase Oil	60%	40%	0%
#3-#6 Fuel Oil /Bunker C	70%	30%	0%
Kerosene and Jet Fuel	30%	70%	0%
Mineral Oil Dielectric Oil	20%	40%	40%
Unknown Oil	100%	0%	0%

Source: Massachusetts Department of Environmental Protection, *Implementation of the MADEP VPH/EPH Approach*, October 2002

For old GRO soil data, consider all of the non-BTEX/MTBE hydrocarbons which have higher molecular weights than C8 to be C9-C10 Aromatics. All non-BTEX/MTBE compounds which

have lighter molecular weights than C9 are considered aliphatic hydrocarbons.

For water data, these conservative assumptions can be made:

- For TPH water data, all of the TPH should be assumed to be the most conservative EPH fractional RBSL for groundwater, although it is permissible to remove the concentrations of target PAH analytes (e.g., naphthalene), if known; and
- For GRO water data, the entire GRO concentration should be assumed to be the most conservative VPH fractional RBSL for groundwater, although it is permissible to remove the concentration of target BTEX/MTBE, if known.

3.5 Using Tier 1 Look-Up Tables

Once the field investigation is complete, the CSM has been established, and all the necessary data has been collected, data are compared to the Tier 1 RBSL look-up tables. These tables contain screening levels for surface soil, subsurface soil, and groundwater (see Tables 1, 2, and 3, respectively). They are arranged in categories that reflect different site conditions such as, current or future land use and varying depths to groundwater. The Tier 1 tables also consider both direct contact and the leaching to ground water pathways and display whichever value is lower. This ensures that the Tier 1 process is protective of human health and the environment. More information on how the RBSLs for the Tier 1 process were developed is provided in section 3.6. To determine the appropriate RBSLs, the responsible party and DEQ staff compare the soil or groundwater values to the RBSLs that correspond with the conditions present at the site.

For the purposes of a Tier 1 evaluation, “surface soil” is 0-2 feet below ground surface and “subsurface soil” is deeper than 2 feet below ground surface. Tier 1 RBSLs for contaminated surface (0-2 feet below ground surface) and subsurface (2-10 feet below ground surface) soils are divided into three categories depending on the distance to groundwater from ground surface and beneath contaminated soil:

- 1) Groundwater less than 10 feet below contamination;
- 2) Groundwater between 10 and 20 feet below contamination; and
- 3) Groundwater greater than 20 feet below contamination.

The distance to groundwater is generally determined using the difference between the depth of the soil sample location and the highest seasonal water level in a well screened in the uppermost zone of saturation within 500 feet of the release. Nearby water supply wells may not be appropriate in some cases to determine the depth to the uppermost saturated zone (first water) as they may be completed in a deeper zone. In determining which Tier 1 table is appropriate, it is necessary to know three depths:

- 1) The depth the sample was taken below the ground surface;
- 2) The depth the water table is below the ground surface; and
- 3) Known distance to groundwater below soil sample collection depth (calculated by subtracting 1 from 2).

For example, if the soil sample is collected below an underground storage tank at a depth of 10 feet below ground surface, and the water table is 25 feet below the ground surface, the depth to

the groundwater is 15 feet and data collected from this point should be compared to the RBSLs listed in the 10-20 feet to groundwater column.

When contamination is present at both surface and subsurface depths, samples with the highest concentrations in each depth zone are compared to the appropriate Tier-1 tables.

The current and reasonably anticipated future use of sites with contaminated surface soil should also be considered. The site may be designated commercial or residential by considering the reasonably anticipated future use of the site. Residential sites are those where someone resides or may reside in the future, potentially including farms and ranches and gas stations with associated residences. Commercial sites are those without residents, used only for commercial/industrial purposes. This determination is only relevant for petroleum-contaminated surface soil, including contaminated surface soil at permitted landfarm locations. When site conditions are not well defined, DEQ uses the most conservative soil RBSLs, corresponding to the shallowest depth to groundwater below contaminated soil with residential use.

If RCRA metals, including zinc are analyzed, concentrations are compared to the following background concentrations and screening levels.

Table F - RCRA Metals and Zinc Screening Levels in Soil

Metal	Screening Level	Background Threshold Value Concentrations^d	Units
Arsenic	0.68 ^a	22.5	mg/kg
Barium	421 ^c	429	mg/kg
Cadmium	3.8 ^b	0.7	mg/kg
Chromium ^e	12,000 ^a	41.7	mg/kg
Lead	140 ^b	29.8	mg/kg
Elemental Mercury	1.0 ^b	<0.05	mg/kg
Selenium	2.6 ^b	0.7	mg/kg
Silver	8.5 ^c	0.3	mg/kg
Zinc	1,233 ^c	118	mg/kg

- Based on the EPA RSL for residential soil (EPA, June 2016).
- Based on the EPA November 2017 maximum contaminant level-based protection of groundwater soil screening level (multiplied by a dilution attenuation factor of 10).
- Based on the following formula:
(DEQ-7 HHS)/(tapwater screening level) * (RBSL) * 10
- DEQ, *Background Concentrations of Inorganic Constituents in Montana Surface Soils*. September 2013.
- The chromium RSL and background concentration are for chromium III as this form of chromium is the most common. If chromium VI is suspected (i.e., plated chrome is associated with the site), please consult DEQ.

For metals, if the screening level is less than the background concentration (e.g., arsenic), the background concentration is used for screening. If the background concentrations or screening levels, whichever are higher, are exceeded, further evaluation is necessary. DEQ should be contacted to determine what evaluation is appropriate.

Should COC concentrations exceed the values in the appropriate Tier 1 RBSL Lookup Table(s), the release is not ready to be resolved under the Tier 1 process. However, it may be possible to remediate a release to Tier 1 RBSLs by removing more contaminated material (e.g., through

further excavation or *in situ* remedial techniques), then resampling and following the Tier 1 evaluation process again. Releases that cannot be resolved under the Tier 1 evaluation process, including those with COCs in groundwater above the DEQ-7 HHSs or Tier 1 RBSLs (Table 3), may be addressed through further evaluation and may need additional corrective action before they can be resolved. Potential corrective actions include a Tier 2 evaluation, a Tier 3 evaluation, and/or cleanup. Please refer to Section 5.0 for details of the Tier 2 evaluation process.

