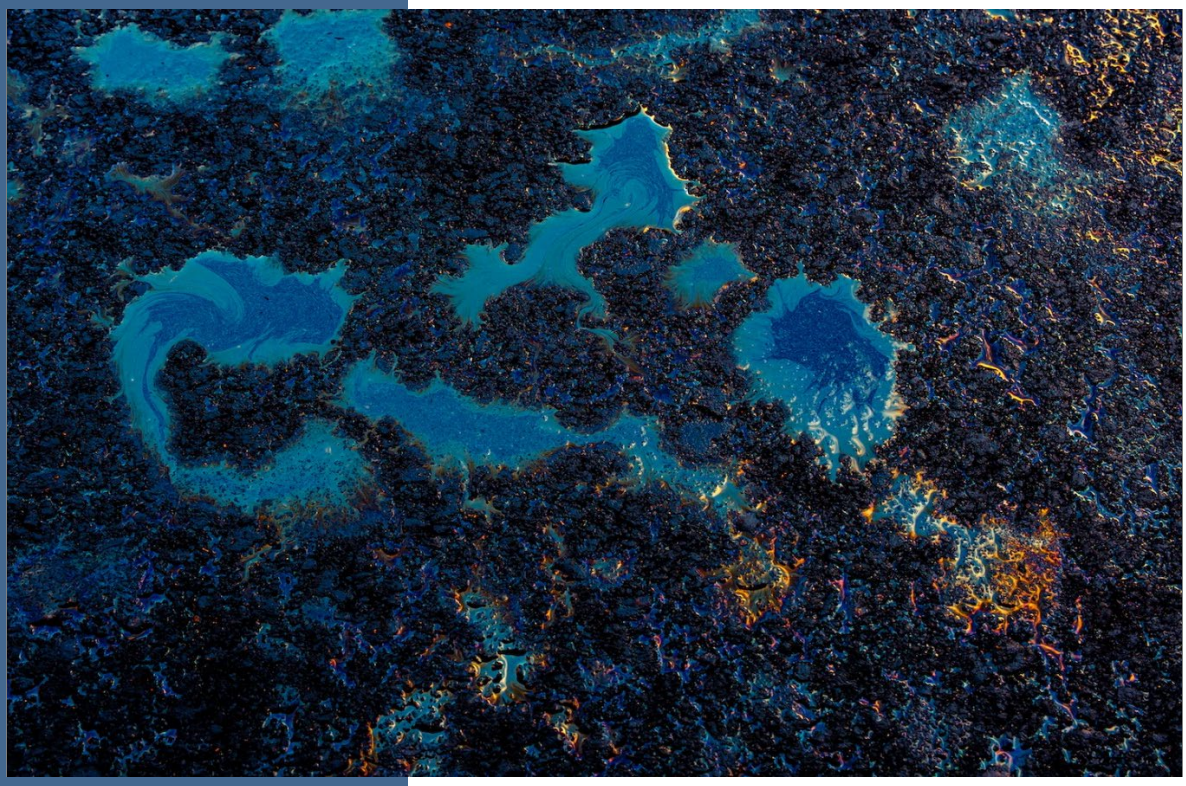

User's Guide for MTCATPH 12.0 & MTCASGL 12.0

Workbook Tools for Calculating Soil and Groundwater Cleanup Levels under the Model Toxics Control Act Cleanup Regulation

Toxics Cleanup Program
Washington State Department of Ecology
Olympia, Washington

Revised November 2023 | Publication No. 01-09-073

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State of Washington

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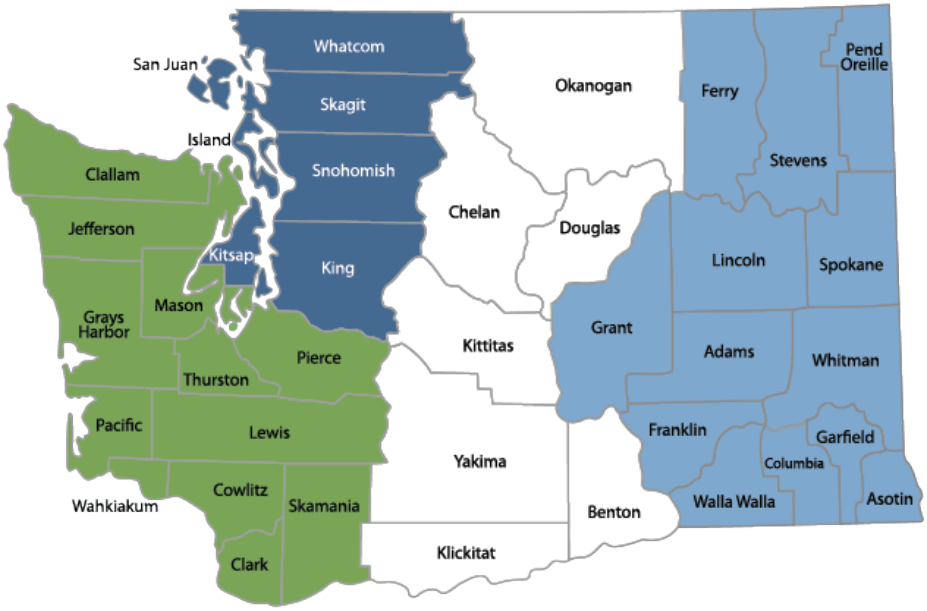
[1] www.ecology.wa.gov/contact

Department of Ecology's Regional Offices

Map of Counties Served



Southwest Region 360-407-6300	Northwest Region 425-649-7000	Central Region 509-575-2490	Eastern Region 509-329-3400

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
Northwest	Island, King, Kitsap, San Juan, Skagit, Snohomish, Whatcom	P.O. Box 330316 Shoreline, WA 98133	206-594-0000
Central	Benton, Chelan, Douglas, Kittitas, Klickitat, Okanogan, Yakima	1250 W Alder St Union Gap, WA 98903	509-575-2490
Eastern	Adams, Asotin, Columbia, Ferry, Franklin, Garfield, Grant, Lincoln, Pend Oreille, Spokane, Stevens, Walla Walla, Whitman	4601 N Monroe Spokane, WA 99205	509-329-3400
Headquarters	Across Washington	PO Box 46700 Olympia, WA 98504	360-407-6000

MTCATPH & MTCASGL User's Guide (Ver. 12.0)

Excel Workbook Tools for Calculating Soil and Groundwater Cleanup Levels under the Model Toxics Control Act Cleanup Regulation

Toxics Cleanup Program
Washington State Department of Ecology
Olympia, WA

Revised November 2023 | Publication No. 01-09-073

Contents

Tables and Figures

Acronyms and Abbreviations

Acronym or abbreviation	Definition
°C	Degrees Celsius
µg/L	micrograms per liter for ground water media sample (same as parts per billion ppb)
1 x 10^{-5} or 1E-05 Cancer Risk	One excess cancer case in a population of one hundred thousand individuals
1 x 10^{-6} or 1E-06 Cancer Risk	One excess cancer case in a population of one million individuals
100% NAPL	TPH concentration at which air-filled pore volume is completely filled by equilibrated NAPL. This concentration is usually well above Residual Saturation Level
AB1	Gastrointestinal absorption fraction
ABS_d	Dermal absorption fraction
ABS_i	Inhalation absorption fraction
ADAF	Age-Dependent Adjustment Factors
AF	Adherence factor
AL	Aliphatic
AL_EC	Aliphatic Equivalent Carbon Number
AR	Aromatic
AR_EC	Aromatic Equivalent Carbon Number
ARAR	Applicable, Relevant, and Appropriate Requirements
atm	Atmosphere
BaP	Benzo(a)pyrene
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CLARC	Ecology, *Cleanup Levels and Risk Calculations under the Model Toxics Control Act Cleanup Regulation*; Refer to Ecology's interactive web site at https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx.
cPAH	Carcinogenic Polycyclic Aromatic Hydrocarbon
CPF	Cancer potency factor
C_{sat}	Soil saturation limit
CUL	Cleanup level
DF	Dilution factor
EC	Equivalent Carbon number
Ecology	Washington State Department of Ecology
ELE	Early-life exposure
EPA	U.S. Environmental Protection Agency
EPH	Extractable petroleum hydrocarbons
foc	Fraction soil organic carbon
f_{oc}	Soil fraction of organic carbon
GI	Gastrointestinal absorption conversion factor

Acronym or abbreviation	Definition
H_{cc}	Henry's law (dimensionless form)
Hg	Mercury
HI	Hazard Index
HQ	Hazard Quotient
INH	Inhalation correction factor
IRIS	Integrated Risk Information System Database
K	Kelvin
K_{oc}	Soil Organic Carbon-Water Partitioning Coefficient
kPA	kilopascal
L/kg	Liters per kilogram
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
mg/kg	milligrams per kilogram for soil media sample (same as part per million: ppm)
mg/L	milligrams of contaminant per liter of water
mm	millimeter
MTCA	Model Toxics Control Act
MTCASGL 12.0	The Excel Workbook Version 12.0 for calculating Soil and Groundwater Cleanup Levels for individual hazardous substances
MTCATPH 12.0	The Excel Workbook Version 12.0 for calculating Method B or C TPH Cleanup Levels
NAPL	Nonaqueous Phase Liquid
NB_s	Natural background soil concentration
ng/kg	nanograms per kilogram for soil media sample (same as part per trillion: ppt)
NWTPH-Dx	Northwest total petroleum hydrocarbons – diesel range organics
NWTPH-Gx	Northwest total petroleum hydrocarbons – gasoline range organics
ORNL	Oak Ridge National Laboratory
ppb	Parts per billion
ppm	Parts per million
PQL	Practical Quantitation Limit
R	Ideal gas constant
RAIS	Risk Assessment Information System
RfD	Reference dose
risk	Cancer or carcinogenic risk
S	Aqueous solubility
SGL	Single chemical
SVOC	Semivolatile organic compound
T	Temperature
TEF	Toxicity equivalent factor
TEQ	Total toxic equivalent

Acronym or abbreviation	Definition
TEQ	Total Toxicity Equivalence
TPH	Total Petroleum Hydrocarbon
VAF	Vapor Attenuation Factor
VBA	Visual Basic Applications
VISL	EPA's Vapor Intrusion Screening Level
VPH	Volatile petroleum hydrocarbon
WAC	Washington Administrative Code
Workbook	MTCATPH Excel-based workbook tool, Version 12.0. (described in the main document); MTCASGL Excel-based workbook tool, Version 12.0 (described in Appendix F)

Chapter 1: Introduction

The Model Toxics Control Act (MTCA) Cleanup Regulation, chapter WAC 173-340, sets forth the requirements and procedures for establishing cleanup levels that are protective of human health and the environment. The purpose of this User's Guide is to introduce the user to the features of two Excel-based Workbooks (MTCATPH and MTCASGL) for calculating Soil and Groundwater Cleanup Levels. This guide is arranged as a set of tutorials that allow the user to learn the basics of the Workbooks in a "hands-on" environment.

- Instructions for using the MTCATPH Version 12.0 workbook tool are provided in the main portion of this document (i.e., Chapters 1 and 2). This workbook tool is used for calculating Soil and Groundwater Cleanup Levels for Total Petroleum Hydrocarbon (TPH) mixtures.

- Instructions for using the MTCASGL Version 12.0 workbook tool are provided in **Appendix F**. The MTCASGL workbook tool is used for calculating Soil and Groundwater Cleanup Levels for Individual Hazardous Substances.

1.0 MTCATPH Version 12.0 – Overview

The MTCATPH Version 12.0 Workbook (also referred to as the Workbook in the main portion of this document) is a tool that may be used to calculate Method B and/or Method C[2] cleanup levels for petroleum mixtures in soil and groundwater based on protection of human health and the environment.

The MTCA regulation provides for the establishment of both standard and modified Methods B and C cleanup levels.

- Under standard Methods B and C, cleanup levels are calculated using standard equations and default assumptions provided in the regulation. Except for petroleum mixtures, cleanup levels calculated for hazardous substances under standard Methods B and C are published in the Washington State Department of Ecology's (Ecology) Cleanup Levels and Risk Calculations (CLARC) database[3].

- Under modified Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The MTCA regulation (see WAC 173-340-708

[2] In the MTCATPH Workbook, Method C is only evaluated for soil direct contact exposure. Groundwater cleanup levels for ingestion of potable water are based on Method B only. Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology for methods to evaluate petroleum mixtures in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1).

[3] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC

(10)) specifically describes which parameters may be adjusted and how they may be adjusted.

> **Note:** The MTCATPH Workbook uses the standard equations and default assumptions and does not allow the user to calculate modified Methods B or C cleanup levels for petroleum mixtures. For calculating modified Methods B or C cleanup levels for individual chemicals, please see Ecology's Workbook for Calculating Cleanup Levels for Individual Hazardous Substances (MTCASGL 12.0 Excel Workbook[4]) and the associated user's guide in **Appendix F** of this document.

For the calculation of soil cleanup levels, the MTCATPH Workbook provides tools for evaluating the direct contact pathway and the leaching pathway (protection of groundwater).

For the evaluation of the direct contact pathway, the Workbook uses the equations provided in WAC 173-340-740 and WAC 173-340-745. The Workbook allows the user to evaluate concurrent exposure due to ingestion and dermal contact with petroleum contaminated soil.

For the evaluation of the leaching pathway, the Workbook uses the 3- and 4-phase equilibrium partitioning models described in the regulation (see WAC 173-340-747) to calculate a soil cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720. That is, this is a soil cleanup level that is protective of groundwater beneficial uses (e.g., potable water ingestion) at the site.

For the calculation of groundwater cleanup levels, the Workbook provides tools for calculating only Method B potable groundwater cleanup levels, as defined in the regulation (see WAC 173-340-720).

When establishing cleanup levels for hazardous substances at a site, the site manager often asks two types of questions.

- Is the measured (or current) concentration at the site protective?
- If not, what is the protective concentration (i.e., cleanup level)?

The Workbook allows the user to answer both questions as discussed in Section 2.0.

This User's Guide describes the capabilities and limitations of the MTCATPH Workbook, provides step-by-step instructions for downloading and using the Workbook, and documents the methods used by Ecology to develop concentrations that meet the acceptable noncancer hazard and cancer risk (risk) levels required by the MTCA Cleanup Regulation. Noncancer

[4] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools

hazard and risk levels are described in WAC 173-340-705 (Method B) and WAC 173-340-706 (Method C).

1.1 Caution on Use of the Workbook

The requirements and procedures for establishing cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation, chapter 173-340 WAC. The use of this User's Guide and the MTCATPH Workbook may not be sufficient to establish cleanup levels under the regulation. The Workbook is merely a computational tool and may not provide all the information necessary to establish cleanup levels for a site. Appropriate background, training, and experience are recommended to accurately use the Workbook. Available resources include guidance provided on our CLARC website[5] and training via our MTCA 101 class[6].

1.2 Overview of Files

1.2.1 File Download

The MTCATPH 12.0 calculations are performed in a single Excel workbook, the "Workbook", which can be downloaded from Ecology's Online tools for cleaning up sites[7] web page. Unlike the prior MTCATPH Workbook (ver. 11.1), this version (12.0) does not include a pop-up dialogue "Navigator" or other pop-up windows as the primary means for navigation but opens as a normal Excel workbook with visible worksheet tabs. To run the Workbook, the Solver Add-in and Macros must be enabled (*see* below).

Install the Solver Add-in function using the steps below.

1. In Excel, go to **File > Options**.
2. Click **Add-ins**, and then in the **Manage box**, select **Excel Add-ins**, and then click **Go**.
3. In the **Add-ins** available box, select the **Solver Add-in** check box, and then click **OK**.
4. After you load the Solver Add-in, the **Solver** command is available in the **Analyze** group on the Data tab.

[5] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Guidance
[6] MTCA 101: Understanding and Applying Washington State's Model Toxics Control Act (hosted by the National Environmental Management Academy (NEMA) – check the training calendar for availability @ https://nemallc.com).
[7] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools

Enable Macros using the steps below.

1. In Excel, go to **File > Options**.
2. Click **Trust Center**, and then click **Trust Center Settings**.
3. In the Trust Center, click **Macro Settings**.
4. Under Macro Settings, click **Enable VBA macros**.

1.3 Getting Started

After downloading the Excel file to your hard drive, open the Workbook using Excel and make sure that the Solver Add-in is installed, and Macros are enabled (see Section 1.2.1 above).

The Workbook consists of 14 individual worksheets that include:

- Supporting information including instructions and navigation
- Data entry worksheets for soil and groundwater
- Soil calculation and cleanup level summary worksheets
- Groundwater calculation worksheets

The worksheets have been color coded as described below.

- **Green Tabs**: Supporting worksheets including updates, instructions, navigation, and the chemical database.
- **Orange Tabs**: Worksheets for soil data entry, Method B soil direct contact calculations, soil leaching calculations, and a soil cleanup level summary worksheet.
- **Red Tabs:** Worksheets for Method C soil direct contact calculations.
- **Blue Tabs:** Worksheets for groundwater data entry and Method B potable groundwater calculations.

Prior to getting started, it's recommended to closely review the Green Tabs labelled "Instructions" and "Navigation". Information in these worksheets provide the user with step-by-step instructions for navigating and using the workbook.

1.4 Saving and Closing the Workbook

Once an analysis is complete, it is good practice to print out a copy (hard copy or pdf) of the results as a record. At this point, you may also wish to save the Workbook under a new name **[File > Save As]**.

Chapter 2: MTCATPH Workbook 12.0 for Calculating Cleanup Levels for a Petroleum Mixture

2.0 Overview

The MTCATPH Workbook 12.0 (the Workbook) allows the user to use pre-established chemical and toxicity data, default exposure assumptions, and site-specific information to calculate any of the following for a **petroleum mixture**.

- **Hazard and Risk for the Measured Sample Concentration**: To evaluate if the measured (or current) concentration at the site is protective, the Workbook provides the tools necessary to calculate the noncancer hazard index (HI) and risk based on site-specific analytical measurements in soil or groundwater (i.e., current conditions). To calculate the HI and risk for the measured concentrations, the Workbook requires the user to enter measured soil and/or groundwater concentrations for petroleum fractions and compounds. The Workbook then automatically executes a "forward" calculation using the equations in the regulation and solving for hazard quotients (HQs) or risks. For soil measurements, the Workbook calculates the HI[8] and risk corresponding to the direct contact pathway considering concurrent exposures via ingestion and dermal contact. For groundwater measurements, the Workbook calculates the HI and risk corresponding to the ingestion pathway (i.e., ingestion of potable water).
- **Site-specific and Risk-based Cleanup Levels for Soil and Groundwater**: The Workbook provides the tools necessary to calculate soil cleanup levels under both Methods B and C (for soil direct contact), and groundwater cleanup levels under Method B only (for potable water ingestion). The Workbook "back-calculates" a TPH cleanup level for the petroleum mixture based on the target HI of 1. It also back-calculates a cleanup level for individual chemicals based on a noncancer HQ of 1, and an excess risk[9] of one in a million (1×10^{-6} or 1E-06) under Method B, and one in one hundred thousand (1×10^{-5} or 1E-05) under Method C.
- **The soil leaching pathway (Protection of Groundwater)**: The Workbook allows the user to calculate a soil TPH cleanup level that is protective of groundwater. This calculation is based on the site-specific composition of the petroleum mixture measured

[8] The HQs, determined for each petroleum fraction and individual compound, by exposure pathway (e.g., soil direct contact or potable water ingestion), are summed to obtain the HI. The HI is an expression of the additivity of noncarcinogenic health effects.

[9] Cancer risk is expressed in terms of lifetime excess cancer risk. This concept assumes that the risk of cancer from a given chemical is in "excess" of the background risk of developing cancer. For example, a risk of 1E-06 equates to approximately one excess cancer case in a population of one million individuals due to exposure to the cancer-causing substance over a lifetime.

in soil, site-specific hydrogeological properties, and a user-defined target TPH groundwater concentration[10].

Note on carcinogens: The TPH cleanup levels calculated in the Workbook for soil direct contact and potable water ingestion are based on a noncancer HI of 1 and are not adjusted to account for carcinogenic chemicals within the petroleum mixture. See WAC 173-340-740(3)(b)(iii)(B)(III); WAC 173-340-745(5)(b)(iii)(B)(III); WAC 173-340-720(4)(b)(iii)(C).

Known or suspected carcinogenic chemicals that contribute to unacceptable risk within the petroleum mixture as calculated in the Workbook are evaluated separately and must meet compliance with soil and groundwater cleanup standards both on an individual basis (i.e., not to exceed a 1E-06 risk under Method B or 1E-05 under Method C), and when accounting for cumulative risk from multiple chemicals and pathways at the site (not to exceed a risk of 1E-05).

2.1 Prerequisites for Use

To use the Workbook, the user should be familiar with the concept of TPH fractions and the analytical requirements for TPH mixtures. Special analyses are required for various types of TPH mixtures (*see* Table 830-1 in WAC 173-340-900) to adequately characterize TPH for evaluation using this Workbook tool. Depending on the type of TPH, analysis may also be required for specific volatile petroleum components (e.g., BTEX[11]), fuel additives, semivolatile organic compounds (SVOCs), and other contaminants. A primer on TPH mixtures, fractions, and analytical requirements is included in **Appendix A**.

Soil Leaching Pathway. The fundamental equations, associated parameters, physical-chemical properties of TPH fractions, and default values for calculating soil cleanup levels based on the leaching pathway (protection of groundwater) are set forth in WAC 173-340-747 and reproduced in **Appendices B** and **C**. An in-depth technical discussion of the model theory behind equilibrium partitioning for contaminants in soil leaching to groundwater is included in a separate article that can be downloaded from the U.S. Environmental Protection Agency (EPA) CLU-IN website[12].

[10] The User Defined Target TPH Groundwater Concentration is the same as the Groundwater Cleanup Level that may be applied to areas of the Site that correspond to a particular product type or if appropriate the whole site (see *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*, Section 8.9, Step 4). https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html

[11] BTEX = Benzene, Toluene, Ethylbenzene, and Xylenes

[12] Hun Seak Park and Charles San Juan, 2000. A Method for Assessing Leaching Potential for Petroleum Hydrocarbons Release Sites: Multiphase and Multi-substance Equilibrium Partitioning, Journal of Soil and Sediment Contamination, 9(6):611-632. EPA CLU-IN webpage: https://clu-in.org/conf/tio/cra6/resources/PARKJUAN_3&4PhaseTheory.pdf

2.2 Restrictions and Cautions on Use

Restrictions and cautions related to use of the soil leaching models and calculating soil and groundwater cleanup levels are discussed below.

2.2.1 Soil Leaching Models

The Workbook uses the three- and four-phase equilibrium partitioning models to calculate soil cleanup levels that are protective of groundwater quality. Restrictions on use of the four-phase model for soil containing fuels that have been enhanced with alcohol are discussed in the MTCA Rule. See WAC 173-340-747(6)(b). Additional guidance on addressing fuel additives is provided in Section 7.10 of our *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*.[13]

The four-phase model is intended for use primarily on fresh or weathered TPH mixtures. Use of the tool for other mixtures of organic compounds (a mixture of solvents and creosote compounds, for example) is not as well tested as for petroleum product applications and the results may not be as reliable. Such applications need to be thoroughly scrutinized (quality checked) to make sure the results are within reasonable bounds.

2.2.2 Calculating Soil Cleanup Levels

The soil cleanup levels calculated using the orange and red tabbed soil worksheets account for the following.

- Soil concentrations based on **protection of the human direct contact pathway** (concurrent ingestion and dermal contact) under Methods B and C.
- Soil concentrations based on **protection of groundwater quality (leaching pathway)**. The user must develop a target TPH groundwater concentration based on the exposure pathway that generates the most stringent cleanup level (i.e., lowest concentration). Exposure pathways to consider (refer to your conceptual site model) are discussed below.
    - **Potable Groundwater**
        - When using Method B or C to develop a soil cleanup level using TPH fractions, the target cleanup level for potable groundwater may be based on site-specific TPH fractionated groundwater data (Method B calculated level if available), or the appropriate Method A TPH potable groundwater cleanup level from WAC 173-340-900, Table 720-1 may be used as a

[13] https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html

default. The higher of the two levels may be applied as the target TPH groundwater concentration for potable water ingestion.

> **Note:** The User Defined Target TPH Groundwater Concentration is the same as the Groundwater Cleanup Level that may be applied to areas of the Site that correspond to a particular product type or if appropriate the whole site (see *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*, Section 8.9, Step 4).

- **Protection of Surface Water** – Where contaminants in groundwater are likely to reach surface water, use the minimum cleanup level (i.e., lowest concentration) between human health and aquatic life pathways (described below) that are applicable to the site.
  - ***Human Health Fish Consumption Pathway***. For surface waters that support or have the potential to support fish or shellfish, the MTCA Rule allows the use of Method A TPH groundwater cleanup levels (from WAC 173-340-900, Table 720-1) as the Method B surface water level (in lieu of using Equation 730-1 in WAC 173-340-730(3)(b)(iii)(C).
  - **Potable Surface Water Pathway**. Use the potable groundwater ingestion level if surface water is suitable as a domestic water supply. See WAC 173-340-730 (3)(b)(iv).
  - **Ecological Pathway**. Ecology's Implementation Memo No. 23[14] (IM #23) contains gasoline and diesel surface water concentrations that are predicted to be protective of aquatic receptors in marine and freshwater using the NWTPH-Gx and NWTPH-Dx methods[15].
- **Nonpotable Groundwater**
  - Where groundwater is determined to be nonpotable and not likely to reach surface water, the potable groundwater ingestion level may still be used as a default (see WAC 173-340-720(6)(b)(i)). In lieu of using levels based on conservative drinking water exposure, a site-specific risk assessment may be performed to develop levels based on all potential exposure pathways and groundwater use at the site (see WAC 173-340-720(6)(b)(ii)).

[14] https://apps.ecology.wa.gov/publications/SummaryPages/1909043.html
[15] NWTPH = Northwest Total Petroleum Hydrocarbon Method; Gx = gasoline range; Dx = diesel range

Caution: The soil cleanup levels calculated using the soil worksheets DO NOT account for the following:

- Concentrations established under applicable state and federal laws
- Natural background concentrations[16]
- Practical quantitation limits (PQLs)
- Concentrations based on protection of air quality (vapor pathway[17])
- Concentrations based on protection of terrestrial ecological receptors
- Residual saturation limit for protection of groundwater
- Total site noncancer hazard and risk (e.g., where chemicals other than petroleum mixtures co-exist at a site, e.g., chlorinated solvents)

The soil cleanup levels calculated using the soil worksheets may need to be manually adjusted to account for these considerations (see WAC 173-340-740(5) and WAC 173-340-745(6)).

2.2.3 Calculating Groundwater Cleanup Levels

The potable groundwater cleanup levels calculated using the blue tabbed groundwater worksheets account for the following:

- Concentrations established under applicable state and federal laws[18]; and
- Concentrations based on protection of human health.

Caution: The potable groundwater cleanup levels calculated using the groundwater worksheets DO NOT account for the following:

- Natural background concentrations[19]
- PQLs
- Concentrations based on protection of air quality (vapor pathway[20])

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[16] Natural background is generally not relevant to petroleum. Except for PAHs, which may be produced naturally during incomplete burning (e.g., forest fires), the compounds provided in the MTCATPH Workbook don't occur naturally. Ecology has not adopted a natural background level for PAHs.
[17] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.
[18] Potable groundwater cleanup levels that have been adjusted to account for levels based on applicable, relevant, and appropriate requirements (ARARs) are provided in the groundwater TPH cleanup level worksheets.
[19] Natural background is generally not relevant to petroleum. Except for PAHs, which may be produced naturally during incomplete burning (e.g., forest fires), the compounds provided in the MTCATPH Workbook don't occur naturally. Ecology has not adopted a natural background level for PAHs.
[20] To assess the vapor pathway for petroleum mixtures, *see* Ecology's Guidance:

- Concentrations based on potential surface water impacts
- Nonaqueous phase liquid (NAPL) limitation[21]
- Total site noncancer hazard and risk (e.g., where chemicals other than petroleum mixtures exist at a site, e.g., chlorinated solvents)
- Potential concentrations of non-petroleum polar organic metabolites from weathered petroleum groundwater plumes (see Ecology's *Guidance for Silica Gel Cleanup in Washington State. November 2023. Publication No. 22-09-059*)
- Biodegradation. For example, if modeling or groundwater monitoring indicates that biological degradation of residual petroleum may result in violation of the drinking water standards for other chemicals (e.g, naturally occurring metals such as arsenic, iron, and manganese). See *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*, Section 8.9, Step 9

The groundwater cleanup levels calculated using the groundwater worksheet may need to be manually adjusted to account for these considerations (see WAC 173-340-720(7)).

