Estimated Human Health and Ecological Transportation Risk for Off-Site Shipment of HD Brines From the Umatilla Chemical Agent Disposal Facility Hermiston, Oregon

Final Report

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1 Executive Summary

This transportation risk assessment was conducted by the Department of Science and Engineering of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) to support planning activities for the Umatilla Chemical Agent Disposal Facility (UMCDF). This analysis identifies and assesses potential release and exposure risks (both human health and ecological) associated with the ground transportation of brines derived during distilled mustard (hereafter called "HD") processing. Transportation risk, expressed as the probability of a spill during the HD campaign, was estimated for three potential destinations (Bremerton, WA; Grandview, ID; and Beatty, NV). The probability of a spill was determined to be 0.038, 0.063, and 0.12[1], during transportation to Bremerton, Grandview, and Beatty, respectively.

Human health risks were estimated for two potential accident scenarios. The first scenario focused on the spill of a shipment of brine into a soil matrix. It was assumed that subsequent post-accident remediation was incomplete and that the remaining contamination is in an area used to grow food-stuffs. Specific details of the assumed accident are as follows:

1. Highway truck accident that results in the spilling of 6500 gallons of HD brines into soil.
2. Spill covers an area of 5214 ft^2 which corresponds to the area covered by the brine if it is spread to an average depth of 2 inches if there were no vertical percolation.
3. The spill undergoes post-accident remediation through the removal of the contaminated soil.
4. Incomplete remediation leaves 4 ft^2 of contaminated soil (0.08% of original).
5. This area is part of a 5 acre (2.18×10^5 ft^2) region used to grow all the foods consumed by the receptor populations.

The chemical composition of the HD brine was assumed to be equivalent to measured properties of Tooele Chemical Agent Disposal Facility (TOCDF) HD brines. Exposure pathways used in this accident scenario included ingestion of contaminated foods, ingestion of contaminated soils, and dermal contact with contaminated soils. Receptors evaluated were similar to those suggested by the Oregon Department of Environmental Quality (ODEQ) in their 2004 combustion risk assessment work plan, hereafter termed the RAWP (ODEQ, 2004). Included in the analysis were adults and children for resident farmers, resident fishers, Native Americans, and suburban residents.

The second accident scenario focused on the spill of a full tanker of HD brine into the Umatilla River at the point I-84 crosses the river. In this scenario it was assumed that remediation would not be conducted since the brine would be swept away by the current and be carried into the much larger Columbia River within a few hours. Receptor exposure was assumed to occur within the Umatilla River over the duration in which the

[1] These probability values represents the likelihood of an accident with a spill and they rages from 0.0 (no change of an accident) to 1.0 (100% chance of an accident).

spill is contained in this water body (3 hours). Only water contact exposure pathways were evaluated in this scenario. These pathways include ingestion of drinking water and dermal exposure during swimming, bathing, and sweat lodge use. Untreated Umatilla River water was assumed to be the water source for each activity for the duration the spill is in the river.

Transportation human health risk results for all scenarios and destinations are detailed in the following two tables. Table ES-1 provides the estimated cumulative cancer related risks while Table ES-2 provides the estimated cumulative non-cancer risks (termed a hazard index, or HI). As indicated in the footnotes of each table, all estimated risks are many orders of magnitude below the acceptable level of risk defined by the ODEQ in their 2004 RAWP.

Table ES-1: Estimated Cancer Risks for Shipment of HD Brine [a,b]

Soils Spill With Remediation Scenario			
Receptor	**Bremerton, WA**	**Grandview, ID**	**Beatty, NV**
Farmer Adult	**8.24E-13**	**1.37E-12**	**2.60E-12**
Farmer Child	**1.80E-12**	**2.99E-12**	**5.69E-12**
Fisher Adult	**3.30E-13**	**5.47E-13**	**1.04E-12**
Fisher Child	**1.55E-12**	**2.57E-12**	**4.90E-12**
Native Adult	**9.45E-13**	**1.57E-12**	**2.99E-12**
Native Child	**1.91E-12**	**3.17E-12**	**6.04E-12**
Resident Adult	**3.30E-13**	**5.47E-13**	**1.04E-12**
Resident Child	**1.55E-12**	**2.57E-12**	**4.90E-12**
Soils Spill Without Remediation Scenario			
Farmer Adult	**1.10E-09**	**1.82E-09**	**3.47E-09**
Farmer Child	**2.40E-09**	**3.98E-09**	**7.58E-09**
Fisher Adult	**4.40E-10**	**7.29E-10**	**1.39E-09**
Fisher Child	**2.07E-09**	**3.43E-09**	**6.52E-09**
Native Adult	**1.26E-09**	**2.09E-09**	**3.98E-09**
Native Child	**2.55E-09**	**4.22E-09**	**8.04E-09**
Resident Adult	**4.40E-10**	**7.29E-10**	**1.39E-09**
Resident Child	**2.07E-09**	**3.43E-09**	**6.52E-09**
Umatilla River-spill Scenario			
Farmer Adult	**2.01E-12**	**3.34E-12**	**6.35E-12**
Farmer Child	**2.15E-11**	**3.56E-11**	**6.78E-11**
Fisher Adult	**2.45E-12**	**4.05E-12**	**7.72E-12**
Fisher Child	**1.48E-11**	**2.45E-11**	**4.67E-11**
Native Adult	**1.86E-12**	**3.08E-12**	**5.86E-12**
Native Child	**3.16E-11**	**5.25E-11**	**9.99E-11**
Resident Adult	**2.45E-12**	**4.05E-12**	**7.72E-12**
Resident Child	**2.15E-11**	**3.56E-11**	**6.78E-11**

[a] Acceptable cancer risk was defined in the ODEQ 2004 RAWP for the UMCDF as less than 1×10^{-5}.

[b] Risk includes both the probability of a spill occurring and the estimated risks from human exposure to the spill.

Table ES-2: Estimated Hazard Index for Shipment of HD Brine [a,b]

Receptor	Bremerton, WA	Grandview, ID	Beatty, NV
Soils Spill With Remediation Scenario			
Farmer Adult	3.74E-06	6.20E-06	1.18E-05
Farmer Child	4.79E-06	7.94E-06	1.51E-05
Fisher Adult	1.37E-06	2.27E-06	4.32E-06
Fisher Child	3.39E-06	5.62E-06	1.07E-05
Native Adult	4.88E-06	8.10E-06	1.54E-05
Native Child	5.01E-06	8.31E-06	1.58E-05
Resident Adult	1.37E-06	2.27E-06	4.32E-06
Resident Child	3.39E-06	5.62E-06	1.07E-05
Soils Spill Without Remediation Scenario			
Farmer Adult	4.98E-03	8.25E-03	1.57E-02
Farmer Child	6.37E-03	1.06E-02	2.01E-02
Fisher Adult	1.82E-03	3.02E-03	5.75E-03
Fisher Child	4.51E-03	7.48E-03	1.42E-02
Native Adult	6.50E-03	1.08E-02	2.05E-02
Native Child	6.67E-03	1.11E-02	2.11E-02
Resident Adult	1.82E-03	3.02E-03	5.75E-03
Resident Child	4.51E-03	7.48E-03	1.42E-02
Umatilla River-spill Scenario			
Farmer Adult	1.50E-08	2.48E-08	4.73E-08
Farmer Child	1.55E-06	2.58E-06	4.91E-06
Fisher Adult	2.66E-08	4.42E-08	8.41E-08
Fisher Child	1.04E-06	1.73E-06	3.29E-06
Native Adult	7.34E-09	1.22E-08	2.32E-08
Native Child	2.33E-06	3.86E-06	7.36E-06
Resident Adult	2.66E-08	4.42E-08	8.41E-08
Resident Child	1.55E-06	2.58E-06	4.91E-06

[a] Acceptable cumulative non-cancer risk was defined in the ODEQ 2004 RAWP for the UMCDF as less than 2.5×10^{-1}.
[b] Risk includes both the probability of a spill occurring and the estimated risks from human exposure to the spill.

The impacts of the assumption of leaving only 4 ft^2 of contaminated soils in the soil-spill scenario was evaluated by including the full assumed area of the spill (5214 ft^2) in the analysis. Results indicate that <u>even under these conditions the estimated carcinogenic and non-carcinogenic transportation risk is more than an order of magnitude below the action levels defined by the ODEQ</u>.

Examination of the relative contributions of each brine constituent and exposure pathway indicate that cancer risk is dominated by exposure to arsenic in food (soil-spill scenario) and drinking water (river-spill scenario). In contrast, non-carcinogenic risk is dominated by cadmium in produce (soil-spill scenario) and cadmium and arsenic in drinking water (river-spill scenario).

Ecological risks were also estimated for the soil-spill and river spill scenarios. Ecological impacts in the soil-spill scenario were evaluated for a shrub-step habitat that contained the unremediated portion of the spill defined for the human health risk analysis. The river-spill ecological risk assessment evaluated a freshwater ecosystem with residual sediment contamination equal to the mass of contaminants in a 6500 gallon tank of brine. Tables ES-3 and ES-4 provide a summary of the total transportation ecological screening quotient (ESQ) for each receptor species for the soil-spill and river-spill scenario, respectively. Maximum total transportation ESQ values for each shipping destination are indicated in bold in these tables. As indicated in the footnotes of each table, all estimated risks are below the acceptable level of risk defined by the ODEQ in their 2004 RAWP.

Table ES-3: Estimated Total Transportation ESQ for Shipment of HD Brine; Soil-Spill Scenario [a,b]

Ecological Receptor	Guild	Total ESQ Results		
		Bremerton, WA	Grandview, ID	Beatty, NV
Peregrine Falcon	Carnivorous Bird	5.87E-09	9.72E-09	1.85E-08
Coyote	Carnivorous Mammal	6.59E-08	1.09E-07	2.08E-07
Mourning Dove	Herbivorous Bird	1.45E-07	2.40E-07	4.57E-07
Pronghorn Sheep	Herbivorous Mammal	1.45E-08	2.40E-08	4.57E-08
Western Meadow Lark	Omnivorous Bird	7.95E-06	1.32E-05	2.51E-05
Deer Mouse	Omnivorous Mammal	8.76E-05	1.45E-04	2.77E-04

[a] Acceptable ESQ was defined in the ODEQ 2004 RAWP for the UMCDF as less than 2.5×10^{-1}.
[b] Risk includes both the probability of a spill occurring and the estimated risks from ecological exposure to the spill.

Table ES-4: Estimated Total ESQ for Shipment of HD Brine; River-Spill Scenario [a,b]

Ecological Receptor	Guild	Total ESQ Results		
		Bremerton, WA	Grandview, ID	Beatty, NV
Bald Eagle	Carnivorous Bird	8.10E-06	1.34E-05	2.56E-05
River Otter	Carnivorous Mammal	4.92E-05	8.16E-05	1.55E-04
Spotted Sandpiper	Carnivorous Shore Bird	3.22E-03	5.35E-03	1.02E-02
Canada Goose	Herbivorous Bird	1.30E-03	2.15E-03	4.10E-03
Long-Tale Vole	Herbivorous Mammal	5.28E-04	8.75E-04	1.67E-03
Mallard Duck	Omnivorous Bird	9.40E-04	1.56E-03	2.97E-03
Raccoon	Omnivorous Mammal	2.59E-03	4.29E-03	8.16E-03

[a] Acceptable ESQ was defined in the ODEQ 2004 RAWP for the UMCDF as less than 2.5×10^{-1}.
[b] Risk includes both the probability of a spill occurring and the estimated risks from exposure to the spill.

2 Introduction

In 1985, Congress directed that the Secretary of the Defense be responsible for overseeing the destruction of the U.S. chemical weapons stockpile. In doing so, the Secretary was to ensure the maximum protection of the environment, the general public, and the workers who are involved in the destruction of the chemical weapons. In response to the order, the Army began research and development efforts to evaluate methods to safely destroy the weapons. In 1997 the Army received a permit from the Oregon Department of Environmental Quality to build an incineration facility at the UMCD to destroy the weapons stored on-site. During the incineration process the plant (hereafter termed the UMCDF) produces pollution abatement system brines which are subsequently dried on site in the brine reduction area (BRA). Although this system has preformed well since the start of operations in 2004, there is concern that processing of mustard agent (called HD) will result in higher brine production rates than can be handled in the BRA and that off-site shipments of HD brines may be necessary.

Some of the communities surrounding the Umatilla Chemical Depot (UMCD) have expressed concern that off-site shipment of UMCDF-generated wastes may pose an unacceptable level of risk. In a May 7, 2002 letter the Chairman of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) stated to the Oregon Environmental Quality Commission that:

> *"It should be noted that no off-site shipment of liquid waste, along with the Army's commitment to not leaving legacy waste at the site, were two important policies that have allowed the BOT to support the incineration project."*

Over the next year the Army, Oregon Department of Environmental Quality (DEQ) and the CTUIR reached a mutually agreeable position to allow off-site shipment of these waste under rare circumstances. However, the Army recognizes that shipments may need to become more frequent during HD processing and is undertaking the analysis contained in this report to determine what human health and public risks would result from more frequent HD brine shipments.

The purpose of this report is to present a study of the human health and ecological risks associated with off-site transportation of brines derived from the Pollution Abatement System (PAS) during the UMCDF HD Campaign. This risk assessment follows the general guidance provided in the federal Hazardous Materials Transportation Authorization Act of 1994.[2] The federal Hazardous Materials Transportation Act of 1975 (HMTA) and its reauthorizing legislation define a hazardous material as a substance or material that, if not regulated, may pose an "unreasonable risk to health, safety, or property when transported in commerce." It is stated in Section 5101 of United States Code (USC) 49 that the purpose of the federal hazmat law is to protect against risks to

[2] Public Law 103-311, August 26, 1994 as amended by Public Law 103-429, October 31, 1994. 49 USC 5101.

life, property, and the environment that are inherent in the transportation of hazardous materials.

As is typical for transportation risk assessments the problem has been broken into three separate components:

1. Determining the probability of an undesirable event (e.g., an accident scenario involving release of hazardous material).
2. Determining the migration and exposure pathways, given the nature of the event.
3. Estimating the magnitude of the consequences (i.e., fatalities, injuries and property damage), given the level of exposure.

Total transportation risk is then calculated as the product of the probability of an undesirable event (accident and spill) and the impact of exposure. This approach equates to a weighted cancer risk and non-cancer risk for the evaluation of human health impacts. For ecological risks, this methodology results in a weighted ecological screening quotient (ESQ).

3 Methods

3.1 Estimation of HD Brine Composition

The composition of distilled mustard (HD) brine for this analysis was estimated using data from Tooele Chemical Agent Disposal Facility (TOCDF) HD brine samples taken between 4 September 2006 and 8 May 2007. The complete data set is provided in Appendix A. Maximum measured values for each compound were used in this analysis and are summarized in Table 1. Iron, sulfate, nitrate, chloride, and fluoride, were detected in HD brines, but were not included in this assessment since toxicity data was not available for these compounds. Organic compounds were not detected in the TOCDF HD brines and are not expected in UMCDF HD brines. Hence, no organics were included in this analysis.

Table 1: Components of HD Brine used in Analysis

Compound	TOCDF Maximum Concentration (mg/L)
Antimony	1.20E-01
Arsenic	7.60E+00
Barium	3.10E-02
Cadmium	3.60E+01
Chromium	7.93E+00
Copper	2.20E+00
Lead	1.00E+00
Mercury	5.26E-02
Nickel	1.50E+00
Selenium	2.00E-02
Silver	1.96E-02
Thallium	3.90E-03
Zinc	2.20E+00

3.2 Approach to Transportation Risk Evaluation

The human health risks and ecological risks associated with HD brine shipment were estimated by combining the risk of release of the brine to the environment during shipment with the risks associated with exposure to the released material. Both carcinogenic and non-carcinogenic risks were evaluated in the human heal analysis Human health exposure risks was expressed as an increased risk of cancer and as a non-carcinogenic hazard quotient (HQ). Hazard quotients for each component were summed for each scenario and expressed as a Hazard Index (HI):

$$HI = \sum_i HQ_i \qquad (1)$$

where HQ_i is the hazard quotient for the i^{th} component of the brine.

Ecological risk was expressed as a ecological screening quotient (ESQ) which is the ratio of the estimated exposure level to a toxicity reference value. In either case the total transportation risk was expressed as:

$$Total\_Transportation\_Risk = (Risk\_of\_release) \cdot (Exposure\_risk) \qquad (2)$$

3.2.1 Estimation of Risk of Release

Risk of release was estimated using shipping information provided to the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) by engineering staff from the UMCDF (Appendix B). This information is summarized in Table 2.

Table 2: HD Brine Shipment Characteristics

PROPERTY	**VALUE**
Total Quantity of HD Brine (gallon)	14,000,000
DOT Hazard Material Class	Class 9 (Miscellaneous Hazardous Material)
DOT Shipping Container	TT – Tanker
Size of Shipping Container (gallon)	5000-6500
Total number of shipments	2154 - 2800
Shipping destination	US Ecology in Grandview, ID (484 mi) US Ecology in Beatty, NV (888 mi) PSC in Bremerton, WA (294 mi)

The mileages listed after each of the proposed destinations were provided by Google Map (Appendix B). The total number of HD brine shipments was estimated from the total volume of brine and the size of the shipping tankers.

The information in Table 2 was translated into a risk of accident using data complied by Abkowitz et al. (2001) and Brown et al. (2000). Relying on truck incident data from the US Department of Transportation Hazardous Materials Information System (HIMS), Abkowitz and co-workers determined that Class 9 shipments had an average of 7.17×10^{-7} accidents per mile. Furthermore, Brown et al. (2000) reported that, for bulk liquids using MC 306 type tanker trucks, there is an approximately 6.5% probability of a release after an accident has occurred. Combining these two findings suggests that for bulk liquids with a Hazardous Class of 9 and which are transported in tanker trucks, there is a 4.66×10^{-7} probability of a spill per road mile traveled. Table 3 provides the total probability of a spill of HD brine given the three potential shipping locations. Values in Table 3 were calculated as follows:

$$P_{spill} = N_{Trips} \cdot M_{Trip} \cdot P_{mile} \qquad (3)$$

Where P_{spill} is the total probability of a spill for a given destination, N_{Trips} is the total number of brine shipments over the HD campaign (2800), M_{Trip} is the length of each trip in miles, and P_{mile} is the probability of a spill per mile traveled (4.66×10^{-7}). It should be noted that no information on the size of an average spill was provided in either Brown et al., or Abkowitz et al. Hence, for this analysis, it was assumed that a spill would be equal to a full shipment of brine.

Table 3: Total Probability of a Brine Spill
For the HD Campaign

DESTINATION	TOTAL SPILL PROBABILITY[3]
Bremerton, WA	0.038
Grandview, ID	0.063
Beatty, NV	0.12

3.2.2 Estimation of Human Exposure for the Soil-Spill Scenario

For this spill scenario it was assumed that a full tanker of brine would be spilled and subsequently contacts only soils. A detailed description of the assumed accident scenario is as follows:

1. Highway truck accident that results in the spilling of 6500 gallons of HD brines into soil.
2. Spill covers an area of 5214 ft^2 which corresponds to the area covered by the brine if it is spread to an average depth of 2 inches if there were no vertical percolation.
3. The spill undergoes post-accident remediation through the removal of the contaminated soil.
4. Incomplete remediation leaves 4 ft^2 of contaminated soil (0.08% of original).
5. This area is part of a 5 acre (2.18×10^5 ft^2) region used to grow all the foods consumed by the receptor populations.

Based on the above assumptions, the exposure pathways indicated in Table 4 were evaluated for the indicated receptors. Inhalation and water ingestion pathways were not included in this accident scenario since HD brine does not contain volatile compounds and the brine was assumed to be spilled onto soils and not surface water.

[3] These probability values represents the likelihood of an accident with a spill and they rages from 0.0 (no change of an accident) to 1.0 (100% chance of an accident).

Table 4: Exposure Pathways and Exposure Receptors for Brine Spill into Soils

EXPOSURE PATHWAYS	RECEPTORS			
	Resident Farmer Adult And Child	**Resident Fisher Adult And Child**	**Native American Adult And Child**	**Suburban Resident Adult And Child**
Produce Ingestion (protected and unprotected aboveground, native vegetation)	X	X	X	X
Meat Ingestion (beef, goat, chicken, fowl, game)	X		X	X
Milk Ingestion	X		X	X
Fish Ingestion		X	X	
Egg Ingestion	X		X	X
Dermal Contact with Soil	X	X	X	X
Soil Ingestion	X		X	X

For each food product it was assumed that 100% is locally grown within the 5 acre region which contains the smaller contaminated area. This assumption results in a contaminated fraction of 1.8×10^{-5} for all food stuffs (equal to the ratio of contaminated area to total area used for food production).

The soil concentration for each toxic chemical in HD brines was estimated from the above assumptions along with the brine composition provided in Table 1. Soil concentrations were determined as follows:

$$C_{i,soil} = \frac{C_{i,brine} \cdot V_{brine}}{V_{soil} \cdot \rho_{bulk}} \tag{4}$$

Where $C_{i,soil}$ is the soil concentration of the i^{th} chemical after the brine spill (mg/kg-soil), $C_{i,brine}$ is the concentration of a i^{th} chemical in the HD brine (mg/l), V_{brine}, is the volume of brine spilled (l), V_{soil} is the volume of soil receiving the brine (m^3), and ρ_{bulk} is the bulk density of the soil (kg/m^3). Table 5 provides estimated soil concentrations for each component of the HD brine listed in Table 1. A soil bulk density of 1.5 g/ml (1500 kg/m^3) was assumed in deriving the values shown in Table 5 along with the assumption that all toxic materials are retained within the top 6 inches of the soil.

Table 5: Estimated Soil Concentration From an HD Brine Spill

Compound	Estimated Soil Concentrations (mg/Kg-soil)
Antimony	2.66E-02
Arsenic	1.69E+00
Barium	6.88E-03
Cadmium	7.99E+00
Chromium	1.76E+00
Copper	4.88E-01
Lead	2.22E-01
Mercury	1.17E-02
Nickel	3.33E-01
Selenium	4.44E-03
Silver	4.35E-03
Thallium	8.66E-04
Zinc	4.88E-01

These soil concentrations were used to calculate exposure and subsequent carcinogenic and non-carcinogenic health risks using the same EPA-based method as applied in the UMCDF combustion risk assessment (ODEQ, 2004; EPA, 2005). The exposure and risk calculations were completed using the IRAP-h-Umatilla software (Lakes Environmental, 2007). Appendix C provides a list of the exposure parameters for each receptor. The toxicity database used by the ODEQ to complete the UMCDF post-trial burn risk assessment was used in this analysis and is provided in Appendix D. Appendix E provides the accompanying site parameters used by IRAP-h-Umatilla. A summary of the EPA-based risk evaluation equations used in this analysis is provided in Appendix G.

