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State of Washington

Technical Document:

Terrestrial Ecological Evaluations under the Model Toxics Control Act

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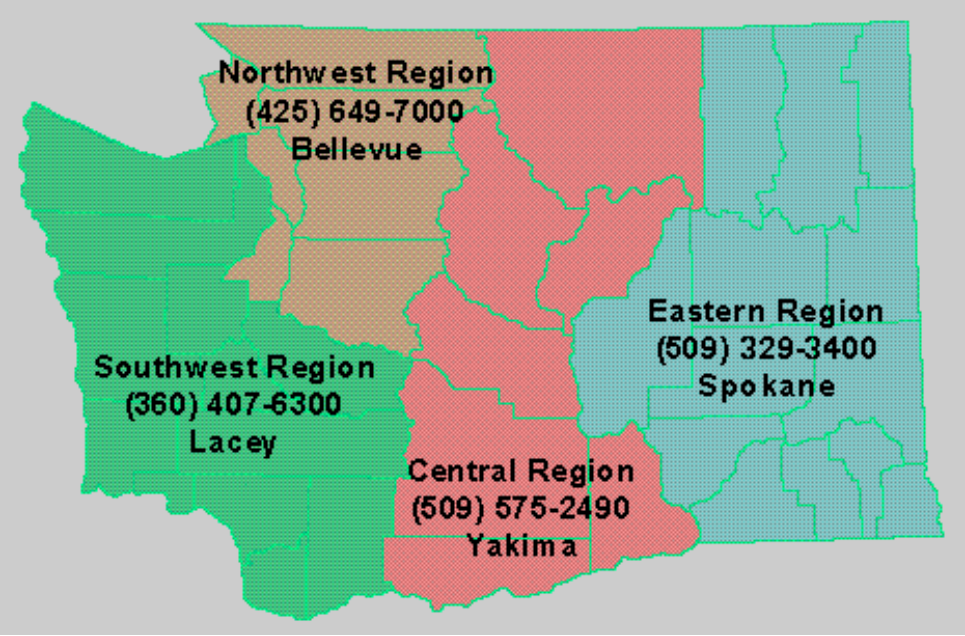

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Technical Document:

Terrestrial Ecological Evaluations under the Model Toxics Control Act

WAC 173-340

Toxics Cleanup Program

Washington State Department of Ecology

Olympia, Washington

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List of Acronyms Used

BAF	Bioaccumulation Factor
CAP	Cleanup Action Plan
CBA	Cost Benefit Analysis
EEC	Estimated Environmental Concentration
H_A	Alternative Hypothesis
HI	Hazard Index
HQ	Hazard Quotient
H_O	Null Hypothesis
ISIS	Integrated Site Information System
LOAEL	Lowest Observed Adverse Effects Level
MDL	Method Detection Limit
MTCA	Model Toxics Control Act
NEBA	Net Environmental Benefit Analysis
NFA	No Further Action
NOAEL	No Observed Adverse Effects Level
NRDA	Natural Resource Damage Assessment
PQL	Practical Quantitation Limit
RCW	Revised Code of Washington
RI/FS	Remedial Investigation/Feasibility Study
TEE	Terrestrial Ecological Evaluation
TEF	Toxicity Equivalency Factor
TPH	Total Petroleum Hydrocarbons
TRV	Toxicity Reference Value
VCP	Voluntary Cleanup Program
WAC	Washington Administrative Code

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Introduction

Washington State's Model Toxics Control Act (MTCA), Washington Administrative Code (WAC) 173-340 (see Compendium – Section A), applies to all facilities where there has been a release or threatened release of a hazardous substance that may pose a threat to human health or the environment. Soil contamination shall be evaluated for both human health and ecological threats, and those remedies selected to address soil contamination shall be protective of both human health and ecological receptors. The Terrestrial Ecological Evaluation (TEE) is a process that evaluates threats posed by contaminants to ecological receptors and is included in MTCA, specifically, WAC 173-340-7490 through 7494. These chapters define the goals and procedures the Washington State Department of Ecology (Ecology) will use for:

- Determining whether a release of hazardous substances to soil may pose a threat to the terrestrial environment.
- Characterizing existing or potential threats to soil biota and terrestrial plants and animals exposed to hazardous substances in soil.
- Establishing soil concentrations that are protective of soil biota and terrestrial plants and animals, and;
- Developing and evaluating cleanup action alternatives and selecting a cleanup action protective of soil biota and terrestrial plants and animals.

TEE's shall be conducted as part of the Remedial Investigation/Feasibility Study (RI/FS). Failure to complete the TEE during the RI/FS could result in unexpected additional cost and/or remediation efforts. A summary of the TEE process includes the following steps:

- Characterization of the site
- Exclusion evaluation, if no exclusion applies, then;
    - Selection of the appropriate evaluation method (simplified or site-specific TEE)
    - Conduct TEE, and then if required:
        - Selection of clean-up actions.
        - Implementation of cleanup actions, and;
        - Compliance monitoring requirements.

It is important to remember to provide documentation of steps and/or actions taken during this process. If the site may be excluded from the TEE process, then no further evaluation of ecological risk is necessary as long as the specific exclusion and its application to the site under investigation have been addressed in the RI/FS. If the site cannot be excluded from the TEE process, a simplified or site-specific TEE is required, in which case the TEE evaluation method and the TEE evaluation itself shall be included in the RI/FS. If cleanup actions/alternatives are required to meet requirements, the selection, implementation, and the compliance requirements of those cleanup actions shall also be included.

The TEE process is required at all MTCA sites where there has been a release or threatened release of a hazardous substance that may pose a threat to human health or the environment. This applies to sites that have formal Ecology oversight and also to those sites requiring a No Further Action (NFA) determination under the Voluntary Cleanup Program (VCP). This document was developed to help both Ecology personnel and the public as they navigate through the TEE process. This document provides an overview of the TEE process, lists exclusionary criteria, describes both the simplified and site-specific TEE, and also gives specifics in terms of examples and questions that have been brought up in the past.

The primary goal of this document is to clarify the range of options available, and to suggest efficient ways for meeting the requirements of MTCA. This document is not intended to provide an exhaustive review of every situation that may be encountered in evaluation of hazardous waste sites. Detailed descriptions of simplified and site-specific TEE's have been provided in the later chapters of this document. In addition, specific guidance has always been available by contacting Ecology staff directly.

Of equal importance is a compendium document that is referenced frequently in this technical assistance document. Frequently you will find the compendium reference in the body of this document. When referenced, it will be noted as; (see Compendium – Section XXX). The reader then has the ability to access the compendium documents directly by hyperlink, simply by left – clicking on the provided hyperlink, or by referencing Appendix A where the complete [url] is listed. Bound copies of the compendium document can also be found at each of the Washington State Department of Ecology regional offices (Northwest, Southwest, Central, Eastern, and Headquarters). An electronic version is available Ecology TEE internet website, under Toxics Cleanup Program:
http://www.ecy.wa.gov/programs/tcp/policies/terrestrial/TEEHome.htm

The purpose of the compendium document is to provide the reader with the references and resources that have been cited. For certain documents, such as private publications, Ecology is only able to provide a hyperlink that allows access to the document under certain conditions. In those circumstances, it would be the responsibility of the reader to obtain a copy for their own reference.

Please note that this document is not a substitute for the regulatory requirements in the MTCA cleanup regulation. Where there are any conflicts between this document and the regulations, users shall always comply with the regulations.

Limitations

When used appropriately, the TEE is an excellent tool that provides an ecological risk assessment for the potential threats of chemical contamination to ecological receptors in upland soil environments. The TEE is intended to be used as an ecological evaluation and not a Natural Resource Damage Assessment (NRDA). Additionally, it is not intended to provide risk assessment to ecological receptors in surface water, sediments, wetlands, or any other environments other that upland soils. Procedures for sediment evaluations are described in WAC 173-340-760 and Chapter 173-240 WAC (see Compendium – Section B), and for surface water evaluations in WAC 173-340-730. Procedures for wetland evaluations shall be determined by the department on a case-by-case basis.

Oftentimes cleanup sites contain multiple media (upland soils, sediments, wetlands) that require evaluation. In those cases, the TEE would only satisfy the requirements for the upland soil environments. MTCA provides the requirements on the implementation of some of the specific tools used in the TEE such as; administrative procedures (institutional controls, consent decrees, agreed orders, and enforcement orders), selection and implementation of cleanup actions, compliance monitoring, and Cost Benefit Analysis (CBA). These tools will be referred to frequently in this document; however, detailed descriptions of their implementation have not been included.

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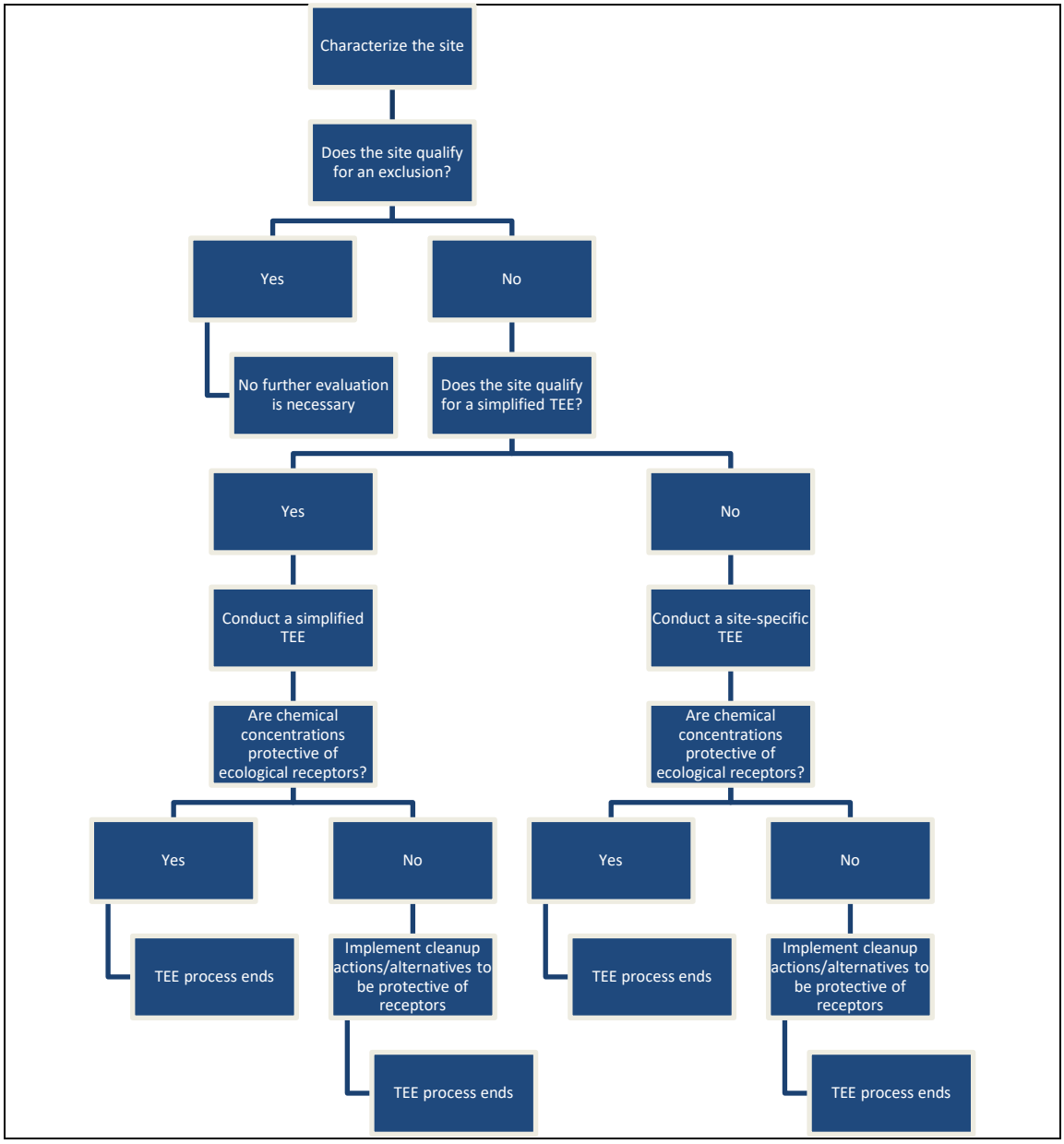
Chapter 1: Overview of the TEE Process

The TEE process is designed to allow the user to quickly identify those sites which have the potential to pose little or no threat to ecological receptors and it also identifies those sites which are of concern to those same ecological receptors. Sites that are of concern are then evaluated in terms of severity of potential threat to the receptors, and cleanup levels are then established based on severity. Cleanup action alternatives are then analyzed, and the selected cleanup action plan (CAP) is documented in the TEE as to how it adequately addresses protection of the ecological receptor (See Figure 1.1).

Figure 1.1: Summary of TEE Process



As Figure 1.1 illustrates, the process itself is not complicated. However, if the TEE process is not implemented during the initial phase of cleanup activities, the remediation efforts involved in a CAP for a site might not meet those requirements of MTCA that were designed to protect the ecological receptors. Oftentimes, the cleanup level of a chosen MTCA method (Methods A, B, or C) is not stringent enough to protect ecological receptors when one of the exclusions does not apply to the site. The result of which is that either a simplified or site-specific TEE would be required at the site, possibly impacting previously agreed upon cleanup levels.

A TEE shall be conducted as part of the RI/FS. The TEE process includes the following steps:

Step 1 – Characterization of the Site

In the remedial investigation, identify and define the extent of habitat at both the site and the surrounding areas, including; wetlands, parks, natural forested areas, riparian areas, greenbelts, buffer zones, and fish and wildlife habitat conservation areas. Also identify any state or federally designated "endangered" or "threatened" species and state "priority species", "species of concern" or "sensitive species" that may be present on or near the site (see Compendium – Section E).

Step 2 – Evaluation of Exclusions

Evaluate and document whether the site qualifies for an exclusion using the criteria specified in MTCA. Most sites located in intensively developed areas are expected to qualify for exclusion (See WAC 173-340-7491).

Step 3 – Select Evaluation Method

Evaluate whether the site qualifies for a simplified TEE using the criteria in MTCA (See WAC 173-340-7491(2)). The simplified TEE process is designed for addressing TEE risk at sites with limited quality habitat and limited potential for soil biota and terrestrial plants and animals to be exposed to hazardous substances.
Note: If the site does not meet the criteria for a simplified evaluation, a site-specific TEE must be conducted. The site-specific evaluation process is designed for addressing terrestrial ecological risk at any site, including sites with endangered or threatened species. The person conducting the evaluation may also voluntarily elect to conduct a site-specific TEE at any site.

Step 4 – Conduct the TEE

If the site is eligible for a simplified evaluation, conduct the evaluation using the procedures listed under Simplified Terrestrial Ecological Evaluation Procedures found in MTCA (WAC 173-340-7492).

- If the TEE can be "ended" due to exposure analysis, pathways analysis, or toxicity (contaminant) analysis, document this in the RI/FS and no further evaluation of terrestrial ecological risk is needed (See WAC 173-340-7492(2)).

Note: Institutional controls are necessary where the evaluation relies on physical barriers to keep plants and animals from being exposed to residual contamination, or a conditional point of compliance is used.

- If the evaluation cannot be "ended," use the simplified TEE table values found in Table 4.1 (MTCA Table 749-2) as screening levels in the remedial investigation to identify all areas of the site posing a potential terrestrial ecological risk. If no value for the contaminant has been provided in the table, conduct one of the site-specific evaluation methods (table values, soil bioassays, wildlife exposure modeling, site-specific field studies, weight of evidence, or literature surveys) to establish a screening level. The simplified TEE table values found in Table 4.1 (MTCA Table 749-2) may also be used as cleanup levels (WAC 173-340-7492(1) (d)).

If the site is ineligible for a simplified TEE, conduct a site-specific TEE using the procedures listed under Site-Specific Terrestrial Ecological Evaluation Procedures found in MTCA (WAC 173-340-7493).

- If the evaluation can be "ended" because the cleanup planned to address human health or aquatic impacts will also adequately protect terrestrial ecological receptors (soil biota, plants and animals), document that fact in the RI/FS. The result would be that no further evaluation of terrestrial ecological risk is needed (WAC 173-340-7493(1) (d) (i)), and;
- If the evaluation cannot be "ended," use the site-specific TEE table values found in Table 5.1 (MTCA Table 749-3) as screening levels to identify all areas of the site posing a potential terrestrial ecological risk. It is also optional to use any of the site-specific evaluation methods (literature surveys, soil bioassays, wildlife exposure model, biomarkers, site-specific field studies, or weight of evidence) to establish a screening level (See WAC 173-340-7493(3)). Alternatively, the site-specific TEE values found in Table 5.1 (MTCA Table 749-3) may also be used as cleanup levels.

Step 5 – Identify Areas of Potential Ecological Concern

The terrestrial ecological risks are just one exposure pathway that must be considered in a site cleanup. In many cases, concentrations needed to protect human health, aquatic organisms, or other media like groundwater will be more stringent than those needed to protect soil biota and terrestrial plants and animals. At these sites, cleanup alternatives addressing these other exposure pathways will usually also address terrestrial ecological risks. For substances or areas of the site where this is not the case, use the screening levels developed in Step 4 to identify cleanup alternatives to be evaluated in the feasibility study.

Step 6 – Conduct the Feasibility Study

Follow the process described in MTCA to identify, screen, and analyze cleanup action alternatives. If, at any time in the process, it is concluded that there are no feasible alternatives meeting the screening levels established under Steps 4 or 5 above, consider using other methods

described for simplified or site-specific evaluations to establish different concentrations that are still protective of the terrestrial ecological exposure pathway.

Step 7 – Document the Process
In the feasibility study, document how the selected remedy adequately addresses the terrestrial ecological exposure pathway. For Ecology Site Managers the TEE process also needs to be documented in ISIS. An example of the electronic form that is filled out within ISIS has been provided (see Compendium – Section C). For consultants who are submitting a VCP cleanup report to Ecology, the TEE process must be filled out on a consultant form, which has been provided (see Compendium – Section D).

The purpose of the TEE process is to identify and provide an additional level of scrutiny to areas that contain significant habitat, wildlife populations, and/or species requiring an additional level of protection. In general, a site qualifies for exclusion from the TEE process if there is little or no threat to ecological receptors. A site qualifies for a simplified TEE if it does not contain significant habitat, sensitive areas, or threatened or endangered species. A site-specific TEE would be required if the contaminated site is located on, or directly adjacent to a natural area, if the site is used by a listed vulnerable species, if there is extensive habitat located on or near the site, or if Ecology determines that the site may present a risk to significant wildlife populations.

Ecological Receptors

The ecological receptor is the soil biota, plant, or animal that would have the potential to be effected by the chemical contamination. The TEE process is intended to protect terrestrial ecological receptors from exposure to contaminated soil when there is the potential to cause significant adverse effects. For species protected under the Endangered Species Act or other applicable laws that extend protection to individuals of a species, a significant adverse effect means an impact that would significantly disrupt the normal behavior patterns such as breeding, feeding, or sheltering. For all other species, significant adverse effects are effects that impair reproduction, growth, or survival.

