APPENDIX B

Risk Based Screening Levels – Direct Contact

1.0 DIRECT CONTACT

Appendix B explains the methods Montana Department of Environmental Quality (DEQ) used to develop direct contact risk-based screening levels (RBSLs) for Tier 1 of the risk-based corrective action (RBCA) process. The appendix is made up of tables and spreadsheets used to develop the RBSLs. The following is a brief explanation of these tables and spreadsheets. Data sources are provided in the spreadsheets and a reference list is provided at the end of this appendix. DEQ chose conservative parameters to develop RBSLs applicable to a wide variety of petroleum release sites.

Risk assessment is an estimate of the likelihood of adverse effects that may result from exposure to certain health hazards, including pollutants in the environment. A risk is the chance that an adverse event will happen, multiplied by the degree or magnitude of an effect that might lead to impacts on human health. Risk assessment in humans can be based on if a chemical has carcinogenic or non-carcinogenic health risks. Potential human carcinogenic risk associated with chemical exposure is expressed in terms of an increased probability of developing cancer during a person's lifetime. For example, a 10^{-6} increased cancer risk over a lifetime means that there is one additional case of cancer during a lifetime in a population of a million people. Cancer risk or Target Risk (TR) is calculated for carcinogens with available cancer risk values (Cancer Slope Factors [SF], Inhalation Unit Risks [IUR]).

For non-carcinogens, the hazard quotient *(*HQ) is calculated to evaluate the potential for non-cancer health hazards to occur from exposure to a contaminant with available non-cancer health guidelines (Oral Reference Doses [RfDo], Inhalation Reference Concentrations [RfC]).

The Waste Management & Remediation Division calculated RBSLs representing both the carcinogenic risk and the non-carcinogenic hazards from exposure to each compound. The more conservative (most protective) concentration was chosen as the RBSL for each compound and is displayed on the tables within the RBCA guidance.

Table B1 provides a compilation of the chemical specific information used to calculate each RBSL, both carcinogenic and non-carcinogenic. Due to size, this table is available upon request.

DEQ chose toxicity values based upon the December 5, 2003, EPA OSWER Directive 9285.7-53, which provides a hierarchy of human health values recommended for risk assessments (EPA, 2003). DEQ's petroleum fraction screening procedure is based on the use of the Massachusetts method for volatile petroleum hydrocarbons and extractable petroleum hydrocarbons to help characterize risks posed by petroleum releases. Therefore, for the fraction toxicity data, RfDo, RfC and RAFw, DEQ used the Massachusetts toxicity values (MADEP, 2002), except for one fraction range, aliphatic C19-C36, for which PPRTV 2022 was used instead (please note the value for this fraction range did not change from 2009 with the 2022 PPRTV update).

For the C5-C8 aliphatics, MADEP 2003 used the previous IRIS RfC value for n-hexane (EPA, 1993) in its C5-C8 aliphatic calculation. The IRIS values for n-hexane has since been updated; therefore, the updated IRIS (EPA, 2005) RfC was used instead of the previous IRIS RfC.

Subchronic s-RfCs and subchronic s-RfDs were calculated where available or where they could be calculated using available toxicity studies.

The fraction subchronic toxicity values were calculated by removing the uncertainty factor of the subchronic toxicity studies to convert them to chronic RfDs and RfCs. Please note these may be more conservative subchronic toxicity numbers as some of the studies were more representative of semi-subchronic numbers (referred to as less-than lifetime studies, i.e., C9-C18 aliphatics).

C5-C8 aliphatics, C9-C12 and C9-C18 aliphatics (C9-C18 in MADEP, 2003), and C9-C10 and C11-C22 aromatics (C9-C32 in MADEP, 2003): removed the uncertainty factors of 10 for subchronic to chronic toxicity for reduced body weight, neurotoxicity and changes in serum chemistry and liver weight, and kidney effects, respectively .

C9-C12 and C9-C18 aliphatics (C9-C18 in MADEP, 2003) removed the uncertainty factor of 3 for subchronic to chronic neurotoxicity found in MADEP, 2003.

C9-C10 aromatics and C11-C22 aromatics (C9-C32 in MADEP, 2003) removed the uncertainty factor of 10 for subchronic to chronic.

The Volatilization Factors spreadsheet was used to calculate volatilization factors for the petroleum fractions using the method provided in the EPA RSL User's Guide (EPA, May 2023a). Volatile chemicals are defined as those chemicals having a Henry's Law constant greater than 10^{-5} (atm-m^3/mol) and a molecular weight less than 200 g/mole (EPA, 2023). DEQ used the EPA RSL Calculator (EPA, 2023) as the source of the volatilization factors for the target analytes, like benzene.