IRAP-h-Umatilla implements the 2005 EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities and is not directly suited to the current problem since it calculates media concentrations (air, soil, water) based on deposition and concentration values from simulated air emissions from a point source. However, the exposure and risk portion of the tool can be applied to the current analysis if proper media concentrations are set in the software. For the evaluation of a brine spill in soils it is necessary to ensure that both vapor and water concentrations were zero and that the soil concentration applied to the exposure pathways outlined in Table 4 are equal to those reported in Table 5. This requirement was achieved by manually entering zero values in IRAP-h-Umatilla for all water body and watershed depositions rates and all air concentrations and setting all deposition terms to zero except for dry particle deposition (*Dydp* with units of g/m^2-s) which was set to 1.0. This allowed an emission rate (*Q* with units of g/s) for a hypothetical point source to be related to soil concentration as follows (EPA, 2005 Table B-1-1):

$$Cs_{tD} = \frac{100 \cdot Q}{Z_s \cdot \rho_{bulk}} \cdot [Dydp] \cdot \frac{1 - \exp(-k_s \cdot tD)}{k_s} \qquad (5)$$

Where Cs_{tD} is the soil concentration after the HD brine spill has occurred (mg/kg), Z_s is the soil mixing depth (20 cm), ρ_{bulk} is the soil bulk density (1.5 g/cm^3), tD the time period for deposition (arbitrarily set at 1 yr), and k_s is the compound specific soil loss constant (yr^{-1}) and is calculated internally in IRAP-h-Umatilla using the equations in Tables B-1-2 through B-1-6 in the 2005 EPA combustor risk assessment guidance. In this manner values of Q were determined for each compound to provide calculated soil concentrations in IRAP-h-Umatilla that were equal to those in Table 5. Table 6 lists the values of Q that provided the desired soil concentrations at the evaluation node.

Table 6: Values of Emission Rates from Hypothetical Point Source that Provided Proper Soil Concentrations at the Risk Evaluation Node

Compound	Q (g/s)
Antimony	1.54E-01
Arsenic	4.67E+02
Barium	2.07E-03
Cadmium	3.44E+01
Chromium	5.54E-01
Copper	1.46E-01
Lead	1.04E-01
Mercury	3.60E-03
Nickel	1.34E+00
Selenium	9.00E-02
Silver	1.31E-03
Thallium	2.60E-04
Zinc	2.04E-01

Table 7 shows the media concentrations calculated by IRAP-h-Umatilla using the above approach. The first soil concentration listed in Table 7 represents the value after the spill (Cs_{tD}) while the second concentration is the average over the exposure period and accounts for various loss mechanisms such as erosion and leaching. Comparison of the Table 5 values with the first soil concentration in Table 7 reveals that the IRAP-h-Umatilla calculated values closely represent those estimated from the spill assumptions (Table 5). Values for water and air concentrations in Table 7 indicate that exposure pathways involving these media were excluded in this analysis.

Table 7: IRAP-h-Umatilla Calculated Media Concentrations for Brine Spill in Soils.

Compound	Soil Concentration at T_0 (mg/kg)	Time Averaged Soil Concentration (mg/kg)	Water Concentration (mg/L)	Air Concentration (ug/m^3)
Antimony compounds	2.66E-02	6.64E-04	0.00E+00	0.00E+00
Arsenic compounds	1.69E+00	4.22E-02	0.00E+00	0.00E+00
Barium compounds	6.89E-03	6.54E-03	0.00E+00	0.00E+00
Cadmium compounds	7.98E+00	2.00E-01	0.00E+00	0.00E+00
Chromium compounds	1.76E+00	1.60E+00	0.00E+00	0.00E+00
Copper compounds	4.87E-01	4.79E-01	0.00E+00	0.00E+00
Lead compounds	2.22E-01	8.98E-03	0.00E+00	0.00E+00
Mercury compounds	1.18E-02	6.43E-03	0.00E+00	0.00E+00
Nickel compounds	3.34E-01	8.35E-03	0.00E+00	0.00E+00
Selenium compounds	4.45E-03	1.11E-04	0.00E+00	0.00E+00
Silver compounds	4.34E-03	3.56E-03	0.00E+00	0.00E+00
Thallium compounds	8.66E-04	8.36E-04	0.00E+00	0.00E+00
Zinc compounds	4.85E-01	1.21E-03	0.00E+00	0.00E+00

3.2.3 Estimating Human Exposure Risk for the River-Spill Scenario

For this spill scenario, it was assumed a full tanker of brine (6500 gallons) is spilled into the Umatilla River where I-84 cross the river (Figure 1) and the spill occurs continuously over the period of 1 hour (108 gal/min). Since the Umatilla River is a flowing water body, the spilled material would be swept away by the current and no remediation would be possible. As shown in Figure 1, the assumed location of the spill is approximately 1 to 2 miles from the confluence of the Umatilla and Columbia Rivers. At this location any spilled material would require approximately 3 hours (0.00034 yrs) to reach the Columbia River where it would be quickly diluted. Properties of the Umatilla and Columbia Rivers required by IRAP-h-Umatilla were taken from the 2008 ODEQ UMCDF risk assessment and are indicated in Table 8 (Ecology and Environment, 2008). Table 9 reveals the estimated maximum contaminant concentration within the Umatilla and Columbia Rivers along with the corresponding drinking water standards[4]. Bold values in Table 9 indicate maximum river concentrations that are predicted to be below the drinking water standard. Clearly, once the material is introduced in the Columbia River concentrations for all but cadmium are below the EPA standard, indicating that health impacts should be minimal.

[4] Drinking water standards indicated in Table 9 are the primary and secondary Maximum Contaminant Levels (MCLs) listed by the EPA on http://www.epa.gov/safewater/contaminants/index.html#listsec.

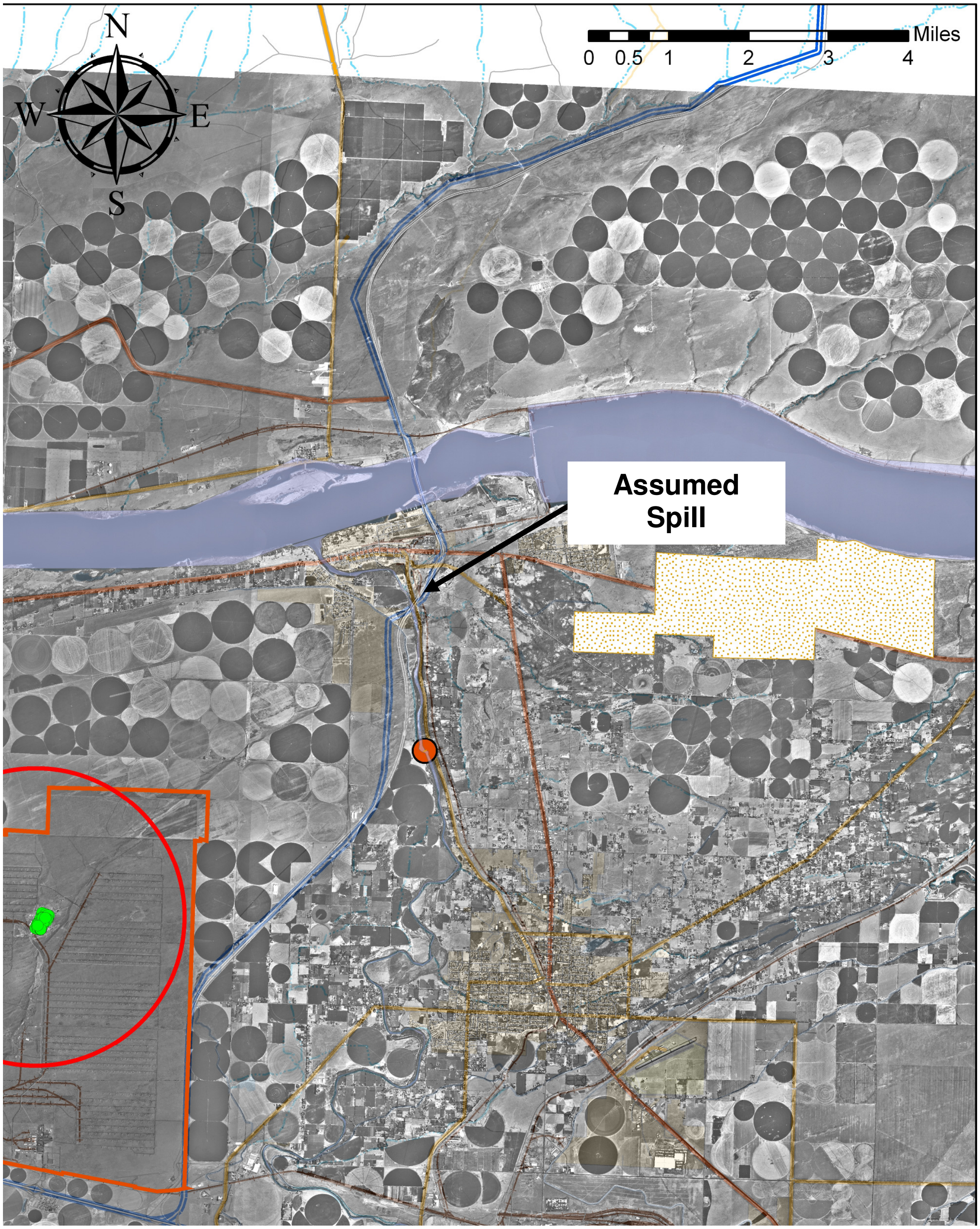

Figure 1: Assumed location of Brine Spill into the Umatilla River.

Table 8: Properties of the Umatilla and Columbia River for IRAP-h-Umatilla

Property	Umatilla River	Columbia River	Units
Surface area of affected area	1	1	m^2
Bed sediment concentration	1	1	g/cm^3
Drag coefficient	0.0011	0.0011	--
Depth of upper benthic layer	0.03	0.03	m
Depth of water column	2	10	m
Dimensionless viscous sublayer thickness	4	4	--
von Karman's constant	0.4	0.4	--
Fraction of mercury speciated into methyl mercury in water	0.08	0.08	--
Fraction of mercury speciated into methyl mercury from runoff	0.08	0.08	
Current velocity	0.35	0.58	m/s
Viscosity of water corresponding to water temp.	1.69E-02	1.69E-02	g/cm-s
Fraction Organic Carbon in bottom sediment	0.04	0.04	--
Density of water corresponding to water temp.	1	1	g/cm^3
Water body temperature	286	286	K
Bed sediment porosity	0.6	0.6	L-water/L-sedim.
Total suspended solids concentration	10	10	mg/L
Average volumetric flow rate through water body	3.93E+08	1.37E+11	m^3/yr
Water body surface area	2.91E+06	2.82E+08	m^2

River water concentrations in Table 9 were estimated using the following mixing point mass balance that assumes the spill us uniformly mixed across the full river width and depth at the point of the spill:

$$C_{i,river} = \frac{C_{i,brine} \cdot Vf_{brine}}{Vf_{river} + Vf_{brine}} \qquad (6)$$

Where $C_{i,river}$ is the concentration of the ith compound in the river (mg/l), $C_{i,brine}$ is the concentration of the ith compound in the brine (mg/l), Vf_{brine} is the flow rate brine is introduced into the river (l/min) , and Vf_{river} is the average volumetric flow rate of the river (l/min).

Significant exposure was assumed to occur only within the Umatilla River over the duration in which the spill is contained in this water body (3 hours). The water contact pathways outlined in Table 10 were included in this analysis for the indicated receptors. Untreated Umatilla River water was assumed to be the sole water source for each activity (swimming, bathing, and drinking) for the duration the spill is in the river. Contaminant free-water was assumed for the remainder of the exposure duration for each receptor type. Exposure parameters, toxicity data, and site parameters, are provided in Appendix

C, D, and E, respectively. A summary of the EPA-based risk evaluation equations used in this analysis is provided in Appendix G.

Table 9: Estimated Concentrations of Brine Constituents in the Umatilla and Columbia River [a]

	Estimated Umatilla River Concentration (mg/L)	Estimated Columbia River Concentration (mg/L)	Drinking Water Standard (mg/L) [b]
Antimony	**5.40E-02**	**1.55E-04**	**6.00E-03**
Arsenic	**3.42E+00**	**9.81E-03**	**1.00E-02**
Barium	**1.40E-02**	**4.02E-05**	**2.00E+00**
Cadmium	**1.62E+01**	**4.65E-02**	**5.00E-03**
Chloride	**1.80E+04**	**5.16E+01**	**2.50E+02**
Chromium	**3.57E+00**	**1.02E-02**	**1.00E-01**
Copper	**9.90E-01**	**2.84E-03**	**1.00E+00**
Iron	**1.80E+01**	**5.16E-02**	**3.00E-01**
Lead	**4.50E-01**	**1.29E-03**	**1.50E-02**
Mercury	**2.37E-02**	**6.80E-05**	**2.00E-03**
Nickel	**6.75E-01**	**1.94E-03**	**No EPA Standard**
Nitrate	**1.59E+01**	**4.56E-02**	**4.43E+01**
Selenium	**9.00E-03**	**2.58E-05**	**5.00E-02**
Silver	**8.82E-03**	**2.53E-05**	**1.00E-01**
Sulfate	**9.90E+03**	**2.84E+01**	**2.50E+02**
Thallium	**1.76E-03**	**5.05E-06**	**2.00E-03**
Zinc	**9.90E-01**	**2.84E-03**	**5.00E+00**

[a] Bold entries indicate vales are below the drinking water standard.
b Drinking water standards are the primary and secondary Maximum Contaminant Levels (MCLs) listed by the EPA on http://www.epa.gov/safewater/contaminants/index.html#listsec.

Table 11 details the IRAP-h-Umatilla calculated media concentrations for each contaminant in HD Brine. Air and soil concentrations were set to zero by assign a zero value in the software to all deposition rates and air concentrations at the calculation node. Water concentrations were established by assigning a unit value to the total water body particle deposition rate for the Umatilla River ($Dytwp_{wb}$), a zero value to all other water body deposition rates and concentrations, and adjusting the release rate of each compound from the hypothetical point source (Q in g/s) to provide total water body concentrations equal to those shown in Table 9 for the Umatilla River. All watershed deposition rates and concentrations were also set to zero to ensure that the only contribution to contaminant concentration at the calculation node was contained in the release rate term (Q).

These assumptions result in IRAP-h-Umatilla calculating the total water concentration as follows (this equation was derived from Equations B-4-7, B-4-8, and B-4-15 of EPA, 2005):

$$C_{wtot} = \frac{Q \cdot A_w \cdot Dytwp_{wb}}{Vf_x \cdot f_{wc} + k_{wt} \cdot A_w \cdot (d_{wc} + d_{bc})} \tag{7}$$

Where A_w is the water body surface area (m^2); Vf_x is the average volumetric flow rate though the water body (m^3/yr); f_{wc} is the fraction of the total water body contaminant concentration in the water column and is calculated using Equation B-4-16 of EPA, 2005; k_{wt} is the overall total water body dissipation rate constant (1/yr) calculated using Equations B-4-17 through B-4-19 of EPA, 2005; d_{wc} is the depth of the water column (m); and d_{bs} the depth of the benthic sediment (m).

Table 10: Exposure Pathways and Exposure Receptors
For a Brine Spill into the Umatilla River

EXPOSURE PATHWAYS	**RECEPTORS**			
	Resident Farmer Adult And Child	**Resident Fisher Adult And Child**	**Native American Adult And Child**	**Suburban Resident Adult And Child**
Drinking Water Ingestion	X	X	X	X
Dermal Contact With Surface Water	X	X	X	X
Sweat Lodge Dermal Contact and Inhalation	X	X	X	X
Ingestion of Local Fish		X	X	

Table 11: IRAP-h-Umatilla Calculated Media Concentrations
For a Brine Spill to the Umatilla River

Compound	**Water Concentration During Release (mg/kg)**	**Time Averaged Soil Concentration (mg/kg)**	**Air Concentration (ug/m^3)**
Antimony compounds	**5.41E-02**	**0.00E+00**	**0.00E+00**
Arsenic compounds	**3.42E+00**	**0.00E+00**	**0.00E+00**
Barium compounds	**1.40E-01**	**0.00E+00**	**0.00E+00**
Cadmium compounds	**1.62E+01**	**0.00E+00**	**0.00E+00**
Chromium compounds	**3.69E+00**	**0.00E+00**	**0.00E+00**

Copper compounds	9.90E-01	0.00E+00	0.00E+00
Lead compounds	4.51E-01	0.00E+00	0.00E+00
Mercury compounds	2.37E-02	0.00E+00	0.00E+00
Nickel compounds	6.80E-01	0.00E+00	0.00E+00
Selenium compounds	8.99E-03	0.00E+00	0.00E+00
Silver compounds	8.80E-03	0.00E+00	0.00E+00
Thallium compounds	1.75E-03	0.00E+00	0.00E+00
Zinc compounds	9.91E-01	0.00E+00	0.00E+00

These media concentrations were subsequently used to calculate exposure and carcinogenic and non-carcinogenic health risks using the same EPA-based method as applied in the UMCDF combustion risk assessment (ODEQ, 2004; EPA, 2005). The exposure and risk calculations were completed using the IRAP-h-Umatilla software. The toxicity database used by the ODEQ to complete the UMCDF post-trial burn risk assessment was used in this analysis and is provided in Appendix D.

3.2.4 Estimation of Ecological Exposure for the Soil-Spill Scenario

A screening level ecological risk assessment was completed for the soil-spill scenario outlined in Section 3.2.2 using the EPA SLRAP (Screening Level Risk Assessment Protocol, EPA, 1999) as implemented in the software, EcoRisk View (Lakes Environmental, 2003). Food web and exposure assessment properties were derived from the Umatilla RAWP (ODEQ, 2004), and are identical to those used in the January 2008 ecological risk assessment reported to the ODEQ (E&E, 2008). Table 12 provides details on the Shrub-Step food-web implement in this study. Table 13 provides the consumption data for each species listed in Table 12. Appendix E lists the EcoRisk View site parameters applied in this analysis.

Table 12: Foods and Other Consumed Materials for Guild Receptor Species for Soil-Spill Scenario

Peregrine Falcon (Carnivor. Bird)	Coyote (Carnivor. Mammal)	Mourning Dove (Herbivor. Bird)	Pronghorn Sheep (Herbivor. Mammal)	Western Meadowlark (Omnivor. Bird)	Deer Mouse (Omnivor. Mammal)
Herbivor. Bird	Herbivor. Bird	Terrestrial Plants	Terrestrial Plants	Terrestrial Plants	Terrestrial Plants
Omnivor. Bird	Omnivor. Bird	Soil	Soil	Terrestrial Invertebrates	Terrestrial Invertebrates
Herbivor. Mammal	Herbivor. Mammal	Water	Water	Soil	Soil
Omnivor. Mammal	Omnivor. Mammal			Water	Water
Soil	Soil				
Water	Water				

Table 13: Ingestion Rates for Receptor Species for Soil-Spill Scenario

Receptor Species	Guild	Body Weights (kg)	Food Ingestion Rate (kg-WW/[kg-BW-day]) [b]	Soil Ingestion Rate (kg-DW/[kg-BW-day]) [a]	Water Ingestion Rate (L/[kg-BW-day])
Peregrine Falcon	Carnivorous Bird	1	0.182	0.00116	0.059
Coyote	Carnivorous Mammal	12.9	0.349	0.00701	0.109
Mourning Dove	Herbivorous Bird	0.15	0.421	0.0139	0.131
Pronghorn Sheep	Herbivorous Mammal	46.1	0.035	0.00031	0.077
Western Meadowlark	Omnivorous Bird	0.09	0.103	0.00062	0.0675
Deer Mouse	Omnivorous Mammal	0.01	0.599	0.00144	0.151

[a] Soil ingestion rates entered into EcoRisk View were multiplied by 1.8×10^{-5} to account of contamination fraction.

[b] The contaminated food fraction was entered into EcoRisk View database file FOODPORT.db

Exposure was assumed to result from the same unremediated portion of the hypothetical soil-spill as analyzed for human health risk. Furthermore, it was assumed that each species ranged predominately within a 5 acre area so that the contaminated fraction for soils and other food-stuffs is equal to 1.8×10^{-5} (equal to the ratio of contaminated area to total area used for food production).

Soil concentrations within the contaminated area were set at the levels identified in Table 5 using the prescribed media option of EcoRisk View which allows independent values for sediment, soil, and water levels to be set at a receptor location. The soil, sediment, and water concentrations used in the ecological risk analysis of a soil-spill are listed in Table 14 for each chemical evaluated.

Table 14: EcoRisk View Prescribed Media Concentrations
For the Soil-Spill Scenario

Compound	EcoRisk View Soil Concentration (mg/kg)	EcoRisk View Sediment Concentration (mg/kg)	EcoRisk View Water Concentration (mg/kg)
Antimony compounds	2.66E-02	0.00E+00	0.00E+00
Arsenic compounds	1.69E+00	0.00E+00	0.00E+00
Barium compounds	6.88E-03	0.00E+00	0.00E+00
Cadmium compounds	7.99E+00	0.00E+00	0.00E+00
Chromium compounds	1.76E+00	0.00E+00	0.00E+00
Copper compounds	4.88E-01	0.00E+00	0.00E+00
Lead compounds	2.22E-01	0.00E+00	0.00E+00
Mercury compounds	1.17E-02	0.00E+00	0.00E+00
Nickel compounds	3.33E-01	0.00E+00	0.00E+00
Selenium compounds	4.44E-03	0.00E+00	0.00E+00
Silver compounds	4.35E-03	0.00E+00	0.00E+00
Thallium compounds	8.66E-04	0.00E+00	0.00E+00
Zinc compounds	4.88E-01	0.00E+00	0.00E+00

Bioconcentration factors (BCF) and Toxicity Reference Values (TRV) for the soil-spill scenarios were obtained from E&E 2008 and are equivalent to their “EE BCF” and “EE TRV” data sets, respectively. Appendix F provides these datasets in detail. All ecological screening quotients (ESQ) were calculated as the ration of the estimated exposure level to the TRV.

3.2.5 Estimation of Ecological Exposure for the River-Spill Scenario

A screening level ecological risk assessment was completed for the river-spill scenario outlined in Section 3.2.3 using the EPA SLRAP (Screening Level Risk Assessment Protocol, EPA, 1999) as implemented by the EcoRisk View software (Lakes Environmental, 2003). Food web and exposure assessment properties were derived from the Umatilla RAWP (ODEQ, 2004), and are identical to those used in the January 2008 ecological risk assessment reported to the ODEQ (E&E, 2008). Table 15 provides details on the freshwater food web implement in this study. Table 16 provides the consumption data for each species listed in Table 15. Appendix E lists the EcoRisk View site parameters applied in this analysis.