An institutional control shall be required to preserve the habitat when the terrestrial remedy chosen to protect the ecological receptors leaves residual concentrations in excess of cleanup levels. Ecology may also require mitigation for the impacts on the environment (such as reduction in habitat productivity) resulting from residual contamination left on site.

Ecological Receptors Based on Land Use

For unrestricted land uses, the focus of the TEE shall be on the assessment and protection of terrestrial plants, wildlife, and the ecologically important functions of soil biota that could affect plants or wildlife. For industrial or commercial properties, the focus of the TEE shall be on assessment and protection of terrestrial wildlife protection unless the species is protected under the Federal Endangered Species Act (see Compendium – Section E), Title 77 RCW (see Compendium – Section F), or Title 79 RCW (see Compendium – Section G). This means that

for any property that does not constitute an “industrial property” or “commercial property” as defined, all ecological receptors must be protected from exposure to soil contamination. “All ecological receptors” includes plants, soil biota, and wildlife. In addition, if the soil contamination is located on an area of an industrial or commercial property where vegetation must be maintained to comply with local government land use regulations, the focus of the TEE shall also address those local land use regulations.

An “industrial property” is defined as a property that currently is (or has been) characterized by, or is to be committed to traditional industrial uses such as processing or manufacturing of materials, marine terminal and transportation areas and facilities, fabrication, assembly, treatment, or distribution of manufactured products or storage of bulk materials. A “commercial property” is defined as a property that is currently zoned for commercial or industrial property use and that is characterized by or is committed to traditional commercial uses such as offices, retail and wholesale sales, professional services, consumer services, and warehousing (WAC 173-340-7490(3) (c)).

Any terrestrial remedy chosen to protect ecological receptors, including exclusions (if based on land use), shall include a completion date for future development acceptable to Ecology.

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Net Environmental Benefit Analysis

Net environmental benefits are the gains in environmental services or other ecological properties attained by remediation or ecological restoration, minus the environmental injuries caused by those actions (Efroymson et al., 2003). Ecosystems and natural resources (including wild animal and plant populations) can be thought of as environmental assets which provide people with a range of "services" which directly or indirectly contribute to our well-being. Decisions where there may be ecological tradeoffs, for example, clearing a vegetated site to access contaminated soil, needs to be balanced with the potential damage caused to the habitat, or "ecosystem" and the wider services that it provides (Deacon et al., 2010). Therefore, a Net Environmental Benefit Analysis (NEBA) would be the procedure of weighing the advantages of active cleanup (remediation) versus the impact that cleanup might have on potentially valuable ecological receptor habitat. Terrestrial ecological evaluation procedures should not create an incentive to cause harm through the destruction of habitat. As a result, WAC 173-340-7490 (5): "Additional measures. The department may require additional measures to evaluate potential threats to terrestrial ecological receptors notwithstanding the provisions in this and the following sections (when based upon a site – specific review), the department determines that such measures are necessary to protect the environment." (Ecology, 2007a).

Limitations: As stated in WAC 173-340-7490 (1) (c): "These procedures [Terrestrial Ecological Evaluation] are not intended to be used to evaluate potential threats to ecological receptors in sediments, surface water, or wetlands. Procedures for sediment evaluations are described in WAC 173-340-760, and for surface water evaluations in WAC 173-340-730. Procedures for wetland evaluations shall be determined by the department on a case-by-case basis." In addition, WAC 173-340 also defines Terrestrial ecological receptors as "plants and animals that live primarily or entirely on land." (Ecology, 2007a). As a result, the intent of this NEBA section is to clarify procedures that would further protect especially valuable habitat that supports terrestrial ecological receptors that would otherwise require remediation to attain cleanup levels. It is not the intent of this NEBA section to delineate between upland, surface water, sediment, and wetland environments.

Prior to performing a NEBA, the proposed non – remediated area needs to be defined as "especially valuable habitat." "Especially valuable habitat" can be designated through the use of one of the below proposed methods (Method 1 or Method 2):

Method 1: Site can be designated "especially valuable habitat" if:

- The site is used by a threatened or endangered species protected under the Federal Endangered Species Act, or;
- The site is used by a "priority species" or "species of concern" designated under Title 77 RCW, or;
- The site is used by a plant species classified as "endangered," "threatened," or "sensitive" under Title 79 RCW, or;
- Wetlands and Fish and Wildlife habitat conservation areas designated as critical areas under Chapter 36.70A.170 RCW. Other critical areas that might be found on the property, such as recharge areas, frequently flooded areas, geologically hazardous areas, steep slopes, and aquatic areas, are not immediately designated as "especially valuable habitat" unless they meet one of the previous criteria. These other types of critical areas must follow the Method 2 process.

Note: For animals, "used" means that individuals of a species have been observed to live, feed or breed at the site. For plants, "used" means that a plant species grows at the site or has been found growing at the site (Ecology, 2007a).

Method 2: Site can be designated "especially valuable habitat" if:

- An experienced field biologist must visit the site and document that:
  - The site can be potentially used by a threatened or endangered species protected under the Federal Endangered Species Act, or;
  - The site can be potentially used by a "priority species" or "species of concern" designated under Title 77 RCW, or;
  - The site can be potentially used by a plant species classified as "endangered," "threatened," or "sensitive" under Title 79 RCW

In addition to meeting the recommended requirements of Method 1 or Method 2, it is recommended that a depth-weighted receptor exposure adjustment is calculated for each contaminant, and that a field biologist (or other department approved individual) must document types of flora and fauna and signs of excessive uptake of the specific contaminants. This will help establish sustainability and whether or not native species occupy the habitat.

Depth Weighted Receptor Adjustment

It is recommended that natural areas that are proposed to be included in the NEBA (areas with native species) have additional sampling to allow for a better understanding of upland ecological receptor exposure to contamination. Depths recommended at each sampling point are:

- 0 – 6" bgs (including duff layer)
- 6 – 12" bgs
- 12 – 24" bgs
- 24 – 36" bgs

Depth Weighted Receptor Adjustment Equation:

$$C_{ea} = (C_{c\,(1)} \times P_{r\,(1)}) + (C_{c\,(2)} \times P_{r\,(2)}) + (C_{c\,(i)} \times P_{r\,(i)})$$

Where:

C_{ea}	=	Exposure adjusted contaminant concentration
$C_{c\,(1)}$	=	Soil contaminant concentration at sample depth 1 (i.e. 0 – 6")
$C_{c\,(i)}$	=	Soil contaminant concentration at sample depth (i)
$P_{r\,(1)}$	=	Proportion of Receptor found at sample depth 1 (i.e. 0 – 6")
$P_{r\,(i)}$	=	Proportion of Receptor found at sample depth (i)

The following is an example of a Depth – Weighted Receptor Exposure Adjustment:

For sample XXXX (As):

1. The soil contaminant concentration at sample depth (0 – 6") is 113 mg/kg
2. The depth weighted receptor adjustment is 0.3
3. The adjusted As level at sample depth (0 – 6") is 33.9 mg/kg
4. Repeat steps for sample depth (6 – 12", 12 – 24", and 24 – 36")

5. Add the four adjusted sample depth concentrations for a Depth – Weighted Receptor Exposure Adjustment total of 34.8 mg/kg (As)

The resulting Depth - Weighted Exposure Adjustment Concentration for Sample XXXX (As) is 34.8 mg/kg.

Justification for Exposure Adjustments

- Adjustment of 0.55 for sample depth 6 to 12”

Soil development is rarely uniform and processes such as erosion and deposition can influence the vertical distribution of biological activity across landscapes. Sampling strategies where a constant depth is collected may not accurately reflect site-specific exposures of environmental contamination to the soil biota. A horizon may not accurately represent contaminant exposure to soil biota, resulting in inaccurate risk estimates. If constant depths are utilized, [our] results suggest that samples should be collected to a depth of approximately 25 – 30 cm as opposed to shallower depths (USEPA, 2015). Result: the majority of receptor exposure to contamination is expected to be at sample depth of 6 to 12” (0.55 or 55%).

- Adjustment of 0.3 for sample depth 0 to 6” (including duff layer)

The organic matter which provides the food base for the earthworm community is vitally important in determining their distribution and abundance, and soil organic matter content can sometimes be a good predictor of earthworm abundance. For example, Hendrix et al. (1992) reported a highly significant correlation between earthworm density and soil organic content over a range of sites in Georgia, U.S.A., including a wide variety of soil and vegetation types and management histories (Curry, 1998). Result: it is assumed that the increased organic matter found at shallower depths (0 to 6”) would be the second most abundant vertical horizon for soil biota (0.3 or 33%).

- Adjustment of 0.1 for 12 to 24” and 0.05 for 24 to 36”

The main source or the organic matter on which earthworms feed is litter from above-ground plant parts in most ecosystems, although dead roots and rhizodeposition can also be important sources (Curry, 1998). Result: As depth increases, receptor exposure should decrease, so at 12 to 24” (0.1 or 10%) and at 24 to 36” (0.05 or 5%).

Additional Field Biologist Responsibilities

1. Document the species of plant, soil biota, and wildlife found at the specific site
    - Differentiate between those that are native and those that are invasive
2. Document if native plant life is well-established (i.e. primary or secondary growth)
3. Document if plant life show signs of contaminant uptake including (but not limited to) signs of:
    - Wilting
    - Chlorosis (pale, yellow or white plant tissue)
    - Browning
    - Excess mortality
    - Reduced growth, photosynthesis, mitosis, or water absorption (dehydration)
4. Document any signs of contaminant uptake in soil biota including (but not limited to):
    - Limited numbers
5. Document any signs of contaminant uptake in wildlife including (but not limited to):

- Muscular incoordination
- Debility
- Slowness
- Jerkiness
- Falling
- Hyperactivity
- Fluffed feathers
- Drooped eyelids
- Seizures

If the above conditions have been met, the Ecology Site Manager (or designee) should then visit the site to make a final determination as to whether or not the proposed non – remediated area appears to be established, sustainable, and native habitat. In granting the request of non – remediation, the Ecology Site Manager (or designee) should consider the following factors prior to making a final decision:

- The rarity of the habitat for the geographic area in which the site is located.
- The size of the habitat.
- Whether the habitat functions as a wildlife corridor.
- Whether the habitat functions as a refuge or feeding area for migratory species.
- The structural diversity of the habitat.
- Surrounding habitat and land uses.
- Whether the habitat is manmade or natural.
- Whether the cleanup would significantly disturb the ecological functions of the habitat.
- The level of human activity in the area.
- The length of time for recovery of the habitat after cleanup.

If non-remediation is chosen as a cleanup action for "especially valuable habitat," then:

- Institutional controls are required that would demonstrably limit or prohibit activities that may interfere with an interim action or cleanup action or result in exposure to hazardous substances at the site. The purpose of institutional controls would be to reduce the risks of current human and/or future land use, and;
- Demonstrably reduce the risk of present or future releases or migration of the hazardous substance located at the site.

References:

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Compliance

Points of Compliance

A point of compliance is the point (or points) where cleanup levels established in accordance with the MTCA requirements shall be attained. This term includes both the standard and conditional point of compliance. Specifically, the standard point of compliance for cleanup levels developed under the TEE process is throughout the soil at the site, from the ground surface to a depth of fifteen feet. This represents a reasonable estimate of the depth of soil that could be excavated and then re – distributed at the soil surface as a result of site development activities. The result of which is the potential for ecological receptors to be exposed to contamination.

Used in conjunction with institutional controls to prevent excavation of deeper soils, a conditional point of compliance may be set to a depth of six feet. This is assumed to be the depth at which the biologically active zone extends to. In addition, Ecology may approve a site – specific depth based on a demonstration that the alternative depth is more appropriate for the site. In making this demonstration, the following shall be considered:

- Depth to which soil macro-invertebrates are likely to occur.
- Depth to which soil turnover is likely to occur due to the activities of soil invertebrates.
- Depth to which animals likely to occur at the site are expected to burrow.
- Depth to which plant roots are likely to extend, and;
- The presence of a manmade subsurface biological barrier (such as a geomembrane cap or cobble barrier designed to limit penetration by plant roots and burrowing animals).

Determining Compliance

Demonstrating compliance with the cleanup levels established during the TEE process is the same as that which is required to demonstrate compliance with the soil cleanup standards for unrestricted land use (WAC 173-340-740(7)). When soil cleanup levels have been established at a site, sampling of the soil shall be conducted to determine if compliance with the established soil cleanup levels have been achieved. Ecology may approve of other sampling methods; however, the sampling and analytical procedures shall be defined in a compliance and monitoring plan prepared in compliance with MTCA requirements. The sample design shall provide data that are representative of the area where exposure to hazardous substances may occur.

Compliance with established cleanup levels shall be determined using the dry weight concentrations of samples based on total analysis of the soil fraction less than two millimeters (mm) in size. Ecology may require that soil cleanup standards also apply to soil particles larger than 2 mm when these particles are enriched with contaminants and ingestion, contact, or inhalation of these particles could result in a toxic dose. Once the appropriate data have been collected, it can be evaluated using direct comparison or statistical methods (see Data Evaluation Section of this Chapter).

When interpreting non – detect values, measurements below the method detection limit (MDL) shall be assigned a value equal to one – half the MDL. Measurements above the MDL but below the practical quantitation limit (PQL) shall be assigned a value equal to the PQL. Measurements below the MDL and/or the PQL may also be evaluated using the Kaplan – Meier method. If a hazardous substance has never been detected in any sample at a site and the substance is not suspected of being present at the site based on site history and other knowledge, then that hazardous substance may be excluded from the compliance analysis. Ecology may also approve alternate procedures for handling values below the MDL and/or PQL.

The MDL is the minimum concentration of a compound that can be measured and reported with ninety – nine percent (99%) confidence that the value is greater than zero. The PQL is the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department-approved methods.

Data Evaluation Using Direct Comparison

Direct comparison of soil sample concentrations to cleanup levels may be used to evaluate compliance with cleanup standards. When using this method, soil samples taken at the point of compliance after remediation are compared to the appropriate soil cleanup levels. Values at or below the soil cleanup level are in compliance. Values above the soil cleanup level are not in compliance. Direct comparison may be used when selective sampling of soil can be reliably expected to find suspected soil contamination, when there is documented reliable information that the soil samples have been taken from the appropriate locations, and it can be demonstrated that the basis used for selecting the soil sample locations provides a high probability that any existing areas of soil contamination have been found.

Data Evaluation Using Statistical Methods

Statistical methods for data evaluation must be conducted if the conditions required for direct comparison have not been met. When conducting a statistical analysis, soil samples taken at the point of compliance after remediation are used in the analysis. Statistical methods include the confidence limit method, non – parametric methods, and other methods approved by Ecology.

When using the confidence limit method, the upper one – sided ninety – five percent (95%) confidence limit on the true mean soil concentration shall be less than or equal to the established cleanup level. For lognormally distributed data, the upper one – sided ninety – five percent (95%) confidence limit shall be calculated using Land's method. The data shall be assumed to be lognormally distributed unless this assumption is rejected by a statistical test. If a lognormal distribution is inappropriate, data shall be assumed to be normally distributed unless this assumption is rejected by a statistical test. The W test, D'Agostino's test, or censored probability plots (as appropriate for the data) shall be the statistical methods used to determine whether the data are lognormally or normally distributed.

Non-parametric methods would be appropriate for determining compliance with established cleanup levels when the data conforms to neither a lognormal nor normal distribution. When using a non – parametric method to calculate an upper confidence limit, the upper ninety – fifth percentile (95%) shall be used to determine compliance.

The method limitations for determining compliance using statistical methods are:

- No single sample concentration shall be greater than two times the soil cleanup level. Higher exceedances to control false positive error rates at five percent (5%) may be approved by Ecology when the cleanup level is based on background concentrations, and;
- Less than ten percent (10%) of the sample concentrations shall exceed the soil cleanup level. Higher exceedances to control false positive error rates at five percent (5%) may be approved by the department when the cleanup level is based on background concentrations.

For more information regarding statistical methods, please see the Washington State Department of Ecology Guidance Document; Statistical Guidance for Site Managers (see Compendium – Section U).

Chapter 2: Exclusions

There are four primary criteria for excluding a contaminated site from further evaluation under the TEE process. As discussed earlier in this document, the site may be excluded from the TEE process and no further evaluation of ecological risk is necessary as long as the specific exclusion and its' application to the site under investigation have been addressed in the RI/FS. If the specifics of the site meet one of the exclusionary criteria, neither a simplified nor site – specific TEE would be required.

Note: Exclusion from performing either a simplified or site – specific TEE does not alleviate the other requirements of MTCA (WAC 173-340).

The four TEE exclusionary criteria are:

- Contamination below the point of compliance.
- Incomplete exposure pathway.
- Type of contamination and proximity to ecological receptors, and;
- Concentrations below background levels.

Contamination below the Point of Compliance

To qualify for an exclusion based on "contamination below the point of compliance," all soil contaminated with hazardous substances is (or will be) located below the established point of compliance. This means all soil contamination shall be below the standard point of compliance (ground surface to a depth of 15 feet), or below the conditional point of compliance (ground surface to a depth of 6 feet). The conditional point of compliance may only be used in conjunction with institutional controls which would prevent excavation of deeper soils. Ecology may approve another site – specific depth based on the demonstration that another depth is more appropriate for the site. In making this demonstration, the following shall be considered:

- Depth to which soil macro-invertebrates are likely to occur.

- Depth to which soil turnover is likely to occur due to the activities of soil invertebrates.
- Depth to which animals likely to occur at the site are expected to burrow.
- Depth to which plant roots are likely to extend, and;
- The presence of a manmade subsurface biological barrier (such as a geomembrane cap or cobble barrier designed to limit penetration by plant roots and burrowing animals).

An exclusion based on planned future land use shall include a completion date for such future development that is acceptable to Ecology.

Incomplete Exposure Pathway

To qualify for an exclusion based on "incomplete exposure pathway," all soil contaminated with hazardous substances is (or will be) covered by buildings, paved roads, pavement, or other physical barriers that will prevent plants or wildlife from being exposed to the soil contamination. These barriers may include engineered caps with geo-textile membranes or other engineered barriers which break the exposure pathway between the ecological receptors and the soil contaminants.

Ecology will make the final determination as to whether or not the barriers will be protective of soil biota, plants and/or wildlife at the site. To qualify for this exclusion, an institutional control shall be required by Ecology and the cleanup action must also comply with the MTCA requirements. An exclusion based on planned future land use shall include a completion date for such future development that is acceptable to Ecology.