3.6 Development of Tier 1 Screening Tables

DEQ calculated Tier 1 RBSLs for exposure pathways commonly associated with petroleum releases. RBSLs for surface soil were calculated for the soil leaching to groundwater pathway, and for the direct-contact pathway assuming residential and commercial land use. RBSLs for subsurface soil were calculated for the soil leaching to groundwater pathway, and for the direct contact pathway to account for exposure of receptors during any construction or excavation at a site (including residential sites). For each of the three distances to groundwater categories in Tables 1 and 2, the RBSLs in Table 1 reflect the most conservative (most protective) COC concentration calculated for any of the three Tier 1 exposure scenarios (i.e., for the soil leaching to groundwater pathway and through direct contact). Table 4 is a comprehensive soil RBSL table presenting the RBSLs calculated for direct contact and leaching to groundwater. This table is the basis for a Tier 2 evaluation. Please refer to section 5.0 for information on the Tier 2 process and the correct use of Table 4.

Tier 1 RBSLs for groundwater provided in Table 3 consist of DEQ-7 human health standards for the individual (target) COCs. For the petroleum fractions, direct contact RBSLs were calculated using parameters associated with surrogate compounds.

3.6.1 Derivation of RBSLs

Tier 1 RBSLs were calculated using chemical fate and transport modeling, exposure models, and data characterizing the mobility, toxicity, and aesthetics of petroleum compounds. The contaminant transport models simulate chemical movement from a release source to underlying groundwater, and incorporate conservative assumptions regarding soil type, the rate of water infiltration, and the behavior of the COCs. Contaminant transport modeling results were used to calculate soil target levels protective of groundwater RBSLs (including DEQ-7 human health standards). Exposure modeling was performed to characterize potential risk from direct contact with contaminated soil, including ingestion, inhalation, and dermal contact exposure routes, and contact with groundwater, including ingestion and inhalation.

Refined petroleum products are typically mixtures of organic chemicals, many of which do not have DEQ-7 HHSs. The groundwater RBSL table (Table 3) includes DEQ-7 HHSs for target COCs for which standards were available. RBSLs for the COCs that do not have a DEQ-7 standard or an RSL have been developed as described in the following paragraphs.

RBSLs for the non-target ranges of petroleum hydrocarbons were developed using a fraction-surrogate approach because DEQ-7 human health standards were not available. These petroleum constituents are divided into fractions (e.g., C5-C8 aliphatics) based on chemical behavior and toxicity. RBSLs were calculated using a chemical representative (“surrogate”) for each fraction. Groundwater RBSLs were developed for each petroleum fraction based on the toxicity of each

surrogate chemical. Toxicity values were combined with exposure parameters used to estimate ingestion and inhalation exposure to the COCs in groundwater to develop RBSLs based solely on risk to human health. These exposure parameters are similar to those used to develop DEQ-7 human health standards. DEQ also considered the lowest reasonably achievable practical quantitation limit (see Table 3) in setting RBSLs for the petroleum fractions.

Soil RBSLs were calculated for each petroleum fraction using the chemical fate and transport model used for the target compounds. These soil RBSLs are designed to be protective of groundwater below releases, so that contaminants leaching from contaminated soil will not cause groundwater to exceed groundwater RBSLs.

Protective, generic estimates of physical, chemical, and exposure parameters were used to develop the Tier 1 RBSLs. These generic estimates produce RBSLs with built-in safety margins, to compensate for the limited site-specific information typically available at Tier 1. The conservative Tier 1 RBSLs were created using several generic “worst-case” assumptions for model parameters.

3.6.2 Models Used to Generate Tier 1 RBSLs

DEQ calculated Tier 1 RBSLs for the soil leaching to groundwater pathway using the “VS2DT Solute Transport in Variably Saturated Porous Media” model (United States Geological Survey, 1996), combined with the “Hydrologic Evaluation of Landfill Performance” (HELP) model, which was used to estimate water infiltration rates. Direct contact RBSLs were calculated using equations developed by the EPA and the Massachusetts Department of Environmental Protection. The specific assumptions used in DEQ’s Tier 1 soil leaching to groundwater models are discussed in Appendix A. The assumptions used in the direct contact modeling, including those associated with the fraction-surrogate approach, are discussed in Appendix B. Since Tier 1 RBSLs are intended for use at a variety of releases throughout the state, the assumptions of Tier 1 provide for a wide margin of safety, and are therefore conservative.

3.7 Summary of Tier 1 Evaluation Procedures

Procedures for evaluating a release using RBCA Tier 1 are summarized as follows:

- 1) Document site conditions by contacting DEQ and, for underground storage tank releases, filling out the proper forms such as the 30-Day Release Report.
- 2) Develop a conceptual site model to characterize the site’s exposure setting identifying the different exposure pathways, points of exposure, exposure routes, and receptors to ensure adequate data are collected for all impacted media.
- 3) Compare data to the Tier 1 RBSL Tables, using the following procedures:
 - a) Determine if the soil sample represents surface or subsurface soil
 - ♦ If the sample depth is two feet or less, the sample represents surface soil and the Tier 1 Surface Soil RBSLs (Table 1) apply.
 - ♦ When samples represent surface soil, use the appropriate land use category in Table 1 (commercial or residential).
 - ♦ If anyone lives at the site or may live at the site in the future (e.g., farms and ranches), residential RBSLs apply to surface soil.
 - ♦ If the site is used as a place of business with regular employee presence and no one lives at the site and an analysis of the reasonably anticipated future uses of the site

- indicates it is unlikely that people may live at the site in the future, commercial RBSLs apply to surface soil.
- ♦ If the sample depth is greater than two feet, the sample represents subsurface soil and the Tier 1 Subsurface Soil RBSLs (Table 2) apply.
- b) Determine the depth to groundwater
- ♦ For both surface (Table 1) and subsurface (Table 2) soils, if the depth to groundwater is less than ten feet below the sample collection location, the first column of RBSLs apply (left hand column(s)).
 - ♦ For both surface (Table 1) and subsurface (Table 2) soil, if groundwater is between ten and twenty feet below the sample collection location, the second column of RBSLs apply (middle column(s)).
 - ♦ For both surface (Table 1) and subsurface (Table 2) soil, if groundwater is greater than twenty feet below the sample collection location, the third column of RBSLs apply (right hand column(s)).
- 4) If the worst-case soil sample results are less than the appropriate RBSL value, no further corrective action may be necessary. DEQ will discuss the results and forward progress with you.
 - 5) If soil sampling results exceed RBSLs, corrective action identified by DEQ should be completed.
 - 6) Following the required corrective actions, complete confirmation soil and groundwater sampling and compare the results with RBSLs on the Tier 1 Tables by repeating step 4.
 - 7) At any point in the process, if groundwater sampling results or site conditions indicate that groundwater is impacted, compare groundwater data to the Tier 1 groundwater RBSLs (Table 3) to evaluate potential groundwater impacts. Groundwater sampling results that represent a range of hydrological scenarios (e.g. seasonal high and low) may be necessary for a complete evaluation (ARM 17.56.605(6) states two years of monitoring or another reasonable time period approved by DEQ may be required).
 - 8) If groundwater sampling results exceed the Tier 1 groundwater RBSLs (Table 3) the release cannot be resolved under the Tier 1 RBCA process, and additional evaluation (e.g., investigation, corrective action, etc.) is necessary.