Table 15: Foods and Other Consumed Materials for Guild Receptor Species for River-Spill Scenario

Bald Eagle (Carnivor. Bird)	River Otter (Carnivor. Mammal)	Spotted Sandpiper (Carnivor. Shore Bird)	Canada Goose (Herbivor. Bird)	Long-Tailed Vole (Herbivor. Mammal)	Mallard Duck (Omnivor. Bird)	Raccoon (Omnivor. Mammal)
Herbivor. Bird	Carnivor. Fish	Benthic Invertebrates	Aquatic Plants	Aquatic Plants	Aquatic Plants	Herbivor. Bird
Carnivor. Fish	Omnivor. Fish	Sediment	Sediment	Sediment	Benthic Invertebrates	Benthic Invertebrates
Omnivor. Fish	Sediment Water	Water	Water	Water	Sediment	Herbivor. Mammal
Herbivor. Mammal					Water	Sediment
Sediment						Water
Water						

Table 16: Ingestion Rates for Receptor Species for River-Spill Scenario

Receptor Species	Guild	Body Weights (kg)	Food Ingestion Rate (kg-WW/[kg-BW-day])	Soil Ingestion Rate (kg-DW/[kg-BW-day])	Water Ingestion Rate (L/[kg-BW-day])
Bald Eagle	Carnivorous Bird	4.01	0.12	0.00072	0.037
River Otter	Carnivorous Mammal	6.67	0.235	0.0043	0.053
Spotted Sandpiper	Carnivorous Shore Bird	0.04	0.179	0.00318	0.0582
Canada Goose	Herbivorous Bird	1.40	0.569	0.0415	0.174
Long-Tailed Vole	Herbivorous Mammal	0.05	0.153	0.00098	0.082
Mallard Duck	Omnivorous Bird	0.25	0.095	0.000274	0.134
Raccoon	Omnivorous Mammal	6.8	0.223	0.0046	0.082

For the river-spill ecological risk assessment, it was assumed a full tanker of brine (6500 gallons) is spilled into the Umatilla River where I-84 cross the river (Figure 1). Contaminants in the brine were assumed to settle equally into the top 3 cm of the river bottom sediments between the spill location and confluence of the Umatilla and Columbia Rivers. The area of the river bottom in this region was estimated from aerial photographs and was equal to 1.4×10^5 m^2. The resulting estimated sediment concentrations are shown in the first column of Table 17 and were calculated as follows:

$$C_{i,sed} = \frac{C_{i,brine} \cdot V_{Brine}}{V_{sed} \cdot \rho_{sed}} \tag{8}$$

Where $C_{i,sed}$ is the sediment concentration for the ith contaminant (mg/kg), V_{sed} is the volume of sediment the contaminant are contained in (4.2×10^6 l), and ρ_{sed} is the bulk density of the sediment (1.2 kg/l).

Evaluation of the impacts of sediment contaminants on ecological risk was accomplished using the prescribed media option of EcoRisk View which allows independent values for sediment, soil, and water levels to be set at a receptor location. The sediment and water concentrations used in this analysis for each chemical species is listed in the last three columns of Table 17. Water concentrations were assumed to be negligent since the flowing river would quickly dilute and sweep away any material not absorbed to the bed sediments. Soil contamination is also neglected in EcoRisk View for freshwater ecology.

Table 17: EcoRisk View Calculated Media Concentrations
and Associated Input Emission Rates for the Hypothetical Point Source.

Compound	Estimated Sediment Concentration (mg/Kg)	EcoRisk View Sediment Concentration (mg/kg)	EcoRisk View Water Concentration (mg/kg)
Antimony	5.85E-04	5.85E-04	0.00E+00
Arsenic	3.71E-02	3.71E-02	0.00E+00
Barium	1.51E-04	1.51E-04	0.00E+00
Cadmium	1.76E-01	1.75E-01	0.00E+00
Chromium	3.87E-02	3.86E-02	0.00E+00
Copper	1.07E-02	1.07E-02	0.00E+00
Lead	4.88E-03	4.88E-03	0.00E+00
Mercury	2.56E-04	2.57E-04	0.00E+00
Nickel	7.31E-03	7.31E-03	0.00E+00
Selenium	9.75E-05	9.77E-05	0.00E+00
Silver	9.56E-05	9.56E-05	0.00E+00
Thallium	1.90E-05	1.90E-05	0.00E+00
Zinc	1.07E-02	1.07E-02	0.00E+00

Bioconcentration factors (BCF) and Toxicity Reference Values (TRV) for the river-spill scenarios were obtained from E&E 2008 and are equivalent to their "EE BCF" and "EE TRV" data sets, respectively. Appendix F provides these datasets in detail. All ecological screening quotients (ESQ) are calculated as the ration of the estimated exposure level to the TRV.

4 Results and Discussion

4.1 Summary of Human Health Risk Results

Table 18 presents a summary of the chronic cancer and non-cancer exposure risks for both the soil-spill and Umatilla river-spill risk scenarios. The maximum risk values for each spill scenarios are highlighted in bold. In general, acceptable levels of incremental cancer risk are recognized to lie below 1×10^{-4} while cumulative non-carcinogenic health risks (termed hazard index, or HI) less than 1 suggest no adverse health effects (ODEQ, 2004). The combustion risk assessment completed for the UMCDF used levels of 1×10^{-5} and 0.25 to define risks of concern for carcinogenic and non-carcinogenic hazards, respectively. <u>Clearly, the risks detailed in Table 18 are many orders of magnitude below both levels for all receptors</u>.

Table 18: Summary of Carcinogenic Risk and Hazard Index for Both Spill Scenarios [a]

Soil-spill Scenario		
Receptor	**Cancer Risk**	**Hazard Index**
Farmer Adult	**2.17E-11**	**9.84E-05**
Farmer Child	**4.74E-11**	**0.000126**
Fisher Adult	**8.69E-12**	**3.6E-05**
Fisher Child	**4.08E-11**	**8.92E-05**
Native Adult	**2.49E-11**	**0.000129**
Native Child	**5.03E-11**	**0.000132**
Resident Adult	**8.69E-12**	**3.6E-05**
Resident Child	**4.08E-11**	**8.92E-05**
Umatilla River-spill Scenario		
Farmer Adult	**5.29E-11**	**3.94E-07**
Farmer Child	**5.65E-10**	**4.09E-05**
Fisher Adult	**6.44E-11**	**7.01E-07**
Fisher Child	**3.89E-10**	**2.74E-05**
Native Adult	**4.88E-11**	**1.93E-07**
Native Child	**8.33E-10**	**6.13E-05**
Resident Adult	**6.44E-11**	**7.01E-07**
Resident Child	**5.65E-10**	**4.09E-05**

[a] Maximum risk values for each spill scenarios are highlighted in bold

A summary of the cancer risks and hazard index for both spill scenarios is presented pictorially in Figure 2. It is evident from this figure that cancer risks are substantially higher for the river-spill scenario than for the soil-spill scenario, especially for child receptors. In contrast, hazard indexes are consistently higher for the soil-spill scenario than for the river-spill scenario. These differences are derived from difference in dominant exposure pathways between the two scenarios and differences in the dominant toxins for carcinogenic and non-carcinogenic effects. As will be seen in the next section, cancer risk is dominated by exposure to arsenic in food (soil-spill scenario) and drinking water (river-spill scenario). In contrast, non-carcinogenic risk is dominated by cadmium in produce for the soil-spill scenario and cadmium and arsenic in drinking water for the river-spill scenario.

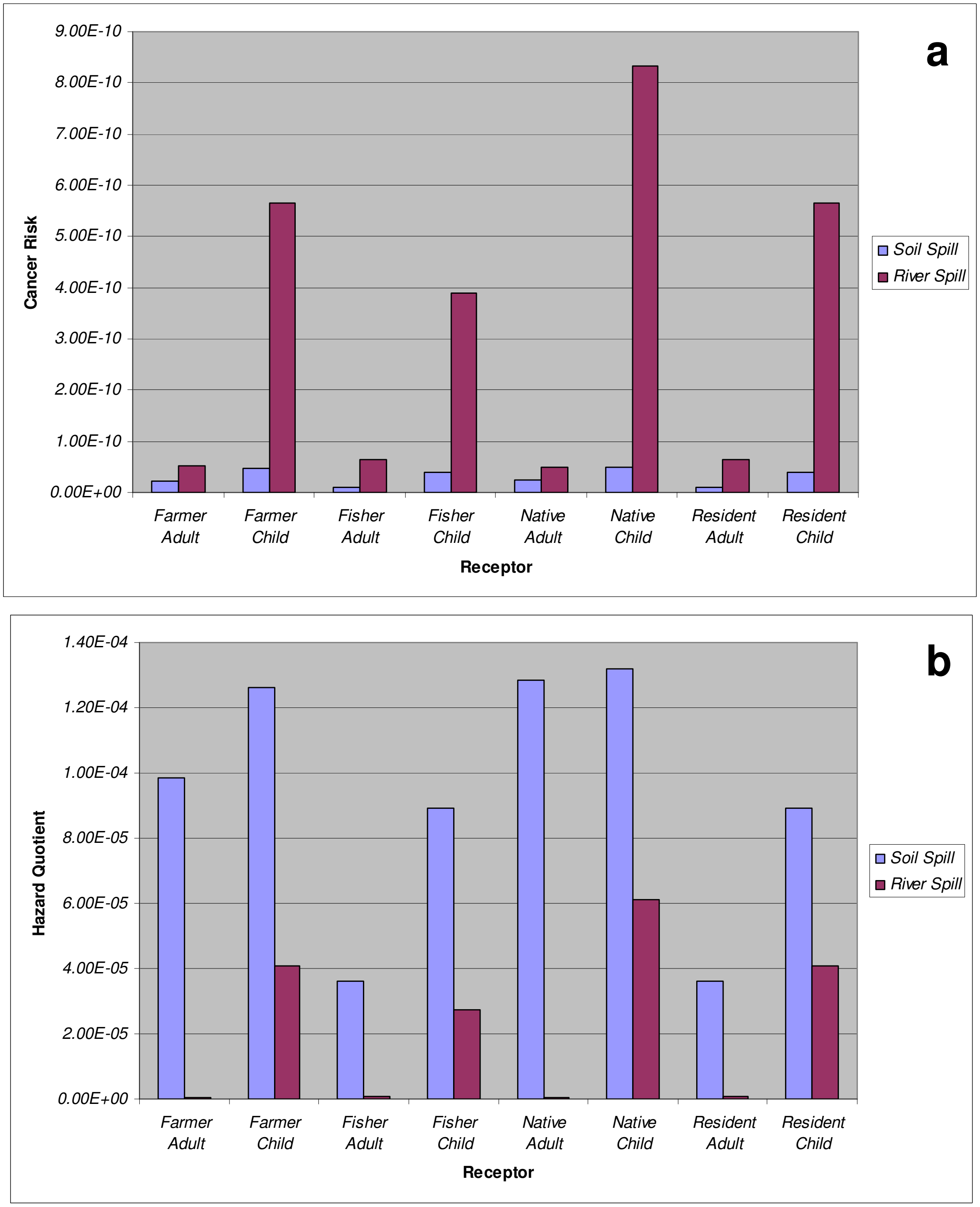

Figure 2: Summary results for cancer risk (a) and hazard index (b) for both spill scenarios.

An additional evaluation was conducted using the full soil spill area (5214 ft^2) to evaluate the impacts of the assumption of only leaving 4 ft^2 of unremediated soil after an HD brine spill and clean-up. Input values for IRAP-h-Umatilla for this additional evaluation are included in Appendix C and E. As Table 19 indicates both the cancer risk and hazard index are still below the threshold levels established in the 2004 RWAP.

Table 19: Summary of Carcinogenic Risk and Hazard Index For Soil-spill Scenario With No Remediation [a]

Receptor	Cancer Risk	Hazard Index
Farmer Adult	2.89E-08	1.31E-01
Farmer Child	6.32E-08	1.68E-01
Fisher Adult	1.16E-08	4.79E-02
Fisher Child	5.44E-08	1.19E-01
Native Adult	3.31E-08	1.71E-01
Native Child	6.70E-08	1.75E-01
Resident Adult	1.16E-08	4.79E-02
Resident Child	5.44E-08	1.19E-01

[a] Maximum risk values for each spill scenarios are highlighted in bold

As indicated by Equation (2), the full risk to human health of shipping HD brine to the three off-site treatment locations listed in Table 3 must account for both the probability of an accident along with the heath-risk impacts of a spill. Table 20 and 21 provide the results of applying Equation (2) to the shipment risks detailed in Table 3 and the health risks presented in Tables 18 and 19. Results for cancer and non-cancer human heath risks are presented in Tables 20 and 21, respectively. <u>All values presented in these tables are several orders of magnitude below the threshold levels established in the 2004 RWAP, which suggests negligible human health risks associated with HD brine shipments</u>.

Table 20: Estimated Cumulative Cancer Risks for Shipment of HD Brine [a,b]

Soils Spill With Remediation Scenario			
Receptor	**Bremerton, WA**	**Grandview, ID**	**Beatty, NV**
Farmer Adult	8.24E-13	1.37E-12	2.60E-12
Farmer Child	1.80E-12	2.99E-12	5.69E-12
Fisher Adult	3.30E-13	5.47E-13	1.04E-12
Fisher Child	1.55E-12	2.57E-12	4.90E-12
Native Adult	9.45E-13	1.57E-12	2.99E-12
Native Child	1.91E-12	3.17E-12	6.04E-12
Resident Adult	3.30E-13	5.47E-13	1.04E-12
Resident Child	1.55E-12	2.57E-12	4.90E-12
Soils Spill Without Remediation Scenario			
Farmer Adult	1.10E-09	1.82E-09	3.47E-09
Farmer Child	2.40E-09	3.98E-09	7.58E-09
Fisher Adult	4.40E-10	7.29E-10	1.39E-09
Fisher Child	2.07E-09	3.43E-09	6.52E-09
Native Adult	1.26E-09	2.09E-09	3.98E-09
Native Child	2.55E-09	4.22E-09	8.04E-09
Resident Adult	4.40E-10	7.29E-10	1.39E-09
Resident Child	2.07E-09	3.43E-09	6.52E-09
Umatilla River-spill Scenario			
Farmer Adult	2.01E-12	3.34E-12	6.35E-12
Farmer Child	2.15E-11	3.56E-11	6.78E-11
Fisher Adult	2.45E-12	4.05E-12	7.72E-12
Fisher Child	1.48E-11	2.45E-11	4.67E-11
Native Adult	1.86E-12	3.08E-12	5.86E-12
Native Child	3.16E-11	5.25E-11	9.99E-11
Resident Adult	2.45E-12	4.05E-12	7.72E-12
Resident Child	2.15E-11	3.56E-11	6.78E-11

[a] Acceptable cancer risk was defined in the ODEQ 2004 RAWP for the UMCDF as less than 1×10^{-5}.
[b] Risk includes both the probability of a spill occurring and the estimated risks from exposure to the spill.

Table 21: Estimated Hazard Index for Shipment of HD Brine [a,b]

Receptor	Bremerton, WA	Grandview, ID	Beatty, NV
Soils Spill With Remediation Scenario			
Farmer Adult	3.74E-06	6.20E-06	1.18E-05
Farmer Child	4.79E-06	7.94E-06	1.51E-05
Fisher Adult	1.37E-06	2.27E-06	4.32E-06
Fisher Child	3.39E-06	5.62E-06	1.07E-05
Native Adult	4.88E-06	8.10E-06	1.54E-05
Native Child	5.01E-06	8.31E-06	1.58E-05
Resident Adult	1.37E-06	2.27E-06	4.32E-06
Resident Child	3.39E-06	5.62E-06	1.07E-05
Soils Spill Without Remediation Scenario			
Farmer Adult	4.98E-03	8.25E-03	1.57E-02
Farmer Child	6.37E-03	1.06E-02	2.01E-02
Fisher Adult	1.82E-03	3.02E-03	5.75E-03
Fisher Child	4.51E-03	7.48E-03	1.42E-02
Native Adult	6.50E-03	1.08E-02	2.05E-02
Native Child	6.67E-03	1.11E-02	2.11E-02
Resident Adult	1.82E-03	3.02E-03	5.75E-03
Resident Child	4.51E-03	7.48E-03	1.42E-02
Umatilla River-spill Scenario			
Farmer Adult	1.50E-08	2.48E-08	4.73E-08
Farmer Child	1.55E-06	2.58E-06	4.91E-06
Fisher Adult	2.66E-08	4.42E-08	8.41E-08
Fisher Child	1.04E-06	1.73E-06	3.29E-06
Native Adult	7.34E-09	1.22E-08	2.32E-08
Native Child	2.33E-06	3.86E-06	7.36E-06
Resident Adult	2.66E-08	4.42E-08	8.41E-08
Resident Child	1.55E-06	2.58E-06	4.91E-06

[a] Acceptable non-cancer risk was defined in the ODEQ 2004 RAWP for the UMCDF as less than 2.5×10^{-1}.

[b] Risk includes both the probability of a spill occurring and the estimated risks from exposure to the spill.

4.2 Summary of Ecological Risk Results

Tables 22 and 23 provide a list of the ecological screening quotients (ESQ) for each of the evaluated chemical species in HD brine for the soil-spill and river spill scenarios, respectively. Total ESQ (calculated as the sum of the chemical specific ESQ values) for each ecological receptor are provided in the last row of both tables. Examinations of these totals indicate that values are well below the ODEQ threshold ESQ level of 0.25 for both spill scenarios. It should be noted that the results in Tables 22 and 23 represent exposure risk and do not include accident risk in the manner indicated in Equation (2). Including the probability of an accident for the three potential destinations results in a reduction of overall risk to levels well below the ODEQ defined threshold for both spill scenarios. These results are presented in Tables 24 and 25. Maximum total ESQ values for each shipping destination are indicated in bold in these tables.

Table 22: Soil-Spill Ecological Risk Assessment ESQ Results

Compound	ESQ Results					
	Peregrine Falcon	Coyote	Mourning Dove	Pronghorn Sheep	Western Meadow Lark	Deer Mouse
Antimony compounds	0.00E+00	5.68E-08	0.00E+00	9.33E-09	9.33E-09	0.00E+00
Arsenic compounds	1.58E-08	2.05E-07	2.13E-07	1.35E-08	3.77E-07	4.66E-06
Barium compounds	6.91E-12	1.67E-11	1.28E-10	2.25E-12	7.67E-11	1.74E-10
Cadmium compounds	1.17E-07	1.32E-06	3.16E-06	3.43E-07	2.05E-04	2.28E-03
Chromium compounds	1.38E-08	9.25E-08	1.70E-07	4.51E-09	1.95E-06	1.25E-05
Copper compounds	2.52E-09	1.10E-08	7.40E-08	3.12E-09	1.78E-07	7.44E-07
Lead compounds	2.85E-09	5.95E-09	3.96E-08	4.24E-10	1.94E-07	3.90E-07
Mercury compounds	5.51E-10	1.47E-09	1.25E-07	4.44E-09	5.11E-07	1.32E-06
Nickel compounds	1.04E-09	2.47E-08	1.39E-08	1.57E-09	2.18E-07	5.00E-06
Selenium compounds	2.32E-10	2.80E-09	2.94E-09	1.51E-10	1.39E-08	1.61E-07
Silver compounds	4.50E-11	9.11E-11	1.32E-09	2.59E-11	5.59E-10	1.06E-09
Thallium compounds	5.17E-11	1.47E-08	6.28E-10	6.88E-10	5.33E-10	1.42E-07
Zinc compounds	7.09E-10	3.85E-10	8.41E-09	1.70E-11	4.03E-07	2.12E-07
Total ESQ	1.54E-07	1.73E-06	3.81E-06	3.81E-07	2.09E-04	2.30E-03

Table 23: River-Spill Ecological Risk Assessment ESQ Results

Compound	ESQ Results						
	Bald Eagle	River Otter	Spotted Sandpiper	Canada Goose	Long-Tail Vole	Mallard Duck	Raccoon
Antimony compounds	0.00E+00	4.26E-05	0.00E+00	0.00E+00	3.13E-04	0.00E+00	7.09E-04
Arsenic compounds	1.20E-05	1.55E-04	1.30E-02	1.03E-03	2.33E-04	3.47E-03	1.17E-02
Barium compounds	5.23E-09	1.25E-08	1.19E-06	9.21E-07	6.98E-08	3.64E-07	2.08E-07
Cadmium compounds	1.81E-04	9.83E-04	6.62E-02	2.98E-02	1.30E-02	1.96E-02	5.37E-02
Chromium compounds	1.05E-05	6.93E-05	5.31E-04	6.66E-04	3.43E-05	1.38E-04	2.97E-04
Copper compounds	1.95E-06	8.22E-06	3.77E-03	7.11E-04	1.19E-04	1.05E-03	1.14E-03
Lead compounds	2.16E-06	4.46E-06	1.84E-04	2.01E-04	8.17E-06	5.36E-05	2.99E-05
Mercury compounds	3.68E-06	1.09E-06	4.07E-04	1.64E-03	1.94E-04	2.43E-04	7.98E-05
Nickel compounds	7.86E-07	1.85E-05	4.52E-05	6.50E-05	2.53E-05	1.30E-05	8.82E-05
Selenium compounds	5.94E-07	2.10E-06	4.00E-05	1.23E-05	1.67E-06	1.07E-05	3.69E-05
Silver compounds	3.43E-08	6.83E-08	7.77E-06	1.27E-05	9.87E-07	2.94E-06	1.14E-06
Thallium compounds	3.92E-08	1.10E-05	8.92E-06	2.38E-06	4.09E-06	2.35E-06	1.84E-04
Zinc compounds	5.39E-07	2.88E-07	6.31E-04	3.06E-05	6.55E-08	1.67E-04	2.40E-05
Total ESQ	*2.13E-04*	*1.30E-03*	*8.49E-02*	*3.41E-02*	*1.39E-02*	*2.47E-02*	*6.80E-02*

Table 24: Estimated ESQ for Shipment of HD Brine; Soil-Spill Scenario [a,b]

Ecological Receptor	Guild	Total ESQ Results		
		Bremerton, WA	Grandview, ID	Beatty, NV
Peregrine Falcon	Carnivorous Bird	5.87E-09	9.72E-09	1.85E-08
Coyote	Carnivorous Mammal	6.59E-08	1.09E-07	2.08E-07
Mourning Dove	Herbivorous Bird	1.45E-07	2.40E-07	4.57E-07
Pronghorn Sheep	Herbivorous Mammal	1.45E-08	2.40E-08	4.57E-08
Western Meadow Lark	Omnivorous Bird	7.95E-06	1.32E-05	2.51E-05
Deer Mouse	Omnivorous Mammal	8.76E-05	1.45E-04	2.77E-04

[a] Acceptable ESQ was defined in the ODEQ 2004 RAWP for the UMCDF as less than 2.5×10^{-1}.
[b] Risk includes both the probability of a spill occurring and the estimated risks from exposure to the spill.

Table 25: Estimated ESQ for Shipment of HD Brine; River-Spill Scenario [a,b]

Ecological Receptor	Guild	Total ESQ Results		
		Bremerton, WA	Grandview, ID	Beatty, NV
Bald Eagle	Carnivorous Bird	8.10E-06	1.34E-05	2.56E-05
River Otter	Carnivorous Mammal	4.92E-05	8.16E-05	1.55E-04
Spotted Sandpiper	Carnivorous Shore Bird	3.22E-03	5.35E-03	1.02E-02
Canada Goose	Herbivorous Bird	1.30E-03	2.15E-03	4.10E-03
Long-Tale Vole	Herbivorous Mammal	5.28E-04	8.75E-04	1.67E-03
Mallard Duck	Omnivorous Bird	9.40E-04	1.56E-03	2.97E-03
Raccoon	Omnivorous Mammal	2.59E-03	4.29E-03	8.16E-03

[a] Acceptable ESQ was defined in the ODEQ 2004 RAWP for the UMCDF as less than 2.5×10^{-1}.
[b] Risk includes both the probability of a spill occurring and the estimated risks from exposure to the spill.