Type of Contamination and Proximity to Ecological Receptors

To qualify for an exclusion based on "type of contamination and proximity to ecological receptors," the site must be located on or near a limited amount of undeveloped land. This exclusion would be based on one of the following two points:

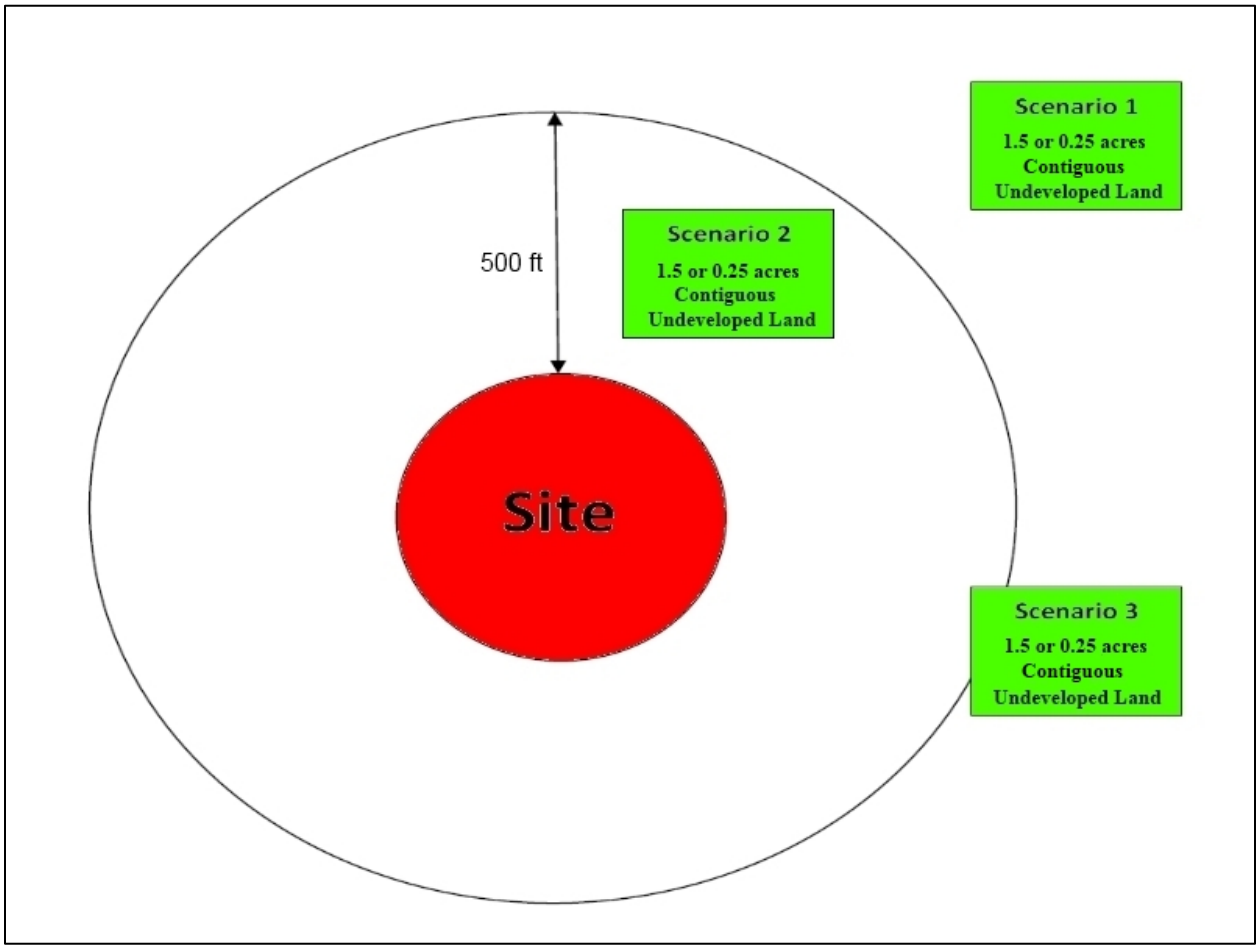
- For sites contaminated with hazardous substances other than those specified below; there must be less than 1.5 acres of contiguous undeveloped land on the site or within 500 feet of any area located on the site, or;
- For sites contaminated with one of the below substances; there must be less than one-quarter acre of contiguous undeveloped land on the site or within 500 feet of any area located on the site:
    - aldrin
    - benzene hexachloride
    - chlordane
    - chlorinated dioxins or furans
    - DDT, DDE, or DDD
    - dieldrin
    - endosulfan
    - endrin

- heptachlor or heptachlor epoxide
- hexachlorobenzene
- PCB mixtures
- pentachlorobenzene
- pentachlorophenol
- toxaphene

Note: This list does not imply that sampling must be conducted for each of these substances at every site. Sampling should be conducted for these substances when they might be present based on available information, such as current and past uses of these substances at the site.

An example of the application of this exclusion is shown in Figure 2.1. Of the three scenarios, Scenario 1and Scenario 3 would qualify for the above exclusion. However, if the contiguous undeveloped land in Scenario 2 was less than 1.5 acres (and none of the above listed contaminants are present) or 0.25 acres (in which any of the above listed contaminants are present) respectively, then it would also qualify for an exclusion.

Figure 2.1: Scenarios for an exclusion based on proximity to ecological receptors



Concentrations below Background Levels

To qualify for an exclusion based on "concentrations below background levels," concentrations of all hazardous substances in soil should not exceed natural background levels based on the determining compliance methodology found in MTCA.

Chapter 3: Do I conduct a Simplified or Site Specific Terrestrial Ecological Evaluation?

Ecology expects the majority of sites to qualify for one of the four primary exclusion criteria mentioned in the previous chapter. For more information regarding those exclusions, please refer to Chapter 2. However, as a brief review, those exclusions are:

- Contamination below the point of compliance.
- Incomplete exposure pathway.
- Type of contamination and proximity to ecological receptors, and;
- Concentrations below background levels.

Once it has been established that none of the above-mentioned exclusionary criteria apply, either a simplified or site-specific terrestrial ecological evaluation is required. MTCA specifically refers to the process of determining the type of evaluation that is required (simplified or site-specific) as "Applicability of a Simplified Terrestrial Ecological Evaluation." The specific regulation that refers to this process can be found in WAC 173-340-7492; Applicability of a Simplified Terrestrial Ecological Evaluation. WAC 173-340-7492 lists four criteria that are to be used in that determination. If any of the below criteria apply to your site, then a site-specific terrestrial ecological evaluation is necessary. Those criteria are:

- Natural areas.
- Vulnerable species.
- Extensive habitat, and;
- Risk to significant wildlife populations.

Natural Areas

If the site is located on, or directly adjacent to an area where management or land use plans will maintain or restore native or semi-native vegetation, then a site-specific terrestrial ecological evaluation is necessary. Examples of these areas include:

- Green-belts.
- Protected wetlands.
- Forestlands.
- Riparian areas.
- Locally designated environmentally sensitive areas.
- Open space areas managed for wildlife, and;
- Some parks and outdoor recreation areas.

The "Some parks and outdoor recreation areas" bulleted item does not include areas used for intensive sporting activities such as baseball, football, or dog parks. For the purposes of this section, the following definitions apply:

Native Vegetation: Means any plant community native to the state of Washington. The following sources shall be used in making this determination: *Natural Vegetation of Oregon and Washington*, J.F. Franklin and C.T. Dyrness, Oregon State University Press, 1988 (see Compendium – Section L); and *Vascular Plants of the Pacific Northwest* (5 Volumes), A. Cronquist, 1955-1969 (see Compendium – Section K).

Semi-native Vegetation: Means a plant community that includes at least some vascular plant species native to the state of Washington. The following shall not be considered semi-native vegetation:

- Areas planted for ornamental or landscaping purposes.

- Areas planted for cultivated crops, and;
- Areas significantly disturbed and predominantly covered by noxious, introduced plant species or weeds (e.g., Scotch broom, Himalayan blackberry or knap-weed).

Vulnerable Species

If the site is used by vulnerable species, a site-specific terrestrial ecological evaluation is necessary. Examples of listed vulnerable species are:

- A threatened or endangered species protected under the Federal Endangered Species Act (see Compendium – Section E).
- A wildlife species classified by the Washington State Department of Fish and Wildlife as a "priority species" or "species of concern" under Title 77 RCW (see Compendium – Section F), and;
- A plant species classified by the Washington State Department of Natural Resources Natural Heritage Program as "endangered," "threatened," or "sensitive" under Title 79 RCW (see Compendium – Section G).

Note: For plants, "used" means that a plant species grows at the site or has been found growing at the site. For animals, "used" means that individuals of a species have been observed to live, feed or breed at the site.

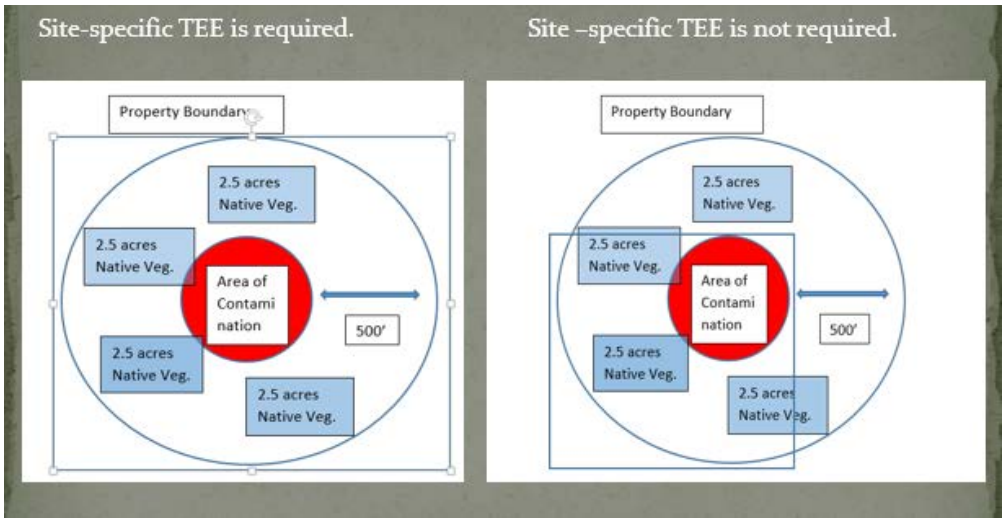
Please see the Compendium for lists of state or federally designated species that were listed at the time this document was completed:

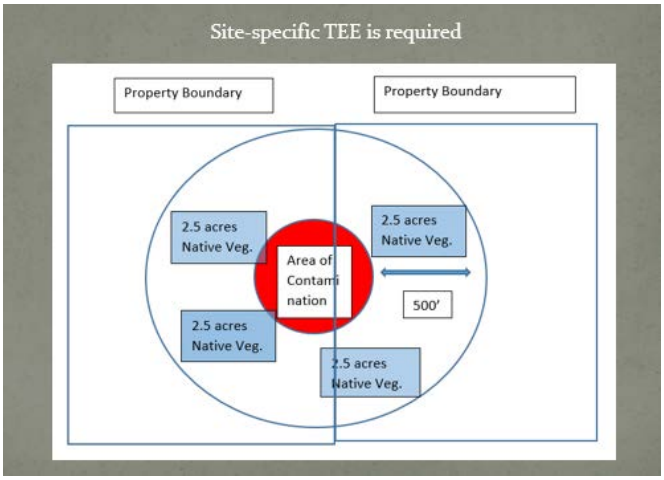
- Federal Endangered Species Act (Species) (see Compendium - Section E).
- Washington State Species of Concern (see Compendium – Section F), and;
- List of Rare Plant Species (see Compendium – Section G).

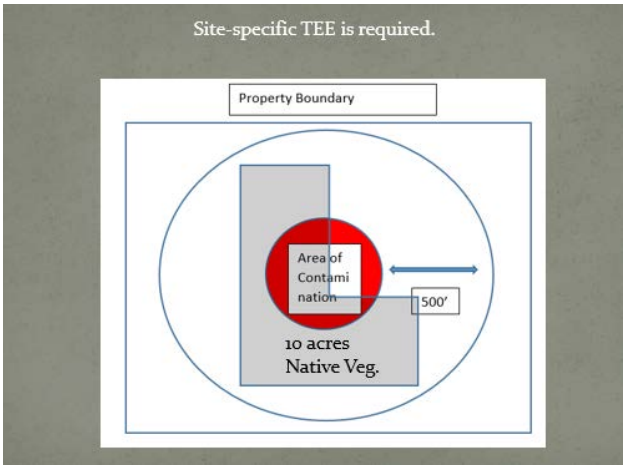
Extensive Habitat

If the site is located on a property that contains at least 10 acres of native vegetation within 500 feet of the site, not including vegetation beyond the property boundaries, a site-specific TEE is necessary. This total (ten acres) is applicable whether or not the native vegetation has been fragmented into smaller areas. See Figure 3.1 for a diagram explaining this section. Both scenarios depicted in figure 3 would require a site-specific terrestrial ecological evaluation.

Figure 3.1: Extensive Habitat Scenarios for Determination if a Site – Specific TEE is Necessary


Site-specific TEE is required.
Site –specific TEE is not required.
Property Boundary
2.5 acres Native Veg.
2.5 acres Native Veg.
Area of Contami nation
500'
2.5 acres Native Veg.
2.5 acres Native Veg.
Property Boundary
2.5 acres Native Veg.
2.5 acres Native Veg.
Area of Contami nation
500'
2.5 acres Native Veg.
2.5 acres Native Veg.


Site-specific TEE is required
Property Boundary
Property Boundary
2.5 acres Native Veg.
2.5 acres Native Veg.
Area of Contami nation
500'
2.5 acres Native Veg.
2.5 acres Native Veg.


Site-specific TEE is required.
Property Boundary
Area of Contami nation
500'
10 acres
Native Veg.

Risk to Significant Wildlife Populations

If the department determines the contamination may present a risk to significant wildlife populations, a site – specific terrestrial ecological evaluation is necessary.

Chapter 4: The Simplified Terrestrial Ecological Evaluation

Once it has been established that none of the criteria requiring a site-specific TEE (as described in the "Applicability of a Simplified Terrestrial Ecological Evaluation") apply to the site, a Simplified Terrestrial Ecological Evaluation (TEE) should fulfill the requirements of the MCTA regulations.

Note: At any point in time, a site-specific TEE may be performed to fulfill the requirements of this chapter.

The simplified TEE process (Figure 4.1) is intended to identify sites which are not likely to pose a significant threat to ecological receptors. For sites that qualify to perform a simplified TEE, the process described in WAC 173-340-7492 must be followed. This chapter is intended to provide guidance for sites performing a simplified TEE.

The simplified TEE can be ended and a determination can be made that the site does not pose a significant risk to the environment if any of the three criteria listed below are met (as described in the subsections of this chapter). Those three criteria are:

- Exposure analysis.
- Pathways analysis, and;
- Toxicity analysis.

Those three criteria will be explained in their own separate sub-chapters. However, it is important to note that if any one of those three criteria has been met, the TEE process can be ended. If none of those three criteria have been met, ecological protective soil concentrations must be established using bioassay techniques or by using the option of conducting a site - specific TEE under WAC 173-340-7493 (see "Establishing Ecological Protective Soil Concentrations" section of this chapter). Alternatively, Table 4.1 (MTCA Table 749-2) indicator soil concentrations may be used as long as the cleanup levels of the contaminants specific to the site have been provided in the referenced table.

Figure 4.1: Summary of the Simplified TEE Process

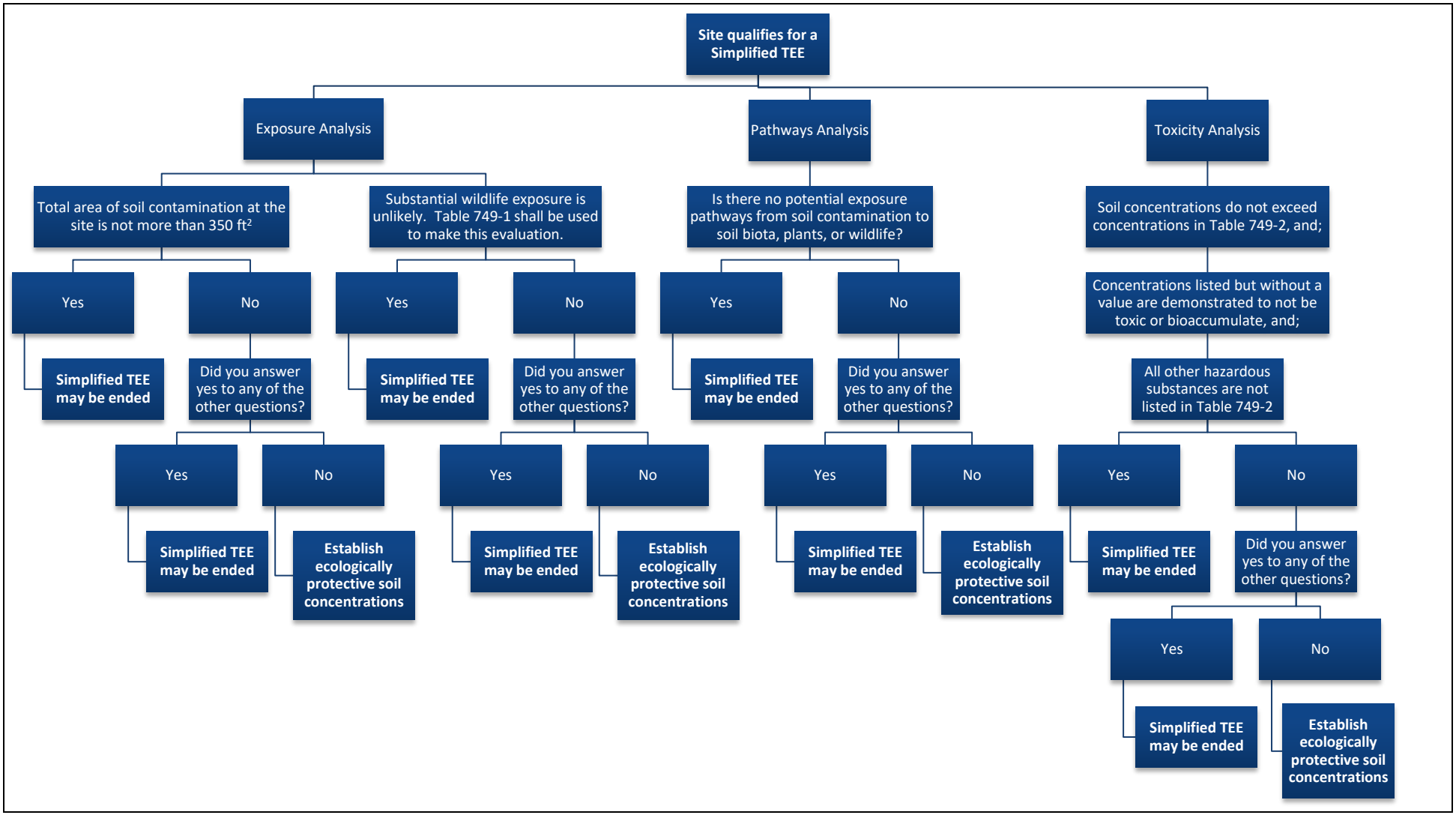


Table 4.1: Priority Contaminants of Ecological Concern for Sites that Qualify for the Simplified TEE[a]