2.3 What's New in MTCATPH Workbook 12.0

The most significant change between MTCATPH Workbook version 12.0 and MTCATPH version 11.1 is that version 12.0 has been updated and modernized in a new Excel based workbook tool. The MTCATPH Workbook 12.0 no longer includes a pop-up dialogue "Navigator" or other pop-up windows as the primary means for navigation but opens as a normal Excel Workbook with visible worksheet tabs. As such, version 12.0 is easier for the user to open and use (without the compatibility issues associated with Version 11.1) and will also be easier to update in the future.

Significant changes have been made to the Table in **Appendix C** of this guidance: "*Properties of Chemicals commonly found at Petroleum Contaminated Sites*" to incorporate updated and new scientific information. The updates reflected in **Appendix C** are documented in our November 2023 CLARC guidance titled: *Toxicity Data and Physical/Chemical Properties for Petroleum Mixtures*[22]. Updates include changes to toxicity data and physical/chemical data used in calculating cleanup levels for petroleum mixtures. Some changes of note are provided below.

Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action.

[21] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

[22] https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/ToxicityChemPropPetroleumMixtures.pdf

- ***Aliphatic (AL) >5-8 fraction:*** The oral toxicity surrogate for the equivalent carbon (EC[23]) AL >5-8 fraction was updated from cyclohexane to cyclohexene. Cyclohexane no longer has an available oral reference dose (RfD), and cyclohexene, a C6 aliphatic, was identified by EPA in 2022[24] as the oral toxicity surrogate for the aliphatic low carbon range (i.e., AL >5-8). Cyclohexene is a constituent of gasoline and is similar structurally to cyclohexane. Also, these compounds have similar physical/chemical attributes.

  Note: N-hexane is a C6 aliphatic and is a component of gasoline and crude oil. N-hexane's contribution to overall toxicity is separately evaluated in the Workbook using its own oral RfD. Testing for n-hexane is required when volatile petroleum hydrocarbon (VPH) analysis is performed for Method B or C (see MTCA WAC 173-340-900, Table 830-1, Footnote 9).

- **Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs)**: Toxicity data for benzo(a)pyrene (which is sometimes known as BaP) has been updated to reflect a new oral RfD and an updated oral cancer potency factor (CPF). In January 2017, EPA published several changes to the toxicity values for BaP in its Integrated Risk Information System (IRIS) database[25]. EPA has also determined that BaP has a mutagenic mode of action, and therefore recommends using Age-Dependent Adjustment Factors (ADAFs) to address increased childhood sensitivity (compared to adults) to its carcinogenic (cancer-causing) effects. The toxicity changes above are documented in Ecology's CLARC guidance titled *Polycyclic Aromatic Hydrocarbons and Benzo[a]pyrene: Changes to MTCA default cleanup levels for 2017, Revised July 2021*[26].

  - **Noncancer Hazard**: Although BaP has an oral RfD in EPA's IRIS, it's not included in the noncancer HI, and the TPH cleanup level calculations associated with soil direct contact, soil leaching, or ingestion of potable water pathways. BaP and associated cPAHs are excluded from these pathways since they are not identified as volatile organic compounds within the petroleum mixture (WAC 173-340-740(3)(b)(iii)(B)(III)).

  - **Cancer Risk**: cPAHs are accounted for separately in the cancer risk calculations. Method B cancer risk calculations for BaP incorporate early-life exposure (ELE) adjustments using ADAFs. Method C cleanup equations are based on adult exposure and therefore do not incorporate ELE adjustments.

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[23] The TPH Criteria Working Group developed the concept of equivalent carbon (EC) number by correlating fate and transport of hydrocarbons based on boiling point to approximate carbon number or EC number.
[24] *Provisional Peer-Reviewed Toxicity Values for Complex Mixtures of Aliphatic and Aromatic Hydrocarbons (various CASRNs).* EPA/690/R-22/003F. September 2022.
[25] https://www.epa.gov/iris
[26] https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MTCA_PAHCleanupLevels.pdf

- **Soil Leaching**: See Ecology's Implementation Memo #10[27] which provides guidance on evaluating the potential for cPAHs in soil to impact groundwater.

- **Double Counting**: Table 8.7 in Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*[28] recommends subtracting substance concentrations from the appropriate fraction. Since individual cPAHs are excluded from the HI and soil leaching calculations, double counting is no longer an issue and the full AR EC>21-34 should be used for both soil and groundwater. That is, do not subtract out the total cPAH concentration from the AR EC>21-34 fraction.

- **Inhalation Toxicity Criteria** – The previous MTCATPH version (Version 11.1) provided an option to evaluate the vapor pathway (protection of air quality) for informational purposes only. In 2022, Ecology updated our guidance for addressing vapor intrusion concerns at MTCA cleanup sites. The option to evaluate the vapor pathway has been removed from the MTCATPH 12.0 Workbook along with the inhalation toxicity criteria. To evaluate the vapor pathway for petroleum mixtures, please see our guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*[29].

- **Criterion for the TPH Soil and Groundwater Cleanup Levels**

  - ***Accounting for Carcinogenic Risk*** – Unlike Version 11.1, the new Workbook (Version 12.0) does not include options to evaluate TPH soil and groundwater cleanup levels based on contributions from carcinogenic risk. The TPH cleanup levels calculated in the Workbook based on soil direct contact and potable water ingestion are based on a noncancer HI of 1 and are not adjusted to account for carcinogenic chemicals within the petroleum mixture. See WAC 173-340-740(3)(b)(iii)(B)(III); WAC 173-340-745(5)(b)(iii)(B)(III); WAC 173-340-720(4)(b)(iii)(C).

    Known or suspected carcinogenic chemicals that contribute to unacceptable risk within the petroleum mixture as calculated in the Workbook are evaluated separately and must meet compliance with soil and groundwater cleanup standards both on an individual basis (i.e., not to exceed a 1E-06 risk under Method B or 1E-05 under Method C), and when accounting for cumulative risk from multiple chemicals and pathways at the site (not to exceed a risk of 1E-05).

    Calculations for the TPH cleanup level (based on the noncancer HI) and carcinogenic risk are presented on separate worksheets within the Workbook.

[27] https://apps.ecology.wa.gov/publications/SummaryPages/1509049.html
[28] https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html
[29] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Vapor-intrusion-overview

- ***Use of Method A Groundwater TPH Cleanup Levels*** – When using Method B or C to develop a soil cleanup level using TPH fractions, the target cleanup level for potable groundwater may be based on site-specific TPH fractionated groundwater data (Method B calculated level if available), or the appropriate Method A TPH potable groundwater cleanup level from WAC 173-340-900, Table 720-1 may be used as a default. The higher of the two levels may be applied as the target TPH groundwater concentration for potable water ingestion. **Note**: Final compliance for the groundwater standards should be conducted consistent with Section 10.3 of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*[30]. Note that the NWTPH method (NWTPH-Gx or Dx) should be used for comparison to Method A TPH groundwater cleanup levels. This method may also be used to compare against site-specific total TPH cleanup levels calculated using EPH/VPH data[31].

- ***Use of Method A Soil TPH Cleanup Levels*** – When using Method B or C to develop a TPH soil cleanup level using fractioned data (i.e., EPH or VPH), and the Method B or C TPH soil cleanup level for the site (or portion of the site contaminated by the same product) is less than the appropriate Method A TPH soil cleanup level from WAC 173-340-900, Table 740-1 (unrestricted land use) or Table 745-1 (industrial land use), the user may default to the appropriate Method A TPH soil value as the cleanup level. **Note**: Final compliance for the TPH remediation area in soil should be conducted consistent with Sections 10.1 and 10.2 of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*[32]. It's important to keep in mind that although a soil excavation may initially be defined and driven by the TPH cleanup level, the final limits of the excavation should include compliance samples analyzed for all parameters that exceed cleanup levels for the remediation area (e.g., TPH and individual compounds like BTEX).

Important: If a Method A TPH soil cleanup level is used rather than a site-specific Method B or C TPH soil cleanup level derived using the Workbook, post-remediation soil samples should be analyzed for TPH concentrations using the NWTPH method (NWTPH-Gx or Dx). This method may also be used to compare against site-specific total TPH cleanup levels calculated using EPH/VPH data.

[30] https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html
[31] The option of using the NWTPH-Dx or -Gx Methods for comparison against total TPH cleanup levels calculated using EPH/VPH data is explained in Table 10.1 (Alternative 1) of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*. Although Table 10.1 is specific to soil cleanup levels, it may also be applied to groundwater cleanup levels. The use of Table 10.1 as applied to groundwater is also discussed in Section 3.2.3 of *Ecology's Guidance for Silica Gel Cleanup in Washington State*. November 2023. Publication No. 22-09-059.
[32] https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html

For Method B or C TPH soil cleanup levels derived using this Workbook, review Table 10.1 of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016* for recommended alternatives for determining compliance with TPH concentrations.

- ***Soil Leaching Calculations*** – The soil leaching calculations have been simplified in Version 12.0 to include one modelling option. This modelling option is based on the site-specific composition of the petroleum mixture measured in soil, site-specific hydrogeological properties, and a user-defined target TPH groundwater concentration. Based on these inputs, the user may run the three- and four-phase equilibrium partitioning models to calculate a TPH soil cleanup level that is protective of the target TPH groundwater concentration based on the most stringent exposure pathway (refer to **Section 2.2.2**). The soil leaching calculations for this option are performed the same as the "Protection of Target TPH GW Co" option in the prior Workbook (Version 11.1).

  Note: Use of Method 1—as described in Section 8.9 of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016* - to derive a site-specific Method B groundwater cleanup level that is protective of drinking water is no longer an option in the soil leaching worksheet. Method 1 involves the use of EPH/VPH soil data and the soil leaching model to calculate a predicted groundwater fractionated composition and then a groundwater cleanup level from this fractionated composition.

2.4 Overview of Equations and Parameters

2.4.1 Calculating Soil Cleanup Levels

The soil worksheets (orange and red tabs) provide tools for evaluating the direct contact and leaching (protection of groundwater) pathways.

Direct Contact Pathway

For evaluation of the direct contact pathway, the worksheet uses the standard equations provided in WAC 173-340-740 and WAC 173-340-745 and summarized below (*see* **Appendix D and Tables 2-1 and 2-2 below**). For petroleum mixtures, evaluation of the direct contact pathway involves a concurrent evaluation of both soil ingestion and dermal contact.

Table 2-1: Method B Soil Equations

TPH Mixture	
Noncarcinogenic hazard	Equation 740-3
Individual Components	
Noncarcinogenic hazard	Equation 740-4
Carcinogenic risk	Equation 740-5

Table 2-2: Method C Soil Equations

TPH Mixture	
Noncarcinogenic hazard	Equation 745-3
Individual Components	
Noncarcinogenic hazard	Equation 745-4
Carcinogenic risk	Equation 745-5

For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The MTCA regulation (*see* WAC 173-340-708 (10)) specifically describes which parameters may be adjusted and how they may be adjusted. However, irrespective of whether a parameter may be adjusted under the regulation, the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.

As mentioned previously in Section 2.3, EPA has determined that BaP has a mutagenic mode of action, and therefore recommends using ADAFs to address increased childhood sensitivity (compared to adults) to its carcinogenic (cancer-causing) effects. Method B cancer risk calculations for BaP incorporate ELE adjustments using ADAFs. Method C cleanup equations are based on adult exposure and therefore do not incorporate ELE adjustments. Equations and methods for applying ELE adjustments to determine risk and cleanup levels for BaP are provided in Ecology's CLARC guidance titled *Polycyclic Aromatic Hydrocarbons and Benzo[a]pyrene: Changes to MTCA default cleanup levels for 2017*[33].

Chemical-specific toxicological properties and exposure parameters used in the soil direct contact cleanup equations are documented in the green tabbed "Chemical Database" worksheet and in **Appendix C**. These properties are also documented in the November 2023 CLARC guidance titled: *Toxicity Data and Physical/Chemical Properties for Petroleum Mixtures*[34].

Leaching Pathway

For evaluation of the leaching pathway, the worksheet uses the three and four-phase equilibrium partitioning models (depending upon NAPL formulation) described in the regulation (*see* **Appendix B**) to calculate a cleanup level that will not cause an exceedance of the target TPH groundwater concentration defined by the user and established per the requirements in WAC 173-340-720 (refer back to **Section 2.2.2**). For each of the soil or chemical parameters

[33] https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MTCA_PAHCleanupLevels.pdf

[34] https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/ToxicityChemPropPetroleumMixtures.pdf

used in the equations, the user may input either the default value provided in the regulation, or a site-specific or chemical-specific value derived under the regulation.

Physical/chemical properties used in the soil leaching cleanup equations are documented in the green tabbed "Chemical Database" worksheet and in **Appendix C**. These properties are also documented in the November 2023 CLARC guidance titled: *Toxicity Data and Physical/Chemical Properties for Petroleum Mixtures*.

2.4.2 Calculating Groundwater Cleanup Levels

The groundwater worksheet (blue tab) uses the standard equations provided in the regulation (*see* **Appendix E and Table 2-3 below**). For each of the exposure parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B cleanup levels[35]. Under **modified** Method B, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The MTCA regulation (*see* WAC 173-340-708 (10)) specifically describes which parameters may be adjusted and how they may be adjusted. However, irrespective of whether a parameter may be adjusted under the regulation, the worksheet uses the default value for that parameter provided in the regulation. Also, exposure parameters are not listed in the worksheet and the user may not input data for these parameters.

Table 2-3: Method B Potable Groundwater Equations

TPH Mixture	
Noncarcinogenic hazard	WAC 173-340-720, Equation 720-3
Individual Components	
Noncarcinogenic hazard	WAC 173-340-720, Equation 720-1
Carcinogenic risk	WAC 173-340-720, Equation 720-2

Groundwater potable ingestion risks and cleanup levels calculated for BaP under Method B incorporate ELE adjustments using ADAFs (*see* prior discussions in **Sections 2.3 and 2.4.1**).

Chemical-specific toxicological properties and exposure parameters used in the cleanup level equations for ingestion of potable groundwater are documented in the green tabbed "Chemical Database" worksheet and in **Appendix C**. These properties are also documented in the

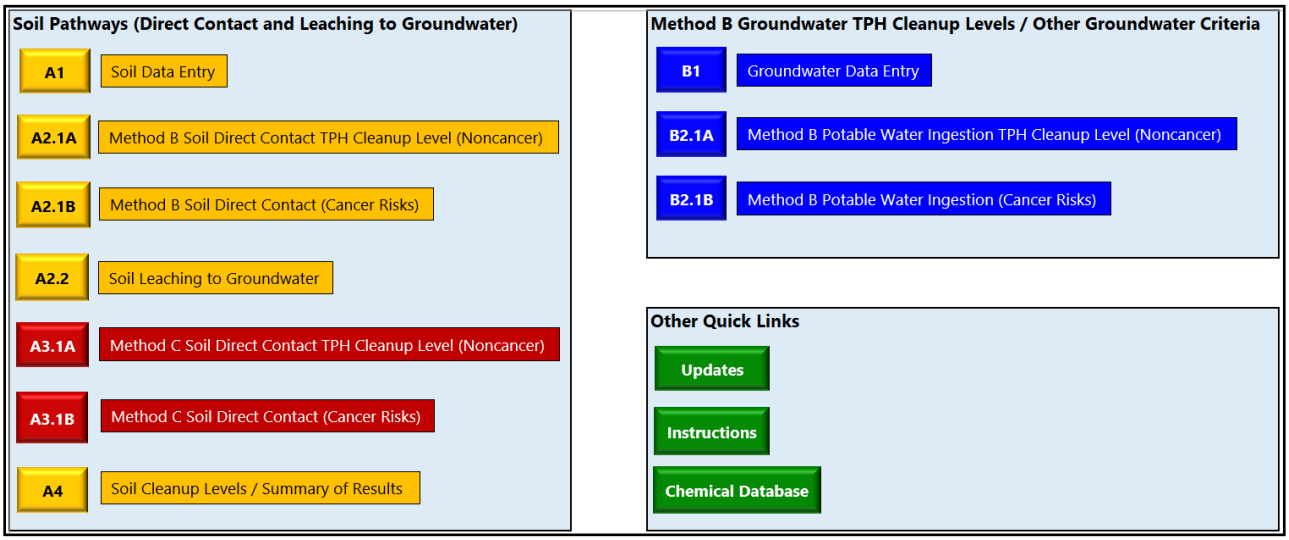
[35] In the Workbook, Method C is only evaluated for soil direct contact exposure. Groundwater cleanup levels for ingestion of potable water are based on Method B only. Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology (*see* second page prior to the table of contents) for methods to evaluate petroleum mixtures in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1).

November 2023 CLARC guidance titled: *Toxicity Data and Physical/Chemical Properties for Petroleum Mixtures*[36].

2.5 Navigating and Using the Workbook

The Workbook includes a "Navigation" worksheet (green tab) that allows the user to easily navigate between worksheets using color coded buttons as shown in **Figure 2-1** below. The buttons have a hyperlink that will take the user to the designated worksheet. Alternatively, users can simply scroll to and click on individual worksheet tabs for navigation.

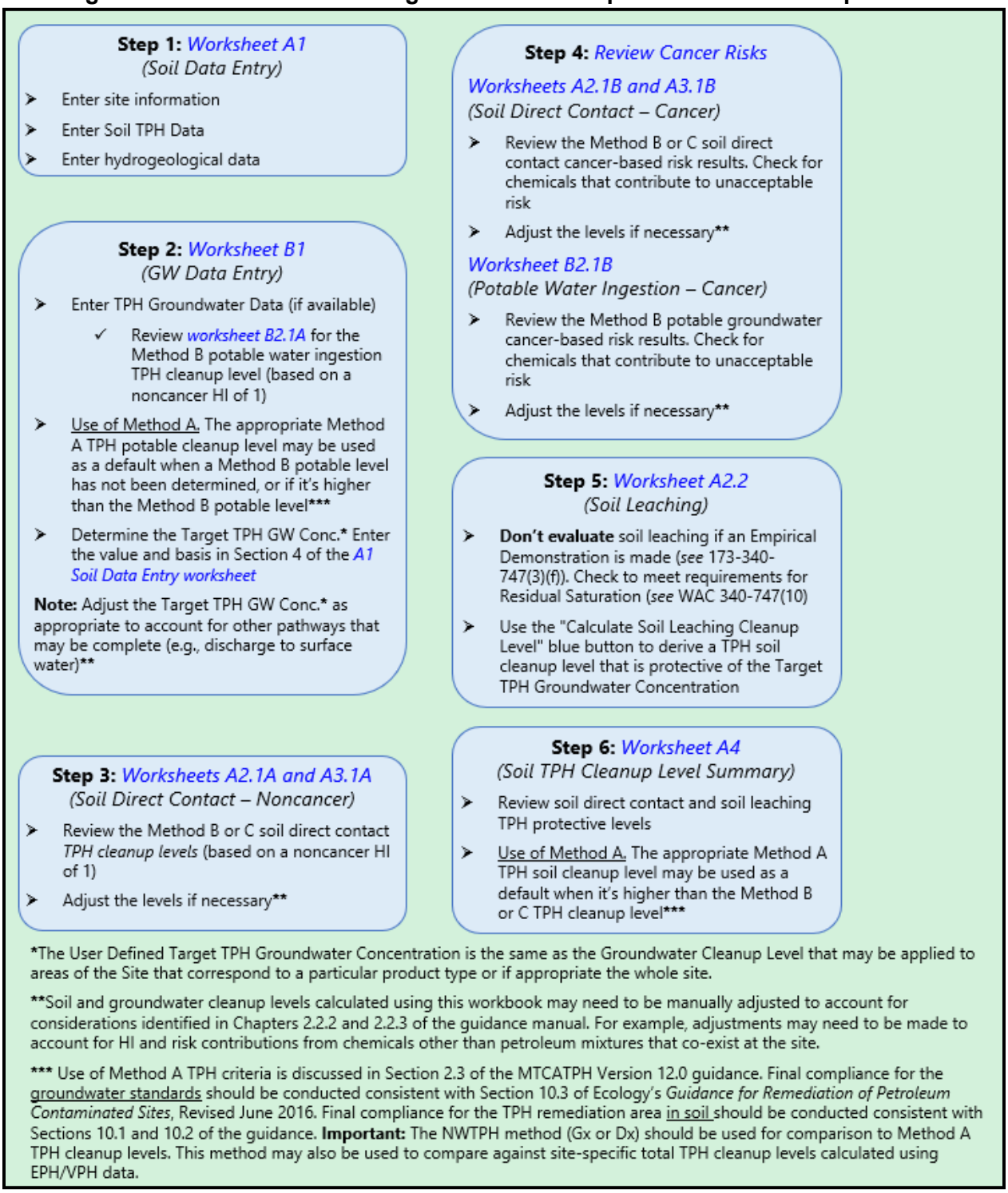
Figure 2-1: Overview of MTCATPH Navigation Buttons



The "Navigation" worksheet provides the recommended steps for navigating the Workbook and determining soil and groundwater TPH cleanup levels. The recommended steps are also provided in the form of a flow chart in the worksheet as shown in **Figure 2-2**.

36 https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/ToxicityChemPropPetroleumMixtures.pdf

Figure 2-2: Flow Chart for Navigation and Development of TPH Cleanup Levels



Additional information provided in the Navigation tab includes.

- **List of Abbreviations**: This shows the list of abbreviations used in the Workbook.
- **Default Residual Saturation Screening Levels**: This shows the default residual saturation screening levels for different TPH mixtures as set forth in WAC 173-340-900, Table 747-5. For a soil concentration to be protective of groundwater, the regulation requires that the concentration must not result in the accumulation of NAPL on or in the groundwater (see WAC 173-340-747(2)(b)). The default residual saturation screening levels may be used to determine whether the soil concentration calculated using the three- and four-phase models meets the regulatory requirement. Site-specific residual saturation screening levels may also be established (see WAC 173-340-747(10)).

2.6 Calculating Soil TPH Cleanup Levels

2.6.1 Instructions on How to Calculate the Soil TPH Cleanup Levels

The "Instructions" worksheet (green tab) provides directions for calculating soil TPH cleanup levels. Calculations for the soil direct contact pathway are conducted automatically and do not require the selection of a button for executing the calculation.

Note: Soil leaching is the only pathway in the Workbook that requires the user to select a button to execute the calculation.

2.6.2 Entering Data – A1_Soil Data Entry Worksheet (Orange Tab)

The user is required to enter all necessary site-specific and analytical data before performing any data analysis for the soil pathways (i.e., direct contact and soil leaching). Note that at any time during the evaluation, the user can go back and change the data that has been entered.

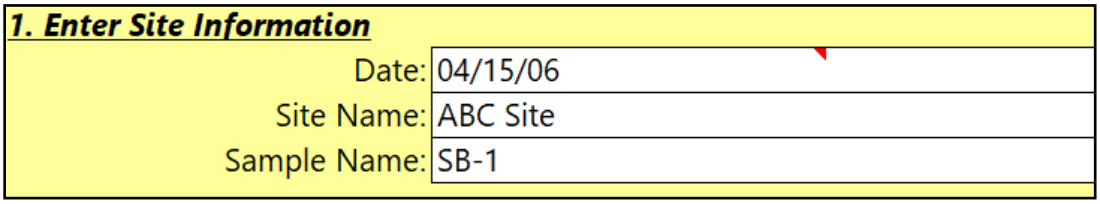
2.6.2.1 Accessing the Soil Data Entry Worksheet

In the "Navigation" worksheet (green tab), select the A1 orange button to take you to the A1_Soil Data Entry worksheet. Alternatively, you can scroll to and click on the orange tabbed worksheet titled "A1_Soil Data Entry".

2.6.2.2 Input Data – Part 1: Enter Logistical Site Information

User-specified text format is entered here. As shown in **Figure 2-3**, enter descriptive text for the identification of a particular site (or a sample or a project) such as date, site name, sample name, and additional information (in the "REMARK" text box) if necessary. The MTCATPH Workbook does not require the user to enter information for any of these entries, as they are solely there for the benefit of the user. The site information entered in the A1_Soil Data Entry worksheet (shown in **Figure 2-3** below) is automatically carried forward to the other soil related worksheets (orange and red tabs).

Figure 2-3: Enter Site Information – Soil Sample



2.6.2.3 Input Data – Part 2: Enter Measured Soil Concentrations

The second part of the worksheet (illustrated in **Figure 2-4**) requires the user to input analytical data (soil concentrations: dry basis mg/kg) in the non-shaded (white) cells for the chemicals of concern and petroleum EC groups appropriate for the type of TPH mixture being evaluated.

Figure 2-4: Entering Soil Concentration Measured

2. Enter Soil Concentration Measured

Chemical or Petroleum Fraction	Measured Soil Conc mg/kg	Composition Ratio %
AL_EC >5-6	35	4.1%
AL_EC >6-8	20	2.4%
AL_EC >8-10	40	4.7%
AL_EC >10-12	57	6.7%
AL_EC >12-16	125	14.8%
AL_EC >16-21	300	35.5%
AL_EC >21-34		0.0%
AR_EC >8-10	1	0.1%
AR_EC >10-12	24	2.8%
AR_EC >12-16	55	6.5%
AR_EC >16-21	145	17.2%
AR_EC >21-34		0.0%
Benzene	0.03	0.0%
Toluene	5	0.6%
Ethylbenzene	7	0.8%
Total Xylenes	13	1.5%
Naphthalene	15	1.8%
1-Methyl Naphthalene		0.0%
2-Methyl Naphthalene		0.0%
n-Hexane		0.0%
MTBE		0.0%
Ethylene Dibromide (EDB)		0.0%
1,2 Dichloroethane (EDC)		0.0%
Benzo(a)anthracene		0.0%
Benzo(b)fluoranthene		0.0%
Benzo(k)fluoranthene	1	0.1%
Benzo(a)pyrene	0.07	0.0%
Chrysene	1	0.1%
Dibenz(a,h)anthracene	0.05	0.0%
Indeno(1,2,3-cd)pyrene	1	0.1%
	845.15	**100%**

Note that the right-hand “Composition Ratio” column automatically calculates the percentage of the total mixture represented by the particular fraction/compound. Be sure that the correct and consistent units are used for all chemical concentrations (milligrams/kilogram = mg/kg = ppm) and that you use the same number of significant figures as reported by the laboratory. Leave blank or enter zero (0) for substances that are not analyzed (e.g., for gasoline, you probably would not test for the cPAHs, so these entries would all be blank or “0”).

For values below the method detection limit (MDL), substitute one-half the MDL. For values above the MDL but below the PQL, use the value reported (e.g., J qualified data). However, for

a hazardous substance or petroleum fraction that has never been detected in any sample at a site and is not suspected of being present at the site based on site history or other knowledge, leave blank or enter "0" for that value.

Note: All analytical data entries must be numeric values. Any text entry may cause an error.

Composition Overlaps: If the sample has been analyzed using both the VPH (volatile petroleum hydrocarbons) and EPH (extractable petroleum hydrocarbons) methods, some EC fractions will have results from both methods. Instructions for handling composition overlaps is provided below.

- If both methods yield detects, use the higher value.
- If one method yields a non-detect and the other a detect, use the detected value.
- If both methods yield non-detects, use the lowest reporting limit for that fraction with one exception: If both the AR >12-13 (VPH) and AR >12-16 (EPH) fractions are non-detect, use the reporting limit for the AR >12-16 fraction.

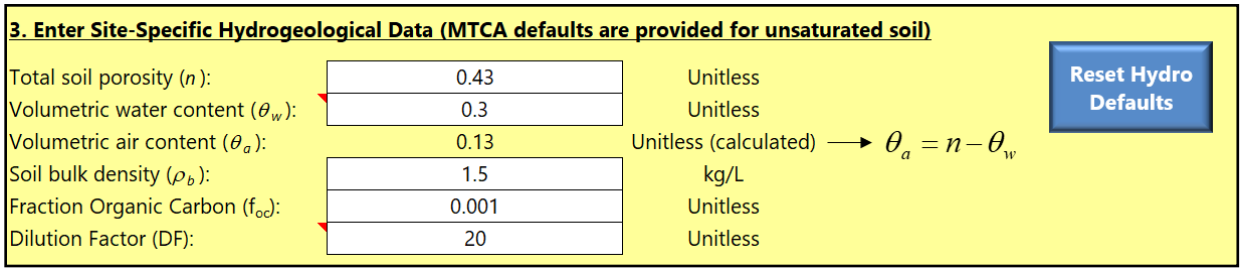
Avoid Double Counting: The petroleum fractions include hazardous substances that may also be individually quantified, depending upon the type of mixture(s) present at a site (see Table 830-1 in WAC 173-340-900). If you have quantified one or more individual hazardous substances that are included in one of the TPH EC fractions, you need to make sure to subtract those concentrations from the appropriate EC fraction concentrations. Otherwise, you are "double counting" that particular substance. Necessary adjustments to EC fractions to avoid double counting are provided below.