4.3 Detailed Human Risk Results for Soil-Spill Scenario

The relative contributions of each toxic constant of the HD brine to cancer risk and hazard index are provided in Tables 26 and 27, respectively. Arsenic represents the over 99% of the cancer risk for all receptors with lead being the only other contributor. For the non-cancer risk, cadmium accounts for approximately 96% of the risk with arsenic, mercury, and antimony creating most of the remaining risk.

Table 26: Cancer Risk Contribution from Each Chemical Species for Soil-spill with Remediation

	Farmer Adult	Farmer Child	Fisher Adult	Fisher Child	Native Adult	Native Child	Resident Adult	Resident Child
Antimony	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	99.82%	99.85%	99.82%	99.85%	99.81%	99.85%	99.82%	99.85%
Barium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cadmium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chromium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Copper	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lead	0.17%	0.15%	0.18%	0.15%	0.19%	0.15%	0.18%	0.15%
Mercury	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Nickel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Selenium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Silver	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Thallium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Zinc	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 27: Hazard Index Contribution from Each Chemical Species for Soil-spill with Remediation

	Farmer Adult	Farmer Child	Fisher Adult	Fisher Child	Native Adult	Native Child	Resident Adult	Resident Child
Antimony	0.12%	0.12%	0.11%	0.12%	0.12%	0.12%	0.11%	0.12%
Arsenic	3.09%	3.32%	2.90%	3.55%	3.01%	3.31%	2.90%	3.55%
Barium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cadmium	96.29%	96.28%	96.93%	96.28%	96.68%	96.42%	96.93%	96.28%
Chromium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Copper	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Lead	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	0.44%	0.22%	0.00%	0.01%	0.14%	0.10%	0.00%	0.01%
Nickel	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Selenium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Silver	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Thallium	0.02%	0.01%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%
Zinc	0.02%	0.02%	0.02%	0.01%	0.02%	0.02%	0.02%	0.01%

Table 28: Relative Contribution of Each Exposure Pathway to Total Risk; Soil-Spill Scenario

	Farmer Adult	Farmer Child	Fisher Adult	Fisher Child	Native Adult	Native Child	Res. Adult	Res. Child
Cancer Risk (% of Total Cancer Risk)								
Inhalation	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Produce	**56.56%**	**31.54%**	**50.44%**	**24.83%**	**65.74%**	**32.50%**	**50.44%**	**24.83%**
Bathing	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Beef/Game	**12.00%**	**3.37%**	**0.00%**	**0.00%**	**5.18%**	**1.69%**	**0.00%**	**0.00%**
Chicken	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Drinking Water	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Egg	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Fish	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Goat	**0.39%**	**0.14%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Sweat Lodge	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Milk	**0.31%**	**0.23%**	**0.00%**	**0.00%**	**0.28%**	**0.23%**	**0.00%**	**0.00%**
Pork	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Soil Dermal Contact and ingestion	**30.73%**	**64.73%**	**49.56%**	**75.17%**	**28.80%**	**65.58%**	**49.56%**	**75.17%**
Swimming	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Hazard Index (% of Total Hazard Index)								
Inhalation	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Produce	**95.96%**	**94.49%**	**97.83%**	**94.04%**	**98.02%**	**95.50%**	**97.83%**	**94.04%**
Bathing	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Beef/Game	**0.86%**	**0.41%**	**0.00%**	**0.00%**	**0.33%**	**0.21%**	**0.00%**	**0.00%**
Chicken	**1.52%**	**0.81%**	**0.00%**	**0.00%**	**0.08%**	**0.05%**	**0.00%**	**0.00%**
Drinking Water	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Egg	**0.06%**	**0.03%**	**0.00%**	**0.00%**	**0.01%**	**0.01%**	**0.00%**	**0.00%**
Fish	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Goat	**0.03%**	**0.02%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Sweat Lodge	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Milk	**0.02%**	**0.02%**	**0.00%**	**0.00%**	**0.01%**	**0.02%**	**0.00%**	**0.00%**
Pork	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Soil Dermal Contact and ingestion Contact	**1.56%**	**4.22%**	**2.17%**	**5.96%**	**1.56%**	**4.22%**	**2.17%**	**5.96%**
Swimming	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Table 28 provides a breakdown of both carcinogenic and non-carcinogenic risk by exposure pathway. Inhalation and water pathways of exposure (bathing, swimming, drinking water ingestion, and sweat lodge use) do not contribute to risk as expected from the initial assumptions. Produce ingestion represents the largest component to cancer risk for all receptors except for the fisher child where dermal contact and ingestion of soil is the highest contribution to risk. In all cases the sum of produce ingestion, beef/game ingestion, and soil dermal contact and ingestion represents more than 99% of the cancer risk. Non-cancer related risks are driven by produce ingestion for all receptors and the sum of produce and soil dermal contact and ingestion represents more than 97%.

4.4 Detailed Human Risk Results for River-Spill Scenario

The relative contributions of each toxic constant of the HD brine to cancer risk and hazard index for the hypothetical spill of HD brine into the Umatilla River are provided in Tables 29 and 30, respectively. As with the soil-spill scenario, arsenic represents over 99% of the cancer risk for all receptors with lead being the only other significant contributor. For the non-cancer risk, cadmium accounts for approximately 65% of the risk with arsenic and copper creating most of the remaining risk.

Table 29: Cancer Risk Contribution from Each Chemical Species for Soil-spill

	Farmer Adult	Farmer Child	Fisher Adult	Fisher Child	Native Adult	Native Child	Resident Adult	Resident Child
Antimony	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%
Barium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cadmium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chromium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Copper	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lead	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Mercury	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Nickel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Selenium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Silver	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Thallium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Zinc	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 30: Hazard Index Contribution from Each Chemical Species for Soil-spill

	Farmer Adult	Farmer Child	Fisher Adult	Fisher Child	Native Adult	Native Child	Resident Adult	Resident Child
Antimony	0.34%	0.34%	0.34%	0.34%	0.34%	0.34%	0.34%	0.34%
Arsenic	33.78%	33.78%	33.78%	33.78%	33.78%	33.78%	33.78%	33.78%
Barium	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cadmium	64.99%	64.99%	64.99%	64.98%	64.99%	64.99%	64.99%	64.99%
Chromium	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Copper	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%	0.73%
Lead	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Nickel	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%
Selenium	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Silver	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Thallium	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%	0.05%
Zinc	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%

Table 31: Relative Contribution of Each Exposure Pathway to Total Risk; River-Spill Scenario

Cancer Risk (% of Total Cancer Risk)								
	Farmer Adult	Farmer Child	Fisher Adult	Fisher Child	Native Adult	Native Child	Res. Adult	Res. Child
Inhalation	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Produce	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bathing	12.96%	2.08%	10.66%	3.02%	14.64%	1.47%	10.66%	2.08%
Beef/Game	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chicken	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Drinking Water	64.71%	94.34%	70.97%	91.78%	60.11%	96.00%	70.97%	94.34%
Egg	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Goat	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sweat Lodge	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Milk	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pork	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Soil Dermal Contact and ingestion	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Swimming	22.34%	3.58%	18.37%	5.20%	25.25%	2.53%	18.37%	3.58%
Hazard Index (% of Total Hazard Index)								
Inhalation	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Produce	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bathing	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Beef/Game	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chicken	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Drinking Water	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Egg	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fish	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Goat	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sweat Lodge	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Milk	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pork	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Soil Dermal Contact and ingestion	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Swimming	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 31 provides a breakdown of both carcinogenic and non-carcinogenic risk by exposure pathway for the Umatilla River brine spill scenario. Inhalation, ingestion, and soil pathways of exposure do not contribute to risk as expected from the initial assumptions. Drinking water represents the largest contributor to cancer risk for all receptors followed by swimming and then bathing. Non-cancer related risks are driven entirely by ingestion of the Umatilla River water as the sole drinking water source on the day of the spill.

5 Risk Assessment Uncertainties

Human health and ecological risks reported in this study are estimates based on numerous accident and exposure assumptions. Changing these underlying assumptions will result in increasing, or decreasing the estimated risk levels. Potential sources of uncertainty in this risk characterization are described in Table 32.

Table 32: Uncertainties in Human Health and Ecological Risk Assessment

ISSUE	UNCERTAINTY	DIRECTION OF EFFECT
Human Exposure assumptions are assumed to be true	The exposure assumptions are based on reasonable maximum exposure scenarios, and exposures at this level may be higher than for most of the general population.	Overestimate Risk
Risks was not quantified for all chemicals in brine	Toxicity data was lacking for nitrate, sulfate, chloride, and fluoride. Hence, these compounds could not be included in this analysis.	Underestimate Risk
Amount of residual contaminants in the soil-spill scenario	The fraction of contaminated foods was set equal to the ratio area of unremediated soils to total area used to generate food-stuffs. Actual remediation practices make it unlikely that any soil would be left unremediated.	Overestimate Risk
Amount of land used to grow food-stuffs	The assumption that all food-stuffs are grown in a 5 acre area and that all ecological receptors are contained within a 5 acre area is likely an underestimate of the land needed for these activities.	Overestimate Risk
Uniform and instantaneous dilution for river-spill	The assumption that a spill into a river is mixed across the full area of the river at the point of entry is not realistic for slow flowing water bodies.	Underestimate Risk
Potential synergistic effects of exposure	Synergistic effects of exposure to multiple contaminants were not evaluated.	Underestimate Risk
Potential antagonistic effects of exposure	Antagonistic effects of exposure to multiple contaminants were not evaluated.	Overestimate Risk
Ecological receptors choice	Representative receptor species were chosen based on available information and may not be the most sensitive populations to particular compounds	Underestimate Risk
Fractioned diet for ecological receptors	A diet composed of equal fractions of each consumed material is not likely an accurate representation of animal eating habits.	Varies
Fish home range	Ecological assessment assumed fish spend 100% of their life span within the contaminated area, which is not an accurate representation of their lifecycle habits	Overestimate Risk

6 References

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7. Lakes Environmental. 2003. EcoRisk View Software. Lakes Environmental, 419 Phillip Street, Unit 3, Waterloo, Ontario Canada, N2L 3X2.
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APPENDIX A – Brine Composition

TOCDF HD Brine Analysis Data

Sample Date	4-Sep-06	4-Sep-06	11-Sep-06	23-Sep-06	27-Sep-06	3-Oct-06	13-Oct-06	2-Nov-06	9-Nov-06	4-Apr-07	8-May-07
Sample Number	6244.35	6244.36	6254.46	6266.38	6270.34	6276.34	6284.38	6306.48	6313.33	7093.39	7128.35
Treated	No	No	No	No	No	No	No	No	No	No	No
Specific Gravity	1.035	NA	NA	NA	NA	NA	NA	NA	NA	1.07	1.1
pH	9.18	NA	NA	NA	NA	NA	NA	NA	NA	7.82	9.75
Total Phosphorous (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.0	0.84
PCB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BOD (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	2400*	1400*
COD (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	5000*	8600*
TSS (ppm)	NA	NA	NA	NA	NA	NA	NA	NA	NA	550	1300
TDS (ppm)	NA	NA	NA	NA	NA	NA	NA	NA	NA	100000	150000
Oil and Grease (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	3.8
Total Chloride (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	31000	40000
Total Residual Chlorine (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND
Total Fluoride (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6	0.18
Silver (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Silver (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Silver (mg/L), TCLP	ND	ND	0.0186	0.0196	ND	ND	BRL	ND	0.0092	NA	NA
Aluminum (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Aluminum (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Arsenic (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.43	0.60
Arsenic (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.36	0.68
Arsenic (mg/L), TCLP	1.3406	1.9698	0.7970	1.3922	4.5180	1.3592	7.6	6.4020	2.6560	NA	NA
Barium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.018	0.020

Barium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.027	0.031
Barium (mg/L), TCLP	ND	ND	ND	ND	ND	ND	BRL	ND	ND	NA	NA
Boron (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Boron (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Beryllium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Beryllium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Cadmium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.17	0.078
Cadmium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.14	0.019
Cadmium (mg/L), TCLP	0.0842	0.1154	0.1496	0.0884	0.1090	0.1824	36	0.008	0.2632	NA	NA
Cobalt (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chromium, Total (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.5	0.35
Chromium, Dissolved (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.15	0.17
Chromium, TCLP (mg/L)	3.2400	7.9320	ND	0.1918	ND	0.1506	BRL	ND	0.2842	NA	NA
Chromium, Hexavalent (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Copper (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.1	2.2
Copper (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.53	2.2
Magnesium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Magnesium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Mercury (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0023	BRL
Mercury (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Mercury (mg/L), TCLP	ND	ND	0.0526	0.0436	0.0436	ND	BRL	0.0226	0.036	NA	NA
Nickel (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5	0.54
Nickel (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.19	0.028
Lead (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	0.60
Lead (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.099	0.0090
Lead (mg/L), TCLP	ND	0.1402	ND	0.9462	0.2172	0.1542	BRL	0.0726	0.1546	NA	NA

Antimony (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	0.12
Antimony (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.022	0.11
Selenium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	0.020
Selenium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Selenium (mg/L), TCLP	ND	ND	ND	ND	ND	ND	BRL	ND	ND	NA	NA
Tin (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tin (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thallium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	0.0039
Thallium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Vanadium (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.2	2.2
Zinc (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.67	1.5
Iron (mg/L), Total	NA	NA	NA	NA	NA	NA	NA	NA	NA	40	5.8
Iron (mg/L), Dissolved	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Iron (mg/L), Ferrous (Fe+2)	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.26	BRL
1,1'-Biphenyl (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,5-Trichlorophenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,6-Trichlorophenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dichlorophenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylphenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dinitrophenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dinitrotoluene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,6-Dinitrotoluene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Chloronaphthalene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Chlorophenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylphenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitroaniline (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitrophenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

3,3´-Dichlorobenzidine (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Nitroaniline (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,6-Dinitro-2-methylphenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Bromophenyl phenyl ether (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloro-3-methylphenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloroaniline (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chlorophenyl phenyl ether (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylphenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methylphenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitroaniline (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitrophenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetophenone (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Atrazine (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benz(a)anthracene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzaldehyde (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroethoxy)methane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroethyl)ether (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

(ug/L)											
Butyl benzyl phthalate (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Caprolactam (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Diethyl phthalate (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dimethyl phthalate (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butyl phthalate (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-octyl phthalate (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobenzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachloroethane (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isophorone (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrobenzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N-Nitrosodi-n-propylamine (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N-Nitrosodiphenylamine (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenol (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyridine (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1,1,1-Trichloroethane (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloroethane (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethane (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dibromoethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloropropane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dichlorobenzene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Hexanone (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetone (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromoform (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromomethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulfide (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon tetrachloride (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloromethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,2-Dichloroethene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

cis-1,3-Dichloropropene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dibromochloromethane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichlorodifluoromethane (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Freon-113 (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopropylbenzene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
m,p-Xylene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl acetate (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl tert-butyl ether (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylcyclohexane (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Styrene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-1,3-Dichloropropene (ug/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride (ug/L)	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,4,5-Tetrachlorobenzene	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4,6-Tetrachlorophenol	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorobenzene	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,2-Trichloro-1,2,2-trifluoroethane	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitropropane	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexanone	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethyl acetate	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Ethyl ether	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isobutyl alcohol	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Butyl alcohol	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylene, Total	BRL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	22000	22000
Sulfite (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	24000	29000
Sulfide (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	35	88
Salinity (ppt)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyanide, Total (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Nitrogen, Nitrate-Nitrite (as N) (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.0	7.1
Nitrogen, Total Kjeldahl (TKN) (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.8	14
Nitrogen, Organic (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.8	14
Nitrogen, Ammonia (As N) (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	BRL	BRL
Organic Carbon, Total (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.0*	51.0*

BRL: Below Reporting Limit
ND: Not Detected (< Method Detection Limit)
NA: Not Analyzed
*According to laboratory, these parameters had interferences causing false positive/false high readings.

APPENDIX B- Shipping Data

From: Carter, Duane B. [Duane.Carter@UMCDF-FO.ORG]
Sent: Thursday, January 17, 2008 11:42 AM
To: Strong, Mike J.
Cc: Rod Skeen
Subject: RE: data for brine risk assessment.

Attachments: JACADS hd_brine.xls; Brine Sample Analytical Results_061307.xls; Brine Analysis.pdf

See Below

1. Estimated chemical composition of HD brine, including pH.

From Permit Application:

Parameter	Concentration*	Parameter	Concentration
pH	8 - 9	Hg	0.25
Na2CO3	29800	Cr	13
Na2SO3	59000	Zn	8.8
NaCL	108300	Cu	<6.3
Na2SO4	39300	Fe	500
Pb	<13	SG	1.2
Cd	<4		

*Units are mg/L except for pH and SG.

Also attached is a limited JACADS sample and monthly sampling for TOCDF through May 07. Still waiting on current data.

2. Total estimated quantity of HD brine.

14,000,000 gallons (from UMCDF HD projections).

3. DOT Hazardous Material class for brine.

Class 9 - Miscellaneous Hazardous Material.

4. Type of DOT classification of shipping container

TT - Tanker

5. Size of shipping container.

5,000 - 6,500 gallons

6. Location the brine will be shipped to (or locations)

US Ecology, Grandview, ID
US Ecology, Beatty, NV
PSC in Bremerton, WA has not been used in a while, and subcontracted with US Ecology last time the site tried to use them.

Duane Carter, MS, CHMM
General Engineer

Umatilla Chemical Agent Disposal Facility
541-564-7025

Google Map Results for Grandview Idaho

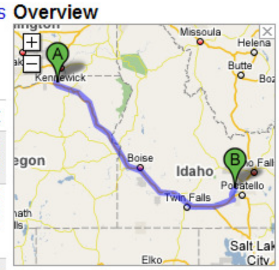
Show original map view. Print

Google Maps

Start **Hermiston, OR**
End **Grandview**
Uninc Bingham County, ID
Travel **484 mi – about 7 hours 30 mins**

Notes: You can enter notes here.

Hide Maps **Overview**

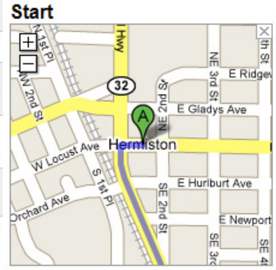


Hermiston, OR

Drive: 484 mi – about 7 hours 30 mins

1.	Head **west** on **E Main St** toward **N 1st St/OR-32/US-395**	190 ft
2.	Turn **left** at **S 1st St/US-395** Continue to follow US-395	7.2 mi 12 mins
3.	Turn **left** to merge onto **I-84 E/US-30 E/US-395 S** Continue to follow I-84 E Entering Idaho	410 mi 5 hours 57 mins
4.	Continue on **I-86 E**	40.2 mi 32 mins
5.	Take exit **40** for **ID-39** toward **American Falls**	0.2 mi
6.	Turn **left** at **I-86-BL/ID-39/Lakeview Rd** Continue to follow I-86-BL/ID-39	0.4 mi 2 mins
7.	Slight **right** to stay on **I-86-BL/ID-39** Continue to follow ID-39	16.1 mi 28 mins
8.	Continue on **N Main St**	0.1 mi 1 min
9.	Continue on **ID-39**	9.2 mi 17 mins

Start



Grandview
Uninc Bingham County, ID

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End

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Done Internet 100%

Google Map Results for Beatty Nevada

Show original map view. Print

Google Maps

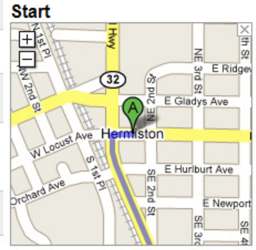
Start **Hermiston, OR**
End **Beatty, NV**
Travel **888 mi – about 14 hours 30 mins**

Notes
You can enter notes here.

Hide Maps

Overview

Start



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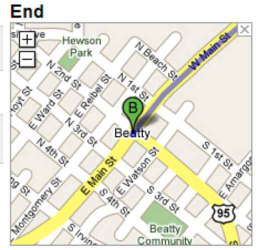

Hermiston, OR

Drive: 888 mi – about 14 hours 30 mins

1.	Head **west** on **E Main St** toward **N 1st St/OR-32/US-395**	190 ft
2.	Turn **left** at **S 1st St/US-395** Continue to follow US-395	7.2 mi 12 mins
3.	Turn **left** to merge onto **I-84 E/US-30 E/US-395 S** Continue to follow I-84 E Entering Idaho	361 mi 5 hours 18 mins
4.	Take exit **173** to merge onto **US-93 S** toward **Wells, Nev./Twin Falls**	5.8 mi 8 mins
5.	Slight **right** at **ID-74**	3.3 mi 8 mins
6.	Turn **right** at **E 3600 Rd N/ID-74** Continue to follow E 3600 Rd N	4.9 mi 6 mins
7.	Turn **left** at **2400 Rd E/US-93** Continue to follow US-93 Entering Nevada	184 mi 3 hours 8 mins
8.	Turn **right** at **Great Basin Hwy/US-93**	59.4 mi 1 hour 3 mins
9.	Turn **left** at **S 7th St/Great Basin Blvd/Great Basin Hwy/US-50/US-93**	0.8 mi 3 mins
10.	Turn **right** at **US-6**	168 mi 2 hours 46 mins
11.	Slight **left** to stay on **US-6**	469 ft 1 min
12.	Turn **left** at **Main St/US-95** Continue to follow US-95	93.0 mi 1 hour 35 mins
13.	Continue on **E Main St/NV-374**	39 ft 1 min

Beatty, NV

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Google Map Results for Bremerton Washington

Google Maps

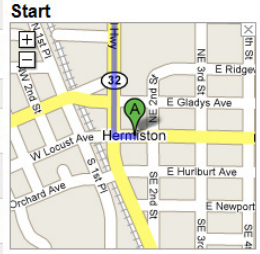
Show original map view. Print

Start **Hermiston, OR**
End **Bremerton, WA**
Travel **294 mi – about 4 hours 49 mins**

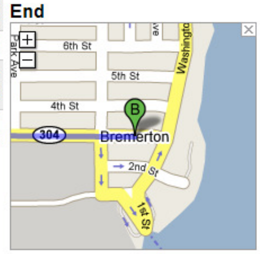
Notes: You can enter notes here.