2.0 Direct Contact Exposure Assumptions

The following exposure assumptions were developed specific to sites located in Montana. These assumptions cannot be changed or altered in the Tier 1 evaluation. Site specific information may be substituted for several exposure assumptions. For DEQ to consider modifications to the default exposure assumptions, Owners/Operators or responsible parties and consultants would have to show the data behind the proposed exposure inputs and get the approval of the DEQ project team. Due to future use considerations, assumptions on worker exposures generally are not modified.

In 2005, DEQ conducted an analysis of Montana climate data from the Western Regional Climate Center going back to the late 1800s. DEQ determined that there was no location in Montana for which climate data were available that did not have a minimum of three months of an average snow depth of at least 2 inches or an average temperature at or below freezing or both. Therefore, DEQ determined that surface soil and dust exposure (ingestion, dermal, and inhalation) would only be likely to occur during the nine months of the year that did not meet those conditions and that Montana default exposure frequencies would be based upon this information.

For residential surface soil exposure, DEQ calculated that during 75% of the 365 days per year, the soil might be available for exposure. The rounded result was 270 days per year. This is the Montana default residential exposure frequency. The typical residential exposure scenarios include a two-week vacation and DEQ's assumption is that those vacation days would occur

throughout the year and not all in any one season.

For commercial/industrial exposure, DEQ calculated that during 75% of the 250 working days per year, the soil might be available for exposure. (The 250 working days is based on 52 weeks of work, five days per week, and assumes a 10-day vacation.) This results in a Montana default commercial/industrial exposure frequency of 187 days per year.

For construction worker exposure, DEQ assumes that a building excavation might be open for exposure for as long as 4 months and that most land uses include some possibility of this type of construction. Therefore, the Montana default construction worker exposure frequency is 124 days per year. If the reasonably anticipated future use of a property (e.g., an active railroad grade) does not include building construction, an alternate utility worker exposure frequency may be appropriate.

Recreational and trespasser exposure frequencies should be site-specific based upon factors such as type of recreation anticipated, site features (e.g., playground equipment or potentially attractive features like ponds or sloughs) security measures in place, and proximity to residential or educational properties. Other exposure parameters (e.g., body weight, skin surface area) are set appropriately based upon the type of receptor and use.

3.0 Direct Contact Receptors – Carcinogenic and Non-carcinogenic Effects

Residential Receptor:
RBSLs for residential exposure to carcinogens are based on a target risk of $1X10^{-6}$, providing some assurance that overall site risks will not exceed $1X10^{-5}$, and are applied to the top 2 feet of soil at sites where the current and reasonably expected future usage is residential.

RBSLs for residential exposure to non-carcinogens are based on a target HQ of 0.1 which provides some assurance that the overall hazard index for a site will not exceed 1. These RBSLs are applied to the top two feet of soil at sites where the current and reasonably expected future usage is residential.

The Commercial Scenario
RBSLs for a commercial worker's exposure to carcinogens are based on a target risk of $1X10^{-6}$, providing some assurance that overall site risks will not exceed $1X10^{-5}$, and are applied to the top two feet of soil at sites where the current and reasonably expected future usage is commercial or industrial.

RBSLs for a commercial worker's exposure to non-carcinogens are based on a target HQ of 0.1 which provides some assurance that the overall hazard index for a site will not exceed 1. The RBSLs are applied to the top two feet of soil at sites where the current and reasonably expected future usage is commercial or industrial.

The Construction Worker
RBSLs for a construction worker's exposure to carcinogens are based on a target risk of $1X10^{-6}$, providing some assurance that overall site risks will not exceed $1X10^{-5}$ and are applied to soil from the ground surface to 10 feet of depth at all sites where there is a potential for residential redevelopment or landscaping, utility installation, pipe repair, or other future excavation.

RBSLs for a construction worker's exposure to non-carcinogens are based on a target HQ of 0.1 for each compound which provides some assurance that the overall hazard index for a site will not exceed 1. The RBSLs may be applied to the 0-10 ft. soil column at all sites where there is a potential for residential redevelopment or landscaping, utility installation, pipe repair, or other excavation in the future. This receptor is assumed an exposure duration of 1 year and is thus, subchronic. For this reason, the construction worker RBSLs were calculated using subchronic toxicity values. These values can be found in Table B1 (available upon request) along with references for each value.