- **AL >5-6 corrected total** = (Reported AL >5-6) – (n-hexane concentration)
- **AR >8-10 corrected total** = (Reported AR >8-10) – (ethylbenzene + total xylenes concentration)
- **AR >10-12 corrected total** = (Reported AR >10-12) – (naphthalene concentration)
- **AR >12-16 corrected total** = (Reported AR >12-16) – (1-methyl + 2-methyl naphthalene concentration)
- **AR >21-34 corrected total** = ***No adjustment necessary***. *See* discussion on "Double Counting" in Section 2.3 under the bullet for cPAHs.

2.6.2.4 Input Data – Part 3: Enter Hydrogeological Characteristics of the Site

The third part of the worksheet requires the user to input default or site-specific data for the hydrogeological parameters illustrated in **Figure 2-5 below**. These parameters are used to calculate a soil leaching cleanup level that is protective of groundwater (i.e., soil concentration that will not cause an exceedance of the target TPH groundwater concentration).

Figure 2-5: Entering Site-specific Hydrological Data



Total Soil Porosity (*n*): Enter the default value of "0.43" or a site-specific value determined under WAC 173-340-747(6)(d)(iii)(D) using site-specific measurements. Note that the sum of the volumetric water content and the volumetric air content must equal the total soil porosity. The site-specific soil porosity may be calculated using the following equation and inputs provided in **Table 2-4**:

$$n = 1 - \frac{\rho_b}{\rho_s}$$

Table 2-4: Porosity Calculation

Parameter	Definition	Default Value	Units
n	Total soil porosity	Calculated	unitless
ρ_b	Dry soil bulk density	1.5[37]	kg/L
ρ_s	Soil particle specific gravity	2.65[38]	kg/L

Volumetric Water Content (θ_w): For unsaturated soil conditions, enter the default value of "0.30" or enter a site-specific value derived under WAC 173-340-747(5)(d) using site-specific measurements. For saturated soil conditions, the value for θ_w is unknown and must be solved for (Excel uses Solver), and the user should leave it as 0.3 as indicated in Equation 747-6 in

[37] Use the default value of 1.5 kg/L or use a site-specific value derived under WAC 173-340-747(5)(c)
[38] Use the default value of 2.65 kg/L or use a site-specific value derived under WAC 173-340-747(6)(d)(iii)(D). A site-specific value may be derived by measuring the soil particle specific gravity using ASTM Method D854-00.

WAC 173-340-747(6). This results in an initial starting point of 0.13 for the volumetric air content in the soil leaching calculation.

Volumetric Air Content (θ_a): The value for volumetric air content CANNOT be entered. The Workbook automatically calculates a value based on the values entered for total soil porosity (*n*) and volumetric water content (θ_w) using the following equation:

$$\theta_a = n - \theta_w$$

As an example, if the default values for total soil porosity (***n*** = 0.43) and volumetric water content (θ_w = 0.3) are entered, then the "default" volumetric air content is 0.13.

Dry Soil Bulk Density (ρ_b): Enter the default value of "1.5" or enter a site-specific value derived under WAC 173-340-747(5)(c) using site-specific measurements.

Fraction Soil Organic Carbon (f_{oc}): The fraction of soil organic carbon is the total mass of organic carbon divided by a unit mass of soil (mass of carbon/mass of soil). Enter the default value of "0.001" or enter a site-specific value derived under WAC 173-340-747(5)(b)(i). The Workbook calculates a value for K_d[39] using the f_{oc} value entered here and the K_{oc}[40] value in the database using **MTCA Equation 747-2:** $K_d = K_{oc} \times f_{oc}$.

Soil samples that are analyzed for f_{oc} must be collected outside the area of contamination and below the root zone. The results are usually reported as percent organic carbon. The reported value can be converted to a fraction by dividing by 100.

Dilution Factor (*DF*): Enter the applicable default value ("20" for unsaturated zone soil and "1" for saturated zone soil) or enter a site-specific value derived under WAC 173-340-747(5)(f) using site-specific estimates of infiltration and groundwater flow rate.

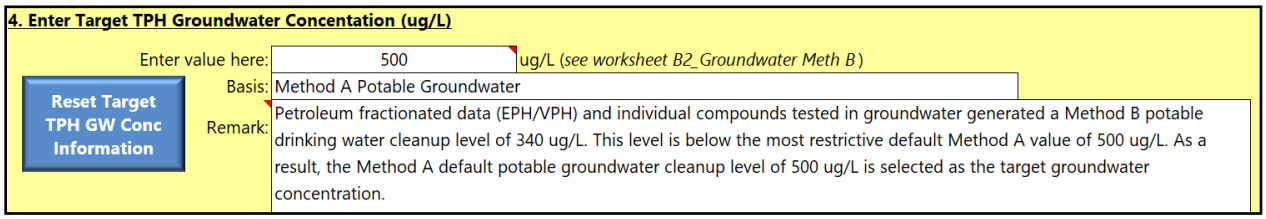
2.6.2.5 Input Data – Part 4: Enter target TPH groundwater concentration

As described in Section 2.2.2, to evaluate the soil leaching pathway, the user must enter a target TPH groundwater concentration based on the exposure pathway that generates the most stringent cleanup level (i.e., lowest concentration). The target TPH groundwater concentration entered here is automatically carried forward to the soil leaching calculations in worksheet A2.2 Soil Leach (orange tab). The user should select the basis for this value from the drop-down menu provided. There is also room to add a remark to clarify the basis for the selected target TPH groundwater concentration. In the example shown in **Figure 2-6**, the Method A default potable groundwater cleanup level of 500 µg/L is selected as the target TPH groundwater concentration. Notes in the "Remark" section explain the rationale for selecting the default

[39] K_d = Distribution coefficient (L/kg). L/kg = liters per kilogram.
[40] K_{oc} = Soil organic carbon-water partitioning coefficient (L/kg).

Method A potable groundwater level as the target TPH groundwater concentration. See prior Section 2.2.2 for guidance in identifying the target TPH groundwater concentration based on potable drinking water.

Figure 2-6: Entering Target TPH Groundwater Concentration



THIS COMPLETES DATA ENTRY FOR THE SOIL WORKSHEET. SAVE YOUR WORK BEFORE CONTINUING. ***You should save the file under a new file name that pertains to the particular site and sample***.

2.6.3 Soil Cleanup Level Calculations

The soil worksheets in the **MTCATPH 12.0 Workbook** provide a means for evaluating the results based on the entered soil data. The following discussion on evaluating the results is **organized by worksheet**. As described previously, the Workbook allows the user to examine **two situations**.

- **First**, the Workbook provides the tools necessary to calculate the noncancer hazard and risk from direct contact with soil for the measured sample concentration (i.e., current conditions).
- **Second**, the Workbook provides the tools necessary to calculate soil cleanup levels based on direct contact exposure under Methods B and C. The Workbook "back-calculates" a cleanup level based on the noncancer hazard and target risk levels set forth in the regulation.

2.6.3.1 Worksheet A2.1A – Evaluation of the Direct Contact Pathway (Noncancer Effects) under Method B (Unrestricted Land Use)

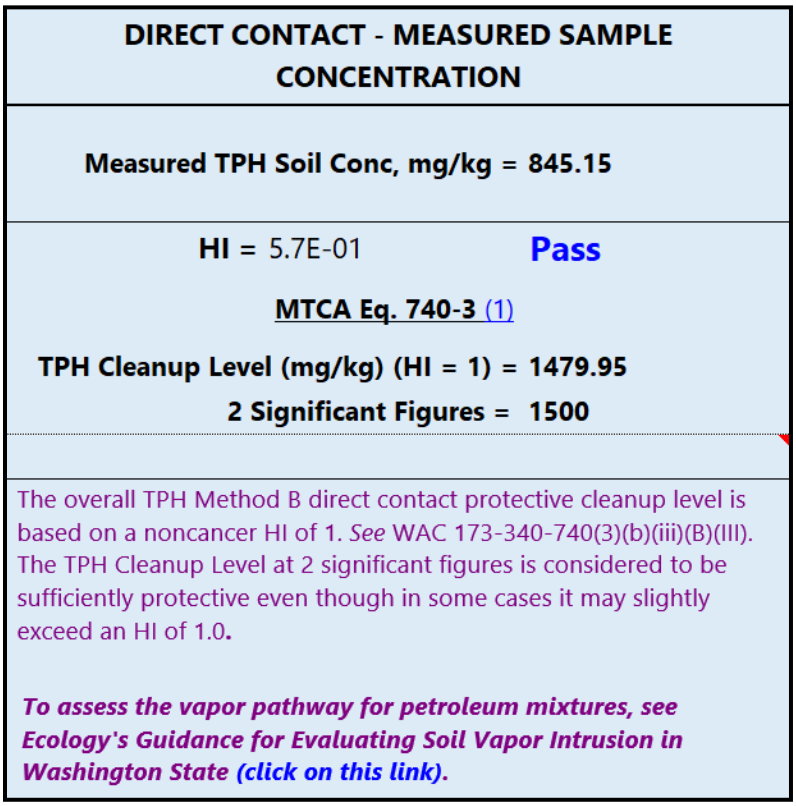
Worksheet A2.1A presents the Method B direct contact noncancer hazard calculations and the TPH cleanup level based on an HI of 1 for the TPH mixture.

To access the worksheet: In the "Navigation" worksheet (green tab), select the A2.1A orange button to take you to the A2.1A Method B Soil Direct Contact TPH Cleanup Level worksheet. Alternatively, you can scroll to and click on the orange tabbed worksheet titled "A2.1A_Soil B_TPH CUL".

Direct Contact Noncancer Hazard Calculations: Results for the measured sample concentration (based on the soil data entered in Worksheet A1_Soil Data Entry) are

automatically calculated as shown in two places in the worksheet (both shaded in light blue). First, a summary box (shown in **Figure 2-7**) is in the upper right-hand portion of the worksheet.

Figure 2-7: HI for Measured Concentration and TPH Cleanup Level – Method B Soil



This box provides the total concentration (mg/kg) of all the TPH fractions and compounds entered by the user (845.15 mg/kg in this example), the corresponding HI (0.57), a Pass or Fail note, the TPH cleanup level based on an HI of 1 (1,500 mg/kg), and notes for interpreting the results. In this particular example, the measured sample concentration received a "Pass" since the HI does not exceed the allowable level (i.e., HI of 1) established for Method B under WAC 173-340-705(4).

Second, the four columns located to the right of the column containing measured soil concentrations (under heading: "Measured Sample Concentration"; *see* **Figure 2-8**[41]) provide the detail necessary to determine which fractions and chemicals are contributing to the HI. The sum of the individual HQs (i.e., the HI) is shown at the bottom of the column. Noncancer exceedances are noted for individual fractions and single hazardous substances that exceed an HQ of 1, and if the HI exceeds 1. Also provided are direct contact (via concurrent ingestion and dermal contact) cleanup levels based on an HQ of 1 for individual compounds detected in the soil sample.

[41] For illustration purposes, the list of individual fractions and chemicals shown in **Figure 2-8** focuses on those that contribute to the noncancer HI.

Figure 2-8: Noncancer Hazard Details (Measured Concentration) – Method B Soil

Chemical of Concern or EC group	Measured Sample Concentration				
		Noncancer Hazards			
	Measured Soil Conc @dry basis	Noncancer HQ MTCA Eq. 740-4 (1)	Percent Contribution to the Total HI	Noncancer Exceedances (2)	Noncancer-based Concentration @ HQ 1
	mg/kg	unitless	percent		mg/kg
Petroleum EC Fraction					
AL_EC >5-6	35	9.47E-02	16.6%		
AL_EC >6-8	20	5.41E-02	9.5%		
AL_EC >8-10	40	5.41E-02	9.5%		
AL_EC >10-12	57	7.71E-02	13.5%		
AL_EC >12-16	125	1.69E-01	29.6%		
AL_EC >16-21	300	1.35E-03	0.2%		
AL_EC >21-34	0				
AR_EC >8-10	1	1.35E-04	0.0%		
AR_EC >10-12	24	1.62E-02	2.8%		
AR_EC >12-16	55	1.98E-03	0.3%		
AR_EC >16-21	145	8.70E-02	15.2%		
AR_EC >21-34	0				
Benzene	0.03	9.39E-05	0.0%		320
Toluene	5	8.33E-04	0.1%		6,000
Ethylbenzene	7	9.38E-04	0.2%		7,500
Total Xylenes	13	8.71E-04	0.2%		15,000
Naphthalene	15	1.24E-02	2.2%		1,200
Sum	**845.15**	5.71E-01	100%	HI ≤ 1	

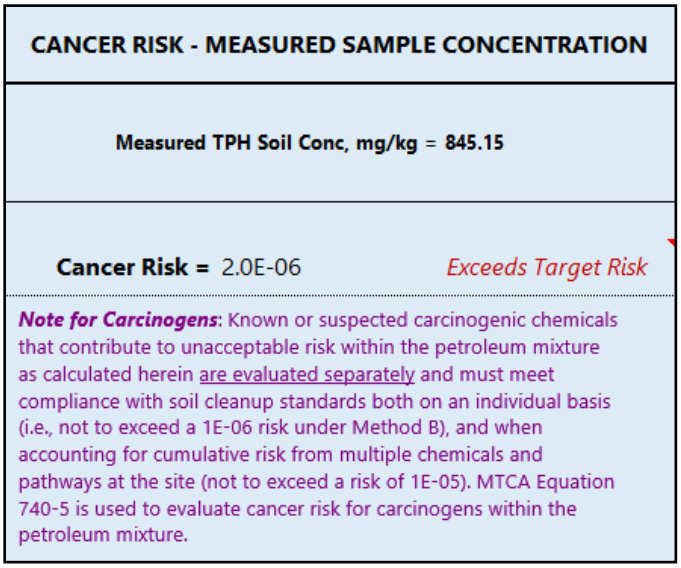
2.6.3.2 Worksheet A2.1B – Evaluation of the Direct Contact Pathway (Carcinogenic Risk) under Method B (Unrestricted Land Use)

Worksheet A2.1B presents the Method B direct contact cancer risk calculations for individual hazardous substances within the TPH mixture. Note that known or suspected carcinogenic chemicals that contribute to unacceptable risk within the TPH mixture are evaluated separately and must meet compliance with soil cleanup standards both on an individual basis (i.e., not to exceed a 1E-06 risk under Method B), and when accounting for cumulative risk from multiple chemicals and pathways at the site (not to exceed a risk of 1E-05). MTCA WAC 173-340-740 Equation 740-5 is used to evaluate cancer risk for carcinogens within the petroleum mixture.

To access the worksheet: In the "Navigation" worksheet (green tab), select the A2.1B orange button to take you to the A2.1B Method B Soil Direct Contact Cancer Risk worksheet. Alternatively, you can scroll to and click on the orange tabbed worksheet titled "A2.1B_Soil B_Cancer Risk".

Direct Contact Risk Calculations: Results for the measured sample concentration (based on the soil data entered in Worksheet A1_Soil Data Entry) are automatically calculated as shown in two places in the worksheet (both shaded in light blue). First, a summary box (shown in **Figure 2-9**) is in the upper right-hand portion of the worksheet.

Figure 2-9: Cancer Risk (Measured Concentration) – Method B Soil



This box provides the total concentration (mg/kg) of all the TPH fractions and compounds entered by the user (845.15 mg/kg in this example), the corresponding total cancer risk (2E-06), a cancer risk exceedance note, and notes for interpreting the results. In this particular example, cPAHs generated a cancer risk of 2E-06 (*see* **Figure 2-10** below), which exceeds the target risk of 1E-06 established for individual hazardous substances under Method B (see WAC 173-340-705(2) and discussion below).

Second, the four columns located to the right of the column containing measured soil concentrations (under heading: "Measured Sample Concentration"; *see* **Figure 2-10**[42]) provide the detail necessary to determine which fractions and chemicals are contributing to the risk. The sum of the individual risks (cumulative risk) is shown at the bottom of the column. Cancer exceedances are noted for individual hazardous substances that exceed a risk of 1E-06, and if the cumulative risk exceeds 1E-05. As shown in **Figure 2-10**, the cPAH concentration in soil (i.e., the total toxic equivalent concentration or TEQ[43]) generated a risk of 2E-06 which exceeds the MTCA Method B individual risk threshold of 1E-06. The TPH cleanup level is not adjusted because of this, but this calculation does indicate that the cPAH TEQ concentration in the sample exceeds the cPAH TEQ cleanup level. No adjustments to the cleanup levels are needed to account for multiple carcinogens since the cumulative risk is less than 1E-05. The

[42] For illustration purposes, only the results for chemicals that generated a cancer risk are shown on **Figure 2-10**. cPAHs accounted for almost 100 percent of the risk in this example.
[43] The cPAH TEQ concentration shown in **Figure 2-10** was derived using the toxicity equivalent factor (TEF) approach outlined in Ecology's Implementation Memorandum No. 10.

worksheet shows that the Method B cleanup level for comparison against the cPAH TEQ concentration is 0.14 mg/kg (based on the toxicity of benzo(a)pyrene at a 1E-06 risk).

Figure 2-10: Cancer Risk Details (Measured Concentration) – Method B Soil

Chemical of Concern or EC group	Measured Sample Concentration				
		Cancer Risk			
	Measured Soil Conc @dry basis	Cancer Risk MTCA Eq. 740-5 (1)	Percent Contribution to the Total Cancer Risk	Cancer Risk Exceedances (2)	Cancer-based Concentration @ 1E-06 Risk
	mg/kg	unitless	percent		mg/kg
Benzene	0.03	1.7E-09	0.1%		18
Benzo(a)anthracene	0				
Benzo(b)fluoranthene	0				
Benzo(k)fluoranthene	1				
Benzo(a)pyrene	0.07				0.14
Chrysene	1				
Dibenz(a,h)anthracene	0.05				
Indeno(1,2,3-cd)pyrene	1				
cPAH TEQ (using TEFs) (3), (4)	***0.285***	2.0E-06	99.9%	> 1E-06	
Sum	**845.15**	2.0E-06	100%	≤ 1E-05	

2.6.3.3 Worksheets A3.1A and 3.1B – Evaluation of the Direct Contact Pathway under Method C (Industrial Land Use)

Worksheets A3.1A and A3.1B present the Method C soil direct contact noncancer and cancer risk calculations, respectively, for individual fractions (noncancer hazard only) and individual hazardous substances within the TPH mixture.

To access the worksheets: In the "Navigation" worksheet (green tab), select the A3.1A red button (for noncancer hazards) or the A3.1B red button (for cancer risk) to see the Method C soil direct contact results. Alternatively, you can scroll to and click on the red tabbed worksheets titled "A3.1A_Soil C_TPH_CUL" or "A3.1B_Soil C_Cancer Risk".

The worksheets for evaluating the direct contact pathway under Method C (industrial land use) all have the same features as described in **Sections 2.6.3.1 and 2.6.3.2** above for the unrestricted land use scenario. Under Method C, cleanup levels are calculated the same as under Method B, except that cleanup levels based on human exposure are calculated using a less stringent target cancer risk for individual hazardous substances (1E-05) and less stringent default exposure assumptions based on adult exposure (see **Appendix D**).

2.6.3.4 Worksheet A2.2 – Evaluation of the Soil Leaching to Groundwater Pathway

Worksheet A2.2 presents soil leaching calculations for deriving a soil cleanup level that is protective of the target TPH groundwater concentration identified by the user. The target TPH groundwater concentration is inputted into Section 4 of the A1_Soil Data Entry worksheet (*see* prior **Sections 2.2.2 and 2.6.2.5**).

Note: See discussion on Residual Saturation at the end of this section.

To access the worksheet: In the "Navigation" worksheet (green tab), select the A2.2 orange button to take you to the A2.2 Soil Leaching to Groundwater worksheet. Alternatively, you can scroll to and click on the orange tabbed worksheet titled "A2.2_Soil_Leach".

Soil Leaching Calculations: Worksheet A2.2 allows the user to run the soil leaching partitioning model based on the measured sample concentration entered in Worksheet A1 (Soil Data Entry). The site-specific hydrogeological properties and target TPH groundwater concentration used in the modelling (taken from Worksheet A1) are summarized in two separate boxes as shown in **Figure 2-11** below.

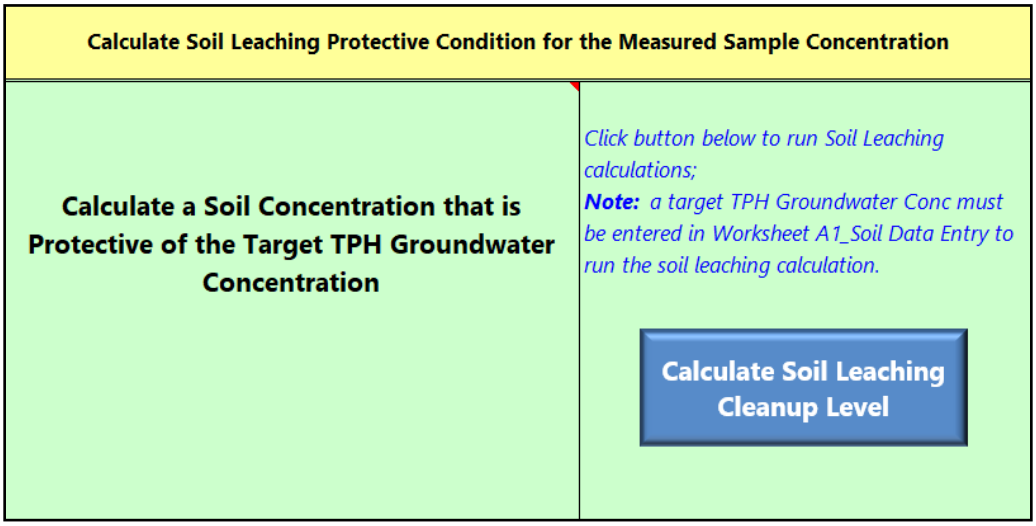
Figure 2-11: Soil Leaching Model Parameters

Site-Specific Hydrogeological Properties previously entered:			
Item	Symbol	Value	Units
Total soil porosity:	*n*	0.43	unitless
Volumetric water content:	*Qw*	0.3	unitless
Volumetric air content:	*Qa*	0.13	unitless
Soil bulk density measured:	*rb*	1.5	kg/L
Fraction Organic Carbon:	*foc*	0.001	unitless
Dilution Factor:	*DF*	20	unitless
Target TPH Groundwater Concentration			
Target Groundwater TPH Conc, ug/L:	500		
Calculate Soil Leaching Protective Condition for the Measured Sample Concentration			

Based on the site-specific composition of the petroleum mixture measured in soil, site-specific hydrogeological properties, and a user-defined target TPH groundwater concentration[44], the user may calculate the soil leaching cleanup level by clicking on the "Calculate Soil Leaching Cleanup Level" blue button in the middle of the worksheet (see **Figure 2-12**).

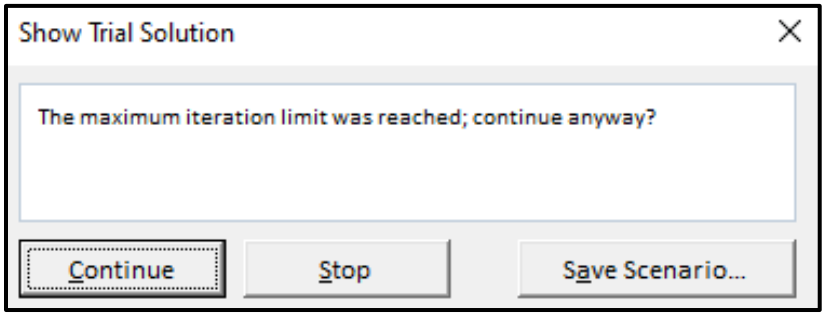
[44] The User Defined Target TPH Groundwater Concentration is the same as the Groundwater Cleanup Level that may be applied to areas of the Site that correspond to a particular product type or if appropriate the whole site (see *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*, Section 8.9, Step 4). https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html.

Figure 2-12: Running the Soil Leaching Model



If the message provided in **Figure 2-13** below appears while running the soil leaching model, click "Continue" to complete the calculation.

Figure 2-13: Soil Leaching Model Maximum Iteration Limit Message



Note: cPAHs are not included in the soil leaching calculations to predict a total TPH concentration protective of potable groundwater. Compliance with cPAHs in soil for the protection of groundwater is determined separately using the 3-phase partitioning model (*see* Ecology Implementation Memo No. 10 - *Evaluating the Human Health Toxicity of Carcinogenic PAHs (cPAHs) Using Toxicity Equivalency Factors (TEFs)* (April 20, 2015)). https://apps.ecology.wa.gov/publications/SummaryPages/1509049.html

Soil leaching pathway results for the petroleum fractions and individual chemicals are provided in the worksheet (from left to right) as follows (see **Figure 2-14**).

Measured Soil Concentration – dry weight basis (mg/kg): These concentrations correspond to the data entered in Worksheet A1. It is provided for reference and is not changed by any of the soil leaching calculations.

Soil Concentration Being Tested (mg/kg): These are the soil leaching concentrations calculated by the partitioning equations presented in **Appendix B**. These modelled soil concentrations are predicted to be protective of the target TPH groundwater concentration.

Predicted Concentration at Well (µg/L): The predicted groundwater concentration based on the partitioning equations presented in **Appendix B**.

In the example calculations provided in **Figure 2-14**, based on the composition ratio of the measured soil data (total TPH concentration of 842.03 mg/kg; excludes cPAHs) and the site-specific hydrogeological parameters, the soil cleanup level predicted to be protective of a target TPH groundwater concentration of 500 µg/L is 172.77 mg/kg (or 170 mg/kg rounded to two significant figures). These results are also summarized in a separate box in the worksheet as illustrated in **Figure 2-15**. As shown in the example provided in **Figure 2-15**, the measured TPH concentration (excluding cPAHs) of 842.03 mg/kg "Fails" the soil leaching pathway because it exceeds the soil leaching cleanup level of 170 mg/kg determined by the model.

Figure 2-14: Soil Leaching Pathway Results

Chemical of Concern or EC Group	Measured Soil Conc @dry basis	Soil Leaching Pathway Results	
		Soil Conc being tested (1)	Predicted Conc @Well
	mg/kg	mg/kg	ug/L
Petroleum EC Fraction			
AL_EC >5-6	35	7.18E+00	6.38E+01
AL_EC >6-8	20	4.10E+00	8.94E+00
AL_EC >8-10	40	8.21E+00	1.49E+00
AL_EC >10-12	57	1.17E+01	1.48E-01
AL_EC >12-16	125	2.56E+01	6.01E-03
AL_EC >16-21	300	6.16E+01	1.77E-05
AL_EC >21-34	0	0.00E+00	0.00E+00
AR_EC >8-10	1	2.05E-01	3.13E+00
AR_EC >10-12	24	4.92E+00	3.60E+01
AR_EC >12-16	55	1.13E+01	2.20E+01
AR_EC >16-21	145	2.98E+01	4.79E+00
AR_EC >21-34	0	0.00E+00	0.00E+00
Benzene	0.03	6.16E-03	9.97E-01
Toluene	5	1.03E+00	1.04E+02
Ethylbenzene	7	1.44E+00	7.86E+01
Total Xylenes	13	2.67E+00	1.43E+02
Naphthalene	15	3.08E+00	3.31E+01
1-Methyl Naphthalene	0	0.00E+00	0.00E+00
2-Methyl Naphthalene	0	0.00E+00	0.00E+00
n-Hexane	0	0.00E+00	0.00E+00
MTBE	0	0.00E+00	0.00E+00
Ethylene Dibromide (EDB)	0	0.00E+00	0.00E+00
1,2 Dichloroethane (EDC)	0	0.00E+00	0.00E+00
Benzo(a)anthracene Benzo(b)fluoranthene Benzo(k)fluoranthene Benzo(a)pyrene Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene		*see Note (2)*	
Sum	842.03	1.73E+02	5.00E+02

Figure 2-15: Soil Leaching Model Results

Model Results			
Soil Leaching Criterion: Protection of Target TPH Groundwater Concentration			
Protective TPH Soil Concentration, mg/kg =	172.77	*@ 2 sig figures*	**170**
TPH GW Concentration, ug/L =	5.00E+02	*@ 2 sig figures*	**500**
Soil Leaching Pass or Fail?		**Fail**	

Additional Model Details: A separate box (see **Figure 2-16**) located underneath the "Model Results" contains additional model simulation results for key parameters and information such as the following.