Hide Maps **Overview**

Start



End



Hermiston, OR

Drive: 294 mi – about 4 hours 49 mins

1.	Head **west** on **E Main St** toward **N 1st St/OR-32/US-395**	190 ft
2.	Turn **right** at **N 1st St/OR-32/US-395** Continue to follow OR-32/US-395	5.4 mi 9 mins
3.	Turn **left** at **6th St/Columbia River Hwy/US-395/US-730**	0.7 mi 2 mins
4.	Turn **right** to merge onto **I-82 W/US-395 N** Continue to follow I-82 W Entering Washington	133 mi 1 hour 56 mins
5.	Take the exit onto **I-90 W/US-97 N** toward **Seattle** Continue to follow I-90 W	85.6 mi 1 hour 15 mins
6.	Take exit **25** for **WA-18 W** toward **Tacoma/Auburn**	0.3 mi
7.	Turn **left** at **WA-18**	27.9 mi 32 mins
8.	Take the exit onto **I-5 S** toward **Portland/Tacoma**	9.5 mi 10 mins
9.	Take exit **132** to merge onto **WA-16 W** toward **Gig Harbor/Bremerton**	27.2 mi 33 mins
10.	Continue on **WA-3 N**	1.8 mi 3 mins
11.	Take the **WA-304 E** exit toward **Ferry/Bremerton**	0.5 mi
12.	Merge onto **Navy Yard Hwy/WA-304** Continue to follow WA-304	1.4 mi 4 mins
13.	Turn **right** at **Burwell St**	1.3 mi 4 mins

Bremerton, WA

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APPENDIX C – Scenario Parameters

Table C-1: Exposure Parameters for Adult Populations for Spill of HD Brines into Soil with Remediation

Parameter	Units	Resident	Farmer	Fisher	Native American
Adherence factor of soil to skin [a]	mg-soil/cm^2-event	1.26E-06	1.8E-06	1.26E-06	1.8E-06
Averaging time for carcinogens	yr	70	70	70	70
Averaging time for noncarcinogens	yr	30	40	30	70
Consumption rate of BEEF (WILD GAME for Natives)	kg/kg-day FW	0	0.00417	0	0.00198
Body weight	kg	70	70	70	70
Consumption rate of POULTRY (FOWL for Natives)	kg/kg-day FW	0	0.00227	0	0.000154
Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	0.00032	0.00176	0.00032	0.00124
Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	0.00014	0.000552	0.00014	0.000706
Consumption rate of DRINKING WATER	L/day	2	2	2	3
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	0.00061	0.00064	0.00061	0.00183
Consumption rate of SOIL	kg/d	0.0001	0.0002	0.0001	0.0002
Exposure duration	yr	30	40	30	70
Exposure frequency	day/yr	350	350	350	365
Exposure frequency of bathing	day/year	350	350	350	365
Exposure frequency during sweat lodge use	events/year	0	0	0	365
Exposure frequency of dermal contact with soil	events/year	350	350	350	365
Exposure frequency of swimming	day/year	10.5	10.5	10.5	10.95
Consumption rate of EGGS	kg/kg-day FW	0	0.00185	0	0.0003
Exposure time during sweat lodge use	hr/event	0	0	0	2
Event frequency of dermal contact with water and soil	events/day	1	1	1	1
Fraction of contaminated ABOVEGROUND PRODUCE	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated DRINKING WATER	--	0	0	0	0
Fraction contaminated SOIL	--	0.000018	0.000018	0.000018	0.000018
Consumption rate of FISH	kg/kg-day FW	0	0	0.0035	0.00849

Parameter	Units	Resident	Farmer	Fisher	Native American
Fraction of contaminated FISH	--	0	0	0	0
Consumption rate of GOAT	kg/kg-day FW	0	0.0017	0	0
Inhalation exposure duration	yr	0	0	0	0
Inhalation exposure frequency	day/yr	350	350	350	365
Inhalation exposure time	hr/day	24	24	24	24
Fraction of contaminated BEEF (WILD GAME for Natives)	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated POULTRY (FOWL for Natives)	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated EGGS	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated GOAT	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated MILK	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated PORK	--	0.000018	0.000018	0.000018	0.000018
Inhalation rate	m^3/hr	0.83	0.83	0.83	1.25
Consumption rate of MILK	kg/kg-day FW	0	0.0044	0	0.0044
Consumption rate of PORK	kg/kg-day FW	0	0	0	0
Skin surface area available for contact with soil	cm^2	5700	5700	5700	5700
Skin surface area available for contact with water	Cm^2	18000	18000	18000	18000
Body surface area available for contact during a sweat	M^2	0	0	0	1.8
Time period at the beginning of combustion	yr	0	0	0	0
Length of exposure duration	yr	30	40	30	70

[a] To account for only a fraction of the soil a receptor is exposed to is contaminated this term is a product of the standard adherence factor and the fraction of contaminated soil (1.8×10^{-5}).

Table C-2: Exposure Parameters for Child Populations for Spill of HD Brines into Soil with Remediation

Parameter	Units	Resident	Farmer	Fisher	Native American
Adherence factor of soil to skin [a]	mg-soil/cm^2-event	3.60E-06	3.6E-06	3.6E-06	3.6E-06
Averaging time for carcinogens	yr	70	70	70	70
Averaging time for noncarcinogens	yr	6	6	6	6
Consumption rate of BEEF (WILD GAME for Natives)	kg/kg-day FW	0	0.00256	0	0.00131
Body weight	kg	15	15	15	15
Consumption rate of POULTRY (FOWL for Natives)	kg/kg-day FW	0	0.00155	0	0.000105
Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	0.00077	0.00176	0.00077	0.00124
Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	0.00023	0.00052	0.00023	0.000706
Consumption rate of DRINKING WATER	L/day	1	1	0.67	1.5
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	0.0015	0.00136	0.0015	0.00183
Consumption rate of SOIL	kg/d	0.0002	0.0002	0.0002	0.0002
Exposure duration	yr	6	6	6	6
Exposure frequency	day/yr	350	350	350	365
Exposure frequency of bathing	day/year	350	350	350	365
Exposure frequency during sweat lodge use	events/year	0	0	0	0
Exposure frequency of dermal contact with soil	events/year	350	350	350	365
Exposure frequency of swimming	day/year	10.5	10.5	10.5	10.95
Consumption rate of EGGS	kg/kg-day FW	0	0.00133	0	0.000216
Exposure time during sweat lodge use	hr/event	0	0	0	0
Event frequency of dermal contact with water and soil	events/day	1	1	1	1
Fraction of contaminated ABOVEGROUND PRODUCE	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated DRINKING WATER	--	0	0	0	0
Fraction contaminated SOIL	--	0.000018	0.000018	0.000018	0.000018
Consumption rate of FISH	kg/kg-day FW	0	0	0.00088	0.00598
Fraction of contaminated FISH	--	0	0	0	0
Consumption rate of GOAT	kg/kg-day FW	0	0.0013	0	0
Inhalation exposure duration	yr	0	0	0	0
Inhalation exposure frequency	day/yr	350	350	350	365

Parameter	Units	Resident	Farmer	Fisher	Native American
Inhalation exposure time	hr/day	24	24	24	24
Fraction of contaminated BEEF (WILD GAME for Natives)	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated POULTRY (FOWL for Natives)	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated EGGS	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated GOAT	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated MILK	--	0.000018	0.000018	0.000018	0.000018
Fraction of contaminated PORK	--	0.000018	0.000018	0.000018	0.000018
Inhalation rate	m^3/hr	0.5	0.5	0.5	0.5
Consumption rate of MILK	kg/kg-day FW	0	0.0073	0	0.0073
Consumption rate of PORK	kg/kg-day FW	0	0	0	0
Skin surface area available for contact with soil	Cm^2	2800	2800	2800	2800
Skin surface area available for contact with water	Cm^2	6600	6600	6600	6600
Body surface area available for contact during a sweat	m^2	0	0	0	0
Time period at the beginning of combustion	yr	0	0	0	0
Length of exposure duration	yr	6	6	6	6

[a] To account for only a fraction of the soil a receptor is exposed to is contaminated this term is a product of the standard adherence factor and the fraction of contaminated soil (1.8×10^{-5}).

Table C-3: Exposure Parameters for Adult Populations for Spill of HD Brines into the Umatilla River

Parameter	Units	Resident	Farmer	Fisher	Native American
Adherence factor of soil to skin	mg-soil/cm^2-event	0.07	0.1	0.07	0.1
Averaging time for carcinogens	yr	70	70	70	70
Averaging time for noncarcinogens	yr	30	40	30	70
Consumption rate of BEEF (WILD GAME for Natives)	kg/kg-day FW	0	0	0	0
Body weight	kg	70	70	70	70
Consumption rate of POULTRY (FOWL for Natives)	kg/kg-day FW	0	0	0	0
Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	0	0	0	0
Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	0	0	0	0
Consumption rate of DRINKING WATER	L/day	2	2	2	3
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	0	0	0	0
Consumption rate of SOIL	kg/d	0	0	0	0
Exposure duration	yr	0.0027	0.0027	0.0027	0.0027
Exposure frequency	day/yr	350	350	350	365
Exposure frequency of bathing	day/year	1	1	1	1
Exposure frequency during sweat lodge use	events/year	0	0	0	1
Exposure frequency of dermal contact with soil	events/year	350	350	350	365
Exposure frequency of swimming	day/year	1	1	1	1
Consumption rate of EGGS	kg/kg-day FW	0	0	0	0
Exposure time during sweat lodge use	hr/event	0	0	0	2
Event frequency of dermal contact with water and soil	events/day	1	1	1	1
Fraction of contaminated ABOVEGROUND PRODUCE	--	0	0	0	0
Fraction of contaminated DRINKING WATER [a]	--	9.52E-05	7.14E-05	9.52E-05	3.91E-05
Fraction contaminated SOIL	--	0	0	0	0
Consumption rate of FISH	kg/kg-day FW	0	0	0.0035	0.00849
Fraction of contaminated FISH	--	0	0	0	0
Consumption rate of GOAT	kg/kg-day FW	0	0	0	0
Inhalation exposure duration	yr	0	0	0	0
Inhalation exposure frequency	day/yr	350	350	350	365
Inhalation exposure time	hr/day	24	24	24	24

Parameter	Units	Resident	Farmer	Fisher	Native American
Fraction of contaminated BEEF (WILD GAME for Natives)	--	0	0	0	0
Fraction of contaminated POULTRY (FOWL for Natives)	--	0	0	0	0
Fraction of contaminated EGGS	--	0	0	0	0
Fraction of contaminated GOAT	--	0	0	0	0
Fraction of contaminated MILK	--	0	0	0	0
Fraction of contaminated PORK	--	0	0	0	0
Inhalation rate	m^3/hr	0	0	0	0
Consumption rate of MILK	kg/kg-day FW	0	0	0	0
Consumption rate of PORK	kg/kg-day FW	0	0	0	0
Skin surface area available for contact with soil	cm^2	5700	5700	5700	5700
Skin surface area available for contact with water	Cm^2	18000	18000	18000	18000
Body surface area available for contact during a sweat	M^2	0	0	0	1.8
Time period at the beginning of combustion	yr	0	0	0	0
Length of exposure duration	yr	0.0027	0.0027	0.0027	0.0027

[a] Term is calculated as the ratio of contaminated drinking water consumed during over the of the spill to the total quantity of drinking water consumed during the full assessment period. The assessment period for each receptor is numerically equal to the values listed for the averaging times for non-carcinogenic effects.

Table C-4: Exposure Parameters for Child Populations for Spill of HD Brines into the Umatilla River

Parameter	Units	Resident	Farmer	Fisher	Native American
Adherence factor of soil to skin	mg-soil/cm^2-event	0.2	0.2	0.2	0.2
Averaging time for carcinogens	yr	70	70	70	70
Averaging time for noncarcinogens	yr	6	6	6	6
Consumption rate of BEEF (WILD GAME for Natives)	kg/kg-day FW	0	0	0	0
Body weight	kg	15	15	15	15
Consumption rate of POULTRY (FOWL for Natives)	kg/kg-day FW	0	0	0	0
Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	0	0	0	0
Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	0	0	0	0
Consumption rate of DRINKING WATER	L/day	1	1	0.67	1.5
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	0	0	0	0
Consumption rate of SOIL	kg/d	0	0	0	0
Exposure duration	yr	0.0027	0.0027	0.0027	0.0027
Exposure frequency	day/yr	350	350	350	365
Exposure frequency of bathing	day/year	1	1	1	1
Exposure frequency during sweat lodge use	events/year	0	0	0	0
Exposure frequency of dermal contact with soil	events/year	350	350	350	365
Exposure frequency of swimming	day/year	1	1	1	1
Consumption rate of EGGS	kg/kg-day FW	0	0	0	0
Exposure time during sweat lodge use	hr/event	0	0	0	0
Event frequency of dermal contact with water and soil	events/day	1	1	1	1
Fraction of contaminated ABOVEGROUND PRODUCE	--	0	0	0	0
Fraction of contaminated DRINKING WATER [a]	--	4.76E-04	4.76E-04	4.76E-04	4.57E-04
Fraction contaminated SOIL	--	0	0	0	0
Consumption rate of FISH	kg/kg-day FW	0	0	0.00088	0.00598
Fraction of contaminated FISH	--	0	0	0	0
Consumption rate of GOAT	kg/kg-day FW	0	0	0	0
Inhalation exposure duration	yr	0	0	0	0
Inhalation exposure frequency	day/yr	350	350	350	365

Parameter	Units	Resident	Farmer	Fisher	Native American
Inhalation exposure time	hr/day	24	24	24	24
Fraction of contaminated BEEF (WILD GAME for Natives)	--	0	0	0	0
Fraction of contaminated POULTRY (FOWL for Natives)	--	0	0	0	0
Fraction of contaminated EGGS	--	0	0	0	0
Fraction of contaminated GOAT	--	0	0	0	0
Fraction of contaminated MILK	--	0	0	0	0
Fraction of contaminated PORK	--	0	0	0	0
Inhalation rate	m^3/hr	0	0	0	0
Consumption rate of MILK	kg/kg-day FW	0	0	0	0
Consumption rate of PORK	kg/kg-day FW	0	0	0	0
Skin surface area available for contact with soil	Cm^2	2800	2800	2800	2800
Skin surface area available for contact with water	Cm^2	6600	6600	6600	6600
Body surface area available for contact during a sweat	m^2	0	0	0	0
Time period at the beginning of combustion	yr	0	0	0	0
Length of exposure duration	yr	0.0027	0.0027	0.0027	0.0027

[a] Term is calculated as the ratio of contaminated drinking water consumed during over the of the spill to the total quantity of drinking water consumed during the full assessment period. The assessment period for each receptor is numerically equal to the values listed for the averaging times for non-carcinogenic effects.

Table C-5: Exposure Parameters for Adult Populations for Spill of HD Brines into Soils With No Subsequent Remediation

Parameter	Units	Resident	Farmer	Fisher	Native American
Adherence factor of soil to skin [a]	mg-soil/cm^2-event	0.00168	0.0024	0.00168	0.0024
Averaging time for carcinogens	yr	70	70	70	70
Averaging time for noncarcinogens	yr	30	40	30	70
Consumption rate of BEEF (WILD GAME for Natives)	kg/kg-day FW	0	0.00417	0	0.00198
Body weight	kg	70	70	70	70
Consumption rate of POULTRY (FOWL for Natives)	kg/kg-day FW	0	0.00227	0	0.000154
Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	0.00032	0.00176	0.00032	0.00124
Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	0.00014	0.000552	0.00014	0.000706
Consumption rate of DRINKING WATER	L/day	2	2	2	3
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	0.00061	0.00064	0.00061	0.00183
Consumption rate of SOIL	kg/d	0.0001	0.0002	0.0001	0.0002
Exposure duration	yr	30	40	30	70
Exposure frequency	day/yr	350	350	350	365
Exposure frequency of bathing	day/year	350	350	350	365
Exposure frequency during sweat lodge use	events/year	0	0	0	365
Exposure frequency of dermal contact with soil	events/year	350	350	350	365
Exposure frequency of swimming	day/year	10.5	10.5	10.5	10.95
Consumption rate of EGGS	kg/kg-day FW	0	0.00185	0	0.0003
Exposure time during sweat lodge use	hr/event	0	0	0	2
Event frequency of dermal contact with water and soil	events/day	1	1	1	1
Fraction of contaminated ABOVEGROUND PRODUCE	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated DRINKING WATER	--	0	0	0	0
Fraction contaminated SOIL	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Consumption rate of FISH	kg/kg-day FW	0	0	0.0035	0.00849
Fraction of contaminated FISH	--	0	0	0	0
Consumption rate of GOAT	kg/kg-day FW	0	0.0017	0	0
Inhalation exposure duration	yr	0	0	0	0
Inhalation exposure frequency	day/yr	350	350	350	365
Inhalation exposure time	hr/day	24	24	24	24

Parameter	Units	Resident	Farmer	Fisher	Native American
Fraction of contaminated BEEF (WILD GAME for Natives)	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated POULTRY (FOWL for Natives)	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated EGGS	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated GOAT	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated MILK	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated PORK	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Inhalation rate	m^3/hr	0.83	0.83	0.83	1.25
Consumption rate of MILK	kg/kg-day FW	0	0.0044	0	0.0044
Consumption rate of PORK	kg/kg-day FW	0	0	0	0
Skin surface area available for contact with soil	cm^2	5700	5700	5700	5700
Skin surface area available for contact with water	Cm^2	18000	18000	18000	18000
Body surface area available for contact during a sweat	M^2	0	0	0	1.8
Time period at the beginning of combustion	yr	0	0	0	0
Length of exposure duration	yr	30	40	30	70

[a] To account for only a fraction of the soil a receptor is exposed to is contaminated this term is a product of the standard adherence factor and the fraction of contaminated soil (2.39×10^{-2}).

Table C-6: Exposure Parameters for Child Populations for Spill of HD Brines into Soils With No Subsequent Remediation

Parameter	Units	Resident	Farmer	Fisher	Native American
Adherence factor of soil to skin [a]	mg-soil/cm^2-event	0.0048	0.0048	0.0048	0.0048
Averaging time for carcinogens	yr	70	70	70	70
Averaging time for noncarcinogens	yr	6	6	6	6
Consumption rate of BEEF (WILD GAME for Natives)	kg/kg-day FW	0	0.00256	0	0.00131
Body weight	kg	15	15	15	15
Consumption rate of POULTRY (FOWL for Natives)	kg/kg-day FW	0	0.00155	0	0.000105
Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	0.00077	0.00176	0.00077	0.00124
Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	0.00023	0.00052	0.00023	0.000706
Consumption rate of DRINKING WATER	L/day	1	1	0.67	1.5
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	0.0015	0.00136	0.0015	0.00183
Consumption rate of SOIL	kg/d	0.0002	0.0002	0.0002	0.0002
Exposure duration	yr	6	6	6	6
Exposure frequency	day/yr	350	350	350	365
Exposure frequency of bathing	day/year	350	350	350	365
Exposure frequency during sweat lodge use	events/year	0	0	0	0
Exposure frequency of dermal contact with soil	events/year	350	350	350	365
Exposure frequency of swimming	day/year	10.5	10.5	10.5	10.95
Consumption rate of EGGS	kg/kg-day FW	0	0.00133	0	0.000216
Exposure time during sweat lodge use	hr/event	0	0	0	0
Event frequency of dermal contact with water and soil	events/day	1	1	1	1
Fraction of contaminated ABOVEGROUND PRODUCE	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated DRINKING WATER	--	0	0	0	0
Fraction contaminated SOIL	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Consumption rate of FISH	kg/kg-day FW	0	0	0.00088	0.00598
Fraction of contaminated FISH	--	0	0	0	0
Consumption rate of GOAT	kg/kg-day FW	0	0.0013	0	0
Inhalation exposure duration	yr	0	0	0	0
Inhalation exposure frequency	day/yr	350	350	350	365

Parameter	Units	Resident	Farmer	Fisher	Native American
Inhalation exposure time	hr/day	24	24	24	24
Fraction of contaminated BEEF (WILD GAME for Natives)	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated POULTRY (FOWL for Natives)	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated EGGS	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated GOAT	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated MILK	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Fraction of contaminated PORK	--	2.39E-02	2.39E-02	2.39E-02	2.39E-02
Inhalation rate	m^3/hr	0.5	0.5	0.5	0.5
Consumption rate of MILK	kg/kg-day FW	0	0.0073	0	0.0073
Consumption rate of PORK	kg/kg-day FW	0	0	0	0
Skin surface area available for contact with soil	Cm^2	2800	2800	2800	2800
Skin surface area available for contact with water	Cm^2	6600	6600	6600	6600
Body surface area available for contact during a sweat	m^2	0	0	0	0
Time period at the beginning of combustion	yr	0	0	0	0
Length of exposure duration	yr	6	6	6	6

[a] To account for only a fraction of the soil a receptor is exposed to is contaminated this term is a product of the standard adherence factor and the fraction of contaminated soil (2.39×10^{-2}).