Priority Contaminant	Unrestricted Land Use[b]	Industrial or Commercial Property	Priority Contaminant	Unrestricted Land Use[b]	Industrial or Commercial Property
Metals:[c]			Chlorpyrifos/chlorpyrifosmethyl (total)	See note d	See note d
Antimony	See note d	See note d	DDT/DDD/DDE (total)	1 mg/kg	1 mg/kg
Arsenic III	20 mg/kg	20 mg/kg	Dieldrin	0.17 mg/kg	0.17 mg/kg
Arsenic V	95 mg/kg	260 mg/kg	Endosulfan	See note d	See note d
Barium	1,250 mg/kg	1,320 mg/kg	Endrin	0.4 mg/kg	0.4 mg/kg
Beryllium	25 mg/kg	See note d	Heptachlor/heptachlor epoxide (total)	0.6 mg/kg	0.6 mg/kg
Cadmium	25 mg/kg	36 mg/kg	Hexachlorobenzene	31 mg/kg	31 mg/kg
Chromium (total)	42 mg/kg	135 mg/kg	Parathion/methyl parathion (total)	See note d	See note d
Cobalt	See note d	See note d	Pentachlorophenol	11 mg/kg	11 mg/kg
Copper	100 mg/kg	550 mg/kg	Toxaphene	See note d	See note d
Lead	220 mg/kg	220 mg/kg	Chlorinated dibenzofurans (total)[e]	3E-06 mg/kg	3E-06 mg/kg
Magnesium	See note d	See note d	Chlorinated dibenzo-p-dioxins (total)[e]	5E-06 mg/kg	5E-06 mg/kg
Manganese	See note d	23,500 mg/kg	Hexachlorophene	See note d	See note d
Mercury, inorganic	9 mg/kg	9 mg/kg	PCB mixtures (total)	2 mg/kg	2 mg/kg
Mercury, organic	0.7 mg/kg	0.7 mg/kg	Pentachlorobenzene	168 mg/kg	See note d
Molybdenum	See note d	See note d	**Other Non-Chlorinated Organics:**		
Nickel	100 mg/kg	1,850 mg/kg	Acenaphthene	See note d	See note d
Selenium	0.8 mg/kg	0.8 mg/kg	Benzo(a)pyrene	30 mg/kg	300 mg/kg
Silver	See note d	See note d	Bis (2-ethylhexyl) phthalate	See note d	See note d
Tin	275 mg/kg	See note d	Di-n-butyl phthalate	200 mg/kg	See note d
Vanadium	26 mg/kg	See note d	**Petroleum:**		
Zinc	270 mg/kg	570 mg/kg	Gasoline Range Organics	200 mg/kg	12,000 mg/kg[g]
Pesticides:			Diesel Range Organics[f]	460 mg/kg	15,000 mg/kg[g]
Aldicarb/aldicarb sulfone (total)	See note d	See note d			
Aldrin	0.17 mg/kg	0.17 mg/kg			
Benzene hexachloride (including lindane)	10 mg/kg	10/mg/kg			
Carbofuran	See note d	See note d			
Chlordane	1 mg/kg	7 mg/kg			

Footnotes:

[a] Caution on misusing these values. They have been developed for use at sites where a site-specific terrestrial ecological evaluation is not required. They are not intended to be protective of terrestrial ecological receptors at every site. Exceedances of the values in this table do not necessarily trigger requirements for cleanup action under this chapter. The table is not intended for purposes such as evaluating sludges or wastes. This list does not imply that sampling must be conducted for each of these chemicals at every site. Sampling should be conducted for those chemicals that might be present based on available information, such as current and past uses of chemicals at the site.

[b] Applies to any site that does not meet the definition of industrial or commercial property under WAC 173-340-200.

[c] For arsenic, use the valence state most likely to be appropriate for site conditions, unless laboratory information is available. Where soil conditions alternate between saturated, anaerobic and unsaturated aerobic states, resulting in the alternating presence of arsenic III and arsenic V, the arsenic III concentrations shall apply.

[d] Safe concentration has not yet been established. See WAC 173-340-7492(2) (c) for procedures for establishing values for these substances.

[e] These values represent a total toxic equivalent concentration of all furan or dioxin congeners. Use the toxicity equivalency factors in Table 749-6 to convert congener mixtures to a total toxic equivalent concentration.

[f] Diesel range organics includes the sum of diesel fuels and heavy oils measured using method the NWTPH-Dx method. Mineral oils are essentially non-toxic to plants and animals and do not need to comply with these values (see Compendium – Section V).

[g] Except that the concentration shall not exceed residual saturation.

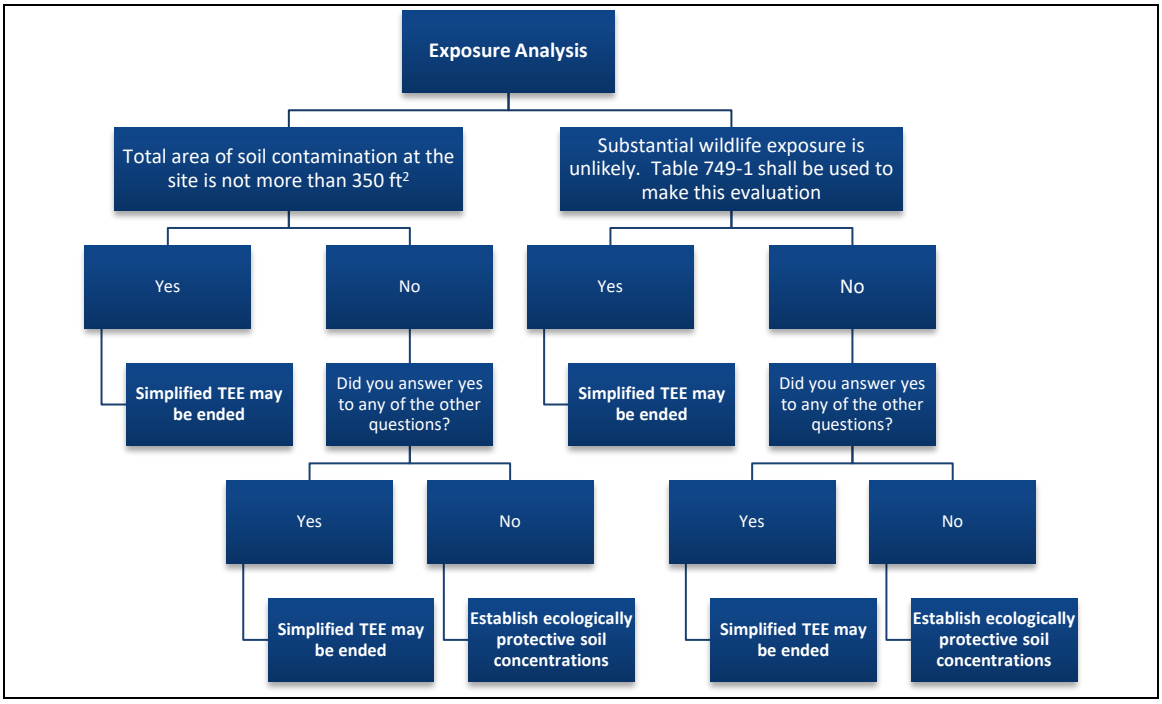
Exposure Analysis

The Exposure Analysis process (Figure 4.2) conducted while performing the simplified TEE is designed to determine the potential for significant exposure to ecological receptors that either use or inhabit sites. The TEE may be ended at a site where:

- The total area of soil contamination is not more than 350 square feet, or;
- Land use at the site and surrounding area make substantial wildlife exposure unlikely.

The determination of land use and wildlife exposure is made with the use of Table 4.2 (MTCA Table 749-1), which is provided for in the MTCA Regulations (WAC 173-340-900). Generally, an experienced field biologist should complete the habitat evaluation. In cases where Table 4.2 (MTCA Table 749-1) is completed by less experienced personnel, conservative assumptions should be made while completing the exposure analysis (Table 4.2 Footnote [a]). The presence of wildlife corridors on or adjacent to the site such as greenbelts, riparian zones, or water bodies should also be considered while determining whether or not a site is likely to attract wildlife. If it has been determined that there is significant potential for ecological receptors to be exposed to contaminants at the site, then an analysis of exposure pathways and/or contaminants must be completed. These procedures have been outlined in the Pathways Analysis and Toxicity Analysis sections. The process for setting cleanup levels for sites evaluated using the TEE has provided in the Establish Ecologically Protective Soil Concentrations section.

Figure 4.2: Summary of Exposure Analysis



Note: Answering (yes) to any of the other questions includes both the pathways analysis and toxicity analysis [sections].

Table 4.2: Simplified Terrestrial Ecological Evaluation – Exposure Analysis Procedures[a]

Estimate the area of contiguous (connected) undeveloped land on or within 500 feet of any area of the contaminated soil to the nearest ½ acre (1/4 acre if the area is less than 0.5 acre). "Undeveloped land" means land that is not covered by existing buildings, roads, paved areas or other barriers that will prevent wildfire from feeding on plants, earthworms, insects or other food in or on the soil.	
1) From the table below, find the number of points corresponding to the area and enter this number in the box to the right.	
Area (acres) / Points 0.25 or less 4 0.5 5 1.0 6 1.5 7 2.0 8 2.5 9 3.0 10 3.5 11 4.0 or more 12	
2) Is this an industrial or commercial property? See the definition in WAC 173-340-200. If yes, enter a score of 3 in the box to the right. If no, enter a score of 1.	
3) Enter a score in the box to the right for the habitat quality of the contaminated soil and surrounding area, using the rating system shown below[b]. (High = 1, Intermediate = 2, Low = 3)	
4) Is the undeveloped land likely to attract wildlife? If yes, enter a score of 1 in the box to the right. If no, enter a score of 2[c].	
5) Are there any of the following soil hazardous substances present: Chlorinated dioxins/furans, PCB mixtures, DDT, DDE, DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, or pentachlorobenzene? If yes, enter a score of 1 in the box to the right. If no, enter a score of 4.	
Add the numbers in the boxes on lines 2 through 5 and enter this number to the right. If this number is larger than the number in the box on line 1, the simplified TEE may be ended under WAC 173-340-7292(2) (a) (ii).	

Footnotes:

[a] It is expected that this habitat evaluation will be undertaken by an experienced field biologist. If this is not the case, enter a conservative score (1) for questions 3 and 4.

[b] **Habitat rating system.** Rate the quality of the habitat as high, intermediate, or low based on your professional judgment as a field biologist. The following are suggested factors to consider in making this evaluation:

- **Low:** Early successional vegetative stands; vegetation predominantly noxious, non-native, exotic plant species or weeds. Areas severely disturbed by human activity, including intensively cultivated croplands. Areas isolated from other habitat used by wildlife.
- **High:** Area is ecologically significant for one or more of the following reasons: Late successional native plant communities present; relatively high species diversity; used by an uncommon or rare species; priority habitat (as defined by the Washington Department of Fish and Wildlife); part of a larger area of habitat where size or fragmentation may be important for the retention of some species.
- **Intermediate:** Area does not rate as either high or low.

[c] Indicate "yes" if the area attracts wildlife or is likely to do so. Examples:

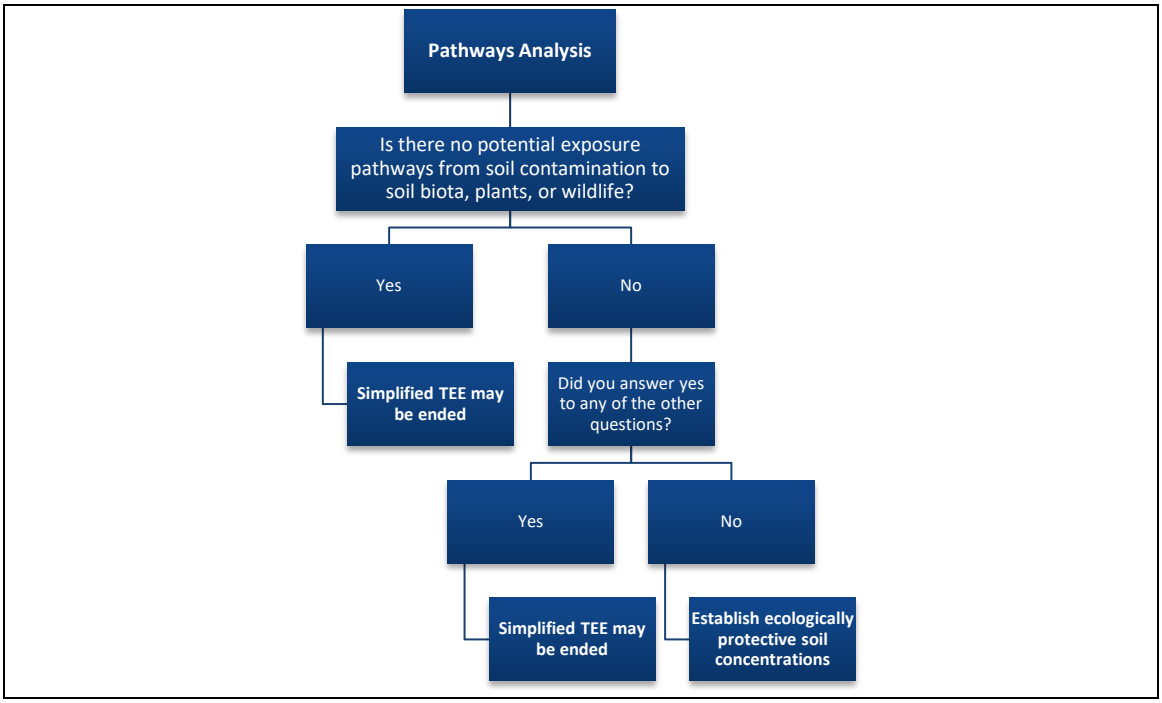
- Birds frequently visit the area to feed
- Evidence of high use by mammals (tracks, scat, etc…)
- Habitat "island" in an industrial area
- Unusual features of an area that make it important for feeding animals
- Heavy use during seasonal migrations
- Areas adjacent to wildlife corridors (i.e. greenbelts and waterways)

Pathways Analysis

The Pathways Analysis process (see Figure 4.3) conducted while performing the simplified TEE is designed to determine the exposure pathways from soil contamination to soil biota, plants or wildlife. For a commercial or industrial property, only potential exposure pathways to wildlife (e.g., small mammals, birds) need be considered. Only exposure pathways for priority chemicals of ecological concern listed in Table 4.1 (MTCA Table 749-2) at or above the concentrations provided must be considered. As a result, the toxicity analysis portion of the TEE should be performed concurrently with the pathways analysis. The results of the toxicity analysis are required to evaluate exposure pathways. Incomplete pathways may be due to the presence of man-made physical barriers, either currently existing or to be placed (future use) within a timeframe acceptable to the department, as part of a remedy or land use. These barriers may include, but are not limited to; parking lots, foundations, or geotextile membranes.

Conditional points of Compliance (See Chapter 1) may be changed to accommodate remedial alternatives provided that all of WAC 173-340-7490 (4) requirements have been satisfied. Barriers must break all significant exposure pathways and their design is dependent on site-specific environmental conditions and the chemical properties of contaminants. To ensure that such man-made barriers are maintained, a restrictive covenant shall be required by the department under WAC 173-340-440 under a consent decree, agreed order, or enforcement order, or as a condition to a written opinion regarding the adequacy of an independent remedial action.

Figure 4.3: Summary of Pathways Analysis



Note: Answering (yes) to any of the other questions includes both the exposure analysis and toxicity analysis [sections].

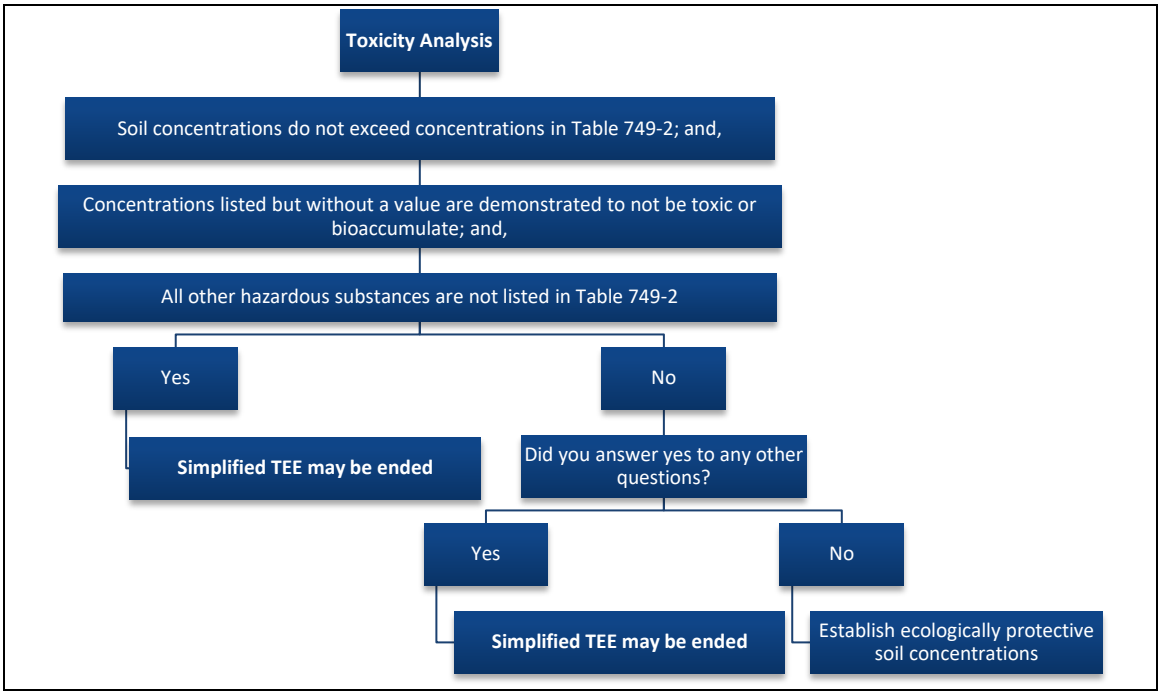
Toxicity Analysis

The Toxicity Analysis process (see Figure 4.4) conducted while performing the simplified TEE is designed to determine whether or not concentrations of toxicants are safe for ecological receptors using or inhabiting the site. The first step in the toxicity analysis process is to determine if site contaminants are listed and/or above Table 4.1 (MTCA Table 749-2) indicator soil concentrations. In cases where the table values are not provided and/or soil concentrations exceed the table values, a number of methods may be used to establish ecologically protective cleanup levels (see Establishing Ecologically Protective Soil Concentrations section). Otherwise, the Table 4.1 (MTCA Table 749-2) values may be used as cleanup levels. The TEE may be ended (without performing the exposure and pathway analyses) provided that cleanup plans are based on Table 4.1 (MTCA Table 749-2) values (provided that table values are available for all of the contaminants on site). Specifically, the evaluation may be ended if all of the following conditions are met at the site:

- For hazardous substances with a value listed in Table 4.1 (MTCA Table 749-2), soil concentrations at the point of compliance (see Chapter 1) do not exceed the applicable concentrations in this table;
- For hazardous substances listed in Table 4.1 (MTCA Table 749-2) but without a value, it is demonstrated that soil concentrations at the point of compliance are unlikely to be toxic or bioaccumulate based on bioassay procedures and wildlife exposure modeling and approved by the department; and,
- For other hazardous substances, the substances are not listed in Table 4.1 (MTCA Table 749-2).

Note: Whether a 6 foot conditional point of compliance is used or an alternative conditional point of compliance is deemed protective by Ecology, an institutional control is required if the contamination is within fifteen feet of the ground surface (see WAC 173-340-7490(4)(b)).