- **Type of model used for computation**. The spreadsheet incorporates either the three- or four-phase partitioning model. The four-phase model is applied when the presence of a NAPL phase is detected mathematically. The three-phase model solution is used where the four-phase solution is not appropriate for any given soil.
- **100% NAPL**. TPH concentration when air space is completely filled with petroleum product.
- **Mass Distribution Pattern @ 4-phase in soil pore system (i.e., water, air, solid, and NAPL phases)**. This is the predicted TPH mass distribution (expressed as a percent) in the soil pore system in all 4-phases after equilibrium partitioning.

Figure 2-16: Detailed Model Results

Additional Model Details			
Type of model used for computation:	4-Phase Model		
Computation completed?	Yes!		
100% NAPL, mg/kg	72382.1		
Mass Distribution Pattern @ 4-phase in soil pore system:			
Total Mass distributed in Water Phase:	1.16%	in Solid:	8.69%
Total Mass distributed in Air Phase:	2.75%	in NAPL:	87.40%

Notes on Residual Saturation: MTCA describes residual saturation as:

…the concentration of hazardous substances in the soil at equilibrium conditions. At concentrations above residual saturation, the NAPL will continue to migrate due to gravimetric and capillary forces and may eventually reach the groundwater, provided a sufficient volume of NAPL is released. See WAC 173-340-747(10)(b).

Soil leaching results for some petroleum compositions, especially those that include heavy fuel oils, may predict a soil-to-groundwater protective level that exceeds the theoretical maximum TPH that would be reached if all of the air space in the porous medium is filled with petroleum product. The soil concentration at this level, which is referred to as "100% NAPL", is usually well above the residual saturation level. For petroleum compositions in soil that reflect these conditions, the soil leaching result will indicate **"Use Residual Saturation Conc"**. In this case, the user should check the regulatory requirements surrounding residual saturation as specified in WAC 173-340-747(10). MTCA Table 747-5 may be used as a default for setting residual saturation levels.

2.6.4 Soil Cleanup Level: Summary of Results

Worksheet A4 (orange tab) presents a summary of the soil direct contact (Method B and C) and soil leaching results.

To access the worksheet: In the "Navigation" worksheet (green tab), select the A4 orange button to take you to the A4 Soil Cleanup Levels/Summary of Results worksheet. Alternatively, you can scroll to and click on the orange tabbed worksheet titled "A4_Soil CUL Summary".

A summary of the calculation results for the measured sample concentration (based on the soil data entered in Worksheet A1) is automatically provided in the worksheet as shown in **Figure 2-17**.

Figure 2-17: Soil Cleanup Levels: Summary of Results

A4 Soil Cleanup Levels: Summary of Results. Refer to WAC 173-340-720, 740, 745, 747

Date: 04/15/06
Site Name: ABC Site
Sample Name: SB-1
Measured Soil TPH Concentration, mg/kg: 845.15

Summary of Calculation Results

Exposure Pathway	Method/Goal	Protective TPH Conc (mg/kg)	With Measured Soil Conc	
			HI or Risk	Pass or Fail
Soil Direct Contact Protection of Soil Incidental Ingestion and Dermal Contact: Human Health	**Method B: Unrestricted Land Use**			
	TPH Soil Cleanup Level (@ HI =1)	1,500	5.7E-01	Pass
	Cancer Risk (1)		2.0E-06	**Fail**
	Method C: Industrial Land Use			
	TPH Soil Cleanup Level (@ HI = 1)	26,000	3.2E-02	Pass
	Cancer Risk (1)		9.4E-08	Pass
Soil Leaching Protection of Groundwater Quality	**Soil Concentration Protective of Target TPH Groundwater Concentration**			
	Protective TPH Soil Concentration, mg/kg =	170	---	**Fail**
	Target TPH Groundwater Concentration (µg/L)			
	500 Method A Potable Groundwater			
Remark:	*Petroleum fractionated data (EPH/VPH) and individual compounds tested in groundwater generated a Method B potable drinking water cleanup level of 340 µg/L (see Worksheet B2.1A). This level is below the most restrictive default Method A value of 500 µg/L. As a result, the Method A default potable groundwater cleanup level of 500 µg/L is selected as the target groundwater concentration to develop a TPH concentration in soil that is protective of potable groundwater.*			

Notes:

(1) Known or suspected carcinogenic chemicals that contribute to unacceptable cancer risk within the petroleum mixture are evaluated separately and must meet compliance with soil cleanup standards both on an individual basis and and when accounting for cumulative risk from multiple chemicals and pathways at the site. *See Worksheets: A2.1B and A3.1B (Soil Direct Contact); B2.1B (Potable Water Ingestion).*

Terrestrial Ecological Pathway: Check to determine if a simplified or site-specific Terrestrial Ecological Evaluation may be required (*see* WAC 173-340-7490 through ~7494).

Soil Leaching Results: Soil leaching results are presented in the box below the soil direct contact results and include the soil leaching concentration calculated (using the soil leaching partitioning models provided in Appendix B) to be protective of the target TPH groundwater concentration (see Figure 2-16). Additional information includes a Pass or Fail note, the user defined target TPH groundwater concentration and basis, and any remarks. Information about the target TPH groundwater concentration is automatically populated in this worksheet based on the information inputted in Worksheet A1 (Soil Data Entry). In this example, based on the

composition ratio of the measured soil data (TPH concentration of 845.15 mg/kg) and the site-specific hydrogeological parameters, the soil cleanup level predicted to be protective of a target TPH groundwater concentration of 500 µg/L is 170 mg/kg. The rationale for applying the Method A TPH groundwater concentration of 500 µg/L as the target TPH groundwater concentration is provided in the remarks. A “Fail” note is indicated because the TPH concentration in the sample exceeds the soil leaching cleanup level.

Note: Method B TPH groundwater cleanup level calculations (see Section 2.7 below) are not summarized in Worksheet A4. The Method B TPH potable groundwater cleanup level based on a noncancer HI of 1 is identified in the worksheet if it is selected as the target TPH groundwater concentration for the soil leaching pathway. Regardless of the target TPH groundwater concentration that is selected (e.g., Method A, Method B potable, etc.), the user still needs to review the cancer-based Method B groundwater risk results for compliance with the target risk levels defined in MTCA (see Worksheet B2.1B and Section 2.7.3.2 below).

Direct Contact Summary: The summary for soil direct contact is presented in the first box under "Exposure Pathway" and includes the following Method B and C results: the TPH cleanup level at an HI of 1, the calculated HI and cancer risk, and a Pass or Fail note. As shown in **Figure 2-17**, the measured TPH concentration of 845.15 mg/kg generates HIs of 0.57 under Method B and 0.032 under C, both of which are less than 1 and are therefore protective for noncancer effects. Calculated TPH soil cleanup levels (based on an HI of 1) are 1,500 mg/kg under Method B and 26,000 mg/kg under Method C.

Cancer risk results under Methods B and C are presented below the TPH Soil Cleanup Level and the associated noncancer results. In this example, the Method B cancer risk of 2E-06 received a "Fail" note because cPAHs generated a cancer risk of 2E-06, which exceeds the target risk of 1E-06 established for individual hazardous substances under Method B (see WAC 173-340-705(2) and Section 2.7.3.2). Cancer risk under Method C received a "Pass" because the cumulative risk is less than 1E-05.

Note: Known or suspected carcinogenic chemicals that contribute to unacceptable risk within the TPH mixture are evaluated separately and must meet compliance with soil cleanup standards both on an individual basis (e.g., not to exceed a 1E-06 risk under Method B), and when accounting for cumulative risk from multiple chemicals and pathways at the site (not to exceed a risk of 1E-05). MTCA Equation 740-5 in WAC 173-340-740 and Equation 745-5 in WAC 173-340-745 are used to evaluate cancer risk for carcinogens within the petroleum mixture under Methods B and C, respectively.

Soil Leaching Results: Soil leaching results are presented in the box below the soil direct contact results and include the soil leaching cleanup level calculated (using the soil leaching partitioning models provided in **Appendix B**) to be protective of the target TPH groundwater cleanup level (see **Figure 2-17**). Additional information includes a Pass or Fail note, the user defined target TPH groundwater cleanup level and basis, and any remarks. Information about the target TPH groundwater cleanup level is automatically populated in this worksheet based on the information inputted in Worksheet A1 (Soil Data Entry). In this example, based on the composition ratio of the measured soil data (TPH concentration of 845.15 mg/kg) and the site-specific hydrogeological parameters, the soil cleanup level predicted to be protective of a target TPH groundwater cleanup level of 500 µg/L is 170 mg/kg. The rationale for applying the Method A TPH groundwater concentration of 500 µg/L as the target TPH groundwater concentration is

provided in the remarks. A "Fail" note is indicated because the TPH concentration in the sample exceeds the soil leaching cleanup level.

Use of Method A Soil TPH Cleanup Levels: When using Method B or C to develop a TPH soil cleanup level using fractioned data (i.e., EPH or VPH), and the Method B or C TPH soil cleanup level for the site (or portion of the site contaminated by the same product) is less than the appropriate Method A TPH soil cleanup level from WAC 173-340-900, Table 740-1 (unrestricted land use) or Table 745-1 (industrial properties), the user may default to the appropriate Method A TPH soil value as the cleanup level. **Note**: Final compliance for the TPH remediation area in soil should be conducted consistent with Sections 10.1 and 10.2 of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*[45]. It's important to keep in mind that although a soil excavation may initially be defined and driven by the TPH cleanup level, the final limits of the excavation should include compliance samples analyzed for all parameters that exceed cleanup levels for the remediation area (e.g., TPH and individual compounds like BTEX).

Important: If a Method A TPH cleanup level is used rather than a site-specific Method B or C TPH cleanup level derived using the Workbook, post-remediation soil samples should be analyzed for TPH concentrations using the NWTPH method (NWTPH-Gx or Dx). This method may also be used to compare against site-specific total TPH cleanup levels calculated using EPH/VPH data.

For Method B or C TPH cleanup levels derived using this Workbook, review Table 10.1 of Ecology's *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016* for recommended alternatives for determining compliance with TPH concentrations.

2.6.5 Output-Adjusting the Results

As noted previously (see Section 2.2.2), the soil cleanup levels calculated using the soil worksheets DO NOT account for several factors. Consequently, to establish a soil cleanup level under the regulation, the cleanup level calculated using the worksheet may need to be manually adjusted to account for the following:

- Concentrations established under applicable state and federal laws (see WAC 173-340-740(3)(b)(i) or WAC 173-340-745(5)(b)(i))
- Natural background concentrations[46] (see WAC 173-340-700(6)(d))
- PQLs (see WAC 173-340-700(6)(d))

[45] https://apps.ecology.wa.gov/publications/SummaryPages/1009057.html
[46] Natural background is generally not relevant to petroleum. Except for PAHs, which may be produced naturally during incomplete burning (e.g., forest fires), the compounds provided in the MTCATPH Workbook don't occur naturally. Ecology has not adopted a natural background level for PAHs.

- Concentrations based on protection of air quality (vapor pathway[47]) (see WAC 173-340-740(3)(b)(iii)(C) or WAC 173-340-745(5)(b)(iii)(C))
- Concentrations based on protection of terrestrial ecological receptors (see WAC 173-340-740(3)(b)(ii) or WAC 173-340-745(5)(b)(ii))
- Residual saturation limit for protection of groundwater (see WAC 173-340-747(2)(b) and (10)) (*see prior discussion of residual saturation provided in Section 2.6.3.4*)
- Total site noncancer hazard and risk (see WAC 173-340-740(5)(a) or WAC 173-340-745(6)(a))

2.7 Calculating Groundwater TPH Cleanup Levels

2.7.1 Instructions on How to Calculate the Groundwater TPH Cleanup Level

The "Instructions" worksheet (green tab) provides directions for calculating groundwater TPH cleanup levels. Calculations for the potable groundwater use pathway are conducted automatically and do not require the selection of a button for executing the calculation.

2.7.2 *Entering Data – B1 Groundwater Data Entry Worksheet (Blue Tab)*

The user is required to enter all necessary analytical data before performing any data analysis for the potable groundwater ingestion pathway. Note that at any time during the evaluation, the user can go back and change the data that has been entered.

2.7.2.1 Accessing the Groundwater Data Entry Worksheet

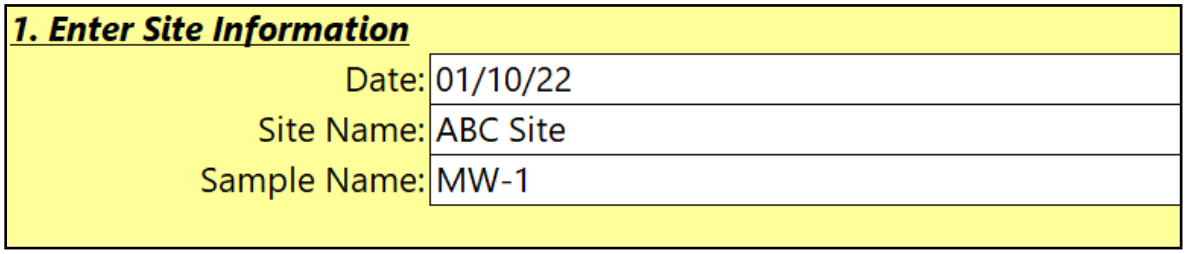
In the "Navigation" worksheet (green tab), select the B1 blue button to take you to the B1_Groundwater Data Entry worksheet. Alternatively, you can scroll to and click on the blue tabbed worksheet titled "B1_Groundwater Data Entry".

2.7.2.2 Input Data – Part 1: Enter Logistical Site Information

User-specified text format is entered here. As shown in **Figure 2-18**, enter descriptive text for the identification of a particular site (or a sample or a project) such as date, site name, sample name, and additional information (in the "REMARK" text box) if necessary. The Workbook does not require the user to enter information for any of these entries, as they are solely there for the benefit of the user. The site information entered in the B1_Groundwater Data Entry worksheet (shown in **Figure 2-18** below) is automatically carried forward to the other groundwater related worksheets (blue tabs).

[47] To assess the vapor pathway for petroleum mixtures, see Ecology's: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.

Figure 2-18: Enter Site Information – Groundwater Sample



2.7.2.3 Input Data – Pat 2: Enter Measured Groundwater Concentrations

The second part of the worksheet (illustrated in **Figure 2-19**) requires the user to input analytical data (groundwater concentrations: µg/L) in the non-shaded (white) cells for the chemicals of concern and petroleum EC groups appropriate for the type of TPH mixture being evaluated.

Figure 2-19: Entering Groundwater Concentration Measured

2. Enter Groundwater Concentration Measured

Chemical or Petroleum Fraction	Measured GW Conc µg/L	Composition Ratio %
AL_EC >5-6		0.0%
AL_EC >6-8		0.0%
AL_EC >8-10	1	0.4%
AL_EC >10-12	1	0.4%
AL_EC >12-16	1	0.4%
AL_EC >16-21	1	0.4%
AL_EC >21-34	1	0.4%
AR_EC >8-10	1	0.4%
AR_EC >10-12	1	0.4%
AR_EC >12-16		0.0%
AR_EC >16-21	1	0.4%
AR_EC >21-34		0.0%
Benzene	6	2.1%
Toluene	23	8.1%
Ethylbenzene	23	8.1%
Total Xylenes	200	70.6%
Naphthalene	5	1.8%
1-Methyl Naphthalene	2	0.7%
2-Methyl Naphthalene	12	4.2%
n-Hexane	2	0.7%
MTBE	1	0.4%
Ethylene Dibromide (EDB)		0.0%
1,2 Dichloroethane (EDC)		0.0%
Benzo(a)anthracene	0.01	0.0%
Benzo(b)fluoranthene	0.1	0.0%
Benzo(k)fluoranthene	1	0.4%
Benzo(a)pyrene		0.0%
Chrysene	0.2	0.1%
Dibenz(a,h)anthracene	0.01	0.0%
Indeno(1,2,3-cd)pyrene	0.1	0.0%
	283.42	**100%**

Note that the right-hand “Composition Ratio” column automatically calculates the percentage of the total mixture represented by the particular fraction/compound. Be sure that the correct and consistent units are used for all chemical concentrations (micrograms/liter = µg/L = ppb) and that you use the same number of significant figures as reported by the laboratory. Leave blank

or enter zero (0) for substances that are not analyzed (e.g., for gasoline, you probably would not test for the cPAHs, so these entries would all be blank or “0”).

For values below the MDL, substitute one-half the MDL. For values above the MDL but below the PQL, use the value reported (e.g., J qualified data). However, for a hazardous substance or petroleum fraction that has never been detected in any sample at a site and is not suspected of being present at the site based on site history or other knowledge, leave blank or enter “0” for that value.

Note: All analytical data entries must be numeric values. Any text entry may cause an error.

Composition Overlaps: Refer to Section 2.6.2.3 for details.

Avoid Double Counting: Refer to Section 2.6.2.3 for details.

THIS COMPLETES DATA ENTRY FOR THE GROUNDWATER WORKSHEET. SAVE YOUR WORK BEFORE CONTINUING. You should save the file under a new file name that pertains to the particular site and sample.

2.7.3 Groundwater Cleanup Level Calculations

The groundwater worksheets in the **MTCATPH 12.0 Workbook** provide a means for evaluating the results based on the entered groundwater data. The following discussion on evaluating the results is **organized by worksheet**. As described previously, the Workbook allows the user to examine **two situations**.

- **First**, the Workbook provides the tools necessary to calculate the noncancer hazard and risk from potable water ingestion for the measured sample concentration (i.e., current conditions).

- **Second**, the Workbook provides the tools necessary to calculate a groundwater cleanup level based on potable water ingestion under Method B. The Workbook “back-calculates” a cleanup level based on the noncancer hazard and target risk levels set forth in the regulation.

2.7.3.1 Worksheet B2.1A – Evaluation of the Groundwater Potable Ingestion Pathway (Noncancer Effects) under Method B (Unrestricted Land Use)

Worksheet B2.1A presents the Method B potable groundwater ingestion noncancer hazard calculations and the TPH cleanup level based on an HI of 1 for the TPH mixture.

To access the worksheet: In the “Navigation” worksheet (green tab), select the B2.1A blue button to take you to the B2.1A Method B Potable Water Ingestion TPH Cleanup Level worksheet. Alternatively, you can scroll to and click on the blue tabbed worksheet titled “B2.1A_GW B_TPH CUL”.

Potable Water Ingestion Noncancer Hazard Calculations: Results for the measured sample concentration (based on the groundwater data entered in Worksheet B1_Groundwater Data Entry) are automatically calculated as shown in two places in the worksheet (both shaded in light blue). First, a summary box (see **Figure 2-20**) is located in the upper right-hand portion of the worksheet.

Figure 2-20: HI and TPH Cleanup Level (Measured Concentration) – Method B Groundwater

TPH CLEANUP LEVEL - MEASURED SAMPLE CONCENTRATION (POTABLE USE)
Measured TPH Groundwater Conc, µg/L = 283.42
HI = 8.4E-01 **Pass** MTCA Eq. 720-3 (2) **Method B TPH Cleanup Level (µg/L) (HI = 1) = 337.23** **2 Significant Figures = 340**
The overal TPH Method B potable groundwater protective cleanup level is based on a noncancer HI of 1. *See* WAC 173-340-720(4)(b)(iii)(C). The TPH Cleanup Level at 2 significant figures is considered to be sufficiently protective even though in some cases it may slightly exceed an HI of 1.0. **Adjustments:** Adjustments downward may be needed to the TPH potable groundwater cleanup level to prevent exceedances of state and federal ARARs such as MCLs and NAPL limitation (*see* WAC 173-340-720(7)(b, d)), including concentrations based on surface water impacts (*see* WAC 173-340-720 (4)(b)(ii)).

This box provides the total concentration (µg/L) of all the TPH fractions and compounds entered by the user (283.42 µg/L in this example), the corresponding HI (0.84), a Pass or Fail note, the TPH cleanup level based on an HI of 1 (340 µg/L), and notes for interpreting the results. In this particular example, the measured sample concentration received a "Pass" since the HI does not exceed the allowable level (i.e., HI of 1) established for Method B mixtures under WAC 173-340-705(4).

Second, the four columns located to the right of the column containing measured groundwater concentrations (under heading: "Measured Sample Concentration"; see **Figure 2-21**[48]) provide the detail necessary to determine which fractions and chemicals are contributing to the HI. The sum of the individual HQs (i.e., the HI) is shown at the bottom of the column. Noncancer exceedances are noted for individual fractions and single hazardous substances that exceed an HQ of 1, and if the HI exceeds 1. Also presented are potable groundwater cleanup levels that have been adjusted to account for levels based on applicable, relevant, and appropriate requirements (ARARs; see discussion below). Exceedances of these levels are noted as ">Pot CUL" as discussed below.

[48] For illustration purposes, the list of individual fractions and chemicals shown in **Figure 2-21** focused on those that contributed to the noncancer HI (with exception of several of the petroleum fractions).

Figure 2-21: Noncancer Hazard Details (Measured Concentration) – Method B Groundwater

Chemical of Concern or EC group	Measured Sample Concentration				
			Noncancer Hazards		
	Measured GW Conc	Potable GW Cleanup Level (1)	Noncancer HQ MTCA Eq. 720-1 (2)	Percent Contribution to the Total HI	Noncancer Exceedances (3)
	µg/L	µg/L	unitless	percent	
Petroleum EC Fraction					
AL_EC >5-6	0				
AL_EC >6-8	0				
AL_EC >8-10	1		1.25E-02	1.5%	
AL_EC >10-12	1		1.25E-02	1.5%	
AL_EC >12-16	1		1.25E-02	1.5%	
AL_EC >16-21	1		4.17E-05	0.0%	
AL_EC >21-34	1		4.17E-05	0.0%	
AR_EC >8-10	1		1.25E-03	0.1%	
AR_EC >10-12	1		6.25E-03	0.7%	
AR_EC >12-16	0				
AR_EC >16-21	1		4.17E-03	0.5%	
AR_EC >21-34	0				
Benzene	6	5 MCL	1.88E-01	22.3%	>Pot CUL
Toluene	23	640 MCL N adj	3.59E-02	4.3%	
Ethylbenzene	23	700 MCL	2.88E-02	3.4%	
Total Xylenes	200	1600 MCL N adj	1.25E-01	14.9%	
Naphthalene	5	160 N	3.13E-02	3.7%	
1-Methyl Naphthalene	2	1.5 C	3.57E-03	0.4%	>Pot CUL
2-Methyl Naphthalene	12	32 N	3.75E-01	44.6%	
n-Hexane	2	480 N	4.17E-03	0.5%	
Sum	**283.42**	---	8.40E-01	100%	HI ≤ 1

ARARs are considered sufficiently protective under MTCA if they are associated with less than an HQ of 1 or a risk of 1E-05. Otherwise, they must be adjusted downward so that they don't exceed these target levels (see WAC 173-340-705(5)). Groundwater concentrations that exceed the potable groundwater cleanup level are noted as ">Pot CUL" as shown in **Figure 2-21**. Cases where the groundwater concentration is greater than the potable groundwater cleanup level, but the HQ is less than 1, occur when the potable groundwater cleanup level is driven by the cancer endpoint or an ARAR such as a maximum contaminant level (MCL). As shown in **Figure 2-21**, although groundwater concentrations of benzene and 1-methyl naphthalene both generate HQs of less than 1, they exceed their respective potable groundwater cleanup levels. The benzene concentration exceeds its MCL (sufficiently protective at a 1E-05 risk), and 1-methyl naphthalene exceeds its groundwater cleanup level based on a risk of 1E-06 (using MTCA WAC 173-340-720, Equation 720-2 because an MCL is not available). As such, although the TPH groundwater concentration "Passes" with an HI of less than 1, the user still needs to address potable groundwater cleanup level exceedances for benzene and 1-methylnaphthalene (see Section 2.7.3.2 below).

Groundwater TPH Cleanup Levels Protective of Other Criteria: The Method B groundwater calculations presented in **Figures 2-20 and 2-21** above apply only to potable water ingestion. As discussed previously in Section 2.2.2, the user must develop a target TPH groundwater concentration based on the exposure pathway that generates the most stringent cleanup level (i.e., lowest concentration). To assist the user in this evaluation, a separate box in the middle of Worksheet B2.1A (shaded in green) identifies options for developing groundwater TPH cleanup levels that are protective of other complete pathways at a site (e.g., protection of surface water and vapor intrusion pathways; see **Figure 2-22**). The most stringent TPH groundwater cleanup level is the one that is inputted in Worksheet A1 (Soil Data Entry) and used in the soil leaching calculations.

Figure 2-22: Groundwater TPH Cleanup Levels Protective of Other Criteria

Groundwater TPH Concentrations Protective of Other Criteria (µg/L)			
	Surface Water - Aquatic Life		
	Freshwater	Marine	
TPH Product	GW $TPH_{fresh\ sw}$	GW $TPH_{marine\ sw}$	Human Health
Gasoline Range Organics	1,000	1,700	
Diesel Range Organics "Unweathered"	150	50	
Diesel Range Organics "Weathered"	3,000	2,100	

Refer to IM No. 23 for gasoline and diesel concentrations protective of surface water. (click on this link)

To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance for Evaluating Soil Vapor Intrusion in Washington State (click on this link).

2.7.3.2 Worksheet B2.1B – Evaluation of the Groundwater Potable Ingestion Pathway (Carcinogenic Risk) under Method B (Unrestricted Land Use)

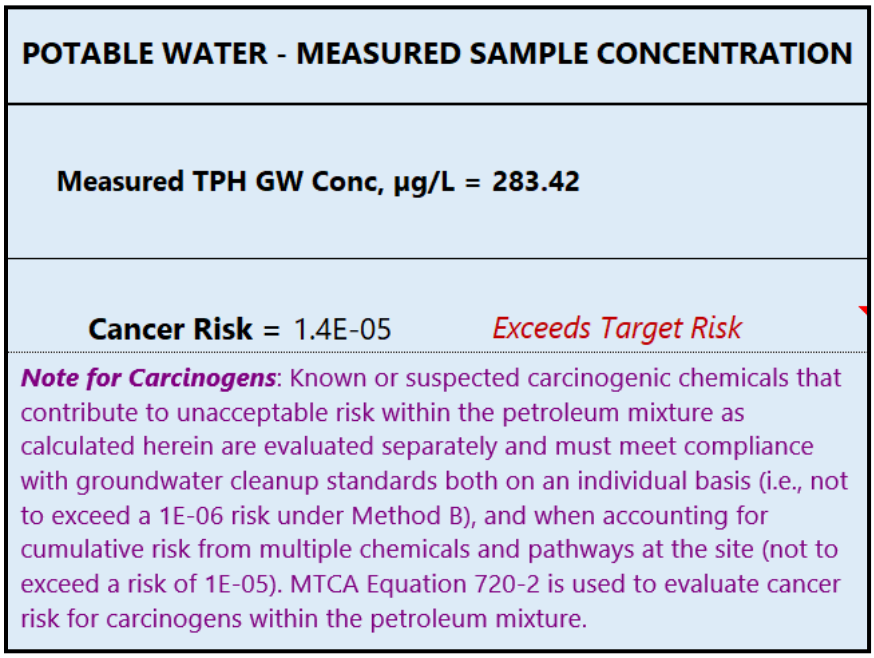
Worksheet B2.1B presents the Method B potable water ingestion cancer risk calculations for individual hazardous substances within the TPH mixture. Note that known or suspected carcinogenic chemicals that contribute to unacceptable risk within the TPH mixture are evaluated separately and must meet compliance with groundwater cleanup standards both on an individual basis (i.e., not to exceed a 1E-06 risk under Method B), and when accounting for cumulative risk from multiple chemicals and pathways at the site (not to exceed a risk of 1E-05). MTCA WAC 173-340-720, Equation 720-2 is used to evaluate cancer risk for carcinogens within the petroleum mixture.

To access the worksheet: In the "Navigation" worksheet (green tab), select the B2.1B blue button to take you to the B2.1B Method B Potable Water Ingestion Cancer Risk worksheet. Alternatively, you can scroll to and click on the blue tabbed worksheet titled "B2.1B_GW B_Cancer Risk".