APPENDIX D – Chemical Property Data

Table D-1: Physical and Toxicological Properties

IRAP-H CAS Identifier	Name	MW (g/mol)	Melting Point (K)	Vp (atm)	Water Solubility (mg/L)	Henry's Law Constant (atm-m^3/mol-K)	Diffusivity in Air (cm^2/sec)	Diffusivity in Water (cm^2/sec)	Octanol Water Partition Coefficient
00-01-3	Antimony compounds	1.25E+02	9.03E+02	9.00E-01	2.30E+04	2.50E-02	7.72E-02	9.57E-06	5.37E+00
00-01-4	Arsenic compounds	7.80E+01	1.09E+03	3.30E-12	3.47E+04	7.70E-01	7.72E-02	9.57E-06	4.79E+00
00-01-5	Barium compounds	1.39E+02	1.00E+03	5.58E-12	5.48E+04	0.00E+00	7.72E-02	9.57E-06	1.70E+00
00-01-7	Cadmium compounds	1.12E+02	5.93E+02	5.45E-12	1.23E+05	3.10E-02	7.72E-02	9.57E-06	8.51E-01
00-01-8	Chromium compounds	5.20E+01	2.17E+03	5.58E-12	8.67E+04	0.00E+00	1.27E-01	1.41E-05	1.70E+00
00-01-9	Copper compounds	6.40E+01	1.10E+03	1.32E-03	5.70E+02	2.50E-02	7.72E-02	9.57E-06	2.69E-01
00-02-0	Lead compounds	2.09E+02	6.03E+02	3.97E-12	9.58E+03	2.50E-02	7.72E-02	9.57E-06	5.37E+00
00-02-3	Mercury compounds	2.01E+02	2.34E+02	2.63E-06	6.00E-02	7.10E-03	1.09E-02	3.01E-05	4.17E+00
00-02-4	Nickel compounds	5.87E+01	1.77E+03	5.58E-12	4.22E+05	2.50E-02	7.72E-02	9.57E-06	2.69E-01
00-02-5	Selenium compounds	7.90E+01	4.93E+02	1.87E-13	2.06E+03	9.70E-03	7.72E-02	9.57E-06	1.74E+00
00-02-6	Silver compounds	1.08E+02	1.23E+03	5.58E-12	7.05E+04	0.00E+00	7.72E-02	9.57E-06	1.70E+00
00-02-7	Thallium compounds	2.05E+02	5.73E+02	5.58E-12	2.65E+04	0.00E+00	7.72E-02	9.57E-06	1.70E+00
00-02-9	Zinc compounds	6.54E+01	6.93E+02	5.09E-12	3.44E+05	2.50E-02	7.72E-02	9.57E-06	3.39E-01

Table D-1: Physical and Toxicological Properties (continued…)

IRAP-H CAS Identifier	Name	Koc (ml/g)	kds (cm3/g)	Kdsw (L/kg)	Kdbs (cm3/g)	K_sg (1/yr)	Vapor fraction	Rcf ([µg/g DW plant]/[µg/ml soil water])	br_root_veg ([µg/g DW plant]/[µg/g soil])
00-01-3	Antimony compounds	0.00E+00	4.50E+01	4.50E+01	4.50E+01	0.00E+00	0.00E+00	0.00E+00	3.00E-02
00-01-4	Arsenic compounds	0.00E+00	2.90E+01	2.90E+01	2.90E+01	0.00E+00	0.00E+00	0.00E+00	8.00E-03
00-01-5	Barium compounds	0.00E+00	4.10E+01	4.10E+01	4.10E+01	0.00E+00	0.00E+00	0.00E+00	1.50E-02
00-01-7	Cadmium compounds	0.00E+00	7.50E+01	7.50E+01	7.50E+01	0.00E+00	0.00E+00	0.00E+00	6.40E-02
00-01-8	Chromium compounds	0.00E+00	1.90E+01	1.90E+01	1.90E+01	0.00E+00	9.00E-03	0.00E+00	4.50E-03
00-01-9	Copper compounds	0.00E+00	4.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.50E-01
00-02-0	Lead compounds	0.00E+00	9.00E+02	9.00E+02	9.00E+02	0.00E+00	0.00E+00	0.00E+00	9.00E-03
00-02-3	Mercury compounds	0.00E+00	1.00E+03	1.00E+03	3.00E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
00-02-4	Nickel compounds	0.00E+00	6.50E+01	6.50E+01	6.50E+01	0.00E+00	0.00E+00	0.00E+00	8.00E-03
00-02-5	Selenium compounds	0.00E+00	5.00E+00	5.00E+00	5.00E+00	0.00E+00	0.00E+00	0.00E+00	2.20E-02
00-02-6	Silver compounds	0.00E+00	8.30E+00	8.30E+00	8.30E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-01
00-02-7	Thallium compounds	0.00E+00	7.10E+01	7.10E+01	7.10E+01	0.00E+00	0.00E+00	0.00E+00	4.00E-04
00-02-9	Zinc compounds	0.00E+00	6.20E+01	6.20E+01	6.20E+01	0.00E+00	0.00E+00	0.00E+00	9.00E-01

Table D-1: Physical and Toxicological Properties (continued…)

IRAP-H CAS Identifier	Name	br_leafy_veg ([µg/g DW plant]/[µg/g soil])	br_forage ([µg/g DW plant]/[µg/g soil])	bv_leafy_veg ([µg/g DW plant]/[µg/g air])	bv_forage ([µg/g DW plant]/[µg/g air])	ba_milk (day/kg FW tissue)	ba_beef (day/kg FW tissue)	ba_pork (day/kg FW tissue)	bcf_egg (day/kg FW tissue)
00-01-3	Antimony compounds	3.19E-02	2.00E-01	0.00E+00	0.00E+00	1.00E-04	1.00E-03	0.00E+00	0.00E+00
00-01-4	Arsenic compounds	6.33E-03	3.60E-02	0.00E+00	0.00E+00	6.00E-05	2.00E-03	0.00E+00	0.00E+00
00-01-5	Barium compounds	3.22E-02	1.50E-01	0.00E+00	0.00E+00	3.50E-04	1.50E-04	0.00E+00	0.00E+00
00-01-7	Cadmium compounds	1.25E-01	3.64E-01	0.00E+00	0.00E+00	6.50E-06	1.20E-04	0.00E+00	0.00E+00
00-01-8	Chromium compounds	4.88E-03	7.50E-03	0.00E+00	0.00E+00	1.50E-03	5.50E-03	0.00E+00	0.00E+00
00-01-9	Copper compounds	2.50E-01	2.50E-01	0.00E+00	0.00E+00	1.50E-03	1.00E-02	0.00E+00	0.00E+00
00-02-0	Lead compounds	1.36E-02	4.50E-02	0.00E+00	0.00E+00	2.50E-04	3.00E-04	0.00E+00	0.00E+00
00-02-3	Mercury compounds	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.50E-04	2.50E-01	0.00E+00	0.00E+00
00-02-4	Nickel compounds	9.31E-03	3.20E-02	0.00E+00	0.00E+00	1.00E-03	6.00E-03	0.00E+00	0.00E+00
00-02-5	Selenium compounds	1.95E-02	1.60E-02	0.00E+00	0.00E+00	5.86E-03	2.27E-03	0.00E+00	0.00E+00
00-02-6	Silver compounds	1.38E-01	4.00E-01	0.00E+00	0.00E+00	2.00E-02	3.00E-03	0.00E+00	0.00E+00
00-02-7	Thallium compounds	8.58E-04	4.00E-03	0.00E+00	0.00E+00	2.00E-03	4.00E-02	0.00E+00	0.00E+00
00-02-9	Zinc compounds	9.70E-02	2.50E-01	0.00E+00	0.00E+00	3.25E-05	9.00E-05	0.00E+00	0.00E+00

Table D-1: Physical and Toxicological Properties (continued…)

IRAP-H CAS Identifier	Name	bcf_chicken (day/kg FW tissue)	BCF_fish (L/kg FW)	BAF_fish (L/kg FW tissue)	BSAF_fish	RfD (mg/kg-day)	Oral_csf (per mg/kg-day)	RfC (mg/m3)	inhalation_urf (per µg/m3)
00-01-3	Antimony compounds	0.00E+00	4.00E+01	0.00E+00	0.00E+00	4.00E-04	0.00E+00	0.00E+00	0.00E+00
00-01-4	Arsenic compounds	0.00E+00	1.14E+02	0.00E+00	0.00E+00	3.00E-04	1.50E+00	3.00E-05	4.30E-03
00-01-5	Barium compounds	0.00E+00	6.33E+02	0.00E+00	0.00E+00	2.00E-01	0.00E+00	5.00E-04	0.00E+00
00-01-7	Cadmium compounds	0.00E+00	9.07E+02	0.00E+00	0.00E+00	5.00E-04	0.00E+00	2.00E-05	1.80E-03
00-01-8	Chromium compounds	0.00E+00	1.90E+01	0.00E+00	0.00E+00	1.50E+00	0.00E+00	0.00E+00	0.00E+00
00-01-9	Copper compounds	0.00E+00	3.16E+00	0.00E+00	0.00E+00	4.00E-01	0.00E+00	0.00E+00	0.00E+00
00-02-0	Lead compounds	0.00E+00	9.00E-02	0.00E+00	0.00E+00	0.00E+00	8.50E-03	0.00E+00	1.20E-05
00-02-3	Mercury compounds	0.00E+00	3.16E+00	0.00E+00	0.00E+00	3.00E-04	0.00E+00	3.00E-04	0.00E+00
00-02-4	Nickel compounds	0.00E+00	7.80E+01	0.00E+00	0.00E+00	2.00E-02	0.00E+00	9.00E-05	2.40E-04
00-02-5	Selenium compounds	0.00E+00	1.29E+02	0.00E+00	0.00E+00	5.00E-03	0.00E+00	2.00E-02	0.00E+00
00-02-6	Silver compounds	0.00E+00	8.77E+01	0.00E+00	0.00E+00	5.00E-03	0.00E+00	0.00E+00	0.00E+00
00-02-7	Thallium compounds	0.00E+00	1.00E+04	0.00E+00	0.00E+00	8.00E-05	0.00E+00	0.00E+00	0.00E+00
00-02-9	Zinc compounds	0.00E+00	2.06E+03	0.00E+00	0.00E+00	3.00E-01	0.00E+00	0.00E+00	0.00E+00

Table D-1: Physical and Toxicological Properties (continued…)

IRAP-H CAS Identifier	Name	inhalation_csf (per mg/kg-day)	Chemical Type	Chemical Subtype	br_grain ([µg/d DW plant]/[µg/g soil])	ba_egg (day/kg FW tissue)	ba_chicken (day/kg FW tissue)	inhalation_rfd (mg/kg/day)	tef
00-01-3	Antimony compounds	0.00E+00	I	Metal	3.00E-02	0.00E+00	0.00E+00	0.00E+00	0
00-01-4	Arsenic compounds	1.50E+01	I	Metal	4.00E-03	0.00E+00	0.00E+00	8.57E-06	0
00-01-5	Barium compounds	0.00E+00	I	Metal	1.50E-02	0.00E+00	0.00E+00	1.43E-04	0
00-01-7	Cadmium compounds	6.30E+00	I	Metal	6.20E-02	2.50E-03	1.06E-01	5.71E-06	0
00-01-8	Chromium compounds	0.00E+00	I	Metal	4.50E-03	0.00E+00	0.00E+00	0.00E+00	0
00-01-9	Copper compounds	0.00E+00	I	Metal	2.50E-01	0.00E+00	0.00E+00	0.00E+00	0
00-02-0	Lead compounds	4.20E-02	I	Metal	9.00E-03	0.00E+00	0.00E+00	0.00E+00	0
00-02-3	Mercury compounds	0.00E+00	I	Metal	0.00E+00	1.00E+00	1.00E+00	9.00E-05	0
00-02-4	Nickel compounds	8.40E-01	I	Metal	6.00E-03	0.00E+00	0.00E+00	2.57E-05	0
00-02-5	Selenium compounds	0.00E+00	I	Metal	2.00E-03	1.13E+00	1.13E+00	5.71E-03	0
00-02-6	Silver compounds	0.00E+00	I	Metal	1.00E-01	0.00E+00	0.00E+00	0.00E+00	0
00-02-7	Thallium compounds	0.00E+00	I	Metal	4.00E-04	0.00E+00	0.00E+00	0.00E+00	0
00-02-9	Zinc compounds	0.00E+00	I	Metal	5.40E-02	8.75E-03	8.75E-03	0.00E+00	0

Table D-1: Physical and Toxicological Properties (continued…)

IRAP-H CAS Identifier	Name	abs	Boiling Point (K)	fa	pc (cm/hr)	Kpv (cm/hr)
00-01-3	Antimony compounds	1.50E-01	1.91E+03	0.00E+00	1.00E-03	0.00E+00
00-01-4	Arsenic compounds	1.00E+00	8.88E+02	0.00E+00	1.00E-03	0.00E+00
00-01-5	Barium compounds	7.00E-02	1.91E+03	0.00E+00	1.00E-03	0.00E+00
00-01-7	Cadmium compounds	2.50E-02	1.04E+03	0.00E+00	1.00E-03	0.00E+00
00-01-8	Chromium compounds	1.30E-02	2.91E+03	0.00E+00	1.00E-03	0.00E+00
00-01-9	Copper compounds	1.00E+00	2.87E+03	0.00E+00	1.00E-03	0.00E+00
00-02-0	Lead compounds	1.00E+00	2.01E+03	0.00E+00	1.00E-03	0.00E+00
00-02-3	Mercury compounds	7.00E-02	6.30E+02	0.00E+00	2.40E-01	0.00E+00
00-02-4	Nickel compounds	4.00E-02	3.00E+03	0.00E+00	2.00E-04	0.00E+00
00-02-5	Selenium compounds	1.00E+00	9.58E+02	0.00E+00	1.00E-03	0.00E+00
00-02-6	Silver compounds	4.00E-02	2.48E+03	0.00E+00	6.00E-04	0.00E+00
00-02-7	Thallium compounds	1.00E+00	1.74E+03	0.00E+00	1.00E-03	0.00E+00
00-02-9	Zinc compounds	1.00E+00	1.18E+03	0.00E+00	6.00E-04	0.00E+00

APPENDIX E – Site Parameters

Table E-1: Site Parameters for Brine Spill in Soils with Remediation

Site Parameter	Value	Units
Soil dry bulk density	1.5	g/cm^3
Forage fraction grown on contam. soil eaten by CATTLE	0.000018	--
Grain fraction grown on contam. soil eaten by CATTLE	0.000018	--
Silage fraction grown on contam. eaten by CATTLE	0.000018	--
Qty of forage eaten by CATTLE each day	11.3	kg DW/day
Qty of grain eaten by CATTLE each day	0.47	kg DW/day
Qty of silage eaten by CATTLE each day	0	kg DW/day
Grain fraction grown on contam. soil eaten by CHICKEN	0.000018	--
Qty of grain eaten by CHICKEN each day	0.2	kg DW/day
Average annual evapotranspiration	81.3	cm/yr
Duration of bathing event	0.58	hr/event
Duration of swimming event	1	hr/event
Fish lipid content	0.07	--
Fraction of CHICKEN's diet that is soil	0.11	--
Fraction of skin area (SA) in contact with water during a sweat	1	--
Universal gas constant	8.21E-05	$atm\text{-}m^3/mol\text{-}K$
Forage fraction grown on contam. soil eaten by GOAT	0.000018	--
Grain fraction grown on contam. soil eaten by GOAT	0.000018	--
Silage fraction grown on contam. eaten by GOAT	0.000018	--
Qty of forage eaten by GOAT each day	0.98	kg DW/day
Qty of grain eaten by GOAT each day	0.041	kg DW/day
Qty of silage eaten by GOAT each day	0	kg DW/day
Average annual irrigation	55	cm/yr
Plant surface loss coefficient	18	yr^{-1}
Fraction of mercury emissions NOT lost to the global cycle	0.48	--
Fraction of mercury speciated into methyl mercury in produce	0.22	--
Fraction of mercury speciated into methyl mercury in soil	0.02	--
Forage fraction grown contam. soil, eaten by MILK CATTLE	0.000018	--
Grain fraction grown contam. soil, eaten by MILK CATTLE	0.000018	--
Silage fraction grown contam. soil, eaten by MILK CATTLE	0.000018	--
Qty of forage eaten by MILK CATTLE each day	17.3	kg DW/day
Qty of grain eaten by MILK CATTLE each day	3	kg DW/day
Qty of silage eaten by MILK CATTLE each day	0	kg DW/day
Averaging time	1	yr
Body weight of infant	9.4	kg
Exposure duration of infant to breast milk	1	yr
Proportion of ingested dioxin that is stored in fat	0.9	--
Proportion of mothers weight that is fat	0.3	--
Fraction of fat in breast milk	0.04	--
Fraction of ingested contaminant that is absorbed	0.9	--

Site Parameter	Value	Units
Half-life of dioxin in adults	2560	days
Ingestion rate of breast milk	0.688	kg/day
Viscosity of air corresponding to air temp.	0.000181	g/cm-s
Average annual precipitation	21.59	cm/yr
Fraction of grain grown on contam. soil eaten by PIGS	0.000018	--
Fraction of silage grown on contam. soil and eaten by PIGS	0.000018	--
Qty of grain eaten by PIGS each day	3.3	kg DW/day
Qty of silage eaten by PIGS each day	1.4	kg DW/day
Qty of soil eaten by CATTLE	0.5	kg/day
Qty of soil eaten by CHICKEN	0.022	kg/day
Qty of soil eaten by GOAT	0.04	kd/day
Qty of soil eaten by DAIRY CATTLE	0.4	kg/day
Qty of soil eaten by PIGS	0.37	kg/day
Average annual runoff	2.54	cm/yr
Density of air	0.0012	g/cm^3
Solids particle density	2.7	g/cm^3
Interception fraction - edible portion ABOVEGROUND	0.39	--
Interception fraction - edible portion FORAGE	0.5	--
Interception fraction - edible portion SILAGE	0.46	--
Radius of sweat lodge	1	m
Ambient air temperature	285	K
Temperature correction factor	1.026	--
Soil volumetric water content	0.244	mL/cm^3
Length of plant expos. to depos. - ABOVEGROUND	0	Yr
Length of plant expos. to depos. - FORAGE	0	Yr
Length of plant expos. to depos. - SILAGE	0	Yr
Average annual wind speed	3.9	m/s
Dry deposition velocity	0.5	cm/s
Volume of water used in a sweat lodge (nonvolatile)	0.34	liters
Volume of water used in a sweat lodge (volatile)	4	liters
Wind velocity	4.5	m/s
Yield/standing crop biomass - edible portion ABOVEGROUND	2.24	kg DW/m^2
Yield/standing crop biomass - edible portion FORAGE	0.24	kg DW/m^2
Yield/standing crop biomass - edible portion SILAGE	0.8	kg DW/m^2
Soil mixing zone depth	20	cm

Table E-2: Site Parameters for Brine Spill in Water

Site Parameter	Value	Units
Soil dry bulk density	1.5	g/cm^3
Forage fraction grown on contam. soil eaten by CATTLE	0	--
Grain fraction grown on contam. soil eaten by CATTLE	0	--
Silage fraction grown on contam. eaten by CATTLE	0	--
Qty of forage eaten by CATTLE each day	11.3	kg DW/day
Qty of grain eaten by CATTLE each day	0.47	kg DW/day
Qty of silage eaten by CATTLE each day	0	kg DW/day
Grain fraction grown on contam. soil eaten by CHICKEN	0	--
Qty of grain eaten by CHICKEN each day	0.2	kg DW/day
Average annual evapotranspiration	81.3	cm/yr
Duration of bathing event	0.58	hr/event
Duration of swimming event	1	hr/event
Fish lipid content	0.07	--
Fraction of CHICKEN's diet that is soil	0.11	--
Fraction of skin area (SA) in contact with water during a sweat	1	--
Universal gas constant	8.21E-05	$atm\text{-}m^3/mol\text{-}K$
Forage fraction grown on contam. soil eaten by GOAT	0	--
Grain fraction grown on contam. soil eaten by GOAT	0	--
Silage fraction grown on contam. eaten by GOAT	0	--
Qty of forage eaten by GOAT each day	0.98	kg DW/day
Qty of grain eaten by GOAT each day	0.041	kg DW/day
Qty of silage eaten by GOAT each day	0	kg DW/day
Average annual irrigation	55	cm/yr
Plant surface loss coefficient	18	yr^{-1}
Fraction of mercury emissions NOT lost to the global cycle	0.48	--
Fraction of mercury speciated into methyl mercury in produce	0.22	--
Fraction of mercury speciated into methyl mercury in soil	0.02	--
Forage fraction grown contam. soil, eaten by MILK CATTLE	0	--
Grain fraction grown contam. soil, eaten by MILK CATTLE	0	--
Silage fraction grown contam. soil, eaten by MILK CATTLE	0	--
Qty of forage eaten by MILK CATTLE each day	17.3	kg DW/day
Qty of grain eaten by MILK CATTLE each day	3	kg DW/day
Qty of silage eaten by MILK CATTLE each day	0	kg DW/day
Averaging time	1	yr
Body weight of infant	9.4	kg
Exposure duration of infant to breast milk	1	yr
Proportion of ingested dioxin that is stored in fat	0.9	--
Proportion of mothers weight that is fat	0.3	--
Fraction of fat in breast milk	0.04	--
Fraction of ingested contaminant that is absorbed	0.9	--
Half-life of dioxin in adults	2560	days
Ingestion rate of breast milk	0.688	kg/day
Viscosity of air corresponding to air temp.	0.000181	g/cm-s
Average annual precipitation	21.59	cm/yr

Site Parameter	Value	Units
Fraction of grain grown on contam. soil eaten by PIGS	0	--
Fraction of silage grown on contam. soil and eaten by PIGS	0	--
Qty of grain eaten by PIGS each day	3.3	kg DW/day
Qty of silage eaten by PIGS each day	1.4	kg DW/day
Qty of soil eaten by CATTLE	0.5	kg/day
Qty of soil eaten by CHICKEN	0.022	kg/day
Qty of soil eaten by GOAT	0.04	kd/day
Qty of soil eaten by DAIRY CATTLE	0.4	kg/day
Qty of soil eaten by PIGS	0.37	kg/day
Average annual runoff	2.54	cm/yr
Density of air	0.0012	g/cm^3
Solids particle density	2.7	g/cm^3
Interception fraction - edible portion ABOVEGROUND	0.39	--
Interception fraction - edible portion FORAGE	0.5	--
Interception fraction - edible portion SILAGE	0.46	--
Radius of sweat lodge	1	m
Ambient air temperature	285	K
Temperature correction factor	1.026	--
Soil volumetric water content	0.244	mL/cm^3
Length of plant expos. to depos. - ABOVEGROUND	0	Yr
Length of plant expos. to depos. - FORAGE	0	Yr
Length of plant expos. to depos. - SILAGE	0	Yr
Average annual wind speed	3.9	m/s
Dry deposition velocity	0.5	cm/s
Volume of water used in a sweat lodge (nonvolatile)	0.34	liters
Volume of water used in a sweat lodge (volatile)	4	liters
Wind velocity	4.5	m/s
Yield/standing crop biomass - edible portion ABOVEGROUND	2.24	$kg DW/m^2$
Yield/standing crop biomass - edible portion FORAGE	0.24	$kg DW/m^2$
Yield/standing crop biomass - edible portion SILAGE	0.8	$kg DW/m^2$
Soil mixing zone depth	20	cm

Table E-3: Site Parameters for Brine Spill in Soils with No Subsequent Remediation

Site Parameter	Value	Units
Soil dry bulk density	1.5	g/cm^3
Forage fraction grown on contam. soil eaten by CATTLE	0.024	--
Grain fraction grown on contam. soil eaten by CATTLE	0.024	--
Silage fraction grown on contam. eaten by CATTLE	0.024	--
Qty of forage eaten by CATTLE each day	11.3	kg DW/day
Qty of grain eaten by CATTLE each day	0.47	kg DW/day
Qty of silage eaten by CATTLE each day	0	kg DW/day
Grain fraction grown on contam. soil eaten by CHICKEN	0.024	--
Qty of grain eaten by CHICKEN each day	0.2	kg DW/day
Average annual evapotranspiration	81.3	cm/yr
Duration of bathing event	0.58	hr/event
Duration of swimming event	1	hr/event
Fish lipid content	0.07	--
Fraction of CHICKEN's diet that is soil	0.11	--
Fraction of skin area (SA) in contact with water during a sweat	1	--
Universal gas constant	8.21E-05	$atm\text{-}m^3/mol\text{-}K$
Forage fraction grown on contam. soil eaten by GOAT	0.024	--
Grain fraction grown on contam. soil eaten by GOAT	0.024	--
Silage fraction grown on contam. eaten by GOAT	0.024	--
Qty of forage eaten by GOAT each day	0.98	kg DW/day
Qty of grain eaten by GOAT each day	0.041	kg DW/day
Qty of silage eaten by GOAT each day	0	kg DW/day
Average annual irrigation	55	cm/yr
Plant surface loss coefficient	18	yr^{-1}
Fraction of mercury emissions NOT lost to the global cycle	0.48	--
Fraction of mercury speciated into methyl mercury in produce	0.22	--
Fraction of mercury speciated into methyl mercury in soil	0.02	--
Forage fraction grown contam. soil, eaten by MILK CATTLE	0.024	--
Grain fraction grown contam. soil, eaten by MILK CATTLE	0.024	--
Silage fraction grown contam. soil, eaten by MILK CATTLE	0.024	--
Qty of forage eaten by MILK CATTLE each day	17.3	kg DW/day
Qty of grain eaten by MILK CATTLE each day	3	kg DW/day
Qty of silage eaten by MILK CATTLE each day	0	kg DW/day
Averaging time	1	yr
Body weight of infant	9.4	kg
Exposure duration of infant to breast milk	1	yr
Proportion of ingested dioxin that is stored in fat	0.9	--
Proportion of mothers weight that is fat	0.3	--
Fraction of fat in breast milk	0.04	--
Fraction of ingested contaminant that is absorbed	0.9	--
Half-life of dioxin in adults	2560	days
Ingestion rate of breast milk	0.688	kg/day
Viscosity of air corresponding to air temp.	0.024	g/cm-s
Average annual precipitation	21.59	cm/yr