4.0 VAPOR INTRUSION TO INDOOR AIR

VI sampling assists in determining whether or not the VI exposure pathway is complete and, if so, whether it poses an unacceptable risk to human health. This section, as with the entire document, describes risk-based approaches for petroleum contamination only. A complete pathway means that humans are exposed to vapors originating from site contamination: either from volatilization from impacted soil, impacted groundwater, or both. The RBSLs for soil and water are not designed to be protective of the VI pathway. If volatile compounds are present in the vicinity of inhabitable structures, then the VI pathway should be evaluated either qualitatively or quantitatively. DEQ has developed the Montana Vapor Intrusion Guide (DEQ, 2011) to aid in the evaluation of risks posed by sub-surface concentrations of chemical contaminants, and DEQ will approve specific evaluation procedures based on this guidance. The Montana Vapor Intrusion Guide has not been adopted as a regulation but does provide guidance on conducting a proper investigation. At this time, DEQ has not adopted the EPA Petroleum Vapor Intrusion Guidance or the EPA Vapor Intrusion Screening Level (VISLs) Calculator.

The VI evaluation is conducted separately from the RBCA Tier 1 and Tier 2 soil and groundwater evaluations. When investigating VI, an initial phase of sample collection and

comparison to generic screening levels will take place and may be followed by a more in-depth investigation and development of site-specific screening levels. More than one set of samples is typically necessary to determine whether VI is occurring and to what extent. Several different types of environmental samples may be collected:

Soil vapor samples are collected to characterize the nature and extent of vapor contamination in the soil in a given area. They may be collected prior to collecting sub-slab vapor and/or indoor air samples to help identify buildings or groups of buildings that need to be sampled. Soil vapor samples are used to determine the potential for vapors to accumulate beneath buildings. Soil vapor samples are not the same as soil samples.

Sub-slab vapor samples are collected to characterize the nature and extent of vapor contamination in the soil/gravel layer immediately beneath a building with a slab or a concrete-floored basement. In buildings without a slab, crawl space air and/or soil gas samples may be collected below the building. Sub-slab vapor results are used to determine the potential for VI.

Indoor air samples are collected to characterize the nature and extent of vapors within a building. Indoor air sample results help to evaluate whether vapors are currently migrating into a building. They are also compared to sub-slab vapor and outdoor air results to help determine where volatile chemicals may be coming from (indoor sources, outdoor sources, and/or beneath the building). To best conduct this comparison/determination, indoor air and sub-slab samples should be collected simultaneously.

Outdoor air samples are collected to characterize site-specific background air conditions. Outdoor air results are used to evaluate the extent to which outdoor sources, such as automobiles, lawn mowers, oil storage tanks, gasoline stations, or commercial/industrial sites may be affecting indoor air quality. However, the presence of a contaminant in the outdoor air does not necessarily mean that the contaminant will be present in indoor air. DEQ recommends that outdoor air samples be collected upwind of the building or air intake point to be representative of ambient conditions.

4.1 Vapor Screening Levels

When indoor air and sub-slab sample data have been collected they can be compared to generic screening levels for an initial evaluation to determine whether the pathway for VI is complete and whether there is a potential for risk associated with the inhalation of vapors from contaminated subsurface media (DEQ, 2011). The screening levels used are based on potential exposure scenarios for residential and industrial (commercial) receptors. The appropriate screening levels to use for VI evaluations are discussed below. If the concentrations are less than generic screening levels, additional investigations may not be needed. In order to make this determination, the data should also indicate that the contaminant source is not increasing or migrating and should represent anticipated seasonal variations. An exceedance of generic screening levels does not necessarily mean that mitigation is necessary. However, it does mean that additional investigations or evaluations may be needed to fully assess VI.

4.1.1 Regional Screening Levels

During initial screening, indoor air concentrations should be compared to the most recent EPA RSL for residential or industrial (commercial) air. The EPA developed generic screening levels based upon typical residential or industrial exposure. The industrial RBSLs should be used when evaluating a commercial exposure scenario under RBCA. When comparing VI data at a site in

Montana, adjustments may need to be made. The EPA RSL screening levels are based upon a cancer risk representing a 1×10^{-6} (or one in one million) excess lifetime cancer risk and therefore allow for as many as 10 cancer-causing compounds to be present at their screening levels before the Montana-allowable 1×10^{-5} excess lifetime cancer risk is exceeded. In Montana, cancer risk is considered to be additive regardless of the type of cancer that may result from exposure. To determine site-specific screening levels based upon non-cancer risk, divide the screening level by 10 to account for multiple compounds that may impact the same target organs or have the same critical effects. Non-cancer risks are considered additive as exposure may affect the same organs or result in the same critical effects.

4.1.2 Typical Indoor Air Concentrations

DEQ has reported Typical Indoor Air Concentrations of Volatile Organic Compounds in Non-Smoking Montana Residences Not Impacted by Vapor Intrusion (DEQ, 2012) to aid in evaluating background indoor air concentrations of various volatile chemical compounds found in petroleum products. Where these background concentrations are higher than the RSLs or other risk-based screening levels, the background concentrations may be used in lieu of either generic or site-specific screening levels as appropriate. This is the case for residential screening levels for 1,2-DCA, benzene, C5-C8 aliphatics, C9-C12 aliphatics, ethylbenzene, and naphthalene.