Potable Water Ingestion Risk Calculations: Results for the measured sample concentration (based on the groundwater data entered in Worksheet B1_Groundwater Data Entry) are automatically calculated as shown in two places in the worksheet (both shaded in light blue).

First, a summary box (shown in **Figure 2-23**) is located in the upper right-hand portion of the worksheet.

Figure 2-23: Cancer Risk (Measured Concentration) – Method B Groundwater



This box provides the total concentration (µg/L) of all the TPH fractions and compounds entered by the user (283.42 µg/L in this example), the corresponding total cancer risk, a cancer risk exceedance note, and notes for interpreting the results. In this particular example, the cumulative risk of 1.4E-05 exceeds the target risk of 1E-05 established for multiple hazardous substances under Method B (see WAC 173-340-705(4)).

Second, the four columns located to the right of the column containing potable groundwater cleanup levels (under heading: "Measured Sample Concentration"; see **Figure 2-24**[49]) provide the detail necessary to determine which fractions and chemicals are contributing to the risk. The sum of the individual risks (cumulative risk) is shown at the bottom of the column. Cancer exceedances are noted for individual fractions and single hazardous substances that exceed a risk of 1E-06, and if the cumulative risk exceeds 1E-05. As shown in **Figure 2-24**, individual risks from benzene, 1-methyl naphthalene, and cPAHs[50] all exceed the MTCA Method B individual risk threshold of 1E-06. These chemicals contributed over 99 percent to the cumulative risk of 1.4E-05. Also presented are potable groundwater cleanup levels that have been adjusted to account for levels based on ARARs (see discussion below), and cancer-based cleanup levels based on a 1E-06 risk.

[49] For illustration purposes, only the results for chemicals that generated a cancer risk are shown on **Figure 2-24**.
[50] The cPAH TEQ concentration shown in **Figure 2-24** was derived using the toxicity equivalent factor (TEF) approach outlined in Ecology's Implementation Memorandum No. 10.

Figure 2-24: Cancer Risk Details (Measured Concentration) – Method B Groundwater

Chemical of Concern or EC group	Measured Sample Concentration					
			Cancer Risk			
	Measured GW Conc	Potable GW Cleanup Level (1)	Cancer Risk MTCA Eq. 720-2 (2)	Percent Contribution to the Total Cancer Risk	Cancer Risk Exceedances (3)	Cancer-based Concentration @ 1E-06 Risk
	µg/L	µg/L	unitless	percent		µg/L
Benzene	6	5 MCL	7.5E-06	52.8%	>1E-06; >Pot CUL	0.8
Toluene	23	640 MCL N adj				
Ethylbenzene	23	700 MCL				
Total Xylenes	200	1600 MCL N adj				
Naphthalene	5	160 N				
1-Methyl Naphthalene	2	1.5 C	1.3E-06	9.3%	>1E-06; >Pot CUL	1.5
2-Methyl Naphthalene	12	32 N				
n-Hexane	2	480 N				
MTBE	1	24 C	4.1E-08	0.3%		24
Ethylene Dibromide (EDB)	0	0.05 MCL				
1,2 Dichloroethane (EDC)	0	4.8 MCL C adj				
Benzo(a)anthracene	0.01					
Benzo(b)fluoranthene	0.1					
Benzo(k)fluoranthene	1					
Benzo(a)pyrene	0	0.2 MCL				0.023
Chrysene	0.2					
Dibenz(a,h)anthracene	0.01					
Indeno(1,2,3-cd)pyrene	0.1					
cPAH TEQ (using TEFs) (5), (6)	***0.124***		5.4E-06	37.7%	>1E-06; see note 4	
Sum	**283.42**	---	1.43E-05	100%	> 1E-05	

ARARs are considered sufficiently protective under MTCA if they are associated with less than an HQ of 1 or a risk of 1E-05. Otherwise, they must be adjusted downward so that they don't exceed these target levels (see WAC 173-340-705(5)). In the example shown on **Figure 2-24**, groundwater concentrations for benzene and 1-methyl naphthalene exceed their respective potable groundwater cleanup levels and are noted as ">Pot CUL".

If the potable groundwater ARAR-based cleanup levels for benzene (5 µg/L) and cPAHs (0.2 µg/L) and the cancer-based cleanup level for 1-methyl naphthalene (1.5 µg/L) are input to Worksheet B1, the cumulative risk for the petroleum mixture is 1.6E-05, which exceeds the MTCA threshold of 1E-05. Therefore, although the ARAR based potable groundwater cleanup levels for benzene and cPAHs are sufficiently protective on an individual basis (i.e., less than a risk of 1E-05), further downward adjustment is needed to achieve the cumulative risk threshold of 1E-05 as required under MTCA.

Note: Only the CULs for individual carcinogenic chemicals need to be adjusted. The TPH cleanup level based on an HI of 1 does not need to be adjusted.

An example of how a downward adjustment may be made to meet the cumulative risk threshold would be to first add up the risk due to 1-methyl naphthalene at its 1E-06 cancer-based level (1.5 µg/L) and the risk generated by MTBE (4.1E-08). This equals a risk of 1.04E-06, which means that the combined risk from benzene and cPAHs can be set to 8.96E-06 (or 4.48E-06 for each) to achieve a cumulative risk of 1E-05.

This results in cleanup levels of 3.6 µg/L for benzene and 0.1 µg/L for cPAHs (rounded to 2 significant figures). Cleanup levels for benzene and cPAHs based on a risk of 4.48E-06 can be calculated using a simple proportion problem as illustrated below.

$$\text{Benzene CUL } (\frac{\mu g}{L}) = \frac{\text{Measured GW Conc } \frac{\mu g}{L} \times \text{Target Risk (i.e., 4.48E-06)}}{\text{Risk @ Measured GW Conc}}$$

$$\text{Benzene CUL } (\frac{\mu g}{L}) = \frac{6 \frac{\mu g}{L} \times \text{4.48E-06}}{\text{7.5E-06}} = 3.58 \; or \; 3.6 \; \mu g/L$$

$$\text{cPAH CUL } (\frac{\mu g}{L}) = \frac{\text{Measured GW Conc } \left(\text{cPAH TEQ}^{51}\right) \frac{\mu g}{L} \times \text{Target Risk (i.e., 4.48E-06)}}{\text{Risk @ Measured GW Conc}}$$

$$\text{cPAH CUL } (\frac{\mu g}{L}) = \frac{0.124 \frac{\mu g}{L} \times \text{4.48E-06}}{\text{5.4E-06}} = 0.103 \; or \; 0.1 \; \mu g/L$$

Note: The risk of 8.96E-06 does not have to be split evenly between benzene and cPAHs. Any apportionment of risk is acceptable if the cleanup level for each carcinogen does not exceed its individual starting cleanup level ("Potable GW Cleanup Level" in third column of **Figure 2-24**) and the total cancer risk summed across all carcinogens does not exceed 1E-05.

2.7.4 Output-Adjusting the Results

As noted previously (see Section 2.2.3), the potable groundwater cleanup levels calculated using the groundwater worksheets DO NOT account for several factors. Consequently, to establish a potable groundwater cleanup level under the regulation, the cleanup level calculated using the worksheets may need to be manually adjusted to account for the following:

- Natural background concentrations[52] (see WAC 173-340-700(6)(d))

[51] The "cPAH TEQ" concentration is derived using the toxicity equivalent factor (TEF) approach outlined in Ecology's Implementation Memorandum No. 10.
https://apps.ecology.wa.gov/publications/documents/1509049.pdf
This concentration represents the total toxic equivalent (TEQ) concentration for the cPAH mixture and is compared to the cleanup level for benzo(a)pyrene. cPAH = Carcinogenic Polycyclic Aromatic Hydrocarbons

[52] Natural background is generally not relevant to petroleum. Except for PAHs, which may be produced naturally during incomplete burning (e.g., forest fires), the compounds provided in the MTCATPH Workbook don't occur naturally. Ecology has not adopted a natural background level for PAHs.

- PQLs (see WAC 173-340-700(6)(d))
- Concentrations based on protection of air (vapor pathway[53]) (see WAC 173-340-720(1)(d)(iv))
- Concentrations based on potential surface water impacts (see WAC 173-340-720(4)(b)(ii) and (5)(b)(ii))
- Nonaqueous phase liquid (NAPL) limitation[54] (see WAC 173-340-720(7)(d))
- Total site noncancer hazard and risk (see WAC 173-340-720(7)(a))
- Potential concentrations of non-petroleum polar organic metabolites from weathered petroleum groundwater plumes (see Ecology's *Guidance for Silica Gel Cleanup in Washington State.* November 2023. Publication No. 22-09-059)
- Biodegradation. For example, if modeling or groundwater monitoring indicates that biological degradation of residual petroleum may result in violation of the drinking water standards for other chemicals (e.g., naturally occurring metals such as arsenic, iron, and manganese). See *Guidance for Remediation of Petroleum Contaminated Sites, Revised June 2016*, Section 8.9, Step 9

[53] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.
[54] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. *See* WAC 173-340-720(7)(d).

Appendix A:

Primer on TPH Fractions and Analytical Requirements for TPH Mixtures

Unlike individual hazardous substances, petroleum hydrocarbon mixtures such as gasoline, diesel fuel, lubricating oils, etc. are comprised of thousands of chemical compounds. Typically, the concentration of these mixtures is measured as "total petroleum hydrocarbons" or "TPH" within a specific range of hydrocarbon chain lengths, such as the "gasoline range" or the "diesel range"[1]. These TPH concentrations are the collective concentrations of the individual petroleum compounds within the specified range.

TPH mixtures can also contain specific chemicals of concern and, depending on the type of mixture, these specific chemicals may need to be tested to make sure a site is adequately characterized and that all cleanup requirements are considered. These include volatile compounds such as benzene, toluene, ethylbenzene, and xylenes (collectively referred to as "BTEX"), n-hexane, and naphthalene, but may also include fuel additives such as methyl tertiary-butyl ether (MTBE). Information contained in WAC 173-340-830 provides a more detailed discussion of the types of testing required for petroleum releases. Table 830-1 in WAC 173-340-900 is a summary of the required testing for different types of petroleum releases.

The MTCA Cleanup Regulation allows for site specific chemical characterization of released petroleum to develop a cleanup level tailored to the specific composition of petroleum present in soil or groundwater. This method, known as "TPH fractionation", measures the concentrations of twelve sub-groups or "fractions" of TPH within the released mixture and is based on work by a consortium of national experts (TPH Criteria Working Group, 1997[2]). These fractions are defined based upon their relative average molecular "sizes", from the lighter-weight (and typically more volatile and soluble) compounds to the heavier, less volatile, and soluble compounds. The measured concentrations of each of the twelve fractions are then assessed, together with their individual chemical and toxicological properties, to determine the appropriate TPH cleanup level. Depending on the particular TPH mixture present, certain hazardous substances (e.g., benzene, carcinogenic PAHs, or MTBE) must also be measured in addition to the individual TPH fractions.

The detailed analytical methods, including VPH (Volatile Petroleum Hydrocarbons) and EPH (Extractable Petroleum Hydrocarbons) for petroleum hydrocarbons, are described in a separate Ecology document (Analytical Methods for Petroleum Hydrocarbons, 1997[3]).

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[1] Fresh gasoline is generally composed of lighter carbon fractions up to Equivalent Carbon (EC) 12. Fresh diesel is generally composed of heavier fractions mostly greater than EC 12 and up to EC 34.

[2] TPH Criteria Working Group, 1997. Total Petroleum Hydrocarbon Criteria Working Group Series. Volume III: Selection of Representative Total Petroleum Hydrocarbon (TPH) Fractions Based on Fate and Transport Considerations, Ed.: J. B. Gustafson, J. G. Tell, and D. Orem, Amherst Scientific Publishers.

> **NOTE**: As of this writing, this and other volumes are available on the Internet at: https://netforum.avectra.com/eweb/Shopping/Shopping.aspx?Site=aehs&WebCode=Shopping&cart=0 (search for "TPH Series" on the web page).

[3] Washington State Department of Ecology, 1997. *Analytical Methods for Petroleum Hydrocarbons*, Publication No. ECY 97-602. https://apps.ecology.wa.gov/publications/SummaryPages/97602.html

Appendix B:

Equations and Default Values for Calculating Soil Cleanup Levels Based on the Leaching Pathway

(Protection of Groundwater)

THREE-PHASE PARTITIONING

Equation 747-1: Three-Phase Partitioning Equilibrium Equation.

$$C_s = C_w \times UCF \times DF \times \left[K_d + \frac{\theta_w + \theta_a \times H_{cc}}{\rho_b}\right]$$

Parameter	Definition	Default Value (Unsaturated Zone)	Default Value (Saturated)	Units
C_s	Soil concentration	(calculated)	(calculated)	mg/kg
C_w	Groundwater cleanup level established under WAC 173-340-720	Chem-specific	Chem-specific	µg/L
UCF	Unit conversion factor	1E-3	1E-3	mg/ug
DF	Dilution factor	20	1	unitless
K_d	Distribution coefficient	Chem-specific **(1)**	Chem-specific **(1)**	L/kg
θ_w	Water-filled soil porosity	0.3	0.43 **(3)**	unitless, ml/ml
θ_a	Air-filled soil porosity	0.13	Zero	unitless, ml/ml
H_{cc}	Henry's law constant	Chem-specific **(2)**	Chem-specific **(2)**	unitless
ρ_b	Dry soil bulk density	1.5	1.5	kg/L

Footnotes:

(1) For K_d, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(c).

(2) For H_{cc}, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(d).

(3) To evaluate saturated soil conditions in the Workbook, the value for θw is unknown and must be solved for (Excel uses Solver), and the user should leave it as 0.3 as indicated in Equation 747-6 of WAC 173-340-747(6). This results in an initial starting point of 0.13 for the volumetric air content in the soil leaching calculation.

Equation 747-2: Derivation of a Distribution Coefficient (K_d) for Organic Hazardous Substances Based on the Soil Organic Carbon-Water Partitioning Coefficient (K_{oc})

$$K_d = K_{oc} \times f_{oc}$$

Parameter	Definition	Default Value	Units
K_d	Distribution coefficient	(Calculated or site-specific)	L/kg
K_{oc}	Soil organic carbon-water partitioning coefficient	Chem-specific **(1)**	L/kg
f_{oc}	Soil fraction of organic carbon	0.001	unitless, g/g

Footnotes:

(1) For K_{oc}, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(c)(i).

Equation 747-3: Deriving a Dilution Factor from Site-Specific Estimates of Infiltration and Groundwater Flow Volume

$$DF = \frac{(Q_p + Q_a)}{Q_p} = 1 + \frac{Q_a}{Q_p}$$

Parameter	Definition	Default Value	Units
DF	Dilution factor	(calculated)	unitless
Q_p	Flowrate of water infiltrating (*see* Equation 747-5)	(calculated)	m^3/yr
Q_a	Ground water flowrate (*see* Equation 747-4)	(calculated)	m^3/yr

Equation 747-4: Calculating Groundwater Flowrate (Q_a)

$$Q_a = K \times A \times I$$

Parameter	Definition	Default Value	Units
Q_a	Ground water flowrate	(calculated)	m^3/yr
K	Hydraulic conductivity	Site-specific measurement	m/yr
A	Cross-sectional area of aquifer mixing zone **(1)**	Site-specific measurement	m^2
I	Hydraulic gradient	Site-specific measurement	unitless, m/m

Footnotes:

(1) The aquifer mixing zone thickness shall not exceed 5 meters in depth and be equal to a unit width of 1 meter, unless it can be demonstrated empirically that the mixing zone thickness exceeds 5 meters.

Equation 747-5: Calculating the Flowrate of Water Infiltrating (Q_p)

$$Q_p = L \times W \times Inf$$

Parameter	Definition	Default Value	Units
Q_p	Flowrate of water infiltrating	(calculated)	m^3/yr
L	Estimated length of contaminant source area parallel to groundwater flow	Site-specific measurement	m
W	Unit width of contaminant source area	1.0	m
Inf	Infiltration rate	Site-specific measurement **(1)**	m/yr

Footnotes:

(1) A default value may be used for infiltration rate. For sites **west** or **east** of the Cascade Mountains, the default annual infiltration value shall be **70 percent** or **25 percent**, respectively, of the average annual precipitation amount.

FOUR-PHASE PARTITIONING

Equation 747-6: Conservation of Volume Equation.

$$n = \theta_w + \theta_a + \theta_{NAPL}$$

Parameter	Definition
n	Total soil porosity (ml total pore space/ml total soil volume). Use a default value of 0.43 ml/ml or use a value determined from site-specific measurements.
θ_w	Volumetric water content (ml water/ml soil). For unsaturated soil use a default value of 0.3 or a value determined from site-specific measurements. For saturated soil this value is unknown and must be solved for. Volumetric water content equals the total soil porosity minus volume occupied by the NAPL.
θ_a	Volumetric air content (ml air volume/ml total soil volume). For unsaturated soil this value is unknown and must be solved for. Volumetric air content equals the total soil porosity minus the volume occupied by the water and NAPL. For saturated soil this value is zero.
θ_{NAPL}	Volumetric NAPL content (ml NAPL volume/ml total soil volume). For both unsaturated and saturated soil this value is unknown and must be solved for.

Equation 747-7: Four-Phase Partitioning Equilibrium Equation

$$\frac{M_T^i}{m_{soil}} = \frac{x_i S_i}{\rho_b}\left[\theta_w + K_{oc}^i\, f_{oc}\, \rho_b + H_{cc}^i\, \theta_a + \frac{GFW_i}{S_i}\ \rho_{NAPL}\, \theta_{NAPL}\right]$$

Parameter	Definition
M_T^i	Total mass of each component in the system (mg). This value is derived from site-specific measurements.
m_{soil}	Total soil mass (kg). This value is derived from site-specific measurements.
x_i	Mole fraction (at equilibrium) of each component (dimensionless). This value is unknown and must be solved for.
S_i	Water Solubility of each component (mg/L). See WAC 173-340-900, Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.
ρ_b	Dry soil bulk density (default is 1.5 kg/L).
θ_w	Volumetric water content (ml water/ml soil).
K_{oc}^i	Soil organic carbon-water partitioning coefficient for each component (L/kg). See Table 747-4 for petroleum hydrocarbons; see WAC 173-340-747(4)(b) for other hazardous substances.
f_{oc}	Mass fraction of soil natural organic carbon (default is 0.001 g organic carbon/g soil).
H_{cc}^i	Henry's law constant for each component (dimensionless). See WAC 173-340-900, Table 747-4 for petroleum hydrocarbons; see WAC 173-340-747(4)(c) for other hazardous substances.
GFW_i	Gram formula weight, or molecular weight of each component (mg/mol). See WAC 173-340-900, Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.
ρ_{NAPL}	Molar density of the mixture (mol/L). See WAC 173-340-747, Equation 747-8.
θ_{NAPL}	Volumetric NAPL content (ml NAPL volume/ml total soil volume).
Component	For petroleum mixtures, this means the petroleum fractions, and organic hazardous substances with a reference dose; for other hazardous substances, this means each organic hazardous substance that is found in the NAPL.

Equation 747-8: Molar Density Equation

$$\rho_{NAPL} = \frac{\left[\sum x_i GFW_i \Big/ \left(\sum x_i GFW_i / \rho_i\right)\right]}{\sum x_i GFW_i}$$

$$= \frac{1}{\sum\left(x_i GFW_i / \rho_i\right)}$$

Parameter	Definition
ρ_{NAPL}	Molar density of the mixture (mol/L).
GFW_i	Gram formula weight, or molecular weight of each component (mg/mol). See WAC 173-340-900, Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.
x_i	Mole fraction (at equilibrium) of each component (dimensionless) after equilibration. This value is unknown and must be solved for.
ρ_i	Density of each component (mg/L). See WAC 173-340-900, Table 747-4 for petroleum hydrocarbons; see the scientific literature for other hazardous substances.
Component	For petroleum mixtures, this means the petroleum fractions plus organic hazardous substances with a reference dose; for other hazardous substances, this means each organic hazardous substance that is found in the NAPL.

Appendix C: Properties of Chemicals Commonly Found at Petroleum Contaminated Sites

TPH Excel Workbook Chemical Database – Updated October 2023

CAS	Chemical or Petroleum Fraction	Toxicity Surrogate Chemical (EC Fractions); Other Notes	Equivalent Carbon Number	Oral Reference Dose (RfDo) mg/kg-day	Dermal Reference Dose (RfDd) mg/kg-day	Inhalation Correction Factor (INH) unitless	Dermal Absorption Fraction (ABS) unitless	Gastrointestinal Absorption Conversion Factor (GI) unitless	Oral Cancer Potency Factor (CPFo) kg-day/mg	Dermal Cancer Potency Factor (CPFd) kg-day/mg	Molecular Weight GFW mg/mol	Aqueous Solubility S mg/L	Henry's Law Constant H_{cc} unitless	Soil Organic Carbon-Water Partitioning Coef K_{oc} L/kg	Liquid Density ρ mg/L
	Petroleum EC Fraction														
110-83-8	AL_EC >5-6	Cyclohexene (1)	5.5	0.005	0.004	2	0.03	0.8	NTV	NTV	8.100E+04	3.600E+01	3.300E+01	8.000E+02	6.700E+05
110-83-8	AL_EC >6-8	Cyclohexene (1)	7	0.005	0.004	2	0.03	0.8	NTV	NTV	1.000E+05	5.400E+00	5.000E+01	3.800E+03	7.000E+05
	AL_EC >8-10	see note (2)	9	0.01	0.008	2	0.03	0.8	NTV	NTV	1.300E+05	4.300E-01	8.000E+01	3.020E+04	7.300E+05
	AL_EC >10-12	see note (2)	11	0.01	0.008	2	0.03	0.8	NTV	NTV	1.600E+05	3.400E-02	1.200E+02	2.340E+05	7.500E+05
	AL_EC >12-16	see note (2)	14	0.01	0.008	2	0.03	0.8	NTV	NTV	2.000E+05	7.600E-04	5.200E+02	5.370E+06	7.700E+05
8012-95-1	AL_EC >16-21	White Mineral Oil	19	3	2.4	2	0.03	0.8	NTV	NTV	2.700E+05	1.300E-06	4.900E+03	9.550E+09	7.800E+05
8012-95-1	AL_EC >21-34	White Mineral Oil	28	3	2.4	2	0.03	0.8	NTV	NTV	4.000E+05	1.500E-11	1.000E+05	1.070E+10	7.900E+05
98-82-8	AR_EC >8-10	Cumene	9	0.1	0.08	2	0.03	0.8	NTV	NTV	1.200E+05	6.500E+01	4.800E-01	1.580E+03	8.700E+05
91-20-3	AR_EC >10-12	Naphthalene	10	0.02	0.016	2	0.03	0.8	NTV	NTV	1.300E+05	2.500E+01	1.400E-01	2.510E+03	9.000E+05
92-52-4	AR_EC >12-16	1,1-Biphenyl	14	0.5	0.25	2	0.1	0.5	NTV	NTV	1.500E+05	5.800E+00	5.300E-02	5.010E+03	1.000E+06
129-00-0	AR_EC >16-21	Pyrene	19	0.03	0.015	2	0.1	0.5	NTV	NTV	1.900E+05	5.100E-01	1.300E-02	1.580E+04	1.160E+06
206-44-0	AR_EC >21-34	Fluoranthene	28	0.04	0.02	1	0.1	0.5	NTV	NTV	2.400E+05	6.600E-03	6.700E-04	1.260E+05	1.300E+06
71-43-2	Benzene		6.5	0.004	0.00388	2	0.0005	0.97	0.055	0.056701031	7.800E+04	1.750E+03	1.339E-01	6.200E+01	8.765E+05
108-88-3	Toluene		7.6	0.08	0.08	2	0.03	1	NTV	NTV	9.200E+04	5.260E+02	1.485E-01	1.400E+02	8.669E+05
100-41-4	Ethylbenzene		8.5	0.1	0.092	2	0.03	0.92	NTV	NTV	1.060E+05	1.690E+02	1.643E-01	2.040E+02	8.670E+05
1330-20-7	Total Xylenes		8.67	0.2	0.184	2	0.03	0.92	NTV	NTV	1.060E+05	1.710E+02	1.414E-01	2.330E+02	8.752E+05
91-20-3	Naphthalene		11.69	0.02	0.0178	2	0.13	0.89	NTV	NTV	1.280E+05	3.100E+01	8.284E-03	1.191E+03	1.145E+06
90-12-0	1-Methyl Naphthalene			0.07	0.0623	2	0.13	0.89	0.029	0.03258427	1.422E+05	2.580E+01	6.321E-03	2.528E+03	1.020E+06
91-57-6	2-Methyl Naphthalene			0.004	0.00356	2	0.13	0.89	NTV	NTV	1.422E+05	2.460E+01	7.002E-03	2.478E+03	1.006E+06
110-54-3	n-Hexane		6	0.06	0.048	2	0.0005	0.8	NTV	NTV	8.600E+04	9.500E+00	4.468E+01	3.410E+03	6.594E+05
1634-04-4	MTBE			NTV	NTV	2	0.0005	0.8	0.0018	0.00225	8.800E+04	5.000E+04	1.122E-02	1.090E+01	7.440E+05
106-93-4	Ethylene Dibromide (EDB)			0.009	0.0072	2	0.03	0.8	2	2.5	1.879E+05	3.910E+03	1.411E-02	6.600E+01	2.168E+06
107-06-2	1,2 Dichloroethane (EDC)			0.006	0.0048	2	0.03	0.8	0.091	0.11375	9.896E+04	8.600E+03	2.755E-02	3.800E+01	1.245E+06
56-55-3	Benzo(a)anthracene	(3)		NTV	NTV	1	0.13	0.89	0.1	0.112359551	2.283E+05	9.400E-03	9.597E-05	3.575E+05	1.274E+06
205-99-2	Benzo(b)fluoranthene	(3)		NTV	NTV	1	0.13	0.89	0.1	0.112359551	2.523E+05	1.500E-03	6.040E-06	5.994E+05	1.300E+06
207-08-9	Benzo(k)fluoranthene	(3)		NTV	NTV	1	0.13	0.89	0.1	0.112359551	2.523E+05	8.000E-04	4.276E-06	5.874E+05	1.300E+06
50-32-8	Benzo(a)pyrene			0.0003	0.000267	1	0.13	0.89	1	1.123595506	2.523E+05	1.620E-03	3.607E-06	9.688E+05	1.351E+06
218-01-9	Chrysene	(3)		NTV	NTV	1	0.13	0.89	0.01	0.011235955	2.283E+05	2.000E-03	3.873E-05	1.805E+05	1.274E+06
53-70-3	Dibenz(a,h)anthracene	(3)		NTV	NTV	1	0.13	0.89	0.1	0.112359551	2.784E+05	2.490E-03	7.446E-07	1.789E+06	1.282E+06
193-39-5	Indeno(1,2,3-cd)pyrene	(3)		NTV	NTV	1	0.13	0.89	0.1	0.112359551	2.763E+05	1.900E-04	2.093E-06	1.951E+06	1.400E+06

Notes:

(1) Cyclohexane no longer has an available RfD, and cyclohexene, a C6 aliphatic, is applied as the toxicity surrogate for the oral RfD for the aliphatic EC 5 to EC 8 fraction. Cyclohexene was identified by EPA in 2022 as the oral toxicity surrogate for this fraction (EPA, 2022). Cyclohexene is a constituent of gasoline and is similar structurally to cyclohexane. Also, these compounds have similar physical/chemical attributes.

Note: N-hexane is a C6 aliphatic and is a component of gasoline and crude oil. N-hexane's contribution to overall toxicity is separately evaluated in the Workbook using its own oral RfD. Testing for n-hexane is required when volatile petroleum hydrocarbon (VPH) analysis is performed for Method B or C (*see* MTCA Rule Table 830-1, Footnote 9).