Figure 4.4: Summary of Toxicity Analysis



Note: Answering (yes) to any of the other questions includes both the pathways analysis and exposure analysis [sections]

Establishing Ecologically Protective Soil Concentrations

Establishing ecologically protective soil concentrations is required when the simplified TEE process cannot be ended under any of the simplified analysis criteria described in the previous subsections; exposure analysis, pathways analysis, or toxicity analysis. The ecologically protective soil concentrations can be established using the following methods:

- Use of the soil concentrations in Table 4.1 (MTCA Table 749-2).
- Derived soil concentrations using bioassay procedures described in WAC 173-340-7494(5) to determine concentrations toxic to soil biota and plants, and concentrations likely to bioaccumulate to toxic levels in animals as follows. Consult with the department before conducting bioassays;
    - For values in Table 4.1 (MTCA Table 749-2) based on toxicity to soil biota or plants, bioassays may be used to override the concentration in that table.
    - Bioassays may also be used to develop site-specific concentrations based on toxicity to soil biota and plants for substances listed in Table 4.1 (MTCA Table 749-2) but without a value.
    - For values in Table 4.1 (MTCA Table 749-2) based on modeling of bioaccumulation in wildlife and for substances listed in Table 4.1 (MTCA Table

749-2) but without a value, bioassays can be used to develop a site-specific earthworm bioaccumulation and/or plant uptake factor for use in the model described in Table 5.2 (MTCA Table 749-4). When using this model to develop protective soil concentrations for simplified ecological evaluations under this provision, all the other default values must be used; or

- The person conducting the evaluation may also voluntarily elect to develop protective soil concentrations using a site-specific terrestrial ecological evaluation under WAC 173-340-7494, instead of under this section.

Setting Cleanup Levels Based on TEE Tables

The indicator soil concentrations provided in Table 4.1 (MTCA Table 749-2) and Table 5.1 (MTCA Table 749-3) may be used as cleanup levels at any site conducting a simplified TEE. A combination of the values from both tables and the results of bioassays may also be used in cases where safe chemical concentrations for one of more of the ecological receptor groups have not been determined. While the use of these table values as cleanup levels is considered acceptable, please note that the values are conservative and those selected cleanup levels may be more stringent than required to protect ecological receptors on a specific site. Ecology chose to use conservative values in the absence of site-specific information. In many cases, the use of bioassays and empirical studies results in ecologically protective cleanup levels that are less stringent than the human-health based cleanup values, in which case, human health is the driving aspect controlling acceptable chemical concentrations.

Assessing Soil Toxicity with Bioassays

An alternative method to setting cleanup levels based on table values would be to derive concentrations using the bioassay procedures. This is completed to determine concentrations considered toxic to soil biota and plants, and those concentrations likely to bioaccumulate to toxic levels in animals. Bioassays may be used to:

- Determine a safe, yet less conservative value than Table 4.1 (MTCA Table 749-2) based on toxicity to soil biota or plants.
- Develop site – specific concentrations based on toxicity to soil biota and plants for substances listed in Table 4.1 (MTCA Table 749-2), but without a value.
- Develop a site – specific earthworm bioaccumulation and/or plant uptake factor for use in the model described in Table 5.2 (MTCA Table 749-4).

For issues where existing or potential threats to plant life are a concern, use the test described in *Early Seedling Growth Protocol for Soil Toxicity Screening*, Ecology Publication No. 96-324 (see Compendium – Section M). For sites where risks to soil biota are a concern, use the test described in *Earthworm Bioassay Protocol for Soil Toxicity Screening*, Ecology Publication No. 96-327 (see Compendium – Section N). A supporting document describing toxicity tests for receptors is *Protocols for Short Term Toxicity Screening of Hazardous Waste* Sites, Environmental Protection Agency Publication No. 600/3-88/029 (see Compendium – Section O).

Soil concentrations protective of soil biota or plants may also be established with soil bioassays that use species ecologically relevant to the site rather than standard test species. Species that do or could occur at the site are considered ecologically relevant.

Chapter 5: The Site – Specific Terrestrial Ecological Evaluation

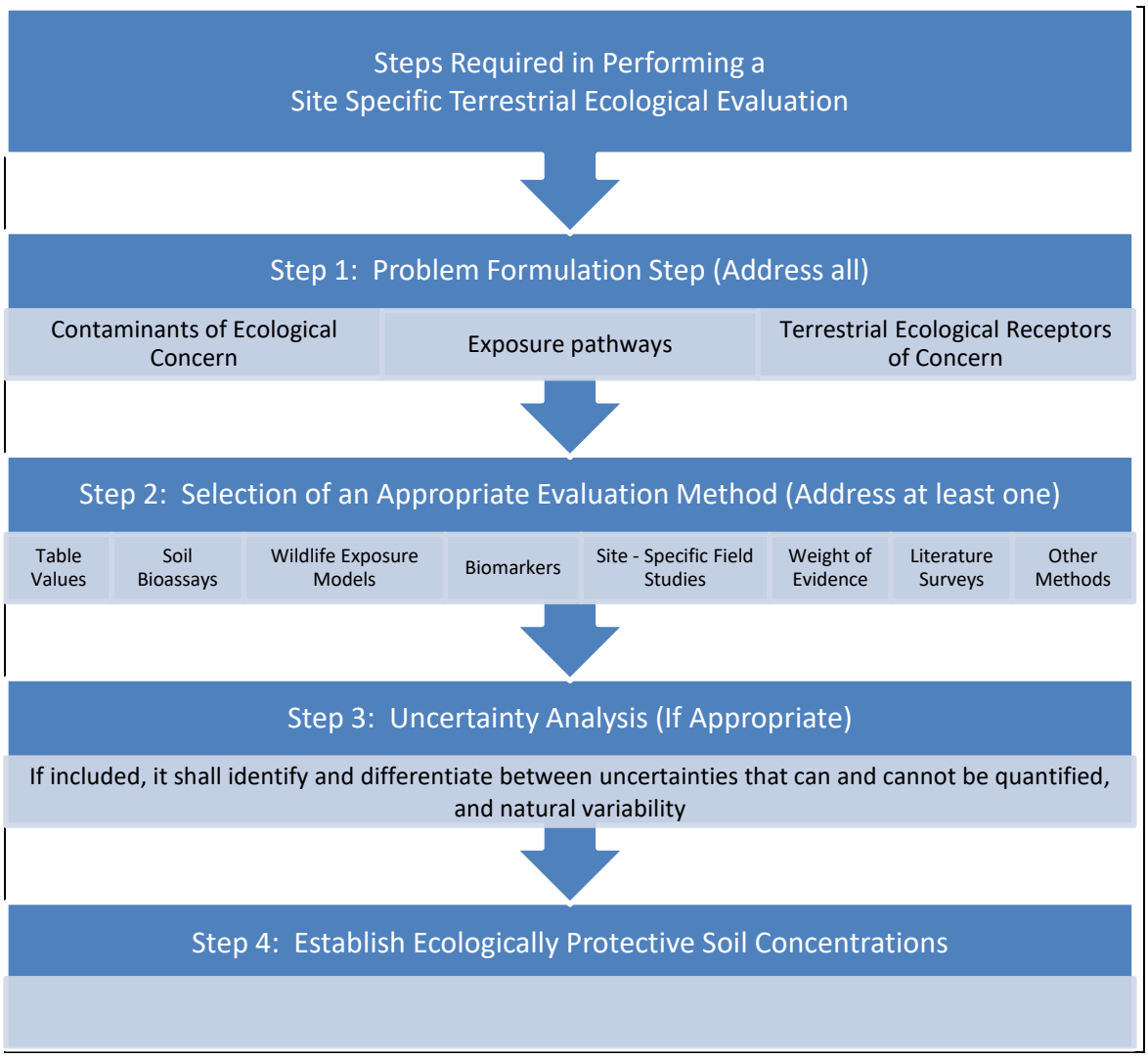
Chapter 3 describes the applicability of a simplified TEE. If it had been established that any one of the criteria described in the "Applicability of a Simplified Terrestrial Ecological Evaluation" section apply to the site, a site-specific TEE is required. The site-specific TEE process is designed to assess ecological risk at any site; including sites with protected status species (see Figure 5.1).

A site-specific TEE shall include the following steps:

- Problem formulation
- Selection of appropriate evaluation method(s)
- Conducting the evaluation
- Establish ecologically protective soil concentrations

Please note, after problem formulation, the department may (at its discretion) determine that the cleanup planned to address human health or possible aquatic impacts will also adequately protect soil biota, plants and animals. In these cases, no further evaluation of terrestrial ecological risk is required. Additionally, the department may determine that a simplified, rather than site-specific TEE may be conducted because a simplified TEE will adequately identify and address any existing or potential threats to ecological receptors.

Figure 5.1: Summary of Site – Specific TEE Procedures



Step 1: Problem Formulation

The purpose of problem formulation is to define the focus of the site-specific TEE. Three criteria are needed to be addressed to complete problem formulation. Those three criteria are:

- Contaminants of ecological concern
- Exposure pathways
- Terrestrial ecological receptors of concern

Contaminants of Ecological Concern

Identify the contaminants of ecological concern at the site. The person conducting the evaluation may eliminate hazardous substances from further consideration where the soil concentrations found at the site does not exceed the screening levels in Table 5.1 (MTCA Table 749-3). Please Note: See Chapter 1, for an explanation of statistical and other methods under "Determining Compliance." For industrial or commercial land uses, only the wildlife values need to be considered.

Any contaminant that exceeds the screening levels found in Table 5.1 (MTCA Table 749-3) shall be included as a contaminant of ecological concern in the evaluation unless it can be eliminated based on the factors listed in WAC 173-340-703. In summary, the department may eliminate from consideration those hazardous substances that contribute a small percentage of the overall threat to human health and the environment. The factors evaluated when eliminating individual hazardous substances from further consideration include (from WAC 173-340-703):

- The toxicological characteristics of the substance that influence its ability to adversely affect human health or the environment relative to the concentration of the substance at the site, including consideration of essential nutrient requirements;
- The chemical and physical characteristics of the substance which govern its tendency to persist in the environment;
- The chemical and physical characteristics of the hazardous substance which govern its tendency to move into and through environmental media;
- The natural background concentrations of the substance;
- The thoroughness of testing for the substance at the site;
- The frequency that the substance has been detected at the site; and
- Degradation by-products of the substance.

Table 5.1: EISC (mg/kg) for Protection of Terrestrial Plants and Animals.[a] For chemicals where a value is not provided see footnote b.

Note: These values represent soil concentrations that are expected to be protective at any MTCA site and are provided for use in eliminating hazardous substances from further consideration under WAC 173-340-7493(2)(a)(i). Where these values are exceeded, various options are provided for demonstrating that the hazardous substance does not pose a threat to ecological receptors at a site, or for developing site – specific remedial standards for eliminating threats to ecological receptors.

Hazardous Substance[b]	Plants[c]	Soil Biota[d]	Wildlife[e]	Hazardous Substance[b]	Plants[c]	Soil Biota[d]	Wildlife[e]
METALS:[f]				2,4,5 – Trichlorophenol	4	9	
Aluminum (soluble salts)	50			2,4,6 – Trichlorophenol		10	
Antimony	5			2,4 – Dichloroaniline		100	
Arsenic III			7	3,4 – Dichloroaniline		20	
Arsenic V	10	60	132	3,4 – Dichlorophenol	20	20	
Barium	500		102	3 – Chloroaniline	20	30	
Beryllium	10			3 – Chlorophenol	7	10	
Boron	0.5			Chlorinated Dibenzofurans (total)			2E-06
Bromine	10			Chloroacetamide		2	
Cadmium	4	20	14	Chlorobenzene		40	
Chromium (total)	42[g]	42[g]	67	Chlorinated dibenzo-p-dioxins (total)			2E-06
Cobalt	20			Hexachlorocyclopentadiene	10		
Copper	100	50	217	PCB mixtures (total)	40		0.65
Fluorine	200			Pentachloroaniline		100	
Iodine	4			Pentachlorobenzene		20	
Lead	50	500	118	**OTHER NONCHLORINATED ORGANICS:**			
Lithium	35[g]			2,4 – Dinitrophenol	20		
Manganese	1,100[g]		1,500	4 – Nitrophenol		7	
Mercury, inorganic	0.3	0.1	5.5	Acenaphthene	20		
Mercury, organic			0.4	Benzo(a)pyrene			12
Molybdenum	2		7	Biphenyl	60		
Nickel	30	200	980	Diethylphthalate	100		
Selenium	1	70	0.3	Dimethylphthalate		200	
Silver	2			Di-n-butyl phthalate	200		
Technetium	0.2			Fluorene		30	
Thallium	1			Furan	600		
Tin	50			Nitrobenzene		40	
Uranium	5			N – nitrosodiphenylamine		20	
Vanadium	2			Phenol	70	30	
Zinc	86[g]	200	360	Styrene	300		
PESTICIDES:				Toluene	200		
Aldrin			0.1	**PETROLEUM:**			
Benzene hexachloride (including lindane)			6	Gasoline Range Organics		100	5,000[h]
Chlordane		1	2.7	Diesel Range Organics[j]		200	6,000[i]
DDT/DDD/DDE (total)			0.75				
Dieldrin			0.07				
Endrin			0.2				
Hexachlorobenzene			17				
Heptachlor/heptachlorepoxide (total)			0.4				
Pentachlorophenol	3	6	4.5				
OTHER CHLORINATED ORGANICS:							
1,2,3,4 – Tetrachlorobenzene		10					
1,2,3 – Trichlorobenzene		20					
1,2,4 – Trichlorobenzene		20					
1,2 – Dichloropropane		700					
1,4 – Dichlorobenzene		20					
2,3,4,5 – Tetrachlorophenol		20					
2,3,5,6 – Tetrachloroaniline	20	20					
2,4,5 – Trichloroaniline	20	20					

See Footnotes Section (Next Page)

Footnotes:

a. Caution on misusing these ecological indicator concentrations. Exceedances of the values in this table do not necessarily trigger requirements for cleanup action under this chapter. Natural background concentrations may be substituted for ecological indicator concentrations provided in this table. The table is not intended for purposes such as evaluating sludges or wastes. This list does not imply that sampling must be conducted for each of these chemicals at every site. Sampling should be conducted for those chemicals that might be present based on available information, such as current and past uses of chemicals at the site.

b. For hazardous substances where a value is not provided, plant and soil biota indicator concentrations shall be based on a literature survey conducted in accordance with WAC 173-340-7493(4) and calculated using methods described in the publications listed below in footnotes c and d. Methods to be used for developing wildlife indicator concentrations are described in Tables 5.2 and 5.3 (MTCA Tables 749-4 and 749-5).

c. Based on benchmarks published in *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants: 1997 Revision,* Oak Ridge National Laboratory, 1997 (see Compendium – Section P).

d. Based on benchmarks published in *Toxicological Benchmarks for Potential Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process,* Oak Ridge National Laboratory, 1997 (see Compendium – Section Q).

e. Calculated using the exposure model provided in Table 5.2 (MTCA Table 749-4) and chemical-specific values provided in Table 5.3 (MTCA Table 749-5). Where both avian and mammalian values are available, the wildlife value is the lower of the two.

f. For arsenic, use the valence state most likely to be appropriate for site conditions, unless laboratory information is available. Where soil conditions alternate between saturated, anaerobic and unsaturated, aerobic states, resulting in the alternating presence of arsenic III and arsenic V, the arsenic III concentrations shall apply.

g. Benchmark replaced by Washington State natural background concentration.

h. 5,000 mg/kg except that the concentration shall not exceed residual saturation at the soil surface.

i. 6,000 mg/kg except that the concentration shall not exceed residual saturation at the soil surface.

j. Diesel range organics includes the sum of diesel fuels and heavy oils measured using method the NWTPH-Dx method. Mineral oils are essentially non-toxic to plants and animals and do not need to comply with these values (see Compendium – Section V).

Exposure Pathways

Identify any complete potential exposure pathways that would be expected for exposure of plants or animals to the contaminants of concern. If there are no complete exposure pathways then no further evaluation is necessary. Incomplete pathways may be due to the presence of man-made physical barriers, either currently existing or for future use within a timeframe acceptable to the department, as part of a remedy or land use.

Terrestrial Ecological Receptors of Concern

Identify current or potential future terrestrial ecological receptor groups reasonably likely to live or feed at the site. Groupings should represent taxonomically related species with similar exposure characteristics. Examples of potential terrestrial species groups include:

- Soil-associated invertebrates
- Vascular plants
- Ground-feeding birds
- Ground-feeding small mammal predators
- Herbivorous small mammals.

From these terrestrial species groups, select those groups to be included in the evaluation. If appropriate, individual terrestrial receptor species may also be included. In selecting species groups or individual species, the following shall be considered:

- Receptors that may be at most risk for significant adverse effects based on; the toxicological characteristics of the contaminants of concern, the sensitivity of the receptor, and the likely degree of exposure.
- Public comments.
- Species protected under applicable state or federal laws that may potentially be exposed to hazardous substances in the soil at the site (see Compendium – Section E) (see Compendium – Section F) (see Compendium – Section G).
- Receptors to be considered under different land uses (see Ecological Receptors Based on Land Use – Chapter 1), as described under WAC 173-340-7490(3).

Note: Surrogate species for which greater information is available, or that are more suitable for site –specific studies, may be used in the analysis when appropriate for addressing issues raised in the problem formulation step.

Toxicological Assessment

Identify significant adverse effects in the receptors of concern that may result from exposure to the contaminants of concern, based on information from the toxicological literature. Example:

Is dieldrin contamination a potential threat to reproduction in birds feeding on invertebrates and ingesting soil at the site? If so, what measures will eliminate any significant adverse effects?
If there are identified information needs for remedy selection, these should also be developed as issues for the problem formulation process. The use of assessment and measurement endpoints, as defined in USEPA *Ecological Risk Assessment Guidance for Superfund*, 1997 (see Compendium – Section T), shall be considered to clarify the logical structure of the site-specific TEE under this chapter. Assessment endpoints shall be consistent with the requirements in WAC 173-340-7490 (3) (see Chapter 1 – Ecological Receptors Based on Land Use). A recommendation for points that should be considered when completing a toxicological assessment includes:

- Relevant chemical information
- Uptake via routes of potential exposure
- Potential to bioaccumulate in plants, invertebrates and vertebrates
- Modes of action
- Range of toxicological endpoints and sensitive endpoints
- Sensitive receptor group (e.g., vascular plants, soil biota, ground-feeding small mammal predators, ground-feeding small mammal herbivores, and ground-feeding birds)
- Other additional information found in the review that may be important

Step 2: Selection of Appropriate Terrestrial Ecological Evaluation Methods

If it is determined during the problem formulation that further evaluation is necessary, one or more of the following methods shall be used to further evaluate terrestrial ecological effects and, if necessary, establish soil concentrations protective of terrestrial ecological receptors:

- Table values
- Soil Bioassays
- Wildlife exposure model
- Biomarkers
- Site – specific field studies
- Weight of evidence
- Literature surveys

When selecting a method, consideration shall be given to the relevance of the method to the issues identified during problem formulation. There is flexibility under the cleanup regulation both in selecting an approach for addressing issues raised problem formulation, and the criteria to be used for interpreting results from the selected approach. Because of this flexibility, it is

important to consult with Ecology during the planning stages to insure that the completed site-specific TEE will be acceptable to the department.