4.0 Risk-Based Screening Level Equation Inputs

Table B1 provides the chemical specific input values and references for each compound included in the RBCA Guidance and is available upon request. All other variables are provided below for each receptor.

4.1 Residential Receptor

RBSLs for the residential receptor were calculated using EPA's RSL calculator (EPA, 2023). Montana-specific values are highlighted in orange and all other values are EPA default variables. The table below is compilation of all parameters used in both the carcinogenic and non-carcinogenic RBSL calculations from the EPA RSL calculator output.

Variable	State-Specific Value
A (PEF Dispersion Constant)	16.2302
A (VF Dispersion Constant)	11.911
A (VF Dispersion Constant - mass limit)	11.911
B (PEF Dispersion Constant)	18.7762
B (VF Dispersion Constant)	18.4385
B (VF Dispersion Constant - mass limit)	18.4385
C (PEF Dispersion Constant)	216.108
C (VF Dispersion Constant)	209.7845
C (VF Dispersion Constant - mass limit)	209.7845
foc (fraction organic carbon in soil) g/g	0.006
F(x) (function dependent on U_m/U_t) unitless	0.194
n (total soil porosity) L_{pore}/L_{soil}	0.43396
p_b (dry soil bulk density) g/cm^3	1.5
p_b (dry soil bulk density - mass limit) g/cm^3	1.5
PEF (particulate emission factor) m^3/kg	1359344438
p_s (soil particle density) g/cm^3	2.65
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
Q/C_{vol} (g/m^2-s per kg/m^3)	68.18
Q/C_{vol} (g/m^2-s per kg/m^3 - mass limit)	68.18
A_s (PEF acres)	0.5

A_s (VF acres)	0.5
A_s (VF mass-limit acres)	0.5
$AF_{0\text{-}2}$ (mutagenic skin adherence factor) mg/cm^2	0.2
$AF_{2\text{-}6}$ (mutagenic skin adherence factor) mg/cm^2	0.2
$AF_{6\text{-}16}$ (mutagenic skin adherence factor) mg/cm^2	0.07
$AF_{16\text{-}26}$ (mutagenic skin adherence factor) mg/cm^2	0.07
$AF_{res\text{-}a}$ (skin adherence factor - adult) mg/cm^2	0.07
$AF_{res\text{-}c}$ (skin adherence factor - child) mg/cm^2	0.2
AT_{res} (averaging time - resident carcinogenic)	365
$BW_{0\text{-}2}$ (mutagenic body weight) kg	15
$BW_{2\text{-}6}$ (mutagenic body weight) kg	15
$BW_{6\text{-}16}$ (mutagenic body weight) kg	80
$BW_{16\text{-}26}$ (mutagenic body weight) kg	80
$BW_{res\text{-}a}$ (body weight - adult) kg	80
$BW_{res\text{-}c}$ (body weight - child) kg	15
$DFS_{res\text{-}adj}$ (age-adjusted soil dermal factor) mg/kg	79758
$DFSM_{res\text{-}adj}$ (mutagenic age-adjusted soil dermal factor) mg/kg	330372
ED_{res} (exposure duration) years	26
$ED_{0\text{-}2}$ (mutagenic exposure duration) years	2
$ED_{2\text{-}6}$ (mutagenic exposure duration) years	4
$ED_{6\text{-}16}$ (mutagenic exposure duration) years	10
$ED_{16\text{-}26}$ (mutagenic exposure duration) years	10
$ED_{res\text{-}a}$ (exposure duration - adult) years	20
$ED_{res\text{-}c}$ (exposure duration - child) years	6
EF_{res} (exposure frequency) days/year	270
$EF_{0\text{-}2}$ (mutagenic exposure frequency) days/year	270
$EF_{2\text{-}6}$ (mutagenic exposure frequency) days/year	270
$EF_{6\text{-}16}$ (mutagenic exposure frequency) days/year	270
$EF_{16\text{-}26}$ (mutagenic exposure frequency) days/year	270
$EF_{res\text{-}a}$ (exposure frequency - adult) days/year	270
$EF_{res\text{-}c}$ (exposure frequency - child) days/year	270
ET_{res} (exposure time) hours/day	24
$ET_{0\text{-}2}$ (mutagenic exposure time) hours/day	24
$ET_{2\text{-}6}$ (mutagenic exposure time) hours/day	24
$ET_{6\text{-}16}$ (mutagenic exposure time) hours/day	24
$ET_{16\text{-}26}$ (mutagenic exposure time) hours/day	24
$ET_{res\text{-}a}$ (adult exposure time) hours/day	24
$ET_{res\text{-}c}$ (child exposure time) hours/day	24
THQ (target hazard quotient) unitless	0.1
$IFS_{res\text{-}adj}$ (age-adjusted soil ingestion factor) mg/kg	28350
$IFSM_{res\text{-}adj}$ (mutagenic age-adjusted soil ingestion factor) mg/kg	128700
$IRS_{0\text{-}2}$ (mutagenic soil intake rate) mg/day	200
$IRS_{2\text{-}6}$ (mutagenic soil intake rate) mg/day	200