Appendix D:

Equations and Default Values for Calculating Soil Cleanup Levels Based on Direct Contact Pathway

Equations 740-3 and 745-3 (WAC 173-340-740 and WAC 173-340-745)**:** Soil Direct Contact (Ingestion + Dermal) – Petroleum Mixtures (Noncarcinogenic Effects)

$$C_{soil} = \frac{HI \times ABW \times AT}{EF \times ED \times \left[\left(\frac{SIR \times AB1}{10^6 mg/kg} \sum_{i=1}^{n} \frac{F_{(i)}}{RfD_{o(i)}}\right) + \left(\frac{SA \times AF}{10^6 mg/kg} \sum_{i=1}^{n} \frac{F_{(i)} \times ABS_{d(i)}}{RfD_{d(i)}}\right)\right]}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-3	Method C Equation 745-3	
C_{soil}	TPH soil cleanup level	(calculated)	(calculated)	mg/kg
HI	Hazard index	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	6.0	20	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
$AB1$	Gastrointestinal absorption fraction	1.0	1.0	unitless
$F_{(i)}$	Fraction (by weight) of petroleum component (i)	Chemical-specific	Chemical-specific	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
$ABS_{d(i)}$	Dermal absorption fraction for petroleum component (i).	*See* Note **(1)**	*See* Note **(1)**	unitless
$RfD_{o(i)}$	Oral reference dose for petroleum component (i)	Chemical-specific	Chemical-specific	mg/kg-day
$RfD_{d(i)}$	Dermal reference dose for petroleum component (i)	*See* Note **(2)**	*See* Note **(2)**	mg/kg-day
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Parameter	Definition	Default Value		Units
		Method B Equation 740-3	Method C Equation 745-3	
n	The number of petroleum components (petroleum fractions plus volatile organic compounds with an RfD_o) present in the petroleum mixture (*See* Table 830-1.)	Mixture-specific	Mixture-specific	unitless

Footnotes:

(1) May use chemical-specific values or the following defaults: 0.0005 for volatile petroleum components with vapor pressure ≥ benzene; 0.03 for volatile petroleum components with vapor pressure < benzene; 0.1 for other petroleum components. See **Appendix C**.

(2) Derived by **RfD_o x GI** *(*see note 3)

(3) May use chemical-specific values or the following defaults: 0.8 for volatile petroleum components; 0.5 for other petroleum components. See **Appendix C**.

Equations 740-4 and 745-4: Soil Direct Contact (Ingestion + Dermal) – Noncarcinogens

For hazardous substances that are part of a petroleum mixture, cleanup levels based on noncancer effects must be calculated using Equation 740-4 under Method B, and Equation 745-4 under Method C. These equations differ from Equation 740-1 by including the dermal contact pathway. See WAC 173-340-740(3)(b)(iii)(B)(III) and 173-340-745(5)(b)(iii)(B)(III).

$$C_{soil} = \frac{HQ \times ABW \times AT}{EF \times ED \times \left[\left(\frac{1}{RfD_o} \times \frac{SIR \times AB1}{10^6 mg/kg}\right) + \left(\frac{1}{RfD_d} \times \frac{SA \times AF \times ABS_d}{10^6 mg/kg}\right)\right]}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-4	Method C Equation 745-4	
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	6.0	20	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
$AB1$	Gastrointestinal absorption fraction	1.0	1.0	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
ABS_d	Dermal absorption fraction	See Note **(1)**	See Note **(1)**	unitless
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day
RfD_d	Dermal reference dose	*See* Note **(2)**	*See* Note **(2)**	mg/kg-day
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Footnotes:

(1) May use chemical-specific values or the following defaults: 0.01 for inorganic hazardous substances; 0.0005 for volatile organic compounds with vapor pressure ≥ benzene; 0.03 for volatile organic compounds with vapor pressure < benzene; 0.1 for other hazardous substances. See **Appendix C**.

(2) Derived by ***RfD_o x GI*** (*see* note 3)

(3) May use chemical-specific values or the following defaults: 0.2 for inorganic hazardous substances; 0.8 for volatile organic compounds; 0.5 for other organic hazardous substances. See **Appendix C**.

Equations 740-5 and 745-5: Soil Direct Contact (Ingestion + Dermal) – Carcinogens

For hazardous substances that are part of a petroleum mixture, cleanup levels based on cancer effects must be calculated using Equations 740-5 and 745-5. These equations differ from Equation 740-2 by including the dermal contact pathway. See WAC 173-340-740(3)(b)(iii)(B)(III) and 173-340-745(5)(b)(iii)(B)(III).

$$C_{soil} = \frac{RISK \times ABW \times AT}{EF \times ED \times \left[\left(\frac{SIR \times AB1 \times CPF_o}{10^6 mg/kg}\right) + \left(\frac{SA \times AF \times ABS_d \times CPF_d}{10^6 mg/kg}\right)\right]}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-5	Method C Equation 745-5	
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
ABS_d	Dermal absorption fraction	See Note **(1)**	See Note **(1)**	unitless
CPF_o	Oral cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg
CPF_d	Dermal cancer potency factor	*See* Note **(2)**	*See* Note **(2)**	kg-day/mg
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Footnotes:

(1) May use chemical-specific values or the following defaults: 0.01 for inorganic hazardous substances; 0.0005 for volatile organic compounds with vapor pressure ≥ benzene; 0.03 for volatile organic compounds with vapor pressure < benzene; 0.1 for other hazardous substances. See **Appendix C**.

(2) Derived by **CPFo ÷ GI** (*see* note 3).

(3) May use chemical-specific values or the following defaults: 0.2 for inorganic hazardous substances; 0.8 for volatile organic compounds; 0.5 for other organic hazardous substances. See **Appendix C**.

Appendix E:

Equations and Default Values for Calculating Potable Groundwater Cleanup Levels

Equation 720-1 (WAC 173-340-720): Potable Groundwater Cleanup Levels – Noncarcinogens

$$Potable\ Groundwater\ Cleanup\ Level\ (\mu g/L) = \frac{RfD_o \times ABW \times UCF \times HQ \times AT}{DWIR \times INH \times DWF \times ED}$$

Parameter	Definition	Default Value		Units
		Method B	Method C	
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit conversion factor	1,000	1,000	ug/mg
HQ	Hazard quotient	1.0	1.0	unitless
AT	Averaging time	6	6	years
DWIR	Drinking water ingestion rate	1.0	2.0	L/day
INH	Inhalation correction factor (1)	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	6	6	years

Footnotes:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances. *See* **Appendix C**.

Equation 720-2 (WAC 173-340-720): Potable Groundwater Cleanup Levels – Carcinogens

$$Potable\ Groundater\ Cleanup\ Level\ (\mu g/L) = \frac{RISK \times ABW \times AT \times UCF}{CPF_o \times DWIR \times ED \times INH \times DWF}$$

Parameter	Definition	Default Value		Units
		Method B	Method C	
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	70	70	kg
AT	Averaging time	75	75	years
UCF	Unit conversion factor	1,000	1,000	ug/mg
CPF_o	Oral carcinogenic potency factor	Chemical-specific	Chemical-specific	kg-day/mg
DWIR	Drinking water ingestion rate	2.0	2.0	L/day
INH	Inhalation correction factor	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	30	30	years

Footnotes:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances. *See* **Appendix C**.

Equation 720-3 (WAC 173-340-720)**:** Potable Groundwater Cleanup Levels – Petroleum Mixtures (Noncarcinogenic Effects)

$$C_w = \frac{HI \times AT}{\left[\frac{DWIR \times DWF \times ED}{ABW \times UCF}\right] \times \sum_{i=1}^{n} \frac{F_{(i)} \times INH_{(i)}}{RfD_{o\,(i)}}}$$

Parameter	Definition	Default Value		Units
		Method B	Method C	
C_w	TPH groundwater cleanup level	(calculated)	(calculated)	µg/L
HI	Hazard index	1.0	1.0	unitless
AT	Averaging time	6	6	years
DWIR	Drinking water ingestion rate	1.0	2.0	L/day
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	6	6	years
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit conversion factor	1,000	1,000	ug/mg
$F_{(i)}$	Fraction (by weight) of petroleum component (i)	Chemical-specific	Chemical-specific	unitless
$INH_{(i)}$	Inhalation correction factor for petroleum component (i)	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
$RfD_{o\,(i)}$	Oral reference dose of petroleum component (i)	Chemical-specific	Chemical-specific	mg/kg-day
n	The number of petroleum components (petroleum fractions plus volatile organic compounds with an ***RfD$_o$***) present in the petroleum mixture (See Table 830-1.)	Mixture-specific	Mixture-specific	unitless

Footnotes:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances. *See* **Appendix C**.

Appendix F:

User's Guide for MTCASGL Workbook 12.0

Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Purpose of the MTCASGL Workbook Tool

The purpose of the MTCASGL User's Guide is to introduce the user to the features of the MTCASGL Excel-based workbook (Workbook) for calculating Soil and Groundwater Cleanup Levels for individual hazardous substances. The MTCASGL guide is arranged as a set of tutorials that allow the user to learn the basics of the Workbook in a "hands-on" environment.

The Model Toxics Control Act (MTCA) Cleanup Regulation, chapter 173-340 WAC, sets forth the requirements and procedures for establishing cleanup levels that are protective of human health and the environment. The Workbook described herein provides tools for the calculation of Method B and Method C[58] cleanup levels for soil and groundwater based on protection of human health for individual hazardous substances.

The regulation provides for the establishment of both **standard** and **modified** Methods B and C cleanup levels.

- Under **standard** Methods B and C, protective concentrations are calculated using standard equations and default assumptions provided in the regulation. Protective concentrations calculated for individual hazardous substances under standard Methods B and C are published in Ecology's Cleanup Levels and Risk Calculations (**CLARC**) database[59].

- Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted. The **Workbook** described herein provides the necessary tools for calculating protective soil and groundwater concentrations under **modified** Method B or Method C.

For the calculation of **soil cleanup levels**, the Workbook provides tools for evaluating the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality).

[58] Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology for methods to evaluate hazardous substances in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1).

[59] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC

- For the evaluation of the **direct contact pathway**, the Workbook uses the equations provided in the regulation. The Workbook allows the user to evaluate the soil ingestion pathway alone or in conjunction with the dermal pathway.

- For the evaluation of the **leaching pathway**, the Workbook uses the 3-phase equilibrium partitioning model described in the regulation to calculate a soil cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720.

- For the evaluation of the **vapor pathway**, the Workbook provides **informational** tools for calculating air cleanup levels and soil concentrations that will not cause an exceedance of the air cleanup level established under WAC 173-340-750.

NOTE: The tools for evaluating the vapor pathway are provided for informational purposes only. Please consult the regulation and the site manager for more information regarding whether the pathway must be evaluated and how the pathway may be evaluated. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*[60].

For the calculation of **groundwater cleanup levels**, the Workbook provides tools for calculating only potable groundwater cleanup levels, as defined in the regulation.

When establishing cleanup levels for hazardous substances at a site, the site manager often asks **two types of questions**.

- Is the measured (or current) concentration at the site protective?

- If not, what is the protective concentration?

The Workbook allows the user to answer both of these questions for an individual hazardous substance. The Workbook provides the tools to calculate the noncancer hazard quotient (HQ) or cancer risk (risk) under current site conditions (forward calculation), and to calculate protective concentrations (backward calculation) if the measured concentration at the site is not protective. In the first instance, the Workbook requires the user to enter a measured soil or groundwater concentration for an individual hazardous substance at the site. The Workbook then executes a "forward" calculation using the equations in the regulation and solving for the noncancer HQ or risk. In the second instance, the Workbook "back-calculates" a protective concentration based on the target HQ and risk level set forth in the regulation. Also, the Workbook provides printing and previewing capabilities for all input and output screens.

[60] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Vapor-intrusion-overview

The MTCASGL User's Guide describes the capabilities and limitations of the Workbook and provides step-by-step instructions for installing and using the Workbook.

This User's Guide is provided to document the methods used by Ecology to develop concentrations that meet the acceptable noncancer hazard and risk levels required by the MTCA Cleanup Regulation, chapter 173-340 WAC. Noncancer hazard and risk levels are described in WAC 173-340-705 (Method B) and WAC 173-340-706 (Method C).

1.2 Caution on Use of the Workbooks

The requirements and procedures for establishing cleanup levels that are protective of human health and the environment are specified in the MTCA Cleanup Regulation, chapter 173-340 WAC. The use of the MTCASGL User's Guide and the associated Workbook may not be sufficient to establish cleanup levels under the regulation. The Workbook is merely a computational tool and does not provide all the information necessary to establish cleanup levels for a site. Appropriate background, training, and experience are necessary to accurately use the Workbook. Some available resources include guidance provided on our CLARC website[61] and training via our MTCA 101 class[62].

1.2.1 Calculation of Soil Cleanup Levels

The **soil cleanup levels** calculated using the Workbook accounts for the following:

- Concentrations based on protection of human health (direct contact pathway)
- Concentrations based on protection of groundwater (leaching pathway)
- Concentrations based on protection of air (vapor pathway – informational only[63])
- Natural background concentrations
- Practical quantitation limits (PQLs)

The **soil cleanup levels** calculated using the Workbook **DO NOT** account for the following:

- Concentrations established under applicable state and federal laws

[61] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Guidance

[62] MTCA 101: Understanding and Applying Washington State's Model Toxics Control Act (hosted by the National Environmental Management Academy (NEMA) – check the training calendar for availability @ https://nemallc.com).

[63] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.

- Concentrations based on protection of terrestrial ecological receptors
- Residual saturation limit for protection of groundwater
- Total site noncancer hazard and risk

The soil cleanup levels calculated using the Workbook might need to be manually adjusted to account for these considerations (see WAC 173-340-740(5) and WAC 173-340-745(6)).

1.2.2 Calculation of Potable Groundwater Cleanup Levels

The potable groundwater cleanup levels calculated using the Workbook accounts for the following:

- Concentrations established under applicable state and federal laws
- Concentrations based on protection of human health
- Natural background concentrations
- PQLs

The potable groundwater cleanup levels calculated using the Workbook **DO NOT** account for the following:

- Concentrations based on protection of air quality (vapor pathway[64])
- Concentrations based on potential surface water impacts
- Nonaqueous phase liquid (NAPL) limitation[65]
- Total site noncancer hazard and risk

The groundwater cleanup levels calculated using the Workbook might need to be manually adjusted to account for these considerations (see WAC 173-340-720(7)).

[64] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.
[65] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

1.3 Overview of Files

1.3.1 File Download

The MTCASGL 12.0 calculations are performed in a single Excel workbook, the "Workbook", which can be downloaded from Ecology's Online tools for cleaning up sites[66] web page.

1.3.2 Hardware and Software Requirements to run the Workbook

Recommended software needed to run the Workbook and associated functions is Excel version 2003 (or later) for Windows. The software is implemented as an Excel Workbook, programmed in Visual Basic and Visual Basic for Applications (VBA), and requires Excel. The Workbook uses automatic procedures programmed in Visual Basic. However, it should not be necessary to have Visual Basic installed on your system to operate the Workbook.

1.4 Getting Started

1.4.1 Installing the Workbook

This section provides instructions for installing and opening the Workbook file.

Download the Excel Workbook from our online tools website to your hard drive. Prior to opening up the Workbook, make sure that Macros are enabled in Excel (*see* below).

Enable Macros using the steps below.

1. In Excel, go to **File > Options**.
2. Click **Trust Center**, and then click **Trust Center Settings**.
3. In the Trust Center, click **Macro Settings**.
4. Under Macro Settings, click **Enable VBA macros**.

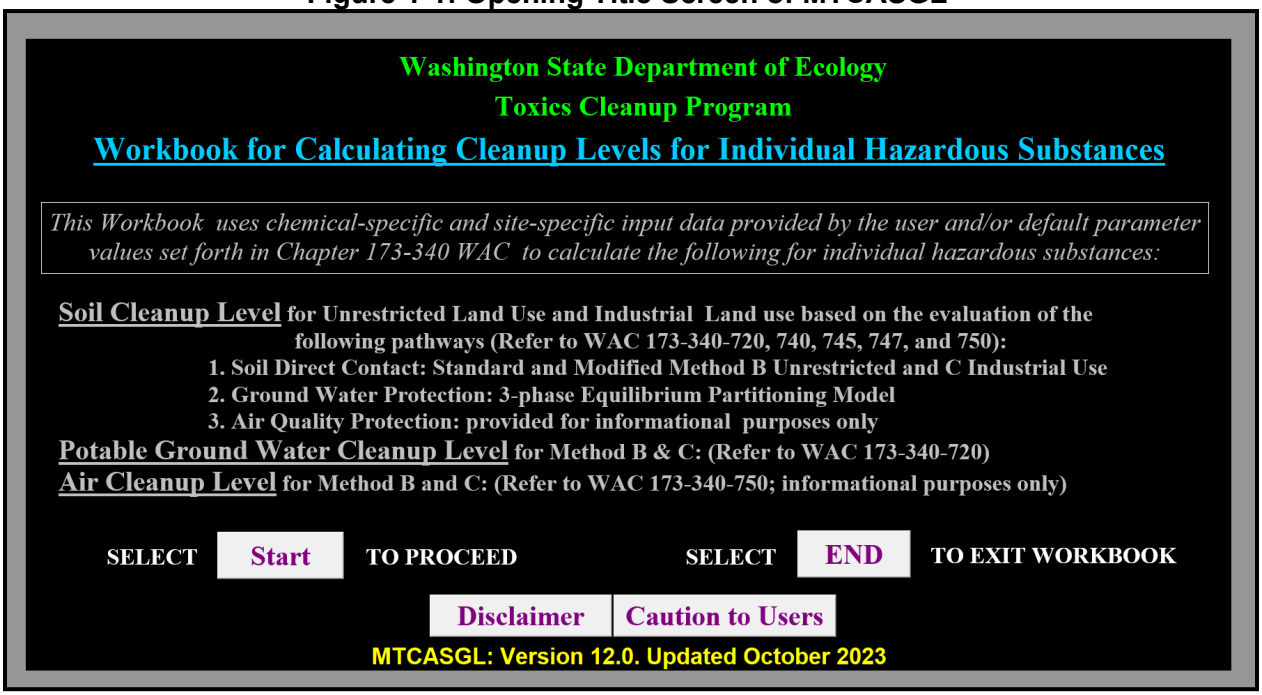
Note: Do not attempt to run the Workbook without saving the file to your hard drive. It may cause error messages, or the Workbook may not run properly. It is important to use the END button when closing the file. And it is good practice to save working files under a new name.

[66] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools

1.4.2 Assessing the Worksheet and Opening the Title Screen

Once the Workbook is successfully opened and loaded into Excel, the title sheet will appear. Be sure that MACROs are enabled (*see* Section 1.4.1). To use the Workbook, click on the START button (to exit, click on the END button). It is important to use the END button to exit the Workbook, so your previous default Excel settings (toolbars, work-area format) are restored. By opening the *MTCASGL_v12.0.xls* file, you will view **Figure 1-1**. At this point, you should see the following title screen as it appears below:

Figure 1-1: Opening Title Screen of MTCASGL



1.5 Potential Error Messages and Troubleshooting/Operating Tips

"# # # #" is displayed in a number box: Display properties chosen by users are not compatible with the cell format originally designed for the value (e.g., the number is too big to fit into the cell window). To fix this problem, select the cell, click on "Home" tab and then the "Format" group, click on "Format Cells" and then select the "Number" category. Change either the format, length of column, or the font size of the cell until the value is visible.

"# DIV/0!" or "#NAME?" is displayed in a box: The most common cause of this problem is that some input data are missing. Double-check to make certain that all of the input cells required for your run have data in them.

The buttons won't work: Click on another cell or hit the enter/return key, and then click the buttons and they should work.

Text labels appear to be cut off: On some monitor resolutions in Microsoft Windows, some cell labels may appear cut off. This should affect only the screen display, and in most cases, printouts should not be affected.

Other potential error messages and opening more than one Workbook at a time: It is possible that you may receive other error messages when trying to open the Workbook. Be sure the MACROs are enabled to use the tools properly (*see* Section 1.4.1). Some error messages may require you to refer to online help or the documentation of the host application. Check with your network operator or information technology specialist to be sure your Excel application can accept MACROs operation and to address other host application-related errors. It is not advisable to load and use more than one copy of the Workbook at the same time. It may cause it to function improperly.

Preview, printout (reporting features) and readability of worksheet: The Workbook provides printing and reviewing capabilities for all input/output screens. To view the printable worksheet, click on the “Preview” button at the top of any worksheet. Each worksheet can be printed by selecting the appropriate “Print” button. The same print options are available on the “Main Menu.” Some users may have difficulty viewing worksheet numbers or text. To enlarge your view of a particular sheet, click on “View” in the main toolbar and select “Zoom.” Choose a magnification that works best for your needs and save it as modified.

Input/output worksheet prints on one page for most computer/printer configurations. The worksheet is designed at “1024 x 768” pixel screen resolution, making it more readable on new computer configurations. For older systems with lower resolution, simply changing the screen “zoom” level to a higher percent (or more) instead of lower percent will improve readability.

Restoring Excel tool bars and miscellaneous options: To maximize screen area on the computer to view the data, most of the typical Excel toolbars are turned off when the Workbook is loaded. However, if you prefer to have these toolbars available, you can restore them by hitting the “Escape” button on your keyboard. To restore the “Formula” bar along with standard Excel row and column labels, select “Formula Bar” and “Headings” within the “View” tab. You can also resize the pages using the “Zoom” feature in the “View” tab to make the tables and text larger or smaller.

1.6 Saving and Closing the Workbook

→ USE THE END BUTTON ←

Once an analysis is complete, it is good practice to print out a copy of the entire Workbook as a record. At this point, you may also wish to save the Workbook under a new name [FILE – SAVE AS]. If you accidentally exit without using the END button, you can re-establish your toolbars by clicking on [VIEW] and selecting the toolbars you wish to use. You may also need to click on [FILE-OPTIONS] and make selections as appropriate to re-establish certain work area components.

When you click on the END button, you will be prompted to save your work and you can do so by answering [yes] and saving the file under a new file name. Otherwise, answer [no] and you will exit the Workbook without saving any changes.

Note: The Workbook should be closed (exited) using the END button at the top of the sheet. Do not close the Workbook using the typical means provided in Excel (i.e., [FILE-CLOSE] or clicking on the "X"). Using the END button allows the programmed routines in the Workbook to return the Excel toolbar displays and other format options to those you normally use.

Chapter 2: MTCASGL – Workbook for Calculating Cleanup Levels for Individual Hazardous Substances

2.1 Overview

The **MTCASGL Workbook** allows the user to use pre-established chemical and toxicity data, default exposure assumptions, and site-specific information to calculate any of the following for a **single** chemical contaminant:

- **Hazard and Risk under Current Conditions:** The Workbook provides the tools necessary to calculate the noncancer HQ and risk under current conditions. To do this, the Workbook requires the user to enter a measured soil or groundwater concentration for a single chemical contaminant. The Workbook then executes a "forward" calculation using the equations in the regulation and solving for noncancer HQ and risk. For soil measurements, the Workbook calculates the noncancer HQ and risk corresponding to the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality). For groundwater measurements, the Workbook calculates the noncancer HQ and risk corresponding to the potable water ingestion pathway. The program indicates whether the measured concentration (current condition) is above or below the acceptable hazard and risk levels (pass/fail).

- **Cleanup Levels for Soil and Potable Groundwater:** The Workbook provides the tools necessary to calculate protective soil and groundwater concentrations under both Methods B and Method C[67]. The Workbook "back-calculates" a protective concentration based on the target noncancer HQ of 1, and an excess risk of one in a million (1×10^{-6} or 1E-06) [68] under Method B, and one in one hundred thousand (1×10^{-5} or 1E-05) under Method C. For soil, the Workbook calculates a protective concentration for the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality). For groundwater, the Workbook calculates a protective concentration for the potable water ingestion pathway. This calculated cleanup level might be lower or higher than the concentration measured in the sample.

[67] Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology for methods to evaluate hazardous substances in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1).

[68] Cancer risk is expressed in terms of lifetime excess cancer risk. This concept assumes that the risk of cancer from a given chemical is in "excess" of the background risk of developing cancer. For example, a risk of 1E-06 equates to approximately one excess cancer case in a population of one million individuals due to exposure to the cancer-causing substance over a lifetime.

The **MTCASGL Workbook** consists of two worksheets – the Worksheet for Calculating Soil Cleanup Levels **(**see **Section 2.3)** and the Worksheet for Calculating Potable Groundwater Cleanup Levels **(**see **Section 2.4)**.

The **Worksheet for Calculating Soil Cleanup Levels** (soil worksheet) provides tools for evaluating the direct contact, soil leaching, and vapor pathways.

- For evaluation of the **direct contact pathway**, the worksheet uses the equations provided in the regulation **(**see **Attachment A)**. The worksheet allows the user to evaluate the soil ingestion pathway alone or in conjunction with the dermal pathway.

- For evaluation of the **leaching pathway**, the worksheet uses the 3-phase equilibrium partitioning model described in the regulation **(**see **Attachment B)** to calculate a soil cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720.

- For evaluation of the **vapor pathway**, the worksheet uses the equations provided in the regulation to calculate an air cleanup level **(**see **Attachment C)**, and then calculates a soil cleanup level that will not cause an exceedance of that air cleanup level using the 3-phase equilibrium partitioning model and the site-specific vapor attenuation factor entered by the user.

NOTE: The tools for evaluating the vapor pathway are provided for informational purposes only. Please consult the regulation and the site manager for more information regarding whether the pathway must be evaluated and how the pathway may be evaluated. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*[69].

The **Worksheet for Calculating Potable Groundwater Cleanup Levels** (groundwater worksheet) provides tools for calculating cleanup levels for the ingestion of potable groundwater. The worksheet uses the equations in the regulation **(**see **Attachment D)**. The worksheet does not provide tools for calculating cleanup levels for nonpotable groundwater.

2.2 What's New in MTCASGL 12.0?

MTCASGL was updated in 2023 to remove the Henry's law conversion tool that allowed the user to enter the constant in units of atm-m^3/mol to determine the unitless form at 13° Celsius. Rather, the user may use the dimensionless Henry's law at 13° Celsius provided in Ecology's CLARC database. The CLARC database was updated in 2021 to include chemical-specific parameters for more chemicals including Henry's law at 25° and 13° Celsius. Data from the Oak

[69] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Vapor-intrusion-overview

Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS)[70] chemical database (i.e., boiling point, critical temperature, enthalpy of vaporization) along with formulas in EPA's Vapor Intrusion Screening Level[71] (VISL) excel spreadsheet system (Chem Props worksheet) were used to adjust Henry's law based on 25° Celsius to 13° Celsius. See updated instructions in Section 2.3.4.4 for inputting Henry's law.

Very minor modifications were made in 2006 to enhance the usability of the program.

- Footnotes are inserted for input parameters to indicate which exposure pathway evaluations these inputs are used for. See **Figure 2-1**.

Figure 2-1: Examples of Footnotes

2.1 Oral Reference Dose[1, 3]
2.2 Oral Carcinogenic Potency Factor[1, 3]
2.3 Inhalation Reference Dose[5]
2.4 Inhalation Carcinogenic Potency Factor[5]

1. Soil ingestion only
2. Soil dermal contact,
3. Soil to groundwater (leaching pathway),
4. Groundwater ingestion,
5. Soil to air (vapor pathway).

- Codes are revised to reduce memory requirements, file size and simulation time and to increase calculation efficiency.

[70] https://rais.ornl.gov/
[71] https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator

2.3 Calculating Soil Cleanup Levels (Soil Worksheet)

2.3.1 Accessing the Soil Worksheet

Once the MTCASGL Workbook is successfully loaded into Excel, the title sheet will appear as shown prior in **Figure 1-1**. Be sure to enable Excel MACROs prior to opening up the Workbook (*see* Section 1.4.1). To use the Workbook tool, click on the START button (to exit, click on the END button). It is important to use the END button to exit the Workbook, so your previous default Excel settings (toolbars, work-area format) are restored. Selecting the START button makes the soil worksheet appear on your screen (light blue background).

Note the following regarding the structure and contents of the soil worksheet.

- Non-colored (white) cells in the sheet are used for data entry (other cells in the Workbook are locked and cannot be modified).
- The worksheet is divided into Sections A and B – Section A is the upper portion of the worksheet and allows users to input data. Section B is the bottom portion of the worksheet and contains the "Summary of Soil Cleanup Level Calculations".

2.3.2 Caution on Use of the Soil Worksheet

The soil cleanup levels calculated using the soil worksheet account for the following:

- Concentrations based on protection of human health (direct contact pathway)
- Concentrations based on protection of groundwater (leaching pathway)
- Concentrations based on protection of air (vapor pathway – informational only[72])
- Natural background concentrations
- PQLs

[72] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.

The soil cleanup levels calculated using the soil worksheet **DO NOT** account for the following:

- Concentrations established under applicable state and federal laws
- Concentrations based on protection of terrestrial ecological receptors
- Residual saturation limit for protection of groundwater
- Total site noncancer hazard and risk

The soil cleanup levels calculated using the soil worksheet may need to be manually adjusted account for these considerations.