Site Parameter	Value	Units
Fraction of grain grown on contam. soil eaten by PIGS	0.024	--
Fraction of silage grown on contam. soil and eaten by PIGS	0.024	--
Qty of grain eaten by PIGS each day	3.3	kg DW/day
Qty of silage eaten by PIGS each day	1.4	kg DW/day
Qty of soil eaten by CATTLE	0.5	kg/day
Qty of soil eaten by CHICKEN	0.022	kg/day
Qty of soil eaten by GOAT	0.04	kd/day
Qty of soil eaten by DAIRY CATTLE	0.4	kg/day
Qty of soil eaten by PIGS	0.37	kg/day
Average annual runoff	2.54	cm/yr
Density of air	0.0012	g/cm^3
Solids particle density	2.7	g/cm^3
Interception fraction - edible portion ABOVEGROUND	0.39	--
Interception fraction - edible portion FORAGE	0.5	--
Interception fraction - edible portion SILAGE	0.46	--
Radius of sweat lodge	1	m
Ambient air temperature	285	K
Temperature correction factor	1.026	--
Soil volumetric water content	0.244	mL/cm^3
Length of plant expos. to depos. - ABOVEGROUND	0	Yr
Length of plant expos. to depos. - FORAGE	0	Yr
Length of plant expos. to depos. - SILAGE	0	Yr
Average annual wind speed	3.9	m/s
Dry deposition velocity	0.5	cm/s
Volume of water used in a sweat lodge (nonvolatile)	0.34	liters
Volume of water used in a sweat lodge (volatile)	4	liters
Wind velocity	4.5	m/s
Yield/standing crop biomass - edible portion ABOVEGROUND	2.24	kg DW/m^2
Yield/standing crop biomass - edible portion FORAGE	0.24	kg DW/m^2
Yield/standing crop biomass - edible portion SILAGE	0.8	kg DW/m^2
Soil mixing zone depth	20	cm

Table E-4: Site Parameters for Ecological Risk Assessment of a Brine Spill in Soils

Site Parameter	Value	Units
Soil dry bulk density	1.5	g/cm^3
Average annual evapotranspiration	81.3	cm/yr
Fish lipid content	0.07	--
Universal gas constant	8.21E-05	atm-m^3/mol-K
Average annual irrigation	55	cm/yr
Plant surface loss coefficient	18	yr^-1
Fraction of mercury emissions NOT lost to the global cycle	0.48	--
Fraction of mercury speciated into methyl mercury in produce	0.22	--
Fraction of mercury speciated into methyl mercury in soil	0.02	--
Fraction of mercury specated into methyl mercury in wetland soil	0.08	--
Viscosity of air corresponding to air temp.	0.000181	g/cm-s
Average annual precipitation	21.59	cm/yr
Average annual runoff	2.54	cm/yr
Density of air	0.0012	g/cm^3
Solids particle density	2.7	g/cm^3
Interception fraction - edible portion FORAGE	0.5	--
Ambient air temperature	285	K
Temperature correction factor	1.026	--
Soil volumetric water content	0.2	mL/cm^3
Length of plant expos. to depos. - FORAGE	0.12	Yr
Average annual wind speed	3.9	m/s
Dry deposition velocity	3	cm/s
Wind velocity	3.9	m/s
Yield/standing crop biomass - edible portion FORAGE	0.24	kg DW/m^2
Soil mixing zone depth	1	Cm
Averaging time for carcinogens	70	yr
Averaging time for noncarcinogens	30	yr
Exposure duration	30	yr
Exposure frequency	350	day/yr
Time period at the beginning of combustion	0	yr
Length of exposure duration	30	yr

Table E-5: Site Parameters for Ecological Risk Assessment of a Brine Spill in the Umatilla River

Site Parameter	Value	Units
Soil dry bulk density	1.5	g/cm^3
Average annual evapotranspiration	81.3	cm/yr
Fish lipid content	0.07	--
Universal gas constant	8.21E-05	atm-m^3/mol-K
Average annual irrigation	55	cm/yr
Plant surface loss coefficient	18	yr^-1
Fraction of mercury emissions NOT lost to the global cycle	0.48	--
Fraction of mercury speciated into methyl mercury in produce	0.22	--
Fraction of mercury speciated into methyl mercury in soil	0.02	--
Fraction of mercury specated into methyl mercury in wetland soil	0.08	--
Viscosity of air corresponding to air temp.	0.000181	g/cm-s
Average annual precipitation	21.59	cm/yr
Average annual runoff	2.54	cm/yr
Density of air	0.0012	g/cm^3
Solids particle density	2.7	g/cm^3
Interception fraction - edible portion FORAGE	0.5	--
Ambient air temperature	285	K
Temperature correction factor	1.026	--
Soil volumetric water content	0.2	mL/cm^3
Length of plant expos. to depos. - FORAGE	0.12	Yr
Average annual wind speed	3.9	m/s
Dry deposition velocity	3	cm/s
Wind velocity	3.9	m/s
Yield/standing crop biomass - edible portion FORAGE	0.24	kg DW/m^2
Soil mixing zone depth	1	Cm
Averaging time for carcinogens	70	yr
Averaging time for noncarcinogens	30	yr
Exposure duration	30	yr
Exposure frequency	350	day/yr
Time period at the beginning of combustion	0	yr
Length of exposure duration	30	yr

APPENDIX F – Ecological Risk TRV and BCF Data

Table F-1: Bioconcentration Factors used in EcoRisk View

Compound	CAS Number Used in EcoRisk View	Soil to Soil Invertebrate	Soil to Terrestrial Plants	Water to Aquatic Plants	Water to Algae	Water to Fish	Sediment to Benthic Invertebrates
Aluminum	00-01-3	0.22	0.2	1475	1475	40	0.9
Antimony	00-01-4	0.523	0.036	293	293	114	4.33
Arsenic	00-01-5	0.22	0.15	260	260	633	0.9
Barium	00-01-7	40.7	0.364	782	782	907	3.073
Beryllium	00-01-8	3.16	0.0075	4406	4406	19	0.186
Cadmium	00-01-9	1.53	0.4	541	541	710	7.957
Chromium	00-02-0	1.52	0.045	1706	1706	0.09	0.326
Copper	00-02-3	20.6	5	NA	NA	1.23	3.981
Lead	00-02-4	4.73	0.032	61	61	78	0.214
Manganese	00-02-5	1.34	0.016	1845	1845	129	0.9
Mercury	00-02-6	0.22	0.4	10696	10696	88	0.9
Nickel	00-02-7	0.22	0.004	15000	15000	10000	0.9
Selenium	00-02-9	12.9	1.20E-12	2175	2175	2060	4.759

Table F-2: Toxicity Reverence Values used in EcoRisk View

Compound	CAS Number Used in EcoRisk View	Chronic water quality benchmark (mg/L)	Low-effect sediment quality benchmark (mg/kg)	Mammalian Test Species NOAEL (mg/kg BW-d) (calculated as test species TRV X UF)	Low-effect soil quality benchmark - invertebrates (mg/kg)	Low-effect soil quality benchmark - plants (mg/kg)
Aluminum	00-01-2	N/D	N/D	1.93	N/D	109.7
Antimony	00-01-3	0.087	58030	0.059	N/D	N/D
Arsenic	00-01-4	0.16	12	1.04	78	2.24
Barium	00-01-5	0.19	9.79	51.8	60	20.8
Beryllium	00-01-6	0.0086	0.0035088	0.532	N/D	N/D
Cadmium	00-01-7	0.11	0.0396	0.77	N/D	1.47
Chromium	00-01-8	5.5	1.386	2.40	N/D	2.66
Copper	00-01-9	N/D	N/D	5.60	N/D	4.05
Lead	00-02-0	0.0032	35.8	4.7	1700	1.63
Manganese	00-02-2	0.12	1081	51.5	450	179.0
Mercury	00-02-3	0.000012	0.18	1.01	0.1	0.45
Nickel	00-02-4	0.16	22.7	1.7	280	6.71
Selenium	00-02-5	0.035	0.1	0.2	7.7	0.4
Silver	00-02-6	0.00012	2	6.02	N/D	2.02
Thallium	00-02-7	0.004	N/D	0.0074	N/D	0.35
Vanadium	00-02-8	0.02	N/D	4.2	N/D	0.344
Zinc	00-02-9	0.11	121	160	199	14.5

APPENDIX G – Risk Equations

Section F-1. HHRA Soil Concentrations Equations

Equation 1

Cs_{nw} = Cs_{tD} Highest annual average COPC concentration in soil [mg COPC/kg soil]

$$Cs_{nw} = Cs_{tD} = \frac{Ds \cdot [\,1 - e^{(-ks \cdot tD)}\,]}{ks}$$

R9A

Reference: EPA 2005, Table B-1-1
nw = non-time weighted

Equation 2

Cs_{tw} Average COPC concentration in soil over the exposure duration [mg COPC/kg soil]

For exposure durations (EDs) greater than the operating period (tD) $T_2 = ED$ --

(A) $$Cs_{tw(\,long\,)} = \frac{\left(\dfrac{Ds \cdot tD - Cs_{tD}}{ks}\right) + \left(\dfrac{Cs_{tD}}{ks} \cdot \left[1 - e^{-ks(ED - tD)}\right]\right)}{ED - T_1}$$

R9D & R10

For exposure durations (EDs) less than or equal to the operating period (tD) --

(B) $$Cs_{tw(\,short\,)} = \frac{Ds}{ks \cdot (tD - T_1)} \cdot \left[\left(tD + \frac{e^{(-ks \cdot tD)}}{ks}\right) - \left(T_1 + \frac{e^{(-ks \cdot T_1)}}{ks}\right)\right]$$

R9B

Reference: Adapted from EPA 2005, Table B-1-1
tw = time-weighted

Equation 3

Ds Deposition term (not to a water body or watershed) [mg COPC/kg soil-yr]

$$Ds = \left[\frac{100 \cdot Q_{ops}}{Z_s \cdot BD} \right] \cdot \left[Fv \cdot (Dydv + Dywv) + (Dydp + Dywp) \cdot (1 - Fv) \right]$$

R11

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}
Elemental mercury: final Ds = (0) initial $Ds_{\text{(elemental mercury)}}$
Divalent mercury: final Ds = (0.98) initial $Ds_{\text{(divalent mercury)}}$
Methyl mercury: final Ds = (0.02) initial $Ds_{\text{(divalent mercury)}}$

Reference: EPA 2005, Table B-1-1

Equation 4

Ds Deposition term (to a water body or watershed) [mg COPC/kg soil-yr]

$$Ds = \left[\frac{100 \cdot Q_{ops}}{Z_s \cdot BD} \right] \cdot \left[Fv \cdot (Dydwv + Dywwv) + (Dydwp + Dywwp) \cdot (1 - Fv) \right]$$

R11

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}
Elemental mercury: final Ds = (0) initial $Ds_{\text{(elemental mercury)}}$
Divalent mercury: final Ds = (0.98) initial $Ds_{\text{(divalent mercury)}}$
Methyl mercury: final Ds = (0.02) initial $Ds_{\text{(divalent mercury)}}$

Reference: EPA 2005, Table B-4-1. Note that EPA 2005 uses the "total" parameters rather than the component parameters that are used in the above equation.

Dytwv = Dydwv + Dywwv and Dytwp = Dydwp + Dywwp

Equation 5

ks COPC soil loss constant due to all processes [(yr)$^{-1}$]

$$ks = ksg + kse + ksr + ksl + ksv$$

R12

Reference: EPA 2005, Table B-1-2

Equation 6

ksr COPC soil loss constant due to surface runoff [(yr)$^{-1}$]

$$ksr = \frac{RO}{\Theta_{sw} \cdot Z_s} \cdot \left(\frac{1}{1 + \left(Kd_s \cdot BD / \Theta_{sw} \right)} \right)$$

R14

Reference: EPA 2005, Table B-1-4

Equation 7

ksl COPC soil loss constant due to leaching [(yr)$^{-1}$]

$$ksl = \frac{P + I - RO - E_v}{\Theta_{sw} \cdot Z_s \cdot \left[1 + \left(BD \cdot Kd_s / \Theta_{sw} \right) \right]}$$

R15

Reference: EPA 2005, Table B-1-5

Equation 8

ksv COPC soil loss constant due to volatilization [(yr)$^{-1}$]

$$ksv = Ke \cdot K_t$$

R16

Reference: EPA 1998a; EPA 1999. Note that EPA 2005 (Table B-1-6) does not change the mathematics from the original guidance, but only simply displays the Ke, Kt, and θ_v calculations (shown in equations 11, 12, and 13 below) within one grand ksv calculation.

Equation 9

Ke Equilibrium coefficient [s/yr-cm]

$$Ke = \frac{3.1536E + 07 \cdot H}{Z_s \cdot Kd_s \cdot R \cdot T_a \cdot BD}$$

R16

Reference: EPA 1998a; EPA 1999. See the note provided in equation 10.

Equation 10

K_t Gas phase mass transfer coefficient [cm/s]

$$K_t = \frac{D_a \cdot \Theta_v}{Z_s}$$

R16

Reference: EPA 1998a; EPA 1999. See the note provided in equation 10.

Equation 11

Θ_v Soil void fraction [cm^3/cm^3]

$$\Theta_v = 1 - \left(\frac{BD}{\rho_s}\right) - \Theta_{sw}$$

R16

Reference: EPA 1998a; EPA 1999. See the note provided in equation 10.

Section F-2. Produce Concentrations Equations

Equation 12

$P_{age(nw)}$ **Highest annual average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage)** [mg COPC/kg dry weight (DW)]

$$P_{age(nw)} = Pd_{age} + Pv_{age} + Pr_{age(nw)}$$

R42A

Reference: Adapted from EPA 2005, Figure 5-3

Equation 13

$P_{age(tw)}$ **Average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) over the exposure duration** [mg COPC/kg DW]

$$P_{age(tw)} = \left[\frac{\left(Pd_{age} + Pv_{age}\right) \cdot tD}{ED - T_1}\right] + Pr_{age(tw)}$$

R42B

Reference: Derived time-averaged equation adapted from EPA 2005, Figure 5-3

Equation 14

$P_{agp(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in above ground protected plant (native vegetation, protected produce or grain) or Average COPC concentration in above ground protected plant (native vegetation, protected produce or grain) over the exposure duration** [mg COPC/kg DW]

$$P_{agp(nw)or(tw)} = Pr_{agp(nw)or(tw)} = Cs_x \cdot Br_x$$

R42 & R45A

Reference: Adapted from EPA 2005, Table B-2-9

Equation 15

$P_{bg(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in below ground native vegetation or produce or Average COPC concentration in below ground native vegetation or produce over the exposure duration** [mg COPC/kg DW]

$$P_{bg(nw)or(tw)} = Pr_{bg(nw)or(tw)} = \frac{Cs_x \cdot RCF \cdot VG_{rootveg}}{Kd_s \cdot 1}$$

R42 & R45B

Reference: Adapted from EPA 2005, Table B-2-10

Equation 16

Pd_{age} COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to direct deposition [mg COPC/kg DW]

$$Pd_{age} = \frac{1000 \cdot Q_{ops} \cdot (1 - Fv) \cdot [\,Dydp + (\,Fw \cdot Dywp\,)] \cdot Rp \cdot \left[1 - e^{(-kp \cdot Tp)}\right]}{Yp \cdot kp}$$

R43

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}
Divalent mercury: final Pd = (0.78) initial $Pd_{\text{(divalent mercury)}}$
Methyl mercury: final Pd = (0.22) initial $Pd_{\text{(divalent mercury)}}$

Reference: Adapted from EPA 2005, Table B-2-7

Equation 17

Pv_{age} COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to air-to-plant transfer [µg COPC/g DW equivalent to mg COPC/kg DW]

$$Pv_{age} = Q_{ops} \cdot Fv \cdot \frac{Cyv \cdot Bv_x \cdot VG_{agx}}{\rho_a \cdot 1E + 06}$$

R44

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}
Divalent mercury: final Pv = (0.78) initial $Pv_{\text{(divalent mercury)}}$
Methyl mercury: final Pv = (0.22) initial $Pv_{\text{(divalent mercury)}}$

Reference: Adapted from EPA 2005, Table B-2-8

Equation 18

$Pr_{age(nw)\text{ or }(tw)}$ Highest annual average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to root uptake or Average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to root uptake over the exposure duration [mg COPC/kg DW]

$$Pr_{age(nw)or(tw)} = Cs_x \cdot Br_x \quad \text{R45}$$

Reference: Adapted from EPA 2005, Table B-2-9

Section F-3. Animal Product Concentrations Equations

Equation 19

$A_{beef(nw)\ or\ (tw)}$ Highest annual average COPC concentration in beef or Average COPC concentration in beef over the exposure duration [mg COPC/kg fresh weight (FW) tissue]

$$A_{beef(nw)or(tw)} = \left[\sum (F_{age} \cdot Qp_{age} \cdot P_{age(x)}) + (F_{agp} \cdot Qp_{agp} \cdot P_{agp(x)}) + Qs \cdot Cs_x \cdot Bs \right] \cdot Ba_{beef} \cdot MF$$

R47

Reference: Adapted from EPA 2005, Table B-3-10

Equation 20

$A_{milk(nw)\ or\ (tw)}$ Highest annual average COPC concentration in cow's milk or Average COPC concentration in cow's milk over the exposure duration [mg COPC/kg FW tissue]

$$A_{milk(nw)or(tw)} = \left[\sum (F_{age} \cdot Qp_{age} \cdot P_{age(x)}) + (F_{agp} \cdot Qp_{agp} \cdot P_{agp(x)}) + Qs \cdot Cs_x \cdot Bs \right] \cdot Ba_{milk} \cdot MF$$

R47

Reference: Adapted from EPA 2005, Table B-3-11

Equation 21

$A_{goat(nw)\ or\ (tw)}$ Highest annual average COPC concentration in goat or Average COPC concentration in goat over the exposure duration [mg COPC/kg FW tissue]

$$A_{goat(nw)or(tw)} = \left[\sum (F_{age} \cdot Qp_{age} \cdot P_{age(x)}) + Qs \cdot Cs_x \cdot Bs \right] \cdot Ba_{goat} \cdot MF$$

R47

Reference: Adapted from EPA 2005, Table B-3-12

Equation 22

$A_{egg(nw)\ or\ (tw)}$ Highest annual average COPC concentration in eggs or Average COPC concentration in eggs over the exposure duration [mg COPC/kg FW tissue]

$$A_{egg(nw)or(tw)} = [(F_{agp} \cdot Qp_{agp} \cdot P_{agp(x)}) + Qs \cdot Cs_x \cdot Bs] \cdot Ba_{egg}$$

R47

Reference: Adapted from EPA 2005, Table B-3-13

Equation 23

$A_{chicken(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in chicken meat or Average COPC concentration in chicken meat over the exposure duration** [mg COPC/kg FW tissue]

$$A_{chicken(nw)or(tw)} = [\left(F_{agp} \cdot Qp_{agp} \cdot P_{agp(x)}\right) + Qs \cdot Cs_x \cdot Bs] \cdot Ba_{chicken}$$

R47

Reference: Adapted from EPA 2005, Table B-3-14

Section F-4. Surface Water, Sediment & Fish Concentrations Equations

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Equation 24

$C_{wtot(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in water body (including water column & bed sediment) or Average COPC concentration in water body (including water column & bed sediment) over the exposure duration** [mg COPC/L water or g COPC/m^3 water]

$$C_{wtot(nw)or(tw)} = \frac{L_{T(x)}}{f_{wc} \cdot Vf_x + k_{wt} \cdot A_w \cdot (d_{wc} + d_{bs})}$$

R19

Reference: EPA 2005, Table B-4-15

Equation 25

$C_{wctot(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in water column or Average COPC concentration in water column over the exposure duration** [mg COPC/L water]

$$C_{wctot(nw)or(tw)} = f_{wc} \cdot C_{wtot(x)} \cdot \frac{d_{wc} + d_{bs}}{d_{wc}}$$

R20

Reference: EPA 2005, Table B-4-23

Equation 28

$C_{dw(nw)\ or\ (tw)}$ **Highest annual average dissolved phase COPC concentration in water body or Average dissolved phase COPC concentration in water body over the exposure duration** [mg COPC/L water]

$$C_{dw(nw)or(tw)} = \frac{C_{wctot(x)}}{1 + Kd_{sw} \cdot TSS \cdot 1E-06}$$

R21

Mercury modeling modifications made to initially computed values:

Elemental mercury: final C_{dw} = (0) initial $C_{dw\ (divalent\ mercury)}$
Divalent mercury: final C_{dw} = (0.85) initial $C_{dw\ (divalent\ mercury)}$
Methyl mercury: final C_{dw} = (0.15) initial $C_{dw\ (divalent\ mercury)}$

Reference: EPA 2005, Table B-4-24

Equation 29

$C_{sb(nw)\ or\ (tw)}$ **Highest annual average COPC concentration sorbed to bed sediment or Average COPC concentration sorbed to bed sediment over the exposure duration** [mg COPC/kg bed sediment]

$$C_{sb(nw)or(tw)} = f_{bs} \cdot C_{wtot(x)} \cdot \left(\frac{Kd_{bs}}{\Theta_{bs} + Kd_{bs} \cdot C_{BS}} \right) \cdot \left(\frac{d_{wc} + d_{bs}}{d_{bs}} \right)$$

R22

Reference: EPA 2005, Table B-4-25

Equation 30

$C_{gamefish(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in game fish or Average COPC concentration in game fish over the exposure duration** [mg COPC/kg FW tissue]

$$C_{gamefish(nw)or(tw)} = C_{dw(x)} \cdot BCF_{gamefish}$$

R37A

Reference: EPA 2005, Table B-4-26

Equation 31

$C_{gamefish(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in game fish or Average COPC concentration in game fish over the exposure duration** [mg COPC/kg FW tissue]

$$C_{gamefish(nw)or(tw)} = C_{dw(x)} \cdot BAF_{gamefish}$$

R37B

Reference: EPA 2005, Table B-4-27

Equation 32

$C_{gamefish(nw)\ or\ (tw)}$ **Highest annual average COPC concentration in game fish or Average COPC concentration in game fish over the exposure duration** [mg COPC/kg FW tissue]

$$C_{gamefish(nw)or(tw)} = \frac{C_{sb(x)} \cdot f_{lipid} \cdot BSAF}{OC_{sed}}$$

R37C

Reference: EPA 2005, Table B-4-28

Equation 33

$L_{T(nw)}$ Highest annual average COPC load to water body [g/yr]

$$L_{T(nw)} = L_{DEP} + L_{dif} + L_{RI} + L_{R(nw)} + L_{E(nw)}$$

R23A

Reference: EPA 2005, Table B-4-7

Equation 34

$L_{T(tw)}$ Average COPC load to water body over the exposure duration [g/yr]

$$L_{T(tw)} = \left[\frac{\left(L_{DEP} + L_{dif} + L_{RI}\right) \cdot tD}{ED - T_1} \right] + L_{R(tw)} + L_{E(tw)}$$

R23B

Reference: Derived time-averaged equation adapted from EPA 2005, Table B-4-7

Equation 35

L_{DEP} COPC load to water body due to (wet & dry) particle phase & wet vapor phase direct deposition [g/yr]

$$L_{DEP} = Q_{ops} \cdot \{ [Fv \cdot (Dydwv + Dywwv)] + [(1 - Fv) \cdot (Dydwp + Dywwp)] \} \cdot A_w$$

R24

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}

Reference: EPA 2005, Table B-4-8. Note that EPA 2005 uses the "total" parameters rather than the component parameters that are used in the above equation.