4.1.3 APH Screening Levels

DEQ developed the Air-Phase Petroleum Hydrocarbon (APH) Vapor Intrusion calculator for use at sites containing only petroleum contamination. If generic screening indicates that petroleum compounds are the only VI COCs for a site, adjustments may be made using the calculator found at <http://deq.mt.gov/Land/statesuperfund/aphvicalc>. The APH is based upon samples collected using the Massachusetts Air-Phase Petroleum Hydrocarbons (APH) method. DEQ developed the screening levels using the same assumptions as those EPA used to calculate the RSLs. For non-carcinogenic COCs, DEQ adjusted the target hazard index by dividing by ten to ensure that cumulative potential health effects were addressed. The petroleum fractions were calculated by DEQ and are based on toxicological information from the EPA Provisional Peer-Reviewed Toxicity Values for Complex Mixtures of Aliphatic and Aromatic Hydrocarbons (EPA, 2009). The remaining petroleum compounds were derived from the RSL Table (EPA, 2016) and adjusted to account for a 78-year life expectancy from the EPA Exposure Factors Handbook (EPA, 2011).

The APH Screening Level Calculator is a computer based screening tool only to be used for petroleum contamination to determine if VI concentrations exceed generic risk-based screening levels. This calculator is not meant to be used with solvent sites or mixed waste sites containing a combination of petroleum and other contaminants. This calculator adjusts RBSLs based upon the COCs present at a site above appropriate RSLs.

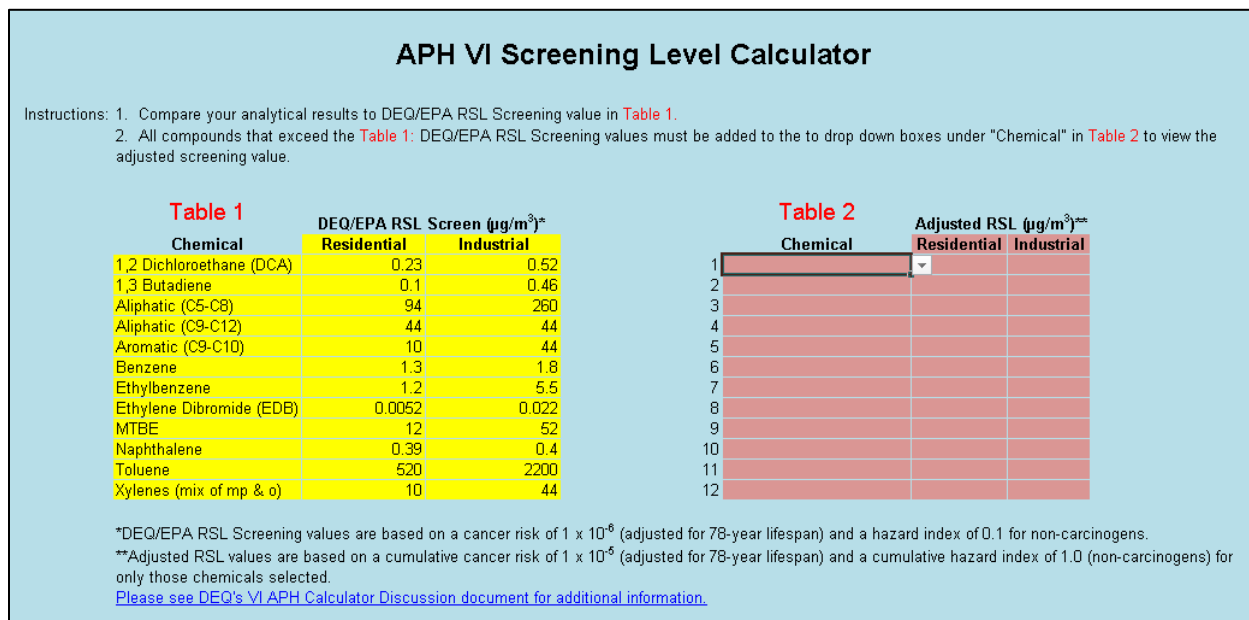


Figure 3 - Screen view of APH Calculator Without Site-Specific COCs

To use this calculator, compare the analytical results to the APH Table 1 DEQ/EPA RSLs as seen in Figure 3. Manually add those compounds that exceed the APH Table 1 screening levels to APH Table 2 shown in Figure 3 by clicking one-by-one on the drop-down tabs (this includes any compounds detected above the RSL that are J-flagged). As compounds are entered, the calculator will display the adjusted residential and industrial screening levels. If the newly adjusted screening level is below typical indoor air concentrations provided in the Typical Indoor Air Concentrations of Volatile Organic Compounds in Non-Smoking Montana Residences Not Impacted by Vapor Intrusion (DEQ, 2012), the calculator will automatically default to background screening levels. For more information about the APH calculator, please refer to the APH VI Calculator Discussion found here: <http://deq.mt.gov/Land/statesuperfund/aphvicalc>.

5.0 TIER 2 RBCA EVALUATION PROCESS

During the Tier 1 evaluation process, site conditions are thoroughly evaluated and data are collected to determine the site COCs and the nature and extent of contamination at the site. Soil and groundwater data are compared to the Tier 1 RBSL Tables and a decision is made as to whether a site can be closed or whether remediation or additional evaluation should be conducted. Using the conservative Tier 1 RBSLs is appropriate for initial screening to determine whether a release has occurred or for a Tier 1 analysis or cleanup. However, because the Tier 1 RBSLs are meant to be conservative, once additional information about the COCs is available for a site, the soil RBSLs may be adjusted on a site-specific basis for a Tier 2 analysis.

A Tier 1 evaluation is conducted prior to implementing the Tier 2 process. If a site has not undergone a Tier 1 evaluation, please refer to Section 3.0 and complete the Tier 1 steps before moving forward with a Tier 2 evaluation.

5.1 COC Exceedance Evaluation

The first step in the Tier 2 evaluation process is determining exceedances that may exist for direct contact and/or leaching to groundwater at the site. Table 4 is the Master Table used to evaluate potential COC exceedances. The Master Table contains RBSLs specific to leaching to groundwater (first three columns) and RBSLs specific to direct contact (last three columns). The leaching to groundwater RBSLs vary depending upon the distance between the bottom of soil contamination and the top of groundwater. The direct contact RBSLs are calculated based on sample depth and a site's use (residential, commercial, etc.). Residential RBSLs include soil samples collected from 0-2 feet bgs and have or could have persons living at the site. Commercial RBSLs include soil samples collected from 0-2 feet bgs from a site with a business where employees and/or visitors come and go, but no one is living at the site. Construction RBSLs are used for samples collected from 0-10 feet bgs and apply to both residential and commercially used properties.