2.3.3 Equations and Parameters

The soil worksheet provides tools for evaluating the direct contact pathway, the leaching pathway (protection of groundwater), and the vapor pathway (protection of air quality).

2.3.3.1 Direct Contact Pathway

For the evaluation of the direct contact pathway, the worksheet uses the standard equations provided in the regulation **(**see **Attachment A)**. The worksheet allows the user to evaluate the soil ingestion pathway alone or in conjunction with the dermal pathway.

For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted.

- IF the regulation does not allow a parameter to be adjusted, THEN the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.
- IF the regulation allows a parameter to be adjusted (e.g., gastrointestinal absorption fraction), THEN the parameter is listed in the worksheet and the user may input either the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

2.3.3.2 Leaching Pathway

For the evaluation of the leaching pathway, the worksheet uses the 3-phase equilibrium partitioning model described in the regulation **(**see **Attachment B)** to calculate a cleanup level that will not cause an exceedance of the groundwater cleanup level established under WAC 173-340-720. For each of the parameters used in the equations, the user may input either the

default value provided in the regulation, or a site-specific or chemical-specific value derived under the regulation.

For the evaluation of the leaching pathway, the worksheet also checks for soil saturation limits and warns the user if the soil saturation condition is exceeded.

2.3.3.3 Vapor Pathway

For the evaluation of the vapor pathway, the worksheet **first** uses the standard equations provided in the regulation **(**see **Attachment C)** to calculate air cleanup levels. For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted.

- IF the regulation does not allow a parameter to be adjusted, THEN the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.

- IF the regulation allows a parameter to be adjusted (e.g., the inhalation absorption fraction), THEN the parameter is listed in the worksheet and the user may input either the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

Second, the worksheet converts the calculated air cleanup level into a soil vapor concentration using the vapor attenuation factor entered by the user.

Third, the worksheet uses the 3-phase equilibrium partitioning model **(**see **Attachment B)** and the soil vapor concentration to calculate the associated soil concentration – the concentration that is protective of air quality at the exposure point (point of compliance).

NOTE: The tools for evaluating the vapor pathway are provided for informational purposes only. Please consult the regulation and the site manager for more information regarding whether the pathway must be evaluated and how the pathway may be evaluated. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*[73].

[73] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Vapor-intrusion-overview

2.3.4 Entering Data for Input Parameters

As discussed above, the worksheet lists only those parameters that may be adjusted by the user. For each of the parameters listed in the worksheet, the user must either enter the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

NOTE: If no data is available for an input parameter, then leave the input box blank unless specified otherwise.

As illustrated in the following sections, the parameters for which the user must enter data are listed on the left side of the worksheet. The user must enter the data in the corresponding non-shaded (white) boxes on the right side of the worksheet.

Section A of the worksheet is organized into **seven parts**. Each of the parameters listed under those parts is listed and described below. For each parameter, this User's Guide lists the default value provided in the regulation and references the applicable procedures for deriving a site-specific or chemical-specific value under the regulation.

Header Information: In the rectangular box at the top of the soil worksheet, enter the date, site name, and evaluator name. **NOTE**: Once an evaluation has been completed for a particular site, it is good practice to print out the results. Click on the Preview or Print button to confirm that the proper header information appears on all printout sheets. Remember to change the header information EACH TIME a new set of data is entered.

2.3.4.1 Input Data – Part 1: General Information

The first part of the worksheet (*see* **Figure 2-2**) requires the user to input the following general information.

Figure 2-2: General Information

1. General information				
1.1 Name of Chemical:			DDT	
1.2 Measured Soil Concentration, if any:		C_s	5	mg/kg
1.3 Natural Background Concentration for Soil, if any:		NB_s		mg/kg
1.4 Practical Quantitation Limit for Soil, if any:		PQL_s	0.002	mg/kg
* To evaluate the ingestion and dermal pathways concurrently, check here and input values for AF, ABS_d, GI:	☑			

Name of Chemical: Enter the name of the chemical to be evaluated.

Measured Soil Concentration (if known): This parameter is used to calculate the carcinogenic risk and noncarcinogenic HQ at the site under current conditions. Enter the soil concentration in milligrams per kilogram of soil (dry weight basis).

Natural Background (NB_s) Soil Concentration (if known): This parameter is used to adjust the soil cleanup level, if necessary. Methods for defining natural background concentrations are provided in WAC 173-340-709. Ecology has published information on background levels of

certain metals (*Natural Background Soil Metals Concentrations in Washington State, Publication No. 94-115*[74]). Also, Ecology has adopted a natural background soil level of 5.2 nanograms/kilogram (ng/kg) for dioxin and furan mixtures. The chemical concentrations of the dioxin and furan mixture in soil are converted to a 2,3,7,8-TCDD total toxicity equivalence (TEQ) concentration which may then be compared to the background soil level of 5.2 ng/kg[75].

Practical Quantitation Limit (*PQL$_s$*) for Soil (if known): This parameter is used to adjust the soil cleanup level, if necessary. The ***PQL$_s$*** is the lowest concentration of the contaminant that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using department approved methods. The analytical laboratory or site manager can assist in identifying the appropriate ***PQL$_s$***.

Checkbox – Is an evaluation of the dermal pathway required? The checkbox item at the bottom of the first part of the worksheet requires the user to indicate whether an evaluation of the dermal pathway is required to calculate a soil concentration that is protective of human health based on direct contact. To determine whether an evaluation of the dermal pathway is required, see WAC 173-340-740(3)(c)(iii) and 173-340-745(5)(c)(iii). If an evaluation of the dermal pathway is required, then the user must enter a check in the checkbox and enter values for the following exposure parameters in **Part 3** below **(see Section 2.3.4.3)**:

- Adherence Factor (***AF***)
- Dermal absorption fraction (***ABS$_d$***)
- Gastrointestinal Absorption Conversion Factor (***GI***)

2.3.4.2 Input Data – Part 2: Toxicological Properties of the Chemical

The second part of the worksheet (see **Figure 2-3)** requires the user to input the following chemical-specific toxicological data.

Figure 2-3: Toxicological Properties

2. Toxicological Properties of the Chemical: Chemical-Specific			
2.1 Oral Reference Dose[1, 3]	RfD_o	0.0005	mg/kg-day
2.2 Oral Carcinogenic Potency Factor[1, 3]	CPF_o	0.34	kg-day/mg
2.3 Inhalation Reference Dose[5]	RfD_i		mg/kg-day
2.4 Inhalation Carcinogenic Potency Factor[5]	CPF_i	0.34	kg-day/mg

Oral Reference Dose (*RfD$_o$*): Enter the oral reference dose (mg/kg-day) for chemicals having noncarcinogenic toxicity. The applicable oral reference dose for a chemical is published in

[74] https://apps.ecology.wa.gov/publications/SummaryPages/94115.html
[75] Ecology, 2010. Technical Memorandum #8: Natural Background for Dioxins/Furans in WA Soils. https://apps.ecology.wa.gov/publications/SummaryPages/1009053.html

CLARC[76]. Note that an oral reference dose may not be available for some chemicals. The process for establishing a reference dose is defined in WAC 173-340-708(7).

Oral Carcinogenic Potency Factor (*CPF_o*): Enter the oral carcinogenic potency factor (kg-day/mg) for chemicals having carcinogenic toxicity. The applicable oral cancer potency factor for a chemical is published in CLARC. Note that an oral cancer potency factor may not be available for some chemicals. The process for establishing a cancer potency factor is defined in WAC 173-340-708(8).

Inhalation Reference Dose (*RfD_i*): Enter the inhalation reference dose (mg/kg-day) for chemicals having noncarcinogenic toxicity. The applicable inhalation reference dose for a chemical is published in CLARC. Note that an inhalation reference dose may not be available for some chemicals. The process for establishing a reference dose is defined in WAC 173-340-708(7).

Inhalation Carcinogenic Potency Factor (*CPF_i*): Enter the inhalation carcinogenic potency factor (kg-day/mg) for chemicals having carcinogenic toxicity. The applicable inhalation cancer potency factor for a chemical is published in CLARC. Note that an inhalation cancer potency factor may not be available for some chemicals. The process for establishing a cancer potency factor is defined in WAC 173-340-708(8).

2.3.4.3 Input Data – Part 3: Exposure Parameters

The third part of the worksheet (see **Figure 2-4**) requires the user to input data for the following exposure parameters.

Figure 2-4 Exposure Parameters

3. Exposure Parameters			
3.1 Inhalation Correction Factor (default = "2" for volatiles; "1" for all others)[4]	*INH*	1	unitless
3.2 Inhalation Absorption Fraction (default = "1")[5]	ABS_i	1	unitless
3.3 Gastrointestinal Absorption Fraction (default = "1")[1, 2]	*AB1*	1	unitless
3.4 Adherence Factor (default = "0.2")[2]	*AF*	0.2	mg/cm^2-day
3.5 Dermal Absorption Fraction (chemical-specific or defaults)[2]	ABS_d	0.1	unitless
3.6 Gastrointestinal Absorption Conversion Factor (chemical-specific or defaults)[2]	*GI*	0.5	unitless

Inhalation Correction Factor (*INH*): This parameter is used to calculate the groundwater cleanup level and accounts for potential exposure to volatile contaminants via non-ingestion groundwater water use (e.g., showering). Enter the applicable default value “2.0” for volatile organic compounds (as defined in WAC 173-340-200) and “1.0” for all other chemicals, or enter a chemical-specific value established under WAC 173-340-720(4)(c)(i). The applicable default value for this parameter is published in CLARC.

[76] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC

Inhalation Absorption Fraction (*ABS_i*): This parameter is used to calculate the air cleanup level. Enter the default value of "1.0" or enter a chemical-specific value established under WAC 173-340-750(3)(c)(i).

Gastrointestinal absorption fraction (*AB1*): This parameter is used to calculate a soil concentration that is protective of human health based on direct contact via incidental ingestion. Enter the default value of "1.0" or enter a chemical-specific value established under WAC 173-340-740(3)(c)(ii)(B) or 173-340-745(5)(c)(ii)(B). The applicable default value for this parameter is published in CLARC.

Adherence Factor (*AF*): This parameter is used to calculate a soil concentration that is protective of human health based on direct contact. The parameter is specifically used to evaluate **dermal contact**. Enter the default value of "0.2" or enter a chemical-specific value established under WAC 173-340-740(3)(c)(ii)(C) or 173-340-745(5)(c)(ii)(C). If an evaluation of the dermal pathway is not required, then leave this input box blank.

Dermal Absorption Fraction (*ABS_d*): This parameter is used to calculate a soil concentration that is protective of human health based on direct contact. The parameter is specifically used to evaluate **dermal contact**. The parameter is chemical-specific. Enter a chemical-specific value established under WAC 173-340-740(3)(c)(ii)(C) or 173-340-745(5)(c)(ii)(C) or enter the applicable default value listed below.

- "0.01" for inorganic hazardous substances.
- "0.0005" for volatile organic compounds with a vapor pressure ≥ benzene.
- "0.03" for volatile organic compounds with a vapor pressure < benzene.
- "0.1" for other organic hazardous substances.

NOTE: Vapor pressure of Benzene is 0.125 atm (or, 95 mm Hg, 95 torr, 12.7 kPa) at 25˚C.

The applicable default value for this parameter is published in CLARC. If an evaluation of the dermal pathway is not required, then leave this input box blank.

Gastrointestinal Absorption Conversion Factor (*GI*): This parameter is used to derive a **dermal** reference dose based on the oral reference dose or a **dermal** cancer potency factor based on the oral cancer potency factor. The dermal toxicity index is derived by dividing or multiplying the oral index by GI (as shown below).

$$RfD_d = RfD_o \times GI \quad or \quad CPF_d = CPF_o \div GI$$

This parameter is chemical-specific. Enter a chemical-specific value established under WAC 173-340-740(3)(c)(ii)(C) or WAC 173-340-745(5)(c)(ii)(C) or enter the applicable default value listed below.

- "0.2" for inorganic hazardous substances.
- "0.8" for volatile organic compounds.
- "0.5" for other organic hazardous substances.

The applicable default value for this parameter is published in CLARC. If an evaluation of the dermal pathway is not required, then leave the input box blank.

2.3.4.4 Input Data – Part 4: Physical and Chemical Properties of the Chemical

The fourth part of the worksheet (see **Figure 2-5**) requires the user to input chemical-specific data for the following physical and chemical properties of the chemical:

Figure 2-5: Physical and Chemical Properties

4. Physical and Chemical Properties of the Chemical: Chemical-Specific			
Soil Organic Carbon-Water Partitioning Coefficient: for metals, enter K_d value here and enter "1" for f_{oc} value	K_{oc}	6.779E+05	l/kg
Henry's Law Constant: for the evaluation of ground water and vapor exposure pathway*	H_{cc}	1.277E-04	unitless
**Enter the dimensionless Henry's law constant at 13 deg Celsius if available in CLARC. Otherwise enter the value at 25 deg Celsius if availabe in CLARC. CLARC = Ecology Cleanup Levels and Risk Calculations Database*			
Solubility of the Chemical in Water: for the calculation of soil saturation limit	S	5.500E-03	mg/l

Soil Organic Carbon-Water Partitioning Coefficient (K_{oc}): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is chemical-specific.

- For **organic hazardous substances**, enter the K_{oc} value. The Workbook calculates a value for the distribution coefficient (K_d) using the K_{oc} value entered here, and the soil fraction of organic carbon (f_{oc}) value entered in the sixth part of the worksheet using MTCA Equation 747-2 (shown in **Attachment B**): $K_d = K_{oc} \times f_{oc}$. Applicable default values for these parameters (i.e., K_{oc} and K_d) are published in CLARC. Methods to derive a site-specific K_d value, which includes the K_d equation above for organic chemicals, are detailed in WAC 173-340-747(5)(b).
- For **metals**, enter the K_d instead of the K_{oc} value here and enter "1.0" for the f_{oc} value in the sixth part of the worksheet. Applicable default values for K_d are published in CLARC. Methods to derive a site-specific K_d value are detailed in WAC 173-340-747(5)(b).

Henry's Law Constant (H_{cc}): The dimensionless (i.e., H_{cc}) form of Henry's law is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is chemical-specific.

- For metals except mercury, enter the default value of "0".

- For mercury, enter the default value of "0.47" or enter a value derived from the scientific literature, provided the requirements in WAC 173-340-702(14), (15) and (16) are met.

To enter Henry's law constant, follow the set of instructions below.

- For default calculation of soil cleanup levels to protect groundwater, Henry's law constants at 13° Celsius should be used. Enter the dimensionless form of Henry's law at 13° Celsius in the "H_{cc} [ ] unitless" box. If chemical-specific data is not available to derive a Henry's law constant at 13° Celsius, the Henry's law constant at 25° Celsius may be used in the calculation, if available. If a Henry's law value is not available, a value of zero may be conservatively used to make the calculation. It's noted that chemical loss due to volatilization based on Henry's law is not a major driver in the 3-phase partitioning model.

  Applicable default values for Henry's law at 25° and 13° Celsius are published in CLARC.

- For individual organic hazardous substances in which a Henry's law value is not available in CLARC, enter a value derived from the scientific literature, provided the requirements in WAC 173-340-702(14), (15) and (16) are met. In this circumstance, the user may opt to use the slightly more conservative dimensionless Henry's law at 25° Celsius in lieu of trying to adjust it to 13° Celsius.

- A Henry's law constant provided in units of **atm-m^3/mol** may be converted to the dimensionless form using the following equation:

$$Hcc = Henry's\ law\ (atm\text{-}m^3/mol) \div (R \times T)$$

  Where:

  R = Ideal gas constant (8.20575 x 10^{-5} atm-m^3/mol-K)

  T = Temperature in Kelvins (25° Celsius = 298.15 K; 13° Celsius = 286.15 K)

  Notes:

  1. The value of (R x T) at 25° Celsius is 0.02446; and 0.02348 at 13° Celsius.
  2. The equation may be simplified as:

     H_{cc} at 25° Celsius = Henry's law at 25° Celsius (atm-m^3/mol) ÷ 0.02446

     H_{cc} at 13° Celsius = Henry's law at 13° Celsius (atm-m^3/mol) ÷ 0.02348

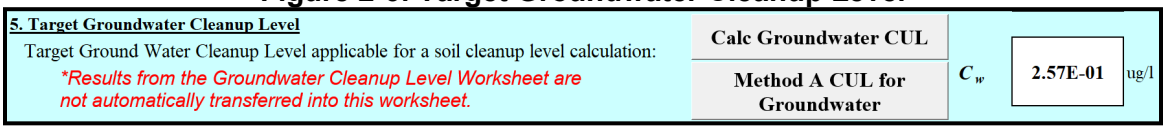
Aqueous Solubility (*S*): This parameter is used to calculate the soil saturation limit (C_{sat}). This soil saturation limit corresponds to the theoretical chemical concentration in soil at which sorption limits of the soil particles, solubility limits of the soil pore water, and saturation of soil pore air have all been reached. The parameter is chemical-specific. The aqueous solubility of the contaminant must be entered as milligrams of contaminant per liter of water (mg/L). Information on solubility for common contaminants can be obtained from the scientific literature.

These literature values may be used, provided the requirements in WAC 173-340-702(14), (15) and (16) are met. The applicable default value for this parameter is published in CLARC.

2.3.4.5 Input Data – Part 5: Target Groundwater Cleanup Level

The fifth part of the worksheet (see **Figure 2-6)** requires the user to input the target groundwater cleanup level for the site[77]. The target groundwater cleanup level is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the target groundwater cleanup level). The parameter is site- and chemical-specific.

Figure 2-6: Target Groundwater Cleanup Level



The Workbook provides two methods for calculating the target groundwater cleanup level. These two methods are described below.

Use and Adjustment of Method A Values in MTCA Table 720-1: For chemicals listed in WAC 173-340-900, Table 720-1 except petroleum mixtures, the value listed in Table 720-1 for a chemical may be used as the target groundwater cleanup level[78], provided the value is manually adjusted based on the following:

- Consideration of potential surface water impacts (see WAC 173-340-720(4)(b)(ii) and 173-340-720(5)(b)(ii))
- Consideration of the nonaqueous phase liquid (NAPL) limitation[79] (see WAC 173-340-720(7)(d))
- Consideration of total site noncancer hazard and risk (see WAC 173-340-720(7)(a))

To see the values listed in WAC 173-340-900, Table 720-1, click the Method A CUL for Groundwater button to activate a "pop-up" list. The value from Table 720-1 must be manually adjusted as described above and then manually entered in the soil worksheet.

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[77] The user must develop a target groundwater cleanup level based on the exposure pathway (e.g., potable water ingestion, protection of surface water, etc.) that generates the most stringent cleanup level (i.e., lowest concentration).

[78] For qualifying cleanups performed under Method A (WAC 173-340-704), all of the indicator hazardous substances at the site should have a Method A standard. See Ecology's *Guidance on the Use of Method A, B, and C Cleanup Levels and Mixing Methods*. https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MixingMethodsABC.pdf

[79] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

WARNING: The Workbook **DOES NOT** automatically enter a value from Table 720-1 in the soil worksheet.

Calculation of Method B or Method C Value: For cleanups performed under Method B (WAC 173-340-705) or C (WAC 173-340-706), the user may calculate a potable groundwater cleanup level using the groundwater worksheet within the Workbook. Alternatively, the user may use the pre-calculated Method B or C potable groundwater levels in CLARC based on standard default exposure assumptions. If there is insufficient data (e.g., lack of toxicity data) to calculate a Method B or C potable groundwater value, or if a Method A value has been adjusted based on natural background (e.g., arsenic in groundwater), the user may default to the Method A potable groundwater level in WAC 173-340-900, Table 720-1 if one is available[80]. To access the worksheet, click on the **Calc Groundwater CUL** button. See **Section 2.4** for instructions on calculating a potable groundwater cleanup level.

Before calculating the potable groundwater cleanup level (before clicking on the button), values for the following parameters must be entered in the soil worksheet.

- Oral Reference Dose (***RfD$_o$***) – Part 2.
- Oral Carcinogenic Potency Factor (***CPF$_o$***) – Part 2.
- Inhalation Correction Factor (***INH***) – Part 3.

The Workbook calculates a potable groundwater cleanup level based on the values entered for these parameters and the parameters listed in the groundwater worksheet. The potable groundwater cleanup level calculated using the groundwater worksheet[81] must be manually adjusted (as described in **Section 2.4**) and then manually entered in the soil worksheet (as noted in **Section 2.4**).

WARNING: The Workbook **DOES NOT** automatically enter the result from the groundwater worksheet.

[80] Examples of when it is appropriate to use a Method A level at a Method B or C site are provided in Ecology's *Guidance on the Use of Method A, B, and C Cleanup Levels and Mixing Methods*. https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MixingMethodsABC.pdf

[81] The Method B or C potable groundwater level within the groundwater worksheet also accounts for user inputted applicable state or federal laws, the PQL, and natural background levels.

2.3.4.6 Input Data – Part 6: Hydrogeological Characteristics of the Site

The sixth part of the worksheet (see **Figure 2-7**) requires the user to input default or site-specific data for the following hydrogeological characteristics of the site:

Figure 2-7: Site-specific Hydrological Information

6. Site-Specific Hydrogeological Characteristics			
Total Soil Porosity (default = "0.43"):	n	0.43	unitless
Volumetric Water Content (default = "0.30"):	Θ_w	0.3	unitless
Volumetric Air Content (default = "0.13"):	Θ_a	0.13	unitless
Dry Soil Bulk Density (default = "1.50"):	ρ_b	1.5	kg/l
Fraction Soil Organic Carbon (default = "0.001"): for metals, enter "1" for f_{oc} value here	f_{oc}	0.001	unitless
Dilution Factor (default = "20" for unsaturated zone soil; "1" for saturated zone soil; or site-specific)	DF	20	unitless

Total Soil Porosity (*n*): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the default value of "0.43" or enter a site-specific value determined under WAC 173-340-747(6)(d)(iii)(D) using site-specific measurements. The site-specific soil porosity may be calculated using the following equation:

$$n = 1 - \frac{\rho_b}{\rho_s}$$

Table 2-1: Porosity and Density Information

Parameter	Definition	Default Value	Units
n	Total soil porosity	Calculated	unitless
ρ_b	Dry soil bulk density	1.5 **(1)**	kg/L
ρ_s	Soil particle specific gravity	2.65 **(2)**	kg/L

Footnotes:

1. Use the default value of 1.5 kg/L or use a site-specific value derived under WAC 173-340-747(5)(c). Use the same value as entered in Part 6 of the worksheet.
2. Use the default value of 2.65 kg/L or use a site-specific value derived under WAC 173-340-747(6)(d)(iii)(D). A site-specific value may be derived by measuring the soil particle specific gravity using ASTM Method D854-00.

Note that the sum of the volumetric water content and the volumetric air content must equal the total soil porosity.

Volumetric Water Content (θ_w): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the default value of "0.30" or enter a site-specific value derived under WAC 173-340-747(5)(d) using site-specific measurements. Note that the sum of the volumetric water content and the volumetric air content must equal the total soil porosity.

Volumetric Air Content (θ_a): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. The value for volumetric air content CANNOT be entered. The Workbook automatically calculates a value based on the values entered for total soil porosity (***n***) and volumetric water content (θ_w) using the equation below.

$$\boldsymbol{\theta_a = n - \theta_w}$$

If the default values for total soil porosity (***n*** = 0.43) and volumetric water content (θ_w = 0.3) are entered, then the "default" volumetric air content is 0.13.

Dry Soil Bulk Density (ρ_b): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the default value of "1.5" or enter a site-specific value derived under WAC 173-340-747(5)(c) using site-specific measurements.

Fraction Soil Organic Carbon (f_{oc}): The fraction of soil organic carbon is the total mass of organic carbon divided by a unit mass of soil (mass of carbon/mass of soil). This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific.

- For **organic hazardous substances**, enter the default value of "0.001" or enter a site-specific value derived under WAC 173-340-747(5)(b)(i). The Workbook calculates a value for K_d using the f_{oc} value entered here and the K_{oc} value entered in the fourth part of the worksheet using Equation 747-2: $K_d = K_{oc} \times f_{oc}$.

- For **metals**, enter "1" for the f_{oc} value here and enter the distribution coefficient (K_d) instead of the K_{oc} value in the fourth part of the worksheet.

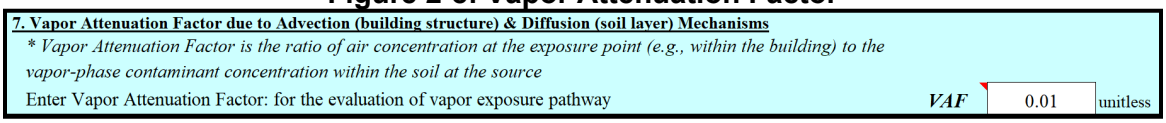
Soil samples that are analyzed for f_{oc} must be collected outside the area of contamination and below the root zone. The results are usually reported as percent organic carbon. The reported value can be converted to a fraction by dividing by 100.

Dilution Factor (*DF*): This parameter is used to calculate a soil concentration that is protective of groundwater (that will not cause an exceedance of the groundwater cleanup level). The parameter is site-specific. Enter the applicable default value ("20" for unsaturated zone soil and "1" for saturated zone soil) or enter a site-specific value derived under WAC 173-340-747(5)(f) using site-specific estimates of infiltration and groundwater flow rate.

2.3.4.7 Input Data – Part 7: Vapor Attenuation Factor for the Site

The seventh part of the worksheet (see **Figure 2-8**) requires the user to input the vapor attenuation factor for the site.

Figure 2-8: Vapor Attenuation Factor



Vapor Attenuation Factor (***VAF***): This parameter is used to calculate a soil concentration that is protective of air quality (that will not cause an exceedance of the air cleanup level at the point of compliance). This parameter is site- and chemical-specific.

The worksheet uses the 3-phase equilibrium partitioning model to predict the soil vapor concentration at the source based on the measured soil concentration. The worksheet then uses the vapor attenuation factor to predict the air concentration at the point of compliance based on the soil vapor concentration at the source. The vapor attenuation factor is based on several factors, including the emission rate of the contaminant from soil (due to diffusion and advection) and the amount of dilution that occurs through mixing with indoor and or outdoor ambient air.

WARNING: To calculate a soil cleanup level based on the vapor pathway, the user must enter a value for VAF. The user must enter a **site-specific** value because **a default value has not been established**.

If it appears that the vapor pathway is a controlling factor at a site, the user needs to consult with the Ecology site manager to identify an appropriate method for evaluating the vapor pathway. For additional information on evaluating the vapor pathway for individual volatile hazardous substances, please see our 2022 guidance titled: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*[82].

THIS COMPLETES DATA ENTRY FOR THE SOIL WORKSHEET.
SAVE YOUR WORK BEFORE CONTINUING.

2.3.5 Output – Interpreting the Result

The worksheet automatically calculates protective soil concentrations for the different pathways and then calculates a soil cleanup level based on those protective concentrations and other limits.

The worksheet displays the calculation results in two tables at the bottom of the active sheet.

[82] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Vapor-intrusion-overview

2.3.5.1 Summary of Results

The first table (example shown below) displays the most stringent soil concentration based on soil direct contact and groundwater protection, as well as other limits.

The first table requires the **user** to make **two decisions** that will affect the results displayed in the table.

1. Can soil cleanup levels be established under Method C (industrial land use)?

   To determine whether soil cleanup levels can be based on industrial land use (Method C), see WAC 173-340-745(1).

   - If the site qualifies for use of Method C to establish soil cleanup levels, then enter a check in the box.
   - If the site does not qualify for use of Method C to establish soil cleanup levels, then leave the checkbox blank.

2. Can air cleanup levels be established under Method C?

   To determine whether the air cleanup level can be based on industrial land use (Method C), see WAC 173-340-745(1).

   - If the site qualifies for use of Method C to establish air cleanup levels, then enter a check in the box.
   - If the site does not qualify for use of Method C to establish air cleanup levels, then leave the checkbox blank.

The first table then displays the results (example shown in **Table 2-2**). A description of the content of the table is provided below.