Dytwv = Dydwv + Dywwv and Dytwp = Dydwp + Dywwp

Equation 36

L_{dif} COPC load to water body due to dry vapor phase diffusion [g/yr]

$$L_{dif} = \frac{K_v \cdot Q_{ops} \cdot Fv \cdot Cywv \cdot A_w \cdot 1E-06}{\frac{H}{R \cdot T_{wk}}}$$

R25

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}

Reference: EPA 2005, Table B-4-12
Note: The *Cywv* is for the waterbody itself, not the watershed.

Equation 37

L_{RI} COPC load to water body due to runoff from impervious surfaces [g/yr]

$$L_{RI} = Q_{ops} \cdot \{ [Fv \cdot (Dydwv + Dywwv)] + [(1 - Fv) \cdot (Dydwp + Dywwp)] \} \cdot A_I$$

R26

Mercury modeling modifications made to initially computed values:

All forms: final Q_{ops} = (0.48) initial Q_{ops}

Reference: EPA 2005, Table B-4-9
Note: The deposition terms are for the watershed, not the waterbody.

Equation 38

$L_{R(nw)\ or\ (tw)}$ Highest annual average COPC load to water body due to runoff from pervious surfaces or Average COPC load to water body due to runoff from pervious surfaces over the exposure duration [g/yr]

$$L_{R(nw)or(tw)} = RO \cdot (A_L - A_I) \cdot \frac{Cs_x \cdot BD}{\Theta_{sw} + Kd_s \cdot BD} \cdot 0.01$$

R27

Reference: EPA 2005, Table B-4-10

Equation 39

$L_{E(nw)\ or\ (tw)}$ Highest annual average COPC load to water body due to soil erosion or Average COPC load to water body due to soil erosion over the exposure duration [g/yr]

$$L_{E(nw)or(tw)} = X_e \cdot (A_L - A_I) \cdot SD \cdot ER \cdot \frac{Cs_x \cdot Kd_s \cdot BD}{\Theta_{sw} + Kd_s \cdot BD} \cdot 0.001$$

R28A

Reference: EPA 2005, Table B-4-11

Equation 40

K_v Overall COPC transfer rate coefficient [m/yr]

$$K_v = \left[K_L^{-1} + \left(K_G \cdot \frac{H}{R \cdot T_{wk}} \right)^{-1} \right]^{-1} \cdot \Theta^{(T_{wk} - 293)}$$

R29

Reference: EPA 2005, Table B-4-19

Equation 41

K_L Liquid phase COPC transfer coefficient [m/yr]

For flowing streams or rivers

$$K_L = \sqrt{\frac{(1E-04) \cdot D_w \cdot u}{d_{wc} + d_{bs}}} \cdot 3.1536E+07$$

R30A

For quiescent lakes or ponds

$$K_L = \left(C_d^{0.5} \cdot W\right) \cdot \left(\frac{\rho_a}{\rho_w}\right)^{0.5} \cdot \frac{k^{0.33}}{\lambda_z} \cdot \left(\frac{\mu_w}{\rho_w \cdot D_w}\right)^{-0.67} \cdot 3.1536E+07$$

R30B

Reference: EPA 2005, Table B-4-20

Equation 42

K_G Gas phase COPC transfer coefficient [m/yr]

For flowing streams or rivers:

$$K_G = 36500$$

For quiescent lakes or ponds:

$$K_G = \left(C_d^{0.5} \cdot W\right) \cdot \frac{k^{0.33}}{\lambda_z} \cdot \left(\frac{\mu_a}{\rho_a \cdot D_a}\right)^{-0.67} \cdot 3.1536E+07$$

R31B
R31A

Reference: EPA 2005, Table B-4-21

Equation 43

X_e Unit soil loss due to water erosion [kg/m^2-yr]

$$X_e = RF \cdot K \cdot LS \cdot C \cdot PF \cdot \frac{907.18}{4047}$$

R18

Reference: EPA 2005, Table B-4-13

Equation 44

SD Watershed sediment delivery ratio [unitless]

$$SD = a \cdot (A_L)^{-b}$$

R17

Reference: EPA 2005, Table B-4-14

Equation 45

f_{wc} Fraction of total water body COPC concentration in the water column [unitless]

$$f_{wc} = \frac{(1 + Kd_{sw} \cdot TSS \cdot 1E-06) \cdot \left(\frac{d_{wc}}{d_{wc} + d_{bs}} \right)}{(1 + Kd_{sw} \cdot TSS \cdot 1E-06) \cdot \left(\frac{d_{wc}}{d_{wc} + d_{bs}} \right) + (\Theta_{bs} + Kd_{bs} \cdot C_{BS}) \cdot \left(\frac{d_{bs}}{d_{wc} + d_{bs}} \right)}$$

R32

Reference: EPA 2005, Table B-4-16

Equation 46

f_{bs} Fraction of total water body COPC concentration in benthic sediment [unitless]

$$f_{bs} = 1 - f_{wc}$$

R33

Reference: EPA 2005, Table B-4-16

Equation 47

k_{wt} Overall total water body dissipation rate constant [$(yr)^{-1}$]

$$k_{wt} = f_{wc} \cdot k_v + f_{bs} \cdot k_b$$

R34

Reference: EPA 2005, Table B-4-17

Equation 48

k_v Water column volatilization rate constant [$(yr)^{-1}$]

$$k_v = \frac{K_v}{(d_{wc} + d_{bs}) \cdot (1 + Kd_{sw} \cdot TSS \cdot 1E-06)}$$

R35

Reference: EPA 2005, Table B-4-18

Equation 49

k_b Benthic burial rate constant [$(yr)^{-1}$]

$$k_b = \left(\frac{X_e \cdot A_L \cdot SD \cdot 1E+03 - Vf_x \cdot TSS}{A_W \cdot TSS} \right) \cdot \left(\frac{TSS \cdot 1E-06}{C_{BS} \cdot d_{bs}} \right)$$

R36A

Reference: EPA 2005, Table B-4-22

Section F-5. Dermal Contact & Sweat Lodge Equations

Equation 50

DAevent$_{soil(nw)\ or\ (tw)}$ **Highest annual average dermally absorbed dose per event for soil contact or Average dermally absorbed dose per event for soil contact over the exposure duration [mg/cm^2-event]**

$$DAevent_{soil(nw)or(tw)} = Cs_x \cdot 1E-06 \cdot AF \cdot ABSd$$

R401

Reference: EPA 2004, Equation 3.12

Equation 51

DAevent$_{sw(nw)\ or\ (tw)}$ **Highest annual average dermally absorbed dose per event for surface water contact or Average dermally absorbed dose per event for surface water contact over the exposure duration [mg/cm^2-event]**

For inorganics or highly ionized organics

$$DAevent_{sw(nw)or(tw)} = Kpw \cdot C_{wctot(x)} \cdot 1E-03 \cdot t_{event}$$

R402

For other organics and $t_{event} \le t^*$:

$$DAevent_{sw(nw)or(tw)} = 2 \cdot FA \cdot Kpw \cdot C_{wctot(x)} \cdot 1E-03 \cdot \sqrt{\frac{6 \cdot \tau_{event} \cdot t_{event}}{\pi}}$$

For other organics and $t_{event} > t^*$:

$$DAevent_{sw(nw)or(tw)} = FA \cdot Kpw \cdot C_{wctot(x)} \cdot 1E-03 \cdot \left[\frac{t_{event}}{1+B} + 2 \cdot \tau_{event} \cdot \left(\frac{1+3 \cdot B + 3 \cdot B^2}{(1+B)^2}\right)\right]$$

Reference: EPA 2004, Equations 3.2 through 3.4

Equation 52

τ_{event} Lag time per dermal contact event for COPC in population [hr/event]

$$\tau_{event} = \frac{lsc}{6 \cdot 10^{(-2.80 - 0.0056 \cdot MW)}}$$

R403

Reference: EPA 2004, Combination of Equations A.3 and A.4

Equation 53

t* **Time for COPC to reach steady state in population [hr]**

For organic substances:

If $\boldsymbol{B} \leq 0.6$:

$$t^* = 2.4 \cdot \tau_{event}$$

If $\boldsymbol{B} > 0.6$:

$$t^* = 6 \cdot \tau_{event} \cdot \left(d - \sqrt{d^2 - c^2} \right)$$

R404

Reference: EPA 2004, Equations A.5 and A.6

Equation 54

$DAevent_{sl(nw)\ or\ (tw)}$ Highest annual average dermally absorbed dose per event for sweat lodge or Average dermally absorbed dose per event for sweat lodge over the exposure duration [mg/cm^2-event]

For volatile & semivolatile organics (***BP*** ≤ 66°C):

$$DAevent_{sl(nw)or(tw)} = C_{wctot(x)} \cdot \left(\frac{Vws}{2}\right) \cdot \left(\frac{1}{2\!/\!3 \cdot \pi \cdot rs^3}\right) \cdot Kpv \cdot ET$$

For inorganics & nonvolatile organics (***BP*** > 66°C):

$$DAevent_{sl(nw)or(tw)} = C_{wctot(x)} \cdot Kpw \cdot ET \cdot 1E-03$$

R405

Reference: Information from ODEQ 2004. The boiling point cutoff (BP_i of 66°C) for semivolatiles and volatiles is a cutoff specific to this exposure pathway, and is based on the expected maximum temperature that will be associated with use of the water in the sweat lodge.

Equation 55

$C_{a(sl)(nw)\ or\ (tw)}$ Highest annual average sweat lodge air concentration or Average sweat lodge air concentration over the exposure duration [mg/m^3]

For volatile & semivolatile organics (***BP*** ≤ 66°C):

$$C_{a(sl)(nw)or(tw)} = C_{wctot(x)} \cdot \left(\frac{Vws}{2}\right) \cdot \left(\frac{1}{2\!/\!3 \cdot \pi \cdot rs^3}\right) \cdot 1E+06$$

For inorganics & nonvolatile organics (***BP*** > 66°C):

$$C_{a(sl)(nw)or(tw)} = C_{wctot(x)} \cdot \left(\frac{NVws}{2\!/\!3 \cdot \pi \cdot rs^3}\right) \cdot 1E+06$$

R406

Reference: Information from ODEQ 2004. The boiling point cutoff (BP_i of 66°C) for semivolatiles and volatiles is a cutoff specific to this exposure pathway, and is based on the expected maximum temperature that will be associated with use of the water in the sweat lodge.

Equation 56

NVws **Volume of surface water from exposure point location that is needed to produce 100 percent saturation in a sweat lodge [L]**

For inorganics & nonvolatile organics ($\boldsymbol{BP_i}$ > 66°C)

$$NVws = (0.252\ atm) \cdot \left[\frac{1}{2} \cdot \left(\frac{4}{3} \cdot \pi \cdot rs^3 \right) \cdot 1E - 03 \right] \cdot (0.000647)$$

R407

Reference: Information from ODEQ 2004 and personal communication with the Confederated Tribes of the Umatilla Indian Reservation. The boiling point cutoff (***BP*** of 66°C) for semivolatiles and volatiles is a cutoff specific to the sweat lodge exposure pathway, and is based on the expected maximum temperature that will be associated with use of the water in the sweat lodge.

The first bracketed term (0.252 atm) represents the vapor pressure of water at 150°F. The second term is the calculated volume of aerosol mist within a hemispheric sweat lodge, using the radius of the sweat lodge (*rs*). The third bracketed term represents the molecular weight of water divided by the product of the universal gas constant, the temperature of the 150°F sweat lodge expressed in units of Kelvin, and the density of water, as shown:

$$0.000647 = \left[\frac{18\ amu}{\frac{0.08206\ atm \cdot L}{g \cdot mol \cdot K} \cdot 339\ K \cdot \frac{1000\ g}{L}} \right]$$

Section F-6. Maternal Milk Concentrations Equations

Equation 57

$C_{milkfat}$ Dioxin-like compounds' concentration in maternal milk [pg COPC/kg milkfat]

$$C_{milkfat} = \frac{m_{nw} \cdot 1E+09 \cdot h \cdot f_1}{0.693 \cdot f_2}$$

R48

Reference: Adapted from EPA 2005, Table C-3-1

Equation 58

m_{nw} Highest annual average maternal daily intake of dioxin-like compounds [mg COPC/kg BW-day]

$$m_{nw} = \sum_{z} ADI_{inh(z)} + \sum_{x} ADI_{ing(x)} + \sum_{y} ADD_{dermal(y)}$$

R48

For residential population:
z = inhalation of ambient air ambient
x = soil ingestion (soil), drinking water ingestion (dw), & produce ingestion (produce)
y = soil dermal contact (soil dc), surface water dermal contact (swdc)

For farming population:
z = ambient
x = soil, dw, produce, beef ingestion (beef), cow's milk ingestion (milk), goat meat ingestion (goat), egg ingestion (egg), & chicken meat ingestion (chicken)
y = soil dc, swdc

For fishing population:
z = ambient
x = soil, dw, produce, & game fish ingestion (fish)
y = soil dc, swdc

For Native American population:
z = ambient, inhalation of sweat lodge vapor/mist (sweat lodge)
x = soil, dw, native vegetation ingestion (vegetation), milk, egg, fish, wild game ingestion (game), & wild fowl ingestion (fowl)
y = soil dc, swdc, & sweat lodge vapor/mist dermal contact (sldc)

For worker population:
z = ambient
x = soil, dw, produce
y = soil dc, swdc

For military population:
z = ambient
x = soil, dw, produce
y = soil dc, swdc

Reference: Adapted from EPA 2005, Table C-1-6, but also includes inhalation

Section F-7. Exposure & Risk Characterization Equations

Equation 59

ADI_{inh} & $LADI_{inh}$ Average daily COPC intake from inhalation of ambient air & Lifetime average daily COPC intake from inhalation of ambient air [mg COPC/kg BW-day]

For noncancer hazards

$$ADI_{inh} = \frac{C_{a(chronic)} \cdot IR \cdot ET \cdot EF \cdot ED \cdot 0.001}{BW \cdot AT_{noncancer} \cdot 365}$$

R54A

For cancer risks

$$LADI_{inh} = \frac{C_{a(chronic)} \cdot IR \cdot ET \cdot EF \cdot ED \cdot 0.001}{BW \cdot AT_{cancer} \cdot 365}$$

The value used for ED will be the ED specified for each particular population (Volume 3, Appendix D) or 10 years (tD), whichever is less.

R55A

Reference: Adapted from EPA 2005, Tables C-2-1 and C-2-2

Equation 60

$ADI_{inh(sl)}$ & $LADI_{inh(sl)}$ Average daily COPC intake from inhalation of sweat lodge vapor/mist & Lifetime average daily COPC intake from inhalation of sweat lodge vapor/mist [mg COPC/kg BW-d]

For noncancer hazards

$$ADI_{inh(sl)} = \frac{C_{a(sl)(nw)} \cdot IR_{sl} \cdot ET \cdot EF \cdot ED}{BW \cdot AT_{noncancer} \cdot 365}$$ R54E

For cancer risks

$$LADI_{inh(sl)} = \frac{C_{a(sl)(tw)} \cdot IR_{sl} \cdot ET \cdot EF \cdot ED}{BW \cdot AT_{cancer} \cdot 365}$$ R55E

Reference: EPA 1989, Exhibit 6-16

Equation 61

ADI_{soil} & $LADI_{soil}$ Average daily COPC intake from soil ingestion & Lifetime average daily COPC intake from soil ingestion [mg COPC/kg BW-day]

For noncancer hazards

$$ADI_{soil} = \frac{Cs_{nw} \cdot CR_{soil} \cdot F_{soil} \cdot EF \cdot ED}{BW \cdot AT_{noncancer} \cdot 365}$$

R54B

For cancer risks

$$LADI_{soil} = \frac{Cs_{tw} \cdot CR_{soil} \cdot F_{soil} \cdot EF \cdot ED}{BW \cdot AT_{cancer} \cdot 365}$$

R55B

Reference: Adapted from EPA 2005, Tables C-1-1, C-1-7, & C-1-8

Equation 62

ADI_{dw} & $LADI_{dw}$ Average daily COPC intake from drinking water ingestion & Lifetime average daily COPC intake from drinking water ingestion [mg COPC/kg BW-day]

For noncancer hazards

$$ADI_{dw} = \frac{C_{dw(nw)} \cdot CR_{dw} \cdot F_{dw} \cdot EF \cdot ED}{BW \cdot AT_{noncancer} \cdot 365}$$

R54B

For cancer risks

$$LADI_{dw} = \frac{C_{dw(tw)} \cdot CR_{dw} \cdot F_{dw} \cdot EF \cdot ED}{BW \cdot AT_{cancer} \cdot 365}$$

R55B

Reference: Adapted from EPA 2005, Tables C-1-5, C-1-7, & C-1-8

Equation 63

$ADI_{produce}$ & $LADI_{produce}$ Average daily COPC intake from native vegetation or produce ingestion & Lifetime average daily COPC intake from native vegetation or produce ingestion [mg COPC/kg BW-day]

For noncancer hazards

$$ADI_{produce} = \frac{\left[\left(P_{age(nw)} \cdot CR_{age}\right) + \left(P_{agp(nw)} \cdot CR_{agp}\right) + \left(P_{bg(nw)} \cdot CR_{bg}\right)\right] \cdot F_{produce} \cdot EF \cdot ED}{AT_{noncancer} \cdot 365}$$

R54C

For cancer risks

$$LADI_{produce} = \frac{\left[\left(P_{age(tw)} \cdot CR_{age}\right) + \left(P_{agp(tw)} \cdot CR_{agp}\right) + \left(P_{bg(tw)} \cdot CR_{bg}\right)\right] \cdot F_{produce} \cdot EF \cdot ED}{AT_{cancer} \cdot 365}$$

R55C

Reference: Adapted from EPA 2005, Tables C-1-2, C-1-7, & C-1-8

Equation 64

ADI_k & $LADI_k$ Average daily COPC intake from animal tissue *k* (beef, cow's milk, chicken eggs, goat, game, fowl) ingestion & Lifetime average daily COPC intake from animal tissue *k* (beef, cow's milk, chicken, eggs, goat, game, fowl) ingestion [mg COPC/kg BW-day]

For noncancer hazards

$$ADI_k = \frac{A_{k(nw)} \cdot CR_k \cdot F_k \cdot EF \cdot ED}{AT_{noncancer} \cdot 365}$$

R54C

For cancer risks

$$LADI_k = \frac{A_{k(tw)} \cdot CR_k \cdot F_k \cdot EF \cdot ED}{AT_{cancer} \cdot 365}$$

R55C

Reference: Adapted from EPA 2005, Tables C-1-3, C-1-7, & C-1-8

Equation 65

$ADI_{gamefish}$ & $LADI_{gamefish}$ Average daily COPC intake from game fish ingestion & Lifetime average daily COPC intake from game fish ingestion [mg COPC/kg BW-day]

For noncancer hazards

$$ADI_{gamefish} = \frac{C_{gamefish(nw)} \cdot CR_{gamefish} \cdot F_{gamefish} \cdot EF \cdot ED}{AT_{noncancer} \cdot 365}$$

R54C

For cancer risks

$$LADI_{gamefish} = \frac{C_{gamefish(tw)} \cdot CR_{gamefish} \cdot F_{gamefish} \cdot EF \cdot ED}{AT_{cancer} \cdot 365}$$

R55C

Reference: Adapted from EPA 2005, Tables C-1-4, C-1-7, & C-1-8

Equation 66

ADD_{dermal} & $LADD_{dermal}$ Average daily COPC dose from dermal contact with soil, surface water, or sweat lodge vapor/mist & Lifetime average daily COPC dose from dermal contact with soil, surface water, or sweat lodge vapor/mist [mg COPC/kg BW-d]

For noncancer hazards

$$ADD_{dermal} = \frac{DAevent_{x(nw)} \cdot SA \cdot EV \cdot EF \cdot ED}{BW \cdot AT_{noncancer} \cdot 365} \qquad \text{R54D}$$

For cancer risks

$$LADD_{dermal} = \frac{DAevent_{x(tw)} \cdot SA \cdot EV \cdot EF \cdot ED}{BW \cdot AT_{cancer} \cdot 365} \qquad \text{R55D}$$

Reference: EPA 2004, Equations 3.1 and 3.11

Equation 67

$HQ_{inh(z)}$ Hazard quotient for COPC from inhalation pathway z (ambient air, sweat lodge vapor/mist) [unitless]

$$HQ_{inh(z)} = \frac{ADI_{inh(z)}}{RfD_{inh}}$$

R65

Reference: Adapted from EPA 2005, Table C-2-2

Equation 68

$HQ_{ing(x)}$ Hazard quotient for COPC from ingestion pathway x (soil, dw, vegetation, produce, beef, milk, goat, egg, chicken, fish, game, fowl) [unitless]

$$HQ_{ing(x)} = \frac{ADI_{ing(x)}}{RfD_{o}} \qquad \text{R65}$$

Reference: Adapted from EPA 2005, Table C-1-8

Equation 69

$HQ_{dermal(y)}$ Hazard quotient for COPC from dermal pathway y (soil, surface water, sweat lodge vapor/mist) [unitless]

$$HQ_{dermal(y)} = \frac{ADD_{dermal(y)}}{RfD_d}$$ R65

Reference: Adapted from EPA 2005, Table C-1-8

Equation 70

HI_{inh} or HI_{ing} or HI_{dermal} Hazard index for all COPCs *i* across pathway [unitless]

For inhalation pathways

$$HI_{inh} = \sum_i HQ_{inh(z)(i)}$$

R67

For ingestion pathways

$$HI_{ing} = \sum_i HQ_{ing(x)(i)}$$

R66 & R67

For dermal pathways

$$HI_{dermal} = \sum_i HQ_{dermal(y)(i)}$$

R67

Reference: Adapted from EPA 2