If leaching to groundwater is not a concern or has otherwise been addressed in an appropriate manner (see Tier 2 Leaching to Groundwater discussion in Section 5.3), it is possible that a Tier 2 evaluation can be conducted by consulting the Master Table and verifying that the direct contact RBSLs are not exceeded. The following example presents a situation where soils exceed Tier 1 RBSLs and groundwater concentrations are now below the RBSLs.

Example 1:

There is a petroleum site with benzene, toluene, and MTBE in residential surface soil where groundwater is 6 feet below the contamination. The compounds detected in soil were previously detected in groundwater, but now samples collected during high and low groundwater conditions indicate that the groundwater meets RBSLs. During the Tier 1 evaluation, the surface soil concentrations are first compared to the Tier 1 RBSLs for direct contact found on Table 1 of the RBCA Guidance.

Compound	Cancer/Non-Cancer Basis	Tier 1 RBSL mg/kg	Site Concentration mg/kg
Benzene	Cancer	0.07	0.9
Toluene	Non-cancer	21	30
MTBE	Cancer	0.078	3

Benzene, Toluene, and MTBE all exceed the Tier 1 RBSLs and are considered COCs for the site. Next, the Master Table (Table 4) is consulted to determine the basis (direct contact or leaching to groundwater) of the Table 1 RBSL.

Compound	Cancer/Non-Cancer Basis	Leaching to Groundwater RBSL mg/kg	Direct Contact Residential RBSL mg/kg	Site Concentration mg/kg
Benzene	Cancer	0.07	1.3	0.9
Toluene	Non-cancer	21	610	30
MTBE	Cancer	0.078	52	3

By using the Master Table, the exceedances seen in the Tier 1 evaluation for all three compounds were based on leaching to groundwater. Since the groundwater data indicated that leaching of remaining contamination is not occurring, soil concentrations can be screened using the Direct

Contact Residential RBSL to determine whether a direct contact risk is present. In this example, leaching has been shown to not be a concern for the site and site concentrations do not exceed the direct contact RBSLs therefore, the site could be closed without further remediation or evaluation.

5.2 Direct Contact Exceedance

Tier 1 site screening is conducted when not much information is known about a site to ensure that any decision not to remediate the site does not leave an unacceptable risk. Because of this conservatism, it may be acceptable to adjust the Tier 1 RBSLs for a Tier 2 site-specific screening evaluation.

These adjustments are only appropriate for direct contact exposure and are NOT appropriate for screening levels (RBSLs and SSLs in the EPA RSL tables) that are based on leaching to groundwater. Section 5.3 outlines the steps that can be taken for site-specific leaching to groundwater evaluations.

Cancer-causing compounds (carcinogens) represent some risk of getting cancer even at low concentrations. In the RBCA Tier 1 or 2 evaluations all cancer risks are treated the same (e.g., there is no differentiation between skin cancer and liver cancer). The State of Montana allows an excess lifetime cancer risk level of 1 in 100,000 or 1×10^{-5} . The RBSLs based upon direct contact for carcinogens are based upon $1/10^{\text{th}}$ of that risk or 1 in 1,000,000 or 1×10^{-6} . Therefore, a site could have up to 10 carcinogenic compounds present at concentrations as high as their respective screening levels and still not have a cumulative cancer risk that exceeds the allowable risk level of 1×10^{-5} .

Carcinogens may also have non-carcinogenic effects and there are other compounds that are not known or suspected to cause cancer (non-carcinogens). Non-carcinogens have known threshold concentrations below which adverse non-cancer health effects are not expected to occur. This threshold is represented by a reference dose that may be compared to the dose associated with exposure to site concentrations. This comparison is represented by a hazard quotient. A hazard quotient of 1 or less indicates that the dose from the contaminant concentration is not greater than the threshold dose. Non-carcinogens may impact different organs or systems (e.g., liver, kidneys, and central nervous system). If there are several non-carcinogens that affect a particular organ or system, the effects are added together and the sum of the hazard quotients for those compounds is referred to as the hazard index. A hazard index greater than 1 represents a risk to a particular organ or system. Therefore, non-cancer Tier 1 RBSLs levels are adjusted to account for multiple compounds impacting the same organ or system to ensure that the hazard index does not exceed 1.

Each direct contact RBSL listed in the master table represents a hazard quotient of 0.125, since there are eight compounds in each analytical suite (VPH and EPH) that have non-cancer effects. Therefore, if as many as eight petroleum compounds or fractions are present at concentrations as high as their screening levels, and even if all the compounds impact the kidneys, there would still be no adverse health effects expected and the hazard index would not exceed 1.

Because the Tier 1 RBSLs were developed on this conservative basis, it is possible to adjust the RBSLs if all compounds or fractions are not present based upon the verified data for the site. The adjustment is made based upon the number of COCs actually present at the site. The

following are examples to illustrate the process.

Example 2:

Compound	Cancer/Non-Cancer Basis	Tier 1 RBSL (mg/kg)	Site Concentration (mg/kg)
Benzene	Cancer	0.07	1.5
Toluene	Non-cancer	21	850
Ethylbenzene	Cancer	6.4	8
C9-C12 Aliphatics	Non-cancer	77	140
Naphthalene	Cancer	4.3	6

A petroleum site contains benzene, toluene, ethylbenzene, C9-C12 aliphatics, and naphthalene in surface soil. Groundwater had previously been contaminated, but was found to meet RBSLs for the last high and low groundwater monitoring events. The concentrations are first compared to the Tier 1 RBSLs found on Table 1 of the RBCA Guidance.

Since leaching to groundwater is no longer occurring, Table 4, the Master Table, is consulted to identify the direct contact RBSLs. The following table depicts the Master Table direct contact RBSLs, as well as the cancer risk levels and hazard quotients represented by the RBSLs.