$IRS_{6\text{-}16}$ (mutagenic soil intake rate) mg/day	100
$IRS_{16\text{-}26}$ (mutagenic soil intake rate) mg/day	100
$IRS_{res\text{-}a}$ (soil intake rate - adult) mg/day	100
$IRS_{res\text{-}c}$ (soil intake rate - child) mg/day	200
LT (lifetime) years	78
$SA_{0\text{-}2}$ (mutagenic skin surface area) cm^2/day	2373
$SA_{2\text{-}6}$ (mutagenic skin surface area) cm^2/day	2373
$SA_{6\text{-}16}$ (mutagenic skin surface area) cm^2/day	6032
$SA_{16\text{-}26}$ (mutagenic skin surface area) cm^2/day	6032
$SA_{res\text{-}a}$ (skin surface area - adult) cm^2/day	6032
$SA_{res\text{-}c}$ (skin surface area - child) cm^2/day	2373
TR (target risk) unitless	0.000001
T_w (groundwater temperature) Celsius	25
$Theta_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396
$Theta_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	819936000
T (exposure interval) yr	26
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
V (fraction of vegetative cover) unitless	0.5

4.2 Commercial Worker Receptor

RBSLs for the commercial worker receptor were calculated using EPA's RSL calculator (EPA, 2023) using EPA's "Composite Worker". Montana-specific values are highlighted in orange and all other values are EPA default variables. The table below is compilation of all parameters used in both the carcinogenic RBSL calculation or the non-carcinogenic RBSL calculation.

Variable	State-Specific Value
A (PEF Dispersion Constant)	16.2302
A (VF Dispersion Constant)	11.911
A (VF Dispersion Constant - mass limit)	11.911
B (PEF Dispersion Constant)	18.7762
B (VF Dispersion Constant)	18.4385
B (VF Dispersion Constant - mass limit)	18.4385
City (PEF Climate Zone) Selection	Default
City (VF Climate Zone) Selection	Default
C (PEF Dispersion Constant)	216.108
C (VF Dispersion Constant)	209.7845
C (VF Dispersion Constant - mass limit)	209.7845
foc (fraction organic carbon in soil) g/g	0.006
F(x) (function dependent on U_m/U_t) unitless	0.194
n (total soil porosity) L_{pore}/L_{soil}	0.43396

p_b (dry soil bulk density) g/cm^3	1.5
p_b (dry soil bulk density - mass limit) g/cm^3	1.5
PEF (particulate emission factor) m^3/kg	1359344438
p_s (soil particle density) g/cm^3	2.65
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
Q/C_{vol} (g/m^2-s per kg/m^3)	68.18
Q/C_{vol} (g/m^2-s per kg/m^3 - mass limit)	68.18
A_s (PEF acres)	0.5
A_s (VF acres)	0.5
A_s (VF mass-limit acres)	0.5
AF_{com} (skin adherence factor - composite worker) mg/cm^2	0.12
AT_{com} (averaging time - composite worker)	365
BW_{com} (body weight - composite worker)	80
ED_{com} (exposure duration - composite worker) yr	25
EF_{com} (exposure frequency - composite worker) day/yr	187
ET_{com} (exposure time - composite worker) hr	8
THQ (target hazard quotient) unitless	0.1
IRS_{com} (soil ingestion rate - composite worker) mg/day	100
LT (lifetime) yr	78
SA_{com} (surface area - composite worker) cm^2/day	3527
TR (target risk) unitless	0.000001
T_w (groundwater temperature) Celsius	25
$Theta_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396
$Theta_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	819936000
T (exposure interval) yr	26
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
V (fraction of vegetative cover) unitless	0.5

4.3 Construction Worker

RBSLs for the construction worker receptor were calculated using EPA's RSL calculator (EPA, 2023) using EPA's "Composite Worker". Montana-specific values are highlighted in orange and all other values are EPA default variables. The table below is compilation of all parameters used in both the carcinogenic RBSL calculation or the non-carcinogenic RBSL calculation.