Table 2-2: Calculation Summary Table

B. SUMMARY OF SOIL CLEANUP LEVEL CALCULATIONS

Chemical of Concern: DDT

1. Summary of Results

To calculate a soil cleanup level based on Industrial Land Use (Method C) for Direct Soil Contact, check ☑

To calculate a soil concentration based on Method C vapor pathway, check here: ☑

Basis for Soil Concentration	Conc	Units
Most stringent soil concentration based on Soil Direct Contact & Ground Water Protection:	3.491E+00	mg/kg
Natural Background concentration for Soil:	N/A	mg/kg
Practical Quantitation Limit for Soil:	0.002	mg/kg
Soil Cleanup Level (not considering vapor pathway):	3.491E+00	mg/kg
Soil concentration based on Vapor Pathway (informational purposes only):	1.367E+02	mg/kg
Soil Saturation Limit, C_{sat}:	3.730E+00	mg/kg
Retardation Factor, R:	2,365.9	unitless

C_{sat} corresponds to the total soil chemical concentration saturated in soil.
R is the ratio of the ground water flow velocity to the contaminant migration velocity in saturated zone.

Chemical of Concern: The name of the chemical as entered by the user.

Most Stringent Soil Concentration based on Evaluation of the Direct Contact Pathway and the Leaching Pathway (mg/kg): The worksheet calculates protective soil concentrations based on the direct contact pathway and the leaching pathway (protection of groundwater). The lower (most stringent) of these two concentrations is presented in the table.

Natural Background Soil Concentration (mg/kg): This is the chemical-specific natural background concentration entered by the user.

Practical Quantitation Limit for Soil (mg/kg): This is the chemical-specific practical quantitation limit entered by the user.

Soil Cleanup Level (mg/kg): The soil cleanup level presented in the table is the most stringent concentration based on evaluation of the direct contact pathway and the leaching pathway unless that concentration is more stringent than either the natural background concentration or the PQL. If the calculated concentration is lower (more stringent) than either the natural background concentration or the PQL, then the worksheet adjusts the calculated concentration upward to the natural background concentration or the PQL, whichever is higher (less stringent).

Soil Saturation Limit (C_{sat}) (mg/kg): The soil saturation limit corresponds to the chemical concentration in soil at which sorption limits of the soil particles, solubility limits of the soil pore water, and saturation of soil pore air have all been reached. It is an indicator (a theoretical threshold) that the chemical may exist as a separate pure phase in the soil and, if it is a liquid, may exist as a nonaqueous phase liquid with additional hazards to groundwater quality.

Retardation Factor (R) (unitless): The retardation factor is the ratio of the groundwater flow velocity to contaminant migration velocity. If the retardation factor is “10”, the contaminant plume in the saturated zone would move, on average, ten times slower than the groundwater flow. This

result is provided so that the user can assess the chemical's relative mobility in the groundwater. The result is not used in calculating the soil cleanup level.

2.3.5.2 Summary of Results by Exposure Pathway

The second table (example shown in **Table 2-3**) displays the results of more detailed calculations for the direct contact pathway, the leaching pathway, and vapor pathway to allow the user to determine the basis of the cleanup level.

Table 2-3: Summary of Calculation for Each Exposure Pathway

2. Summary of Calculation for each Exposure Pathway

Summary by Exposure Pathway

			Method B Unrestricted Land @ HQ=1.0; RISK =1.0E-6		Method C Industrial Land Use @ HQ=1.0; RISK =1.0E-5	
			Ingestion only	Ingestion & Dermal	Ingestion only	Ingestion & Dermal
Soil Direct Contact	Under the Current Condition	HQ? @ Exposure Point	1.250E-01	1.800E-01	2.857E-03	1.500E-02
		RISK? @ Exposure Point	1.700E-06	2.448E-06	1.295E-07	6.800E-07
	Target Soil CUL? mg/kg	@HQ=1.0	4.000E+01	2.778E+01	1.750E+03	3.333E+02
		@RISK =1.0E-6 or 1.0E-5	2.941E+00	2.042E+00	3.860E+02	7.353E+01

			Method B @ HQ=1.0; RISK =1.0E-6	Method C @ HQ=1.0; RISK =1.0E-5
Protection of Potable Ground Water	Under the Current Condition	Predicted Ground Water Conc? ug/l	3.687E-01	
		HQ? @ Exposure Point	4.608E-02	2.107E-02
		RISK? @ Exposure Point	1.433E-06	1.433E-06
	Target Ground Water CUL? ug/l		2.574E-01	
	Target Soil CUL? mg/kg		3.491E+00	

			Method B @ HQ=1.0; RISK =1.0E-6	Method C @ HQ=1.0; RISK =1.0E-5
Protection of Air Quality *(for informational purpose only)*	Under the Current Condition	Predicted Air Conc? ug/m^3 @Exposure Point	9.415E-03	
		HQ? @ Exposure Point	N/A	N/A
		RISK? @ Exposure Point	3.658E-07	3.658E-07
	Target Air CUL? ug/m^3	@ HQ=1.0	N/A	N/A
		@ RISK=1.0E-6 or 1.0E-5	2.574E-02	2.574E-01
	Target Soil CUL? mg/kg	@ HQ=1.0	N/A	N/A
		@ RISK=1.0E-6 or 1.0E-5	1.367E+01	1.367E+02

For the **direct contact pathway**, the worksheet first calculates HQ and RISK under Method B and Method C based on the current site conditions.

- **Noncarcinogenic HQ under the Current Condition:** This is the hazard quotient (HQ) based on the measured soil concentration. The worksheet calculates the HQ using the direct contact equations in the regulation (ingestion only AND ingestion + dermal) and solving for HQ.

- **Carcinogenic Risk under the Current Condition:** This is the carcinogenic risk under the current condition based on the measured soil concentration. The worksheet calculates the carcinogenic risk using the direct contact equations in the regulation (ingestion only AND ingestion + dermal) and solving for carcinogenic RISK.

For the **direct contact pathway**, the worksheet next calculates protective soil concentrations under Method B and Method C based on the regulatory standards for HQ and RISK.

- **Target Soil Cleanup Level (CUL) @ HQ = 1:** This is the protective soil concentration based on noncarcinogenic effects. The worksheet calculates the protective soil concentration using the direct contact equations in the regulation (ingestion only AND ingestion + dermal).

- **Target Soil CUL @ RISK = 1 x 10^{-6} (Method B) or 1 x 10^{-5} (Method C):** This is the protective soil concentration based on carcinogenic risk. The worksheet calculates the protective soil concentration using the direct contact equations in the regulation (ingestion only AND ingestion + dermal).

For the **leaching pathway (Protection of Potable Groundwater)**, the worksheet first calculates the predicted groundwater concentration based on current site conditions using the 3-phase model and then calculates the HQ and RISK under Method B and Method C based on the predicted groundwater concentration.

- **Noncarcinogenic HQ under the Current Condition:** This is the hazard quotient (HQ) based on the measured soil concentration and the predicted groundwater concentration. The worksheet calculates the HQ using the equation in the regulation and solving for HQ.

- **Carcinogenic Risk under the Current Condition:** This is the carcinogenic risk based on the measured soil concentration and the predicted groundwater concentration. The worksheet calculates the RISK using the equation in the regulation and solving for carcinogenic RISK.

For the **leaching pathway**, the worksheet next calculates the soil concentration that is protective of groundwater under either Method B or Method C using the 3-phase model. The protective soil concentration is based on the target groundwater cleanup level calculated using the groundwater worksheet or defined by the user.

2.3.6 Output – Adjustment of Result

As noted previously (see **Section 2.3**), the soil cleanup levels calculated using the soil worksheet **DO NOT** account for several factors. Consequently, to establish a soil cleanup level under the regulation, the cleanup level calculated using the worksheet may need to be manually adjusted to account for the following:

- Concentrations established under applicable state and federal laws (WAC 173-340-740(3)(b)(i) or 173-340-745(5)(b)(i));
- Terrestrial ecological impacts (see WAC 173-340-740(3)(b)(ii) or 173-340-745(5)(b)(ii));
- Impacts on air quality (vapor pathway) (see WAC 173-340-740(3)(b)(iii)(C), (c)(iv) or 173-340-745(5)(b)(iii)(C), (c)(iv));
- Residual saturation (see WAC 173-340-747(2)(b) and (10)); and
- Total site risk (see WAC 173-340-740(5)(a) or 173-340-745(6)(a)).

2.4 Calculating Potable Groundwater Cleanup Levels (Groundwater Worksheet)

This worksheet calculates a Method B or Method C potable groundwater cleanup level.

2.4.1 Accessing the Groundwater Worksheet

The groundwater worksheet is accessed by selecting the **Calc Groundwater CUL** button in **Part 5** of the soil worksheet described in **Section 2.3.4.5** above.

2.4.2 Caution on Use of the Groundwater Worksheet

The potable groundwater cleanup levels calculated using the groundwater worksheet account for the following:

- Concentrations established under applicable state and federal laws
- Concentrations based on protection of human health
- Natural background concentrations
- Practical quantitation limits

The potable groundwater cleanup levels calculated using the groundwater worksheet **DO NOT** account for the following:

- Concentrations based on protection of air quality (vapor pathway[83])

[83] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.

- Concentrations based on potential surface water impacts
- Nonaqueous phase liquid (NAPL) limitation[84]
- Total site noncancer hazard and risk

The groundwater cleanup levels calculated using the groundwater worksheet may need to be manually adjusted to account for these considerations.

2.4.3 Equations and Parameters

The worksheet uses the standard equations for calculating potable groundwater cleanup levels provided in the regulation (see **Attachment D**). For each of the parameters used in the equations, default assumptions (values) are set forth in the regulation to calculate **standard** Method B or C[85] cleanup levels. Under **modified** Methods B and C, specified default assumptions may be adjusted based on site-specific or chemical-specific data. The regulation specifically describes which parameters may be adjusted and how they may be adjusted.

- IF the regulation does not allow a parameter to be adjusted, THEN the worksheet uses the default value for that parameter provided in the regulation. Also, the parameter is not listed in the worksheet and the user may not input data for that parameter.
- IF the regulation allows a parameter to be adjusted, THEN the parameter is listed in the worksheet and the user may input either the default value provided in the regulation or a site-specific or chemical-specific value derived under the regulation.

2.4.4 User Input – Soil and Groundwater Worksheets

To calculate a potable groundwater cleanup level, the Workbook requires the user to input data for several parameters, some of which are listed in the soil worksheet.

The following parameters necessary for calculating a potable groundwater cleanup level are listed in the soil worksheet and must be entered there.

- Oral Reference Dose (***RfD$_o$***) – Part 2.
- Oral Carcinogenic Potency Factor (***CPF$_o$***) – Part 2.

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[84] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

[85] Method C groundwater cleanup levels based on potable water ingestion may only be used at sites qualifying under the strict conditions set forth in WAC 173-340-706(1). Contact Ecology for methods to evaluate hazardous substances in groundwater that may qualify for a Method C groundwater cleanup level in accordance with WAC 173-340-706(1).

- Inhalation Correction Factor (***INH***) – Part 3.

The following parameters necessary for calculating a potable groundwater cleanup level are listed in Part 1 of the groundwater worksheet and must be entered there.

- Practical Quantitation Limit for Groundwater (if known).
- Natural Background Groundwater Concentration (if known).
- Most stringent groundwater concentration based on applicable state and federal laws.

This worksheet requires the user to provide information listed on the left side (see **Figure 2-9**). Data is entered in the corresponding non-shaded (white) boxes on the right.

Figure 2-9 Example: Method B Groundwater Cleanup Levels

Name of Chemical: ***DDT***

1. Calculation of Method B Cleanup Levels for Potable Groundwater

Basis for Groundwater Concentration	Concentration, ug/l
Concentration based on non-carcinogenic risk @ HQ=1.0	8.000E+00
Concentration based on carcinogenic risk @ Risk = 1 in 1,000,000 (1.0E-6)	2.574E-01
Concentration based on carcinogenic risk @ Risk = 1 in 100,000 (1.0E-5)	2.574E+00
Enter Practical Quantitation Limit of Groundwater	0.01
Enter Natural Background Level of Groundwater	
Enter Most stringent concentration based on Applicable State or Federal Laws	
Method B Potable Groundwater Cleanup Level =	2.574E-01

Practical Quantitation Limit (PQL) for Groundwater (if known): This parameter is used to adjust the groundwater cleanup level as provided in WAC 173-340-720(7)(c), if necessary. The parameter is chemical-specific. The PQL is the lowest concentration of the contaminant that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during routine laboratory operating conditions, using Department-approved methods. The analytical laboratory or site manager can assist the user in identifying the appropriate PQL. Enter the PQL for the chemical, if known. If the PQL is not known, leave the entry box blank.

Natural Background Groundwater Concentration (if known): This parameter is used to adjust the groundwater cleanup level as provided in WAC 173-340-720(7)(c), if necessary. The parameter is chemical- and site-specific. Enter the natural background groundwater concentration, if known. Methods for defining natural background concentrations are provided in WAC 173-340-709. Ecology has published information on arsenic background levels in groundwater (*Natural Background Groundwater Arsenic Concentrations in Washington State:*

Study Results, Publication No. 14-09-044[86]). If the natural background concentration is not known, leave the entry box blank.

Most Stringent Groundwater Concentration Based on Applicable State or Federal Laws: This parameter is used to calculate a groundwater cleanup level and is chemical-specific. Enter the most stringent (lowest) groundwater concentration (criteria) established under applicable state or federal law for the chemical of concern. Groundwater concentrations (criteria) established under applicable state or federal law are published in CLARC.

THIS COMPLETES DATA ENTRY FOR THE GROUND WATER WORKSHEET. SAVE YOUR WORK BEFORE CONTINUING.

2.4.5 Output – Interpreting the Result

For hazardous substances for which sufficiently protective, health-based concentrations have been established under applicable state and federal laws, the worksheet establishes a groundwater cleanup level based on the most stringent of those concentrations. A concentration established under applicable state and federal laws is sufficiently protective if the excess cancer risk does not exceed 1 in 100,000 (1×10^{-5}) and the hazard quotient does not exceed one (1). If the concentration is not sufficiently protective, the worksheet calculates a protective concentration by adjusting the concentration downward in accordance with WAC 173-340-720(7)(b), using the equations provided in the regulation.

For hazardous substances for which health-based concentrations have not been established under applicable state and federal laws, the worksheet calculates a protective concentration using the equations provided in the regulation.

If the groundwater cleanup level is lower (more stringent) than either the natural background concentration or the PQL, then the worksheet adjusts the cleanup level upward to the natural background concentration or the PQL, whichever is higher (less stringent).

2.4.6 Output – Adjustment of Result

As noted previously (see **Section 2.4.2**), the potable groundwater cleanup levels calculated using the groundwater worksheet **DO NOT** account for several factors. Consequently, to establish a potable groundwater cleanup level under the regulation, the cleanup level calculated using the worksheet may need to be manually adjusted to account for the following:

- Concentrations based on protection of air quality (vapor pathway[87])

[86] https://apps.ecology.wa.gov/publications/SummaryPages/1409044.html
[87] To assess the vapor pathway for petroleum mixtures, see Ecology's Guidance: *Guidance for Evaluating Vapor Intrusion in Washington State: Investigation and Remedial Action*.

- Concentrations based on potential surface water impacts (see WAC 173-340-720(4)(b)(ii) and (5)(b)(ii))
- Nonaqueous phase liquid (NAPL) limitation[88] (see WAC 173-340-720(7)(d))
- Total site noncancer hazard and risk (see WAC 173-340-720(7)(a))

2.4.7 Output – Transfer of Adjusted Result to Soil Worksheet

To calculate a corresponding soil cleanup level using the soil worksheet, the potable groundwater cleanup level calculated using the groundwater worksheet must be manually adjusted (as described above) and then manually entered in the soil worksheet. The Workbook DOES NOT automatically enter the result from the groundwater worksheet.

[88] The cleanup level determined in WAC 173-340-720 shall not exceed a concentration that would result in NAPL being present in or on the groundwater. See WAC 173-340-720(7)(d).

Attachment A:

Equations and Default Values for Calculating Protective Soil Concentrations based on the Direct Contact Pathway

Equations 740-1 and 745-1: Soil Direct Contact (Ingestion Only) – Noncarcinogens

$$C_{soil} = \frac{RfD_o \times ABW \times UCF \times HQ \times AT}{SIR \times AB1 \times EF \times ED}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-1	Method C Equation 745-1	
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit Conversion Factor	1.0E+6	1.0E+6	mg/kg
AT	Averaging time	6.0	20	years
EF	Exposure frequency	1.0	0.4	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day

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Equations 740-2 and 745-2: Soil Direct Contact (Ingestion Only) – Carcinogens

$$C_{soil} = \frac{RISK \times ABW \times AT \times UCF}{CPF_o \times SIR \times AB1 \times EF \times ED}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-5	Method C Equation 745-5	
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit Conversion Factor	1.0E+6	1.0E+6	mg/kg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	0.4	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
CPF_o	Oral cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg

Equations 740-4 and 745-5: Soil Direct Contact (Ingestion + Dermal) – Noncarcinogens

For hazardous substances that are part of a petroleum mixture, cleanup levels based on noncancer effects must be calculated using Equation 740-4 under Method B, and 745-4 under Method C. These equations differ from 740-1 by including the dermal contact pathway. See WAC 173-340-740(3)(b)(iii)(B)(III) and 173-340-745(5)(b)(iii)(B)(III).

For hazardous substances other than petroleum mixtures, cleanup levels for dermal contact with the soil must be evaluated whenever the proposed changes to Equations 740-1/745-1 or 740-2/745-2 would result in a significantly higher soil cleanup level than would be calculated without the proposed changes. See WAC 173-340-740(3)(c)(iii) and 173-340-745(5)(c)(iii).

$$C_{soil} = \frac{HQ \times ABW \times AT}{EF \times ED \times \left[\left(\frac{1}{RfD_o} \times \frac{SIR \times AB1}{10^6 mg/kg}\right) + \left(\frac{1}{RfD_d} \times \frac{SA \times AF \times ABS_d}{10^6 mg/kg}\right)\right]}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-4	Method C Equation 745-4	
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	6.0	20	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
ABS_d	Dermal absorption fraction	*See* Note **(1)**	*See* Note **(1)**	unitless
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day
RfD_d	Dermal reference dose	*See* Note **(2)**	*See* Note **(2)**	mg/kg-day
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Footnotes:

1. May use chemical-specific values or the following defaults: 0.01 for inorganic hazardous substances; 0.0005 for volatile organic compounds with vapor pressure ≥ benzene; 0.03 for volatile organic compounds with vapor pressure < benzene; 0.1 for other hazardous substances.
2. Derived by ***RfD_o*** x ***GI*** (*see* **note 3**).
3. May use chemical-specific values or the following defaults: 0.2 for inorganic hazardous substances; 0.8 for volatile organic compounds; 0.5 for other organic hazardous substances.

Equations 740-5 and 745-5: Soil Direct Contact (Ingestion + Dermal) – Carcinogens

For hazardous substances that are part of a petroleum mixture, cleanup levels based on cancer effects must be calculated using Equations 740-5 and 745-5. These equations differ from 740-2 by including the dermal contact pathway. See WAC 173-340-740(3)(b)(iii)(B)(III) and 173-340-745(5)(b)(iii)(B)(III).

For hazardous substances other than petroleum mixtures, cleanup levels for dermal contact with the soil must be evaluated whenever the proposed changes to Equations 740-1/745-1 or 740-2/745-2 would result in a significantly higher soil cleanup level than would be calculated without the proposed changes. See WAC 173-340-740(3)(c)(iii) and 173-340-745(5)(c)(iii).

$$C_{soil} = \frac{RISK \times ABW \times AT}{EF \times ED \times \left[\left(\frac{SIR \times AB1 \times CPF_o}{10^6 mg/kg}\right) + \left(\frac{SA \times AF \times ABS_d \times CPF_d}{10^6 mg/kg}\right)\right]}$$

Parameter	Definition	Default Value		Units
		Method B Equation 740-5	Method C Equation 745-5	
C_{soil}	Soil cleanup level	(calculated)	(calculated)	mg/kg
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	16	70	kg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	0.7	unitless
ED	Exposure duration	6.0	20	years
SIR	Soil ingestion rate	200	50	mg/day
AB1	Gastrointestinal absorption fraction	1.0	1.0	unitless
SA	Dermal surface area	2,200	2,500	cm^2
AF	Adherence factor	0.2	0.2	mg/cm^2-day
ABS_d	Dermal absorption fraction	*See* Note **(1)**	*See* Note **(1)**	unitless
CPF_o	Oral cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg
CPF_d	Dermal cancer potency factor	*See* Note **(2)**	*See* Note **(2)**	kg-day/mg
GI	Gastrointestinal absorption conversion factor	*See* Note **(3)**	*See* Note **(3)**	unitless

Footnotes:

(1) May use chemical-specific values or the following defaults: 0.01 for inorganic hazardous substances; 0.0005 for volatile organic compounds with vapor pressure ≥ benzene; 0.03 for volatile organic compounds with vapor pressure < benzene; 0.1 for other hazardous substances.

(2) Derived by ***CPF_o*** ÷ ***GI*** (see **note 3**).

(3) May use chemical-specific values or the following defaults: 0.2 for inorganic hazardous substances; 0.8 for volatile organic compounds; 0.5 for other organic hazardous substances.

Attachment B:

Equations and Default Values for Calculating Protective Soil Concentrations based on the Leaching Pathway

(Protection of Groundwater)

THREE-PHASE PARTITIONING

Equation 747-1: Three-Phase Partitioning Equilibrium Equation.

$$C_s = C_w \times UCF \times DF \times \left[K_d + \frac{\theta_w + \theta_a \times H_{cc}}{\rho_b}\right]$$

Parameter	Definition	Default Value (Unsaturated Zone)	Default Value (Saturated)	Units
C_s	Soil concentration	(calculated)	(calculated)	mg/kg
C_w	Groundwater cleanup level established under WAC 173-340-720	Chem-specific	Chem-specific	ug/L
UCF	Unit conversion factor	1E-3	1E-3	mg/ug
DF	Dilution factor	20	1	unitless
K_d	Distribution coefficient	Chem-specific **(1)**	Chem-specific **(1)**	L/kg
θ_w	Water-filled soil porosity	0.3	0.43	unitless, ml/ml
θ_a	Air-filled soil porosity	0.13	Zero	unitless, ml/ml
H_{cc}	Henry's law constant	Chem-specific **(2)**	Chem-specific **(2)**	unitless
ρ_b	Dry soil bulk density	1.5	1.5	kg/L

Footnotes:

(1) For K_d, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(c).

(2) For H_{cc}, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(d).

Equation 747-2: Derivation of a Distribution Coefficient (K_d) for Organic Hazardous Substances Based on the Soil Organic Carbon-Water Partitioning Coefficient (K_{oc})

$$K_d = K_{oc} \times f_{oc}$$

Parameter	Definition	Default Value	Units
K_d	Distribution coefficient	(Calculated or site-specific)	L/kg
K_{oc}	Soil organic carbon-water partitioning coefficient	Chem-specific **(1)**	L/kg
f_{oc}	Soil fraction of organic carbon	0.001	unitless, g/g

Footnote:

(1) For K_{oc}, the regulation specifies default values for certain chemicals. It also has procedures for establishing chemical-specific values. See WAC 173-340-747(4)(c)(i).

Equation 747-3: Deriving a Dilution Factor from Site-Specific Estimates of Infiltration and Groundwater Flow Volume

$$DF = \frac{(Q_p + Q_a)}{Q_p} = 1 + \frac{Q_a}{Q_p}$$

Parameter	Definition	Default Value	Units
DF	Dilution factor	(calculated)	unitless
Q_p	Flowrate of water infiltrating (*see* Equation 747-5)	(calculated)	m^3/yr
Q_a	Ground water flowrate (*see* Equation 747-4)	(calculated)	m^3/yr

Equation 747-4: Calculating Groundwater Flowrate (Q_a)

$$Q_a = K \times A \times I$$

Parameter	Definition	Default Value	Units
Q_a	Ground water flowrate	(calculated)	m^3/yr
K	Hydraulic conductivity	Site-specific measurement	m/yr
A	Cross-sectional area of aquifer mixing zone **(1)**	Site-specific measurement	m^2
I	Hydraulic gradient	Site-specific measurement	unitless, m/m

Footnote:

(1) The aquifer mixing zone thickness shall not exceed 5 meters in depth and be equal to a unit width of 1 meter, unless it can be demonstrated empirically that the mixing zone thickness exceeds 5 meters.

Equation 747-5: Calculating the Flowrate of Water Infiltrating (Q_p)

$$Q_p = L \times W \times Inf$$

Parameter	Definition	Default Value	Units
Q_p	Flowrate of water infiltrating	(calculated)	m^3/yr
L	Estimated length of contaminant source area parallel to groundwater flow	Site-specific measurement	m
W	Unit width of contaminant source area	1.0	m
Inf	Infiltration rate	Site-specific measurement **(1)**	m/yr

Footnote:

(1) A default value may be used. For sites **west** or **east** of the Cascade Mountains, the default annual infiltration value shall be **70 percent** or **25 percent**, respectively, of the average annual precipitation amount.

Attachment C:

Equations and Default Values for Calculating Air Cleanup Levels

Equation 750-1: Air Cleanup Levels – Noncarcinogens

$$Air\ Cleanup\ Level\ (\frac{\mu g}{m^3}) = \frac{RfD_i \times ABW \times UCF \times HQ \times AT}{BR \times ABS_i \times EF \times ED}$$

Parameter	Definition	Default Value		Units
		Method B Equation 750-1	Method C Equation 750-1	
HQ	Hazard quotient	1	1	unitless
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit Conversion Factor	1.0E+3	1.0E+3	µg/mg
AT	Averaging time	6.0	6.0	years
EF	Exposure frequency	1.0	1.0	unitless
ED	Exposure duration	6.0	6.0	years
BR	Breathing rate	10	20	m^3/day
ABS_i	Inhalation absorption fraction	1.0	1.0	unitless
RfD_i	Inhalation reference dose	Chemical-specific	Chemical-specific	mg/kg-day

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Equation 750-2: Air Cleanup Levels – Carcinogens

$$Air\ Cleanup\ Level\ (\frac{\mu g}{m^3}) = \frac{RISK \times ABW \times UCF \times AT}{CPF_i \times BR \times ABS_i \times EF \times ED}$$

Parameter	Definition	Default Value		Units
		Method B Equation 750-2	Method C Equation 750-2	
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	70	70	kg
UCF	Unit Conversion Factor	1,000	1,000	µg/mg
AT	Averaging time	75	75	years
EF	Exposure frequency	1.0	1.0	unitless
ED	Exposure duration	30	30	years
BR	Breathing rate	20	20	m^3/day
ABS_i	Inhalation absorption fraction	1.0	1.0	unitless
CPF_i	Inhalation cancer potency factor	Chemical-specific	Chemical-specific	kg-day/mg

Attachment D:

Equations and Default Values for Calculating Potable Groundwater Cleanup Levels

Equation 720-1: Potable Groundwater Cleanup Levels – Noncarcinogens

$$Potable\ Groundwater\ Cleanup\ Level\ (\mu g/L) = \frac{RfD_o \times ABW \times UCF \times HQ \times AT}{DWIR \times INH \times DWF \times ED}$$

Parameter	Definition	Default Value		Units
		Method B	Method C	
RfD_o	Oral reference dose	Chemical-specific	Chemical-specific	mg/kg-day
ABW	Average body weight over the exposure duration	16	70	kg
UCF	Unit conversion factor	1,000	1,000	µg/mg
HQ	Hazard quotient	1.0	1.0	unitless
AT	Averaging time	6	6	years
DWIR	Drinking water ingestion rate	1.0	2.0	L/day
INH	Inhalation correction factor (1)	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	6	6	years

Footnotes:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances.

Equation 720-2: Potable Groundwater Cleanup Levels – Carcinogens

$$Potable\ Groundater\ Cleanup\ Level\ (\mu g/L) = \frac{RISK \times ABW \times AT \times UCF}{CPF_o \times DWIR \times ED \times INH \times DWF}$$

Parameter	Definition	Default Value		Units
		Method B	Method C	
RISK	Acceptable cancer risk level	1.0E-6	1.0E-5	unitless
ABW	Average body weight over the exposure duration	70	70	kg
AT	Averaging time	75	75	years
UCF	Unit conversion factor	1,000	1,000	µg/mg
CPF_o	Oral carcinogenic potency factor	Chemical-specific	Chemical-specific	kg-day/mg
DWIR	Drinking water ingestion rate	2.0	2.0	L/day
INH	Inhalation correction factor	Chemical-specific **(1)**	Chemical-specific **(1)**	unitless
DWF	Drinking water fraction	1.0	1.0	unitless
ED	Exposure duration	30	30	years

Footnotes:

(1) Use value of 2 for volatile organic compounds and 1 for all other substances.