Compound	Cancer/Non-Cancer Basis	Direct Contact Residential RBSL (mg/kg)	Cancer Risk Level	Hazard Quotient*
Benzene	Cancer	1.3	1×10^{-6}	NA
Toluene	Non-cancer	610	NA	0.125
Ethylbenzene	Cancer	6.4	1×10^{-6}	NA
C9-C12 Aliphatics	Non-cancer	77	NA	0.125
Naphthalene	Cancer	4.3	1×10^{-6}	NA
Totals	--	--	3×10^{-6}	0.25

Because the sum of the cancer risks and the total hazard index based on the direct contact RBSLs for all the compounds present at the site are less than 1×10^{-5} and 1, respectively, it is acceptable to adjust the RBSLs. The first step is to multiply the Master Table Direct Contact RBSL for each compound by 10 for carcinogens, and by 8 for the non-carcinogens. This removes the conservatism built into the Tier 1 RBSLs to account for the potential presence of all the COCs. Then the adjusted RBSLs for carcinogenic compounds are divided by the number of carcinogenic compounds at the site to divide the risks equally between the different carcinogenic compounds while ensuring that the total risk does not exceed 1×10^{-5} . The same process is conducted for the non-carcinogenic compounds, while ensuring that the combined total does not exceed a hazard index of 1. The following table depicts these adjustments.

Compound	Cancer/ Non-Cancer	Adjustment mg/kg * adj. factor	Adjusted Tier 2 RBSL mg/kg	Cancer Risk Level	Hazard Quotient
Benzene	Cancer	1.3 * 10/3	4.3	3.3 x 10 ⁻⁶	NA
Toluene	Non-cancer	610 * 8/2	2440	NA	0.5
Ethylbenzene	Cancer	6.4 * 10/3	21	3.3 x 10 ⁻⁶	NA
C9-C12 Aliphatics	Non-cancer	77 * 8/2	308	NA	0.5
Naphthalene	Cancer	4.3 * 10/3	14	3.3 x 10 ⁻⁶	NA
Totals	--	--	--	1 x 10⁻⁵	1

In this example, the adjustment results in each of the carcinogens representing a 3.3 x 10⁻⁶ or one third of the total 1 x 10⁻⁵ risk. The adjustment results in each of the non-carcinogens representing a hazard index of 0.5 or one half of the total hazard index of 1. Next the site concentrations are compared to the adjusted Tier 2 RBSLs.

Compound	Cancer/Non- Cancer Basis	Adjusted Tier 2 RBSL (mg/kg)	Site Concentration (mg/kg)
Benzene	Cancer	4.3	1.5
Toluene	Non-cancer	2440	850
Ethylbenzene	Cancer	21	8
C9-C12 Aliphatics	Non-cancer	308	140
Naphthalene	Cancer	14	6

Therefore, based upon the groundwater data indicating that leaching of remaining contamination is not occurring and that site concentrations do not exceed the adjusted Tier 2 direct contact RBSLs, the site could be closed without further remediation or evaluation.

The groundwater RBSLs may not be adjusted in the same manner as the soil RBSLs. Many of the Tier 1 RBSLs are DEQ-7 human health standards and therefore may not be adjusted. The RBSLs for the petroleum fractions are already based upon a hazard quotient of 1, similar to the DEQ-7 standards, and may not be adjusted. Finally, the RSLs for 1-methylnaphthalene and 2-methylnaphthalene included in Table 3 have also already been adjusted to be based upon a 1 x 10⁻⁵ excess lifetime cancer risk and a hazard quotient of 1. Therefore, site groundwater concentrations should be compared directly to these RBSLs and DEQ-7 human health standards. An exception exists for Class IV groundwater. If the natural condition of the groundwater, is Class IV as defined in Administrative Rules of Montana 17.30.1006, only the carcinogenic HHSs apply.

5.3 Leaching to Groundwater Exceedances

If site soil concentrations exceed leaching to groundwater RBSLs included in the Master Table, it may be possible to demonstrate via groundwater sampling that the groundwater is not or is no longer contaminated. However, it may be necessary to conduct a site-specific Tier 2 analysis. Multiple approaches can be used to calculate site-specific screening levels based on leaching. These calculations vary from simple to complex and generally site-specific soil and hydrological

data are necessary to estimate contaminant travel time through the vadose zone, calculate a site-specific dilution attenuation factor (DAF) and/or conduct fate and transport modeling.

The following sections outline the options available. One of the options below or a combination of more than one may be used to evaluate site-specific leaching to groundwater.

5.3.1 Data Needs

In order to develop site-specific screening levels for leaching to groundwater, it may be necessary to collect additional data to characterize chemical partitioning behavior and the site-specific DAF. Collecting this data during the initial site characterization phase in Tier 1 is recommended to save time and money. Site-specific data needed may include the following, depending on the complexity of the evaluation (i.e., site-specific DAF versus fate and transport modeling):

- **Soil characteristics** from the major soil types present in surface and subsurface soils, and aquifer sediments below the water table: fraction of organic carbon (foc) from uncontaminated areas of the site; dry bulk density; soil moisture; soil pH; and soil texture.
- **Hydrologic characteristics:** hydraulic conductivity; hydraulic gradient; and aquifer thickness.
- **Source characteristics:** COC source dimensions and concentrations; COC leaching characteristics; and non-aqueous phase liquids composition.
- **Chemical biodegradation:** groundwater COC concentrations and geochemical data.

DEQ's Technical Guidance "General Field Data Needs for Fate and Transport Modeling" (DEQ, 2008) identifies the information needed and describes how the data are used for fate and transport modeling. A copy of this guidance can be found under "Guidance/References" at:

<http://deq.mt.gov/Land/StateSuperfund/resources>.

5.3.2 Calculating a Site-Specific Dilution Attenuation Factor

As precipitation moves through contaminated soil, contamination is dissolved in the water. During this movement through the soil column, contaminant concentrations in this liquid, or soil leachate, may be reduced by adsorption and degradation, and once the soil leachate reaches the groundwater, it may be diluted by the clean groundwater within the aquifer. The reduction in concentration is represented by the DAF, defined as the ratio of the contaminant concentration in soil leachate to the concentration in groundwater at the receptor point (EPA, 1996). The DAF is used to assess whether soil concentrations are likely to cause groundwater contamination above DEQ-7 standards or RBSLs for groundwater. A low DAF value indicates little to no dilution or attenuation of contaminants (soil leachate and receptor well concentrations are equal), and high DAF values correspond to a large reduction in contaminant concentration from the soil to the receptor well. The variables in the DAF calculation represent conditions and physical processes occurring at the site; therefore, the following site information is needed for a site-specific DAF assessment:

- Aquifer parameters including hydraulic conductivity, hydraulic gradient, and aquifer thickness
 - ♦ Hydraulic conductivity as determined through site-specific aquifer tests (pump or slug tests) or estimated through knowledge of local hydrogeologic conditions (EPA, 1996);

- ♦ Hydraulic gradient as measured on a map of the site's water table, or based on estimates from knowledge of local hydrogeologic conditions (EPA, 1996);
- ♦ Aquifer thickness as determined from soil boring or well logs or based on estimates from knowledge of local hydrogeologic conditions. This information will be used to calculate the mixing zone depth (see equation below). Mixing zone depth should not exceed the aquifer thickness, so if the calculation results in a number larger than the aquifer thickness, use the aquifer thickness in place of the mixing zone depth (EPA, 1996).
- Source length parallel to groundwater flow as determined through site-specific sampling data.
- Infiltration or recharge rate as determined through use of the Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et al., 1984) or based on estimates of local/regional precipitation to estimate the fraction of the annual precipitation which percolates vertically through the soil column and into the aquifer.