There are two general categories of methods available for addressing concerns developed during problem formulation: Empirical studies and literature surveys. Empirical studies range from the characterization of physical or chemical properties of contaminated soil to measurements conducted on biota at the site. In some instances, the data from these studies may be used in conjunction with a wildlife exposure model that has been provided for (and discussed later in this chapter) in the regulations.

The other method is literature surveys. Literature surveys may be used to develop site-specific information, but will generally need to begin with some relevant site data. For example, if the chemical form of a site contaminant is known, there may be justification for substituting a literature-derived value for the default value provided for in the regulation.

Table Values

At the discretion of the person conducting the evaluation, the screening values in Table 5.1 (MTCA Table 749-3) may be used as the cleanup level when terrestrial ecological risk drives the cleanup level.

Soil Bioassays

Bioassays may use sensitive surrogate organisms not necessarily found at the site provided that the test adequately addresses the issues raised in the problem formulation. For issues where existing or potential threats to plant life are a concern, use the test described in *Early Seedling Growth Protocol for Soil Toxicity Screening*, Ecology Publication No. 96-324 (see Compendium – Section M). For sites where risks to soil biota are a concern, use the test described in *Earthworm Bioassay Protocol for Soil Toxicity Screening*, Ecology Publication No. 96-327 (see Compendium – Section N). Preparation of test soils and dilution factors can be found in the procedures listed in *Protocols for Short Term Toxicity Screening of Hazardous Waste Sites*, USEPA Publication No. 600/3-88/029 (see Compendium – Section O). Other bioassay tests approved by the department may also be used.

Soil concentrations protective of soil biota or plants may also be established with soil bioassays that use species ecologically relevant to the site rather than standard test species. Species that do or could occur at the site are considered ecologically relevant.

Wildlife Exposure Model

Modeling may be used to determine soil concentrations protective of terrestrial wildlife using the equations and exposure parameters in Tables 5.2 and 5.3 (MTCA Tables 749-4 and 749-5). Alternative values for parameters listed in Table 5.3 (MTCA Table 749-5) may be used if it can be demonstrated that the alternative values are more relevant to site-specific conditions (for example, the value is based on a chemical form of a hazardous substance actually present at the

site). Alternative values obtained from the literature shall be supported by a literature survey conducted in accordance with the literature survey requirements and the requirements of:

- Burden of Proof – Demonstration to the department that requirements in this chapter have been met to ensure protection of human health and the environment. The department shall only approve of such proposals when it determines that this burden of proof is met.
- New Scientific Information – The department shall consider new scientific information when establishing cleanup levels and remediation levels for individual sites. Any proposal to use new scientific information shall meet the quality of information requirements described below. To minimize delay in cleanups, any proposal to use new scientific information should be introduced as early in the cleanup process as possible.
- Criteria for quality of information:
    - Whether the information is based on a theory or technique that has widespread acceptance within the relevant scientific community.
    - Whether the information was derived using standard testing methods or other widely accepted scientific methods.
    - Whether a review of relevant available information, both in support of and not in support of the proposed modification, has been provided along with the rationale explaining the reasons for the proposed modification.
    - Whether the assumptions used in applying the information to the facility are valid and would ensure the proposed modification would err on behalf of protection of human health and the environment.
    - Whether the information adequately addresses populations that are more highly exposed than the population as a whole and are reasonably likely to be present at the site.
    - Whether adequate quality assurance and quality control procedures have been used, and significant anomalies are adequately explained, the limitations of the information are identified, and the known or potential rate of error is acceptable.

For more information regarding substitution of screening values, please see Chapter 6: Substitution of Screening Values.

Receptor species of concern or exposure pathways identified in the problem formulation step may be added to the model if appropriate on a site-specific basis. Substitutions of receptor species and the associated values in the wildlife exposure model described in Table 5.2 (MTCA Table 749-4) may be made subject to the following conditions:

- There is scientifically supportable evidence that a receptor identified in Table 5.2 (MTCA Table 749-4) is not characteristic or a reasonable surrogate for a receptor that is characteristic of the ecoregion where the site is located. "Ecoregions" are defined using EPA's *Ecoregions of the Pacific Northwest* Document No. 600/3-86/033 July 1986 by Omerick and Gallant (see Compendium – Section S).
- The proposed substitute receptor is characteristic of the ecoregion where the site is located and will serve as a surrogate for wildlife species that are, or may become exposed to hazardous substances in the soil at the site. The selected surrogate shall be a species that is expected to be vulnerable to the effects of soil contamination relative to the current default species because of high exposure or known sensitivity to hazardous substances found in the soil at the site.
- Scientific studies concerning the proposed substitute receptor species are available in the literature to select reasonable maximum exposure estimates for variables listed in Table 5.2 (MTCA Table 749-4).

Note: In choosing among potential substitute receptor species that meet the criteria in the above two provisions, preference shall be given to the species most ecologically similar to the default receptor being replaced.

- Unless there is clear and convincing evidence that they are not characteristic of the ecoregion where the site is located, the following groups shall be included in the wildlife exposure model: A small mammalian predator on soil-associated invertebrates, a small avian predator on soil-associated invertebrates, and a small mammalian herbivore. Selected groups should have a small foraging range.
- To account for uncertainties in the level of protection provided to substitute receptor species and toxicologically sensitive species, the department may require any of the following:
    - Use of toxicity reference values (TRV) based on no observed adverse effects levels.
    - Use of uncertainty factors to account for extrapolations between species in toxicity or exposure parameter values; or
    - Use of a hazard index (HI) approach for multiple hazardous substances to account for additive toxic effects.

Table 5.2: Wildlife Exposure Model for Site – Specific Evaluations

Table 749-4
Wildlife Exposure Model for Site-specific Evaluations.[a]

PLANT	
K_{Plant}	Plant uptake coefficient (dry weight basis)
	Units: mg/kg plant / mg/kg soil
	Value: chemical-specific (see Table 749-5)
SOIL BIOTA Surrogate receptor: Earthworm	
BAF_{Worm}	Earthworm bioaccumulation factor (dry weight basis)
	Units: mg/kg worm / mg/kg soil
	Value: chemical-specific (see Table 749-5)
MAMMALIAN PREDATOR Surrogate receptor: Shrew (*Sorex*)	
$P_{SB\ (shrew)}$	Proportion of contaminated food (earthworms) in shrew diet
	Units: unitless
	Value: 0.50
$FIR_{Shrew,DW}$	Food ingestion rate (dry weight basis)
	Units: kg dry food / kg body weight – day
	Value: 0.45
$SIR_{Shrew,DW}$	Soil ingestion rate (dry weight basis)
	Units: kg dry soil / kg body weight – day
	Value: 0.0045
$RGAF_{Soil,\ shrew}$	Gut absorption factor for a hazardous substance in soil expressed relative to the gut absorption factor for the hazardous substance in food.
	Units: unitless
	Value: chemical-specific (see Table 749-5)
T_{Shrew}	Toxicity reference value for shrew
	Units: mg/kg - day
	Value: chemical-specific (see Table 749-5)
Home range	0.1 Acres
AVIAN PREDATOR Surrogate receptor: American robin (*Turdus migratorius*)	
$P_{SB\ (Robin)}$	Proportion of contaminated food (soil biota) in robin diet
	Unit: unitless
	Value: 0.52
$FIR_{Robin,DW}$	Food ingestion rate (dry weight basis)
	Units: kg dry food / kg body weight – day
	Value: 0.207
$SIR_{Robin,DW}$	Soil ingestion rate (dry weight basis)
	Units: kg dry soil / kg body weight – day
	Value: 0.0215
$RGAF_{Soil,\ robin}$	Gut absorption factor for a hazardous substance in soil expressed relative to the gut absorption factor for the hazardous substance in food.
	Units: unitless
	Value: chemical-specific (see Table 749-5)
T_{Robin}	Toxicity reference value for robin
	Units: mg/kg – day
	Value: chemical-specific (see Table 749-5)
Home range	0.6 acres
MAMMALIAN HERBIVORE Surrogate receptor: Vole (*Microtus*)	
$P_{Plant,\ vole}$	Proportion of contaminated food (plants) in vole diet
	Units: unitless
	Value: 1.0
$FIR_{Vole,DW}$	Food ingestion rate (dry weight basis)
	Units: kg dry food / kg body weight – day
	Value: 0.315
$SIR_{Vole,DW}$	Soil ingestion rate (dry weight basis)
	Units: kg dry soil / kg body weight – day
	Value: 0.0079
$RGAF_{Soil,\ vole}$	Gut absorption factor for a hazardous substance in soil expressed relative to the gut absorption factor for the hazardous substance in food.
	Units: unitless
	Value: chemical-specific (see Table 749-5)
T_{Vole}	Toxicity reference value for vole
	Units: mg/kg – day
	Value: chemical-specific (see Table 749-5)
Home range	0.08 acres
SOIL CONCENTRATIONS FOR WILDLIFE PROTECTION[b]	
(1) Mammalian predator: $SC_{MP} = (T_{Shrew})/[(FIR_{Shrew,DW} \times P_{SB\ (shrew)} \times BAF_{Worm}) + (SIR_{Shrew,DW} \times RGAF_{Soil,\ shrew})]$	
(2) Avian predator: $SC_{AP} = (T_{Robin})/[(FIR_{Robin,DW} \times P_{SB\ (Robin)} \times BAF_{Worm}) + (SIR_{Robin,DW} \times RGAF_{Soil,\ robin})]$	
(3) Mammalian herbivore: $SC_{MH} = (T_{Vole})/[(FIR_{Vole,DW} \times P_{Plant,vole} \times K_{Plant}) + (SIR_{Vole,DW} \times RGAF_{Soil,\ vole})]$	

Footnotes:

a Substitutions for default receptors may be made as provided for in WAC 173-340-7493(7). If a substitute species is used, the values for food and soil ingestion rates, and proportion of contaminated food in the diet, may be modified to reasonable maximum exposure estimates for the substitute species based on a literature search conducted in accordance with WAC 173-340-7493(4).
Additional species may be added on a site-specific basis as provided in WAC 173-340-7493 (2)(a).
The department shall consider proposals for modifications to default values provided in this table based on new scientific information in accordance with WAC 173-340-702(14).

b Use the lowest of the three concentrations calculated as the wildlife value.

Table 5.3: Default Values for Substances for use with the Wildlife Exposure Model

Table 749-5
Default Values for Selected Hazardous Substances for use with the Wildlife Exposure Model in Table 749-4.[a]

Hazardous Substance	Toxicity Reference Value (mg/kg - d)				
	BAF_{Worm}	K_{Plant}	Shrew	Vole	Robin
METALS:					
Arsenic III	1.16	0.06	1.89	1.15	
Arsenic V	1.16	0.06	35	35	22
Barium	0.36		43.5	33.3	
Cadmium	4.6	0.14	15	15	20
Chromium	0.49		35.2	29.6	5
Copper	0.88	0.020	44	33.6	61.7
Lead	0.69	0.0047	20	20	11.3
Manganese	0.29		624	477	
Mercury, inorganic	1.32	0.0854	2.86	2.18	0.9
Mercury, organic	1.32		0.352	0.27	0.064
Molybdenum	0.48	1.01	3.09	2.36	35.3
Nickel	0.78	0.047	175.8	134.4	107
Selenium	10.5	0.0065	0.725	0.55	1
Zinc	3.19	0.095	703.3	537.4	131
PESTICIDES:					
Aldrin	4.77	0.007[b]	2.198	1.68	0.06
Benzene hexachloride (including lindane)	10.1				7
Chlordane	17.8	0.011[b]	10.9	8.36	10.7
DDT/DDD/ DDE	10.6	0.004[b]	8.79	6.72	0.87
Dieldrin	28.8	0.029[b]	0.44	0.34	4.37
Endrin	3.6	0.038[b]	1.094	0.836	0.1
Heptachlor/ heptachlor epoxide	10.9	0.027[b]	2.857	2.18	0.48
Hexachloro-benzene	1.08				2.4
Pentachloro-phenol	5.18	0.043[b]	5.275	4.03	
OTHER CHLORINATED ORGANICS:					
Chlorinated dibenzofurans	48				1.0E-05
Chlorinated dibenzo-p-dioxins	48	0.005[b]	2.2E-05	1.7E-05	1.4E-04
PCB mixtures	4.58	0.087[b]	0.668	0.51	1.8
OTHER NONCHLORINATED ORGANICS:					
Benzo(a)pyrene	0.43	0.011	1.19	0.91	

Footnotes:

a For hazardous substances not shown in this table, use the following default values. Alternatively, use values established from a literature survey conducted in accordance with WAC 173-340-7493(4) and approved by the department.

K_{Plant}:
- Metals (including metalloid elements): 1.01
- Organic chemicals: $K_{Plant} = 10^{(1.588-(0.578 \log Kow))}$, where $\log K_{ow}$ is the logarithm of the octanol-water partition coefficient.

BAF_{Worm}:
- Metals (including metalloid elements): 4.6
- Nonchlorinated organic chemicals:
  $\log K_{ow} < 5$: 0.7
  $\log K_{ow} \geq 5$: 0.9
- Chlorinated organic chemicals:
  $\log K_{ow} < 5$: 4.7
  $\log K_{ow} \geq 5$: 11.8

$RGAF_{Soil}$ (all receptors): 1.0
Toxicity reference values (all receptors): Values established from a literature survey conducted in accordance with WAC 173-340-7493(4).

Site-specific values may be substituted for default values, as described below:

K_{Plant}: Value from a literature survey conducted in accordance with WAC 173-340-7493(4) or from empirical studies at the site.
BAF_{Worm}: Value from a literature survey conducted in accordance with WAC 173-340-7493(4) or from empirical studies at the site.
$RGAF_{Soil}$ (all receptors): Value established from a literature survey conducted in accordance with WAC 173-340-7493(4).
Toxicity reference values (all receptors): Default toxicity reference values provided in this table may be replaced by a value established from a literature survey conducted in accordance with WAC 173-340-7493(4).

b Calculated from $\log K_{ow}$ using formula in footnote a.

Biomarkers

Biomarker methods may be used if the measurements have clear relevance to issues raised in the problem formulation and the approach has a high probability of detecting a significant adverse effect if it is occurring at the site. The person conducting the evaluation may elect to use criteria such as biomarker effects that serve as a sensitive surrogate for significant adverse effects.

Biomarkers are another alternative to full-scale field studies. Animals from a site can be tested for a variety of symptoms to evaluate whether they are being affected by soil contaminants. Typically, these symptoms collectively termed "biomarkers" are sensitive, early indicators of exposure that may precede the onset of more damaging health effects. Biomarkers are most useful where they are chemical-specific and there are well established, relatively inexpensive laboratory tests available.

For site-specific evaluations where biomarkers are chosen to address issues raised in problem formulation, it is important to reach agreement in the planning stages as to how the testing results will be used. For example, if there is an agreement to use a biomarker as a surrogate for an adverse effect as defined in WAC 173-340-7490(3), positive results could be a criterion for proceeding with remediation.

Site – Specific Field Studies

Site-specific empirical studies that involve hypothesis testing should use a conventional "no difference" null hypothesis (that is, H_O: Earthworm densities are the same in the contaminated area and the reference [control] area. H_A: Earthworm densities are higher in the reference area than in the contaminated area). In preparing a work plan, consideration shall be given to the adequacy of the proposed study to detect an ongoing adverse effect and this issue shall be addressed in reporting results from the study.

Weight of Evidence

A weight of evidence approach shall include a balance in the application of literature, field, and laboratory data, recognizing that each has particular strengths and weaknesses. Site-specific data shall be given greater weight than default values or assumptions where appropriate.

Literature Surveys

A literature survey may be used to address the issues raised in the problem formulation. An analysis based on a literature survey may be used for:

- Developing a soil concentration for contaminants of concern not listed in Table 5.1 (MTCA Table 749-3).

- Identifying a soil concentration for the protection of plants or soil biota more relevant to site-specific conditions than the value listed in Table 5.1 (MTCA Table 749-3).
- Obtaining a value for any of the wildlife exposure model variables listed in Table 5.3 (MTCA Table 749-5) to calculate a soil concentration for the protection of wildlife more relevant to site-specific conditions than the values listed in Table 5.1 (MTCA Table 749-3).

When using a literature survey, the following requirements must be met:

- TRV or soil concentrations established from the literature shall represent the lowest relevant lowest observed adverse effects level (LOAEL) found in the literature. Bioaccumulation factor (BAF) values and plant uptake (K_{plant}) factors shall represent a reasonable maximum value from relevant information found in the literature. In assessing relevance, the following principals shall be considered:
    - Literature benchmark values should be obtained from studies that have test conditions as similar as possible to site conditions.
    - The literature benchmark values or TRV should correspond to the exposure route being assessed.
    - The TRV, BAF, or K_{plant} value shall be as appropriate as possible for the receptor being assessed. The toxicity reference value should be based on a significant endpoint, as described under "endpoints" of this chapter.
    - The literature benchmark value or TRV should preferably be based on chronic exposure.
    - The literature benchmark value, TRV, BAF, or K_{plant} should preferably correspond to the chemical form being assessed. Exceptions may apply for TRV's where documented biological transformations occur following uptake of the chemical or where chemical transformations are known to occur in the environment under conditions appropriate to the site.

A list of relevant journals and other literature consulted in the survey shall be provided to the department. A table summarizing information from all relevant studies shall be provided to the department in a report, and the studies used to select a proposed value shall be identified. Copies of literature cited in the table that are not in the possession of the department shall be provided with the report. The department may identify relevant articles, books or other documents that shall be included in the survey.

A bioaccumulation factor (BAF) is obtained as the ratio of the chemical concentration in soil macroinvertebrates form the site (e.g., earthworms) to the concentration in soil samples from the site. Both measurements should be made on a dry weight basis. Depending on the macroinvertebrate abundance at the site and the quantity of biomass needed for laboratory analysis, it may be feasible to calculate an empirical BAF value. A variation on this approach involves the addition of laboratory-reared earthworms or other appropriate macroinvertebrates to soil samples and subsequent measurement of chemical concentrations in tissue and soil.

A plant uptake factor (K_{plant}) is calculated as the ratio of the chemical concentration in plants from the site to the concentration in soil samples from the site, with both measurements made on a dry weight basis. This parameter is needed for the calculation of a soil concentration for the protection of mammalian herbivores. In general, chemical concentrations should therefore be measured in grasses and forbs rather than woody shrubs or trees.

Other methods

The department may approve of other methods for conducting a TEE. This may include a qualitative evaluation if relevant toxicological data are not available and cannot be otherwise developed (e.g.., through soil bioassay testing).

Uncertainty Analysis

If a site-specific terrestrial ecological evaluation includes an uncertainty analysis, the discussion of uncertainty shall identify and differentiate between uncertainties that can and cannot be quantified and natural variability. The discussion shall describe the range of potential ecological risks from the hazardous substances present at the site, based on the toxicological characteristics of the hazardous substances present, and evaluate the uncertainty regarding these risks. Potential methods for reducing uncertainty shall also be discussed, such as additional studies or post-remedial monitoring. If multiple lines of independent evidence have been developed, a weight of evidence approach may be used in characterizing uncertainty.