Variable	State-Specific Value
A (PEF Dispersion Constant)	16.2302
A (VF Dispersion Constant)	11.911
A (VF Dispersion Constant - mass limit)	11.911

B (PEF Dispersion Constant)	18.7762
B (VF Dispersion Constant)	18.4385
B (VF Dispersion Constant - mass limit)	18.4385
City (PEF Climate Zone) Selection	Default
City (VF Climate Zone) Selection	Default
C (PEF Dispersion Constant)	216.108
C (VF Dispersion Constant)	209.7845
C (VF Dispersion Constant - mass limit)	209.7845
foc (fraction organic carbon in soil) g/g	0.006
F(x) (function dependent on U_m/U_t) unitless	0.194
n (total soil porosity) L_{pore}/L_{soil}	0.43396
p_b (dry soil bulk density) g/cm^3	1.5
p_b (dry soil bulk density - mass limit) g/cm^3	1.5
PEF (particulate emission factor) m^3/kg	1359344438
p_s (soil particle density) g/cm^3	2.65
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77
Q/C_{vol} (g/m^2-s per kg/m^3)	68.18
Q/C_{vol} (g/m^2-s per kg/m^3 - mass limit)	68.18
A_s (PEF acres)	0.5
A_s (VF acres)	0.5
A_s (VF mass-limit acres)	0.5
AF_{com} (skin adherence factor - composite worker) mg/cm^2	0.3
AT_{com} (averaging time - composite worker)	365
BW_{com} (body weight - composite worker)	80
ED_{com} (exposure duration - composite worker) yr	1
EF_{com} (exposure frequency - composite worker) day/yr	124
ET_{com} (exposure time - composite worker) hr	8
THQ (target hazard quotient) unitless	0.1
IRS_{com} (soil ingestion rate - composite worker) mg/day	330
LT (lifetime) yr	78
SA_{com} (surface area - composite worker) cm^2/day	3527
TR (target risk) unitless	0.000001
T_w (groundwater temperature) Celsius	25
$Theta_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396
$Theta_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15
T (exposure interval) s	819936000
T (exposure interval) yr	26
U_m (mean annual wind speed) m/s	4.69
U_t (equivalent threshold value)	11.32
V (fraction of vegetative cover) unitless	0.5

4.3 Calculating Petroleum Fractions

Equation Parameters	Values
THQ (Target hazard quotient)	0.1

BWc (Child body weight - kg; EPA, November 2022)	15
AT (Averaging time - day; EPA, November 2022)	2190
ED (Exposure duration - yr; EPA, November 2022)	6
EF (Exposure frequency - day/yr; DEQ Generic Residential, DEQ 2023)	270
GIABS (Chemical specific oral relative absorption factor - unitless; MADEP, October 2003)	1
RfDo (Chemical specific oral reference dose - mg/kg-day; MADEP, November 2003	CS
IRSc (Child soil ingestion rate - mg soil/day; EPA, November 2022)	200
RfC (Chemical specific inhalation reference concentration - mg/m^3; PPRTV 2009)	CS
ETres (Residential exposure time - 24 hr/day*1 day/24 hr; EPA, November 2022)	1
VF (Chemical Specific, Volatilization factor - m^3/kg; EPA, November 2022)	CS
PEF (Particulate emission factor - m^3/kg; EPA, November 2022)	1.36E+09
ABSd (Chemical specific dermal relative absorption factor - unitless; EPA; November 2022)	CS
SAc (Child surface area - cm^2/day; EPA, November 2022)	2373
AFc (Child adherence factor - mg/cm^2; EPA, November 2022)	0.2
CS = Chemical Specific Parameter (See Table B1)	

- The Residential equation used for fraction calculation with values from Table B1 (available upon request) and DEQ-specific factors is below:

Cs = [(THQ*AT)/(ED*EF*(((1/RfDo*GIABS*CF*IRSc)/BWc)+(1/RfC*ETres*(1/PEF+1/VF))))]

- The Commercial Worker equation used for fraction calculation with values from Table B1 and DEQ-specific factors is below:

Cs = [(THQ*AT)/(ED*EF*(((1/RfDo*GIABS*CF*IRSa)/BWa)+(1/RfC*ETcom*(1/PEF+1/VF))))]

- The Construction Worker equation used for fraction calculation with values from Table B1 and DEQ-specific factors is below:

Cs = [(THQ*AT)/(ED*EF*(((1/RfDo*GIABS*CF*IRSa)/BWa)+(1/RfC*ETcom*(1/PEF+1/VF))))]

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