Example Calculation of a site-specific mixing zone depth using the following equation (EPA, 1996):

$$D = [0.0112 \times L^2]^{0.5} + d_a \left\{ 1 - \text{EXP} \left[\frac{(-LI)}{(Kid_a)} \right] \right\}$$

Where:

- D = Mixing zone depth (ft)
- L = Length of source parallel to groundwater flow (ft)
- d_a = Aquifer Thickness (ft)
- I = Infiltration rate (ft/day)
- K = Aquifer hydraulic conductivity (ft/day)
- i = Hydraulic gradient (ft/ft)

As identified above, if $D > d_a$, replace value for D with d_a in DAF equation below.

Example Calculation of a site-specific DAF using the following equation (EPA, 1996):

$$\text{DAF} = 1 + \frac{KiD}{iL}$$

Where:

- DAF = Dilution attenuation factor (unitless)
- K = Aquifer hydraulic conductivity (ft/day)
- i = Hydraulic gradient (ft/ft)
- D = Mixing zone depth (ft)
- I = Infiltration rate (ft/day)
- L = Length of source parallel to flow (ft)

In this example DAF values previously calculated using a Tier 1 soil leaching to groundwater model which incorporated Tier 1 model assumptions have been replaced with site-specific conditions.

Parameter	Tier 2 Site-Specific Values	Units
Aquifer hydraulic conductivity	165	ft/day
Hydraulic gradient	0.0057	ft/ft
Mixing zone depth	10	ft
Infiltration rate	0.00081	ft/day
Length of source parallel to flow	400	ft
Site -Specific DAF	30	--

Once a site-specific DAF is determined, it can be used in place of the default DAF of 10 built into the leaching-based RBSLs to provide a site-specific evaluation of leaching (e.g., divide the leaching-based RBSL by 10 to remove the default DAF and then multiply the number by the site-specific DAF to get the adjusted, or site-specific, leaching-based screening level). If the contaminant concentrations are less than this site-specific screening level, the leaching to groundwater pathway can be eliminated from concern. For example, assume that a site has benzene in subsurface soil at a concentration of 0.15 mg/kg. The leaching-based RBSL, from Table 4, for benzene is 0.07 mg/kg, so if the RBSL is divided by 10 to remove the generic DAF, and then multiplied by the site-specific DAF of 30 (the DAF calculated in the example above), the resulting site-specific screening level is 0.21 mg/kg. The site concentration of benzene is 0.15 mg/kg, which is less than the site-specific screening level of 0.21 mg/kg, so the benzene concentration is not a concern for the leaching to groundwater pathway.

5.3.3 Vadose Zone Travel Time

The vadose zone travel time of a contaminant is an estimate of how long it will take a COC in the vadose zone to reach groundwater. This information can be used to determine the amount of time it took or the time it will take for a compound to leach to groundwater. It is particularly useful when the date of a release is known and can be used to illustrate that contaminants have already leached and have diluted, attenuated, or degraded, when they will likely reach groundwater, or when their contaminant-specific characteristics are such that they are not likely to reach groundwater. The following steps are included in calculating a COC's travel time:

Step 1 - Calculate vertical pore water velocity through the vadose zone

- (a) Estimate infiltration rate based on precipitation and any water application at the site;
- (b) Estimate representative water filled porosity of vadose zone soils based on measured soil moisture content;
- (c) Divide infiltration rate by water filled porosity = vertical pore water velocity.

Step 2 - Calculate chemical partitioning coefficient K_d – Two Options

- **Option 1** - Calculate using EPA equations in the Soil Screening Guidance Document: Technical Background Document - Part 2: Development Of Pathway-Specific Soil Screening Levels (EPA, 1996; available at <https://www.epa.gov/superfund/superfund->

[soil-screening-guidance](#)) and site-measured f_{oc} :

- (a) **If dealing with pentachlorophenol or other ionizing organic chemicals not addressed under RBCA** use Equation 27 on Page 39 to calculate K_{oc} values as a function of pH. Otherwise, use the EPA-tabulated value for K_{oc} .
 - (b) For organics use Equation 23 on Page 37 to calculate $K_d = K_{oc}f_{oc}$; for inorganics use the EPA-tabulated value for K_d .
- **Option 2 - If Synthetic Precipitation Leaching Procedure (SPLP) analysis has been conducted:** calculate site-specific K_d using Equation 22 on Page 36 of the Soil Screening Guidance – Part 2 (see Option 1 above for link). Use the measured SPLP water concentration for C_w , and the measured chemical concentration in the soil concentration for C_t .

Step 3 Calculate chemical retardation coefficient in vadose zone soils

Use Equation (3) in the Simple Derivation of the Retardation Equation and Application to Preferential Flow and Macrodispersion (Bouwer, 1991; available at <http://info.ngwa.org/gwol/pdf/910655328.PDF>) to calculate the chemical retardation coefficient.

Step 4 Calculate chemical velocity in vadose zone soils

Chemical velocity in vadose zone = (vertical pore water velocity) / (retardation coefficient)

Step 5 Solve for chemical travel time to water table

Chemical travel time to water table = (distance between contamination and groundwater) / (chemical velocity in vadose zone)

The following discussion provides an example of a situation where this approach may be used to evaluate the leaching potential at a site.