Step 3: Establishing Ecologically Protective Soil Concentrations

Soil concentrations shall be established to protect soil biota and terrestrial plants and animals, as appropriate, at sites not meeting the criteria in the Ecological Receptors subsection of this chapter for ending the evaluation of conducting a simplified evaluation. The soil concentrations shall be established using one or a combination of the following methods as provided:

- The values in Table 5.1 (MTCA Table 749-3)
- Soil bioassays
- Wildlife exposure modeling
- Biomarkers
- Site-specific field studies
- Weight of evidence
- Literature survey
- Other methods approved by the department

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Chapter 6: Specifics

The Requirements for Substitution of Screening Values

The purpose of the Wildlife Exposure Model is to develop soil concentrations that are protective of wildlife receptors (see Chapter 5 – Wildlife Exposure Model). The screening levels that are protective of wildlife found in Table 5.1 (MTCA Table 749-3) were developed from the Wildlife Exposure Model using the default Toxicity Reference Values (BAF_{Worm}, K_{Plant}, Shrew, Vole, Robin) found in Table 5.3 (MTCA Table 5.3 (MTCA Table 749-5) and applying those values to the wildlife exposure models found in Table 5.2 (MTCA Table 749-4). Many of these values were obtained from Toxicological Benchmarks for Wildlife (Sample et al., 1996) (see Compendium – Section R). Substitution of alternate TRV's and BAF's in place of the default values can be performed by the use of a literature review. The results of the literature review should identify a soil concentration for protecting soil biota, plants, and wildlife more relevant to site-specific conditions than values listed in Table 5.1 (MTCA Table 749-3). The use of replacement values for default values shall be considered only when it can be verified that the proposed replacement value is considered new scientific information developed subsequent to publishing the MTCA rule (See Chapter 5 – Wildlife Exposure Model – Criteria for New Scientific Information).

The design of the approach of establishing criteria for the use of new scientific information is so that changes are not made to some of the underlying policy choices reflected in the Table 5.1 (MTCA Table 749-3). WAC 173-340-7493(4) (a) specifies that "…toxicity reference values or soil concentrations established from the literature shall represent the lowest relevant LOAEL found in the literature. Bioaccumulation factor values shall represent a reasonable maximum value from relevant information found in the literature…"

Alternately, bioassays may be performed to develop soil concentrations that are protective of plants and soil biota (see Chapter 5 – Bioassays). The screening levels that are protective of plants and soil biota found in Table 5.1 (MTCA Table 749-3) were developed from an extensive literature review prior to publishing the MCTA rule. However, Ecology recognizes the value in performing site-specific bioassays to develop site-specific protective concentrations. An example of such would be a 3% dilution series of site-specific soil contaminated with TPH under the guidelines of Protocols for Short Term Toxicity Screening of Hazardous Waste Sites (Greene et al., 1988).

Dioxins, Furans, and Dioxin-Like PCB Congeners: Addressing Non-Detects and Establishing PQLs for Ecological Risk Assessments in Upland Soil (Ecology, 2015)

This memorandum is an interpretation from Ecology for:

1) Evaluating detection limits and non-detects for the purposes of summing congeners for site evaluations; and
2) Establishing a PQL for dioxin-like congeners, specifically for:
    a. Chlorinated dibenzo-p-dioxins (PCDDs) (TCDD is a member of this class);
    b. Chlorinated dibenzofurans (PCDFs); and
    c. Dioxin-like polychlorinated biphenyls (PCBs).

This memorandum can be found at:
https://fortress.wa.gov/ecy/publications/SummaryPages/1609044.html

When to Use EPA Method 1668 for PCB Congener Analysis (Ecology, 2015)
This memorandum is an interpretation form Ecology for:

1) Describes the circumstances when Ecology may require or allow the use of EPA Method 1668 instead of the standard analytical method, EPA method 8082, to analyze PCB mixtures at contaminated sites being cleaned up under
    a. Chapter 173-340 WAC (MTCA rule); or
    b. Chapter 173-204 WAC (SMS rule).

This memorandum can be found at:
https://fortress.wa.gov/ecy/publications/SummaryPages/1509052.html

Dioxins, Furans, and Dioxin-Like PCB Congeners: Ecological Risk Calculation Methodology for Upland Soil (Ecology, 2016)

This memorandum is an interpretation from Ecology for:

1) Procedures that should be used to calculate site contaminant concentrations for three types of contaminants when conducting a Terrestrial Ecological Evaluation under the Model Toxics Control Act (WAC 173-340-7490 through 7494). The three contaminant types are:
    a. Chlorinated dibenzo-p-dioxins (PCDDs) (2,3,7,8-TCDD is a member of this class);
    b. Chlorinated dibenzofurans (PCDFs); an
    c. Polychlorinated biphenyls (PCBs) (includes both total PCBs and dioxin-like PCBs).
2) This memorandum can be found at:

https://fortress.wa.gov/ecy/publications/SummaryPages/1609044.html

Calculating Cleanup Levels and Compliance Monitoring for TPH

The process for calculating cleanup levels and compliance monitoring for Total Petroleum Hydrocarbons (TPH) is described in: Guidance for Remediation of Petroleum Contaminated Sites (Ecology, 2011). A summary of the screening levels for both simplified and site-specific TEE's are highlighted in Table 6.3 and Table 6.4. Residual saturation screening levels have been provided in Table 6.5. The respective screening levels shall be used with the required TEE (simplified or site – specific).

If those screening levels (Tables 6.3 and 6.4) have not been chosen as cleanup levels, bioassays may be performed to establish site – specific cleanup levels. The guidelines established in Early Seedling Growth Protocol for Soil Toxicity Screening (see Compendium – Section M), Earthworm Bioassay Protocol for Soil Toxicity Screening (see Compendium – Section N), and Protocols for Short Term Toxicity Screening of Hazardous Waste Sites (see Compendium – Section O) should be followed when performing bioassays.

Toxicity tests of soils contaminated with mixtures of contaminants (e.g., TPH) should follow the procedures listed in Protocols for Short Term Toxicity Screening of Hazardous Waste Sites (Greene et al., 1988) for earthworm (*Eisenia foetida*) survival, seed (*Lactuca sativa*) germination, and lettuce (*Lactuca sativa*) root elongation. Please consult with Ecology prior to performing bioassays.

Table 6.3: Simplified TEE Soil Screening Levels for Petroleum Products and Constituents[1]

Petroleum Products	Unrestricted Land Use	Industrial/Commercial Site[3]
Gasoline Range Organics	200 mg/kg	1,000 to 12,000 mg/kg[4]
Diesel Range Organics[2]	460 mg/kg	2,000 to 15,000 mg/kg[4]
PCB Mixtures[5]	2 mg/kg	2 mg/kg
Benzo(a)Pyrene	30 mg/kg	300 mg/kg

1 **Source:** WAC 173-340-900, Table 749-2

2 Diesel range organics includes the sum of diesel fuels and heavy oils measured using the NWTPH-Dx method. Mineral oils are essentially non-toxic to plants and animals and do not need to comply with these values.

3 Must have environmental covenant on property committing to commercial or industrial use.

4 Concentration at ground surface cannot exceed residual saturation. The lower end of the range shown is the default residual saturation concentration from Table 747-5. Where information can be provided demonstrating a higher site – specific residual saturation concentration, the screening level may go as high as the upper end of the range.

5 PCB's are included in this table because they can sometimes be a contaminant in petroleum mixtures, especially heavy oils and transformer fluids.

Table 6.4: Site-Specific TEE Soil Screening Levels for Petroleum Products and Constituents[1]

Petroleum Products	Plants	Soil Biota	Wildlife
Gasoline Range Organics	No value available	100 mg/kg	1,000 to 5,000 mg/kg[3]
Diesel Range Organics[2]	No value available	200 mg/kg	2,000 to 6,000 mg/kg[3]
PCB Mixtures[4]	40 mg/kg	No value available	0.65 mg/kg
Benzo(a)Pyrene	No value available	No value available	12 mg/kg

1 **Source:** WAC 173-340-900, Table 749-3

2 Diesel range organics includes the sum of diesel fuels and heavy oils measured using the NWTPH-Dx method. Mineral oils are essentially non-toxic to plants and animals and do not need to comply with these values.

3 Concentration at ground surface cannot exceed residual saturation. The lower end of the range shown is the default residual saturation concentration from Table 747-5. Where information can be provided demonstrating a higher site-specific residual saturation concentration, the screening level may go as high as the upper end of the range.

4 PCB's are included in this table because they can sometimes be a contaminant in petroleum mixtures, especially heavy oils and transformer fluids.

Table 6.5: Residual Saturation Screening Levels for TPH

Fuel	**Screening Level (mg/kg)**
Weathered Gasoline	1,000
Middle Distillates (e.g., Diesel No. 2 Fuel Oil)	2,000
Heavy Fuel Oils (e.g., No. 6 Fuel Oil)	2,000
Mineral Oil	4,000
Unknown Composition or Type	1,000

Note: The residual saturation screening levels for petroleum hydrocarbons specified in Table 747-5 (Table 6.4 of this document) are based on coarse sand and gravelly soils; however, they may be used for any soil type. Screening levels are based on the presumption that there are no preferential pathways for NAPL to flow downward to ground water. If such pathways exist, more stringent residual saturation screening levels need to be established.

Evaluation of Multiple Hazardous Substances

Adverse effects resulting from exposure to two or more hazardous substances with similar types of toxic response are assumed to be additive unless scientific evidence is available to demonstrate otherwise. As per MTCA (WAC 173-340-708 (5) …the health threats resulting from exposure to two or more hazardous substances with similar types of toxic response may be apportioned between those hazardous substances in any combination as long as the hazard index (HI) does not exceed (1). The HI is estimated using the hazard quotient (HQ) approach as described in Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (see Compendium – Section T).

Note: *Calculating cleanup levels for single hazardous substances or multiple hazardous substances with different types of toxic responses have been discussed in the earlier chapters (simplified or site-specific TEE).*

A quantitative screening-level risk can be estimated using the exposure estimates developed according to the HQ. The HQ approach compares point estimates of screening ecotoxicity values and exposure values. The HQ can be expressed as the ratio of a potential exposure level to the LOAEL.

$$HI = \frac{Dose}{LOAEL} \quad \text{or} \quad HI = \frac{EEC}{LOAEL}$$

HI = Hazard Index

Dose = Estimated contaminant intake at the site (e.g., mg contaminant/kg body weight per day)

EEC = Estimated Environmental Concentration at the site (e.g., mg contaminant/L water, mg contaminant/kg soil, mg contaminant/kg food)

LOAEL = Lowest Observed Adverse Effects Level (in units that match the dose or EEC)

When multiple contaminants of ecological concern exist at a site, it is appropriate to sum the HQs for receptors that could be simultaneously exposed to the contaminants that produce effects by the same toxic mechanism. The sum of the HQs is called a hazard index (HI). A HI less than one indicate that the group of contaminants is unlikely to cause adverse ecological effects.

$$HI = EEC_1/LOAEL_1 + EEC_2/LOAEL_2 + EEC_i/LOAEL_i$$

Or:

$$HI = HQ_1 + HQ_2 + HQ_i$$

HI	=	Hazard Index
HQ	=	Hazard Quotient
EEC	=	Estimated Environmental Concentration
LOAEL	=	Lowest Observed Adverse Effects Level

This risk calculation is a conservative estimate to ensure that the potential additive affects similar types of toxic contaminants could have on ecological receptors have been addressed. For more information on the use of the hazard quotient approach, see Compendium – Section T.

Using Bioassays to Evaluate the Toxicity of Complex Chemical Mixtures of Unknown Composition

A toxicity-based approach should be used to evaluate the toxicity of complex chemical mixtures of unknown composition in soil. For example, petroleum contamination is the most common type of hazardous substance encountered at contaminated sites in Washington State. However, if the person(s) responsible for the cleanup have chosen to develop cleanup levels other than those found in Tables 4.1 and 5.1 WAC 173-340 (MTCA Tables 749-2 and 749-3), the use of bioassays (specifically a toxicity-based approach) would be an appropriate method. In general, bioassays are a way to develop site-specific contaminant toxicity information.

Unlike toxicity tests with single compounds, which usually result in a regular progression in percent mortality or effect with increasing toxicant concentration, toxicity tests in soils with complex mixtures tend to yield all-or-nothing responses. Exposures to one or more of the higher sample concentrations (lower dilutions) result in 100% mortality of the test organisms, whereas exposures at lower concentrations (higher dilutions) all result in 100% survival. These results eliminate the use of some candidate methods for calculating the LC_{50} or EC_{50} at the recommended dilutions.

Earthworm Survival: The toxicity-based testing procedures for earthworm survival can be found in: A.8.5 EARTHWORM SURVIVAL (EISENIA FOETIDA) (Greene et al., 1988) (see Compendium – Section O). A dilution factor of 0.3 is commonly used which allows testing between 100% and 1% (100%, 30%, 10%, 3%, and 1%). Regression analysis may be used to approximate a final result (therefore eliminating some dilution factors); however, confirmation sampling at the approximation (dilution) is required. The effect measured during the toxicity tests is death. Data analysis indicating no significant difference from the control using applicable statistical procedures (e.g., T-Test at 0.05 α level) is required for the test to be considered a pass. A summary of recommended test conditions can be found in Table A-9 of the above document (Greene et al., 1988).

Lettuce Seed Germination: The toxicity-based testing procedures for lettuce seed germination can be found in A.8.6 LETTUCE SEED GERMINATION (LACTUCA SATIVA) (Greene et al., 1988) (see Compendium – Section O). A dilution factor of 0.3 is commonly used which allows testing between 100% and 1% (100%, 30%, 10%, 3%, and 1%). Regression analysis may be used to approximate a final result (therefore eliminating some dilution factors); however, confirmation sampling at the approximation (dilution) is required. The effect measured during the toxicity tests is germination. Data analysis indicating no significant difference from the control using applicable statistical procedures (e.g., T-Test at 0.05 α level) is required for the test to be considered a pass. A summary of recommended test conditions can be found in Table A-10 of the above document (Greene et al., 1988).

Lettuce Root Elongation: The toxicity-based testing procedures for lettuce rood elongation can be found in A.8.7 LETTUCE ROOT ELONGATION (LACTUCA SATIVA) (Greene et al., 1988) (see Compendium – Section O). A dilution factor of 0.3 is commonly used which allows testing between 100% and 1% (100%, 30%, 10%, 3%, and 1%). Regression analysis may be used to approximate a final result (therefore eliminating some dilution factors); however, confirmation sampling at the approximation (dilution) is required. The effect measured during the toxicity tests is percent inhibition of lettuce root elongation compared to controls. Data analysis indicating no significant difference from the control using applicable statistical procedures (e.g., T-Test at 0.05 α level) is required for the test to be considered a pass. A summary of recommended test conditions can be found in Table A-11 of the above document (Greene et al., 1988).

Results of the toxicity-based bioassay tests should be used in conjunction with other methods (e.g., Wildlife Exposure Modeling) to determine final concentrations of contaminants that are not expected to not have adverse effects on ecological receptors.

Using Literature Survey Data to Develop Ecological Indicator Soil Concentrations

The cleanup regulation defines methods to be used for establishing Ecological Indicator Soil Concentrations (EISC) from data obtained through a literature survey in Table 5.1 (MTCA Table 749-3 footnotes). These methods are used to calculate a value where none is provided in Table 5.1 (MTCA – Table 749-3) or where a chemical has not been listed in that table. They are also used to calculate substitute values for those provided in Table 5.1 (MTCA Table 749-3), using literature data shown to be more relevant to site – specific conditions.

Literature surveys must be objective, transparent, and thorough. The cleanup regulation sets standards for meeting this requirement (WAC 173-340-7493(4)). Submittals to Ecology that advocate a particular value without verification from data analysis and the literature review are not acceptable.

Where a value is not provided in Table 5.1 (MTCA Table 749-3), there is no assurance that a literature survey will locate the data needed to develop a value. If the search is unsuccessful, this should be reported together with a brief description of how the search was conducted. For example:

"To develop a Plant Ecological Indicator Soil Concentration for aldrin, a literature search was performed using Google Scholar (http://scholar.google.com/advanced_scholar_search?) and the search terms: (aldrin AND plant) AND (phytotoxic OR toxic). Approximately 1,160 citations were found (see enclosed CD). However, none of these publications provided LOEC data for plants grown in soil, and a plant Ecological Indicator Soil Concentration for aldrin could not be developed."

The following summarizes some details regarding the methods for using literature values to calculate Ecological Indicator Soil Concentrations. The calculated value may be replaced by the Washington State Natural background Concentration, if this value is higher (see Table 5.1 [MTCA Table 749-3] footnote g).

Plants: Use LOEC (lowest observed effect concentration) values from published plant toxicity data. Exclude data for plants grown in solution. Ecological Indicator Soil Concentration is the 10^{th} percentile of the LOEC values. Other details can be found in Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision) (Efroymson et al., 1997) (see Compendium – Section P). The nonparametric 10^{th} percentile is preferred over the judgmental method described in that publication. For a description of the nonparametric percentile calculation, see Statistical Guidance for Site Managers (Ecology, 1992) (see Compendium – Section U).

Soil Biota: Use LOEC (lowest observed effect concentration) values from published earthworm toxicity data. Ecological Indicator Soil Concentration is the 10^{th} percentile of the LOEC values. Other details can be found in Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision (Efroymson et al., 1997) (see Compendium – Section Q). The nonparametric 10^{th} percentile is

preferred over the judgmental method described in that publication. For a description of the nonparametric percentile calculation, see Statistical Guidance for Site Managers (Ecology, 1992) (see Compendium – Section U).

For locations where earthworm are not naturally present, toxicity data for other soil invertebrates may be more relevant. Examples cited in Efroymson et al., 1997 include nematodes, collembolans, mites, isopods, and snails. Ground-feeding beetles (e.g., tenebrionids) are another possible example.

Wildlife: The wildlife Ecological Indicator Soil Concentration is the lowest of the values calculated that would provide protection for ecological receptors considered wildlife species. Representative species that were chosen are: small mammalian herbivore (vole), small mammalian predator (shrew), and ground feeding avian predator (robin). The values were calculated using the wildlife exposure model in Table 5.2 (MTCA Table 749-4). The model includes four variables whose values are chemical specific:

- K_{plant} (plant uptake factor) – used in calculations for small mammalian herbivores.
- BAF_{worm} (soil biota bioaccumulation factor) – used in calculations for small mammalian predators and ground feeding avian predators.
- $RGAF_{soil}$ (gut absorption factor for the chemical in ingested soil, expressed relative to the gut absorption factor for the chemical in food) – used in calculations for all three groups.
- TRV (toxicity reference value) – used in calculations for all three groups

For each of these variables, a literature survey can be used to develop wildlife Ecological Indicator Soil Concentrations for chemicals where none is provided in Table 5.1 (MTCA Table 749-3).

Plant uptake factor (K_{plant})

Requires multiple pair-wise data on chemical concentrations in soil and plant tissue from different locations. K_{plant} is calculated on a dry weight basis and is unitless but can be represented as $(mg/kg_{plant})/ (mg/kg_{soil})$. Data for plants likely to be used by small mammal ground feeding herbivores are preferable to other plants, such as trees. The cleanup regulation does not specify a method for calculating a value for this variable from literature data; however, values in Table 5.3 (MTCA Table 749-5) are the geometric means of chemical-specific uptake factors for forage grasses reported in USEPA (1992). The reported uptake slopes were converted from a kg/ha basis to mg/kg basis using the standard conversion (kg/ha) / 2 = mg/kg in soil.

Soil biota bioaccumulation factor (BAF_{worm})

Calculation of site-specific BAFs requires multiple pair-wise data on chemical concentrations in soil and earthworms from different locations. BAFs should be calculated on a dry weight basis. BAFs are unitless but can be represented as $(mg/kg_{worm})/ (mg/kg_{soil})$. The cleanup regulation does not specify a method for calculating a value for this variable from literature data. However,

values in Table 5.3 (MTCA Table 749-5 are the arithmetic means of chemical-specific BAF values for reported in the literature.

This is the most suitable variable for making direct measurements at the site to calculate a site-specific wildlife Ecological Indicator Soil Concentration. Paired measurements of chemical concentrations in soil and earthworms from different locations could be used to calculate a BAF, or earthworms could be added to site soil samples under controlled laboratory testing conditions.

For locations where earthworms are not naturally present, BAF data for other soil invertebrates may be more relevant for calculating a site-specific BAF and wildlife Ecological Indicator Soil Concentration. Examples of other soil invertebrates include nematodes, collembolans, mites, isopods, snails or ground feeding beetles (e.g., tenebrionids). Data for these invertebrates might be obtained either from a literature survey of through sampling at the site.

Gut absorption factor ($RGAF_{soil}$)

Although chemical-specific toxicity benchmarks (LOAELs) are typically based on food ingestion and already reflect the degree of gut absorption, it is possible that absorption of the chemical from soil may be different than for food. If so, the $RGAF_{soil}$ value may be adjusted from the default value of 1 to a higher or lower value. For example, if bioavailability of the chemical in contaminated soil is only half that in contaminated food, $RGAF_{soil}$ could be set to 0.5. In practice, chemical – specific literature data for this variable are seldom available and direct site-specific measurements are rarely performed.

Toxicity reference value (T_{shrew}, T_{robin}, T_{vole})

Although the cleanup regulation specifies that the literature survey must be conducted in accordance with WAC 173-340-7493(4), it does not specify a method for using a literature values to calculate toxicity reference values. The recommended methods, used to calculate values for Table 4.1 (MTCA Table 749-2) and Table 5.1 (MTCA Table 749-3) are described in Sample et al. (1996). Some additional details are provided below:

- Although Sample et al. (1996) provide other additional benchmarks, only LOAELs based on food ingestion should be used.
- Candidate data for mammalian and avian LOAEL doses obtained from the literature survey should be succinctly summarized, as illustrated in Appendix [A] of Sample et al. (1996). Indicate which of the candidate values found in the literature was chosen and why.
- Toxicity reference values for the three surrogate species should be calculated with the allometric scaling equations used by Sample et al. (1996, section 3). Note that their avian scaling factor is 1, so an appropriate LOAEL dose from the literature for an avian species can be used for T_{robin} without further adjustments for body weight.

Specific Questions

Question 1: Is an evaluation required if the site is contaminated with a chemical that is not listed in Table 5.1 (MTCA Table 749-3)?

Answer: Yes. If the site meets the criteria for a site-specific TEE, the fact that a chemical is not included in Table 5.1 (MTCA Table 749-3) does not automatically mean that it can be dropped from consideration. This issue is addressed in the footnotes to Table 5.1 (MTCA Table 749-3). Even when insufficient information is available from the literature to calculate a safe soil concentration, if might still be appropriate to use an affects-based approach (e.g., bioassay) to conduct an evaluation of the contaminated soil.

Question 2: Can an ecological risk assessment be substituted for the requirements in MTCA Section 7493?

Answer: The procedures required under MTCA Section 7493 describe the required form of ecological risk assessment. They differ from older ecological risk assessments that were conducted at hazardous waste sites before regulatory policies have been established. In the absence of a regulatory framework, there was considerable flexibility for the risk assessor to make many decisions on subtle but important policy issues that could influence the outcome of the risk assessment. With the 1996 revisions to the cleanup regulation, the term "ecological evaluation" was introduced to distinguish ecological risk assessments conducted within the policy framework in MTCA Sections 7490 – 7494 from the older risk assessments that were previously conducted.

Question 3: Do I have to follow the TEE procedures at every site? What if it is a small area of contamination in the middle of an urban area?

Answer: Yes, the TEE procedures need to be followed at every site. It is very likely that a small area of contamination in the middle of an urban area would qualify for exclusion; however that exclusion still needs to be documented in the RI/FS. The TEE process includes multiple stages; the characterization, exclusion evaluation, applicability, the evaluation itself, cleanup actions and compliance monitoring. The specifics of the site are what determine how far (stages) into the TEE process must be investigated.

Question 4: Could the TEE procedures create an incentive to cause harm through the destruction of habitat?

Answer: If implemented correctly, the TEE procedures should not create an incentive to cause harm through the destruction of habitat. A cleanup action cannot be selected unless a determination is made that each of the minimum requirements in WAC 173-340-360(2) is met, including the requirements that the cleanup action protects the environment and uses permanent solutions to the maximum extent practicable. Determining whether a cleanup action is permanent to the maximum extent practicable further requires the use of a disproportionate cost

analysis specified in WAC 173-340-360(3) (e). That analysis compares the costs and benefits of the cleanup action alternatives evaluated in the feasibility study.

One of the criteria that must be considered as part of the analysis is the overall protectiveness of the environment. Finally, as an additional safeguard, under WAC 173-340-7490(5), Ecology "may require additional measures to evaluate potential threats to terrestrial ecological receptors…, when based on a site-specific review, the department determines that such measures are necessary to protect the environment." Chapter one of this document includes a Net Environmental Benefit Analysis, the purpose of which is to evaluate the potential impact of cleanup on existing "especially valuable habitat."

Question 5: Should the TEE process determine contamination levels that provide protection for populations or individuals in terms of ecological receptors of concern?

Answer: Ecology has addressed the concept of population protection by defining "significant adverse effects" as "effects that impair reproduction, growth or survival" because these effects on individuals are generally considered to be relevant to the health of populations (e.g., EPA 1997 – see Compendium – Section T). Any of these effects is necessary and sufficient evidence of an adverse effect on the health of populations in a TEE, although some consideration for the scale of the effects is provided in the regulation (see e.g., 173-340-7491(1) (c), -7492(2) (a) (i), and -7492(2) (a) (ii)). Ecology believes that this approach meets the goals of providing a practical and objective basis for cleanup decisions, and this is consistent with the statutory mandate to ensure that site cleanups will restore a healthy environment.

Question 6: What constitutes "industrial property" and "commercial property" for the purposes of determining the categories of terrestrial ecological receptors that require protection?

Answer: For industrial and commercial properties, only wildlife (not soil biota or plants) must be protected from exposure to contaminated soil, except under certain circumstances identifies in WAC 173-340-7490(3) (b) (i-ii). Under those specified circumstances, not only must wildlife be protected, but soil biota and plants must also be protected. For the purposes of determining the categories of terrestrial ecological receptors that require protection, a definition of "industrial property" and "commercial property" have been included in this document (see Chapter 1 – Ecological Receptors based on Land Use). The underlying rationale of the categorical exemption focuses on "designated use" rather than "intensive use." The underlying rationale is that the properties that qualify for the exemption represent areas of land specifically designated for uses that may preclude growing plants and obviate the value of functions provided by soil biota. For example, land beneath an office building cannot be used to grow plants, and soil biota living beneath the building are assumed not to provide any benefits to plants or wildlife.

Question 7: Should agriculture or recreational land uses be considered categorically exempt, just as "industrial" and "commercial" properties, from the general requirement that not only wildlife, but also plants and soil biota must be protected from exposure to contaminated soil?

Answer: For any property that does not constitute an "industrial property" or "commercial property" as defined in WAC 173-340-7490(3) (c), all terrestrial ecological receptors must be protected from exposure to soil contamination (WAC 173-340-7490(3) (b)). The underlying rationale of the categorical exemption for "industrial" and "commercial" properties discussed in the previous response does not apply to properties with agricultural or recreational land uses.

Question 8: Should the standard point of compliance be established in the soils throughout the site from the ground surface to fifteen feet below the ground surface?

Answer: Unless a conditional point of compliance under WAC 173-340-7490(4) (a) is applicable, the requirement is the establishment of a standard point of compliance in the soils throughout the site from the ground surface to fifteen feet below the ground surface. WAC 173-340-7490(4) (b). Ecology believes fifteen feet "represents a reasonable estimate of the depth of sol that could be excavated and distributed at the soil surface as a result of site development activities, resulting in exposure by terrestrial ecological receptors." (WAC 173-340-7490(4) (b)). This determination reflects the determination that formed the basis for the point for compliance for soil cleanup levels based on human exposure through direct contact (WAC 173-340-740(6) (c).

Question 9: Where are the most appropriate locations depths to sample for conformational sampling (evaluation that the cleanup action is protective of ecological receptors)?

Answer: Conformational sampling should be done on a site specific basis. Under WAC 173-340-740(7) (b), it states that "Sampling and analytical procedures shall be defined in a compliance monitoring plan prepared under WAC 173-340-410. The sample design shall provide data that are representative of the area where exposure to hazardous substances may occur." There is potential for ecological receptors of concern to be exposed to hazardous substances at a variety of depths and locations. For example, soil biota (earthworm) feeds and inhabits a variety of depths. An avian predator (robin) feeds on soil biota, but is restricted to soil surface levels. Therefore, consultation with Ecology is recommended prior to submitting a compliance monitoring plan, so it can be verified and/or agreed upon that the confirmation locations/depths are representative to where exposure to hazardous substances might occur.

Question 10: If a hazardous substance listed in Table 4.1 (MTCA Table 749-2) does not have a value listed, what options are available?

Answer: Note that most sites are expected to be able to obtain an exclusion from conducting a simplified or site-specific TEE. Where the process cannot be ended by obtaining exclusion under WAC 173-340-7491, then the process includes the following options under the simplified TEE process in WAC 173-340-7492:

- The evaluation may be ended using the exposure analysis subsection
- The evaluation may be ended using the pathways analysis subsection
- The evaluation may be ended using the contaminants analysis subsection which requires a soil bioassay

Where the process cannot be ended under the simplified TEE process, the process includes the following options under the site-specific TEE process in WAC 173-340-7493:

- Using the concentrations specified in Table 5.1 (MTCA Table 749-3) as cleanup levels
- Ending the process or establishing cleanup levels using a site – specific TEE

Question 11: For contaminants without values for industrial or commercial sites in Table 4.1 (MTCA Table 749-2), may the values for unrestricted land use be substituted for the purposes of the contaminants analysis in WAC 173-340-7492(c) (i)?

Answer: Yes, for contaminants without values for industrial or commercial sites in Table 749-2, the values for unrestricted land use may be substituted for the purposes of the contaminants analysis in WAC 173-340-7492(2)(c)(i). However, note that the reverse is not true (i.e., the values specified in Table 749-2 for industrial and commercial sites cannot be substituted for the values for unrestricted land use).

Question 12: For contaminants with values in Table 749-2 or 749-3 that are below natural background levels, may the natural background levels be substituted for the purposes of the contaminants analysis in WAC 173-340-7492(2)(c) or for the purpose of establishing cleanup levels?

Answer: Yes, for contaminants with values in Table 749-2 or 749-3 that are below natural background levels, the natural background levels may be substituted for the purposes of the contaminants analysis in WAC 173-340-7492(2)(c), Table 4.1 (MTCA Table 749-2), or the purpose of establishing cleanup levels. Ecology attempted to insure that the values were below natural background levels. Note also that a site qualifies for exclusion under WAC 173-340-7491(1) (d) if "concentrations of hazardous substances in soil do not exceed natural background levels as determined under WAC 173-340-709." Furthermore, the regulation does not require the establishment of cleanup levels below natural background levels (see WAC 173-340-700(6) (d)).

Question 13: For independent remedial actions, must the elements in planning a site-specific terrestrial ecological evaluation identified in WAC 173-340-7493(1) (c) be conducted in consultation with and approved by Ecology?

Answer: Independent remedial actions do not require the elements in planning a TEE. However, if a consultation, approval, or determination is required from Ecology, then all applicable elements of a TEE are required. As provided in WAC 173-340-515(3) (b):

When this chapter requires a consultation with, or an approval or determination by the department, such a consultation, approval or determination is not necessary in order to conduct an independent remedial action. However, independent remedial actions must still meet the substantive requirements of this chapter.

Question 14: What is the purpose of the values specified in Table 5.1 (MTCA Table 749-3)? May the values be used as cleanup levels? What is the basis for those values?

Answer: The values for the hazardous substances listed in Table 5.1 (MTCA Table 749-3) are used to help narrow the focus of the site-specific TEE by identifying those substances that do not need to be addressed as part of that evaluation (see WAC 173-340-7493(2) (a) (i)). Note that the person conducting the evaluation may eliminate hazardous substances from further consideration where the maximum or the upper ninety-five percent confidence limit soil concentration found at the site does not exceed ecological indicator concentrations described in Table 5.1 (MTCA Table 749-3) (see WAC 173-340-7493(2)(a)(i)). Table 749-3 does not establish ecologically based cleanup levels. However, note that the values in Table 5.1 (MTCA Table 749-3) may be used for either a screening level or cleanup level to end the evaluation process at any stage in the process.

Ecological risk assessments typically include a step to narrow the focus of the assessment by eliminating from further consideration those site contaminants that do not exceed conservative risk based concentrations. If all of the site contaminants are eliminated, the risk assessment need not proceed any further. These reference concentrations are frequently described as "screening levels" or "benchmarks" (see Compendium – Section T). In ecological risk assessments conducted to date under MTCA, a variety of different generic "screening level" concentrations have been used by persons at different sites in the absence of guidance from Ecology. Consequently, a priority for Ecology in developing the rule amendments was to establish a consistent policy on the use of generic ecologically based soil concentrations that Ecology will accept as safe without further evaluation of terrestrial ecological risks.

Table 749-3 was developed for site at sites where a site-specific TEE is required or otherwise conducted. The values specified in the table are intended to be protective of terrestrial ecological receptors at any site. The values specified in Table 5.1 (MTCA Table 749-3) for conducting a site-specific evaluation were calculated based on a lower level of acceptable risk than the values specified in Table 4.1 (MTCA Table 749-2) for conducting a simplified evaluation. This is the baseline or default level of acceptable risk. A higher level of acceptable risk is allowed for conducting a simplified TEE.

The values specified in Table 5.1 (MTCA Table 749-3) were developed by Ecology in consultation with the MTCA Science Advisory Board Ecological Risk Subcommittee. Allowing for a lower level of risk, plant and soil biota values are based on the 10^{th} percentile (Q_{10}) of Lowest Observed Adverse Effect Concentrations (LOAECs) instead of the 50^{th} percentile (Q_{50}) used to calculate values in Table 4.1 (MTCA Table 749-2). Wildlife values are the lowest of three values calculated for different wildlife groups using standardized exposure assumptions and chemical-specific threshold reference values and uptake factors. The value for unrestricted land use is the lowest of the values specified for each of the three categories of terrestrial ecological receptors – plant, soil biota, and wildlife. The value for industrial and commercial land uses is the wildlife value.

Question 15: Should proposals for modifications to default values provided in WAC 173-340-7493 meet the requirements in WAC 173-340-702(14), (15) and (16) for new scientific information?

Answer: Yes. This requirement is consistent with the stated applicability of the referenced subsections (see Chapter 6: Specifics – The Requirements for Substitution of Screening Values).

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Appendix A: Hyperlink Page

Reference/Resource	Section
Model Toxics Control Act – WAC 173-340: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340	**A**
Sediment Management Standards – WAC 173-204: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-204	**B**
Current Rule Making Activity can be found at: https://www.ecy.wa.gov/Spills-Cleanup/Contamination-cleanup/Rules-directing-our-cleanup-work/Model-Toxics-Control-Act	
Voluntary Cleanup Program Site Manager TEE Form: https://www.ecy.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-process/Cleanup-options/Voluntary-cleanup-program	**C**
Voluntary Cleanup Program Consultant TEE Form: https://www.ecy.wa.gov/Spills-Cleanup/Contamination-cleanup/Cleanup-process/Cleanup-options/Voluntary-cleanup-program	**D**
Federal Endangered Species Act:	**E**
http://ecos.fws.gov/tess_public/pub/stateListingAndOccurrenceIndividual.jsp?state=WA&s8fid=112761032792&s8fid=112762573902	
Washington State Species of Concern – Title 77 RCW: http://wdfw.wa.gov/conservation/endangered/	**F**
County List of Rare Plants – Title 79 RCW: https://www.dnr.wa.gov/NHPlists	**G**
Natural Resource Lands and Critical Areas – RCW 36.70A.170: http://apps.leg.wa.gov/rcw/default.aspx?cite=36.70A.170	**H**
A Framework for Net Environmental Benefit Analysis for Remediation or Restoration of Petroleum – Contaminated Sites: http://esanalysis.colmex.mx/Sorted%20Papers/2004/2004%20USA%20-3F%20Interd%203.pdf	**I**
Restoration and Recovery: Regenerating Land and Communities:	**J**
http://www.api.org/~/media/Files/EHS/Clean_Water/Oil_Spill_Prevention/NEBA/NEBA-Net-Environmental-Benefit-Analysis-July-2013.pdf	

Vascular Plants of the Pacific Northwest: **K**
http://www.jstor.org/discover/10.2307/1217932?uid=3739960&uid=2&uid=4&uid=3739256&sid=47699053777847

Natural Vegetation of Oregon and Washington: **L**
http://www.treesearch.fs.fed.us/pubs/26203

Early Seedling Growth Protocol for Soil Toxicity Screening: **M**
https://fortress.wa.gov/ecy/publications/summarypages/96324.html

Earthworm Bioassay Protocol for Soil Toxicity Screening: **N**
https://fortress.wa.gov/ecy/publications/summarypages/96327.html

Protocols for Short Term Toxicity Screening of Hazardous Waste Sites: **O**
http://nepis.epa.gov/Exe/ZyNET.exe/2000HUXX.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000007%5C2000HUXX.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

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Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision: **Q**
http://rais.ornl.gov/documents/tm126r21.pdf

Toxicological Benchmarks for Wildlife: 1996 Revision: **R**
http://rais.ornl.gov/documents/tm86r3.pdf

Ecoregions of the Pacific Northwest: **S**
http://nepis.epa.gov/Exe/ZyNET.exe/2000IAS8.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=FNAME%3D2000IAS8.TXT%20or%20(%20ecoregions%20or%20the%20or%20pacific%20or%20northwest)&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=1&ExtQFieldOp=1&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000007%5C2000IAS8.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=10&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: **T**

https://www.epa.gov/risk/ecological-risk-assessment-guidance-superfund-process-designing-and-conducting-ecological-risk

Statistical Guidance for Site Managers: **U**
https://fortress.wa.gov/ecy/publications/summarypages/9254.html

Guidance for Remediation of Petroleum Contaminated Sites: **V**
https://fortress.wa.gov/ecy/publications/summarypages/1009057.html