The following compounds are present in the silty clay soil at a site at concentrations above the leaching-based Tier 1 RBSLs: benzene, naphthalene, benzo(a)anthracene, and benzo(a)pyrene. The calculations show that benzene would have leached in approximately two years, naphthalene in 24 years, benzo(a)anthracene in 7,100 years, and benzo(a)pyrene in 19,000 years. The release was documented to have occurred 22 years previously and groundwater has been sampled periodically since the release. Evaluation of the groundwater data shows that benzene has routinely been detected at concentrations above the DEQ-7 standard/RBSL, naphthalene was detected in samples historically, but is no longer seen at concentrations above the DEQ-7 standard/RBSL, and benzo(a)anthracene and benzo(a)pyrene have never been detected in groundwater at the site. As a result of this exercise, benzene remains the only compound of concern. Naphthalene, while a problem historically, has leached and concentrations are now reduced below the DEQ-7 standard/RBSL and the PAH compounds are unlikely to ever reach groundwater given their relative immobility in this setting, as determined through the calculations.

5.3.4 Synthetic Precipitation Leaching Procedure

SPLP is a sample preparation method developed by the EPA to model an acid rain leaching environment. It is designed to predict the mobility of organic and inorganic compounds and determine the potential for leaching to ground and surface waters. SPLP data can be used to quantify contaminant partitioning in soils but should not be used by directly comparing to DEQ-7 standards. Soil samples need to be collected from the same interval and analyzed for the COC using the normal soil analytical methods and SPLP (which will result in a leachate (liquid - $\mu\text{g/L}$) concentration). Once collected, the data can be used to develop a site-specific leaching to groundwater screening level. This can be done in the following ways:

- To define site-specific partitioning behavior (i.e., calculate the soil water partitioning coefficient or K_d). The ratio between the total soil concentration and the reported COC SPLP concentration can be used to define the partitioning behavior. This can be used in fate and transport modeling in place of literature values and is discussed in DEQ's Technical Guidance "General Field Data Needs for Fate and Transport Modeling" (DEQ, 2008). A copy of this guidance can be found under "Guidance/References" at: <http://deq.mt.gov/Land/StateSuperfund/resources>.
- To develop a site-specific leaching to groundwater screening level. There are several ways to do this, as described in New Jersey Department of Environmental Protection's "Development of Site-Specific Impact to Ground Water Soil Remediation Standards Using the Synthetic Precipitation Leaching Procedure" (NJDEP, 2013).

5.4 Summary of Tier 2 Evaluation Procedures

Procedures for evaluating a release using RBCA Tier 2 are summarized as follows:

- 1) Complete a RBCA Tier 1 evaluation. If groundwater has been impacted or direct contact/leaching to groundwater COCs cannot easily be cleaned up to meet Tier 1 RBSLs, it may be appropriate to proceed with the following steps.
- 2) Conduct a Tier 2 COC Exceedance Evaluation:
 - a) Determine both direct contact and leaching to groundwater COCs based on the Master Table, Table 4.
 - Leaching to groundwater RBSLs are based on the sample depth and distance to groundwater. Distance to groundwater is the distance between the sample depth and the depth to high groundwater.
 - For both surface (0-2 feet bgs) and subsurface (>2 feet bgs) soils, if groundwater at the site is less than ten feet below the sample location, the first column of RBSLs apply.
 - For both surface (0-2 feet bgs) and subsurface (>2 feet bgs) soil, if groundwater at the site is between ten and twenty feet below the bottom of soil contamination location, the second column of RBSLs apply.
 - For both surface (0-2 feet bgs) and subsurface (>2 feet bgs) soil, if groundwater at the site is greater than twenty feet below the bottom of soil contamination location, the third column of RBSLs apply.
 - Direct contact RBSLs for surface soils (0.-2 ft. bgs) are based on a site's use (residential or commercial). Both current and future use of the site should be evaluated.

- ♦ If anyone lives at the site or may live at the site in the future, residential RBSLs apply to surface soil.
 - ♦ If the site is used as a place of business with employees present regularly and no one lives at the site or may live there in the future, commercial RBSLs apply to surface soil.
 - ♦ Construction RBSLs are used for samples collected from 0-10 ft. bgs and apply to both residential and commercially used properties.
- b) If leaching to groundwater is not a concern or has been previously addressed then soil data may be compared to the Master Table direct contact RBSLs. If no Tier 2 direct contact exceedances are present the site may be considered for closure.
 - c) If Tier 2 direct contact or leaching to groundwater RBSLs are exceeded, then remediation or further evaluation outlined in the following steps may be appropriate.
- 3) Direct Contact Evaluation - RBSL Adjustments:
 - a) If soil sampling results, following the Tier 2 COC exceedance evaluation, exceed direct contact RBSLs, site-specific screening levels may be calculated following the steps in Section 5.2.
 - b) If site COC concentrations are below site-specific screening levels, the site may be evaluated for closure.
 - c) If site COC concentrations are above site-specific screening levels, additional remediation or evaluation may need to be implemented.
 - 4) Leaching to Groundwater Evaluation:
 - a) If site soil concentrations exceed Tier 2 leaching to groundwater RBSLs (Table 4), a site-specific leaching to groundwater analysis may be appropriate.
 - b) If soil sampling results, following the Tier 2 COC exceedance evaluation, exceed leaching to groundwater RBSLs, site-specific screening levels should be calculated.
 - c) Collection of site-specific soil and hydrologic data may be needed prior to completing the steps below.
 - d) The site-specific leaching to groundwater evaluation may include calculating a site-specific DAF, modeling vadose zone travel time of COCs, or calculating a site-specific screening level using the SPLP method. See Section 5.3 for details on each option.
 - e) If site COC concentrations are below site-specific screening levels, the site may be evaluated for closure.
 - f) If site COC concentrations are above site-specific screening levels, additional remediation or evaluation may need to be completed.

6.0 TIER 3 RBCA EVALUATION

The amount of contamination at some sites or the complexity of the site may warrant a thorough site-specific risk-based analysis, or Tier 3 RBCA evaluation. For these sites, a baseline human health and possibly even a baseline ecological risk assessment may be appropriate. These analyses may take into account recreational or other land uses, may evaluate risks to surface water, may take into account climate or soil temperature data, and may include analyses of target organs, among other things. Please refer to DEQ's Frequently Asked Questions at <http://deq.mt.gov/Land/StateSuperfund/FrequentlyAskedQuestions> for additional information on these types of risk assessments.

Computer modeling programs may be appropriate to support a detailed assessment (or Tier 3 evaluation) of chemicals leaching to groundwater. Complexity should only be added when

compelling reasons exist to warrant detailed modeling of chemical behavior or site characteristics. Several well documented computer programs have been developed to model chemical leaching to groundwater, including, but not limited to, VS2DI and HYDRUS. Tier 3 computer modeling should be coordinated with DEQ during the design, execution, and evaluation of modeling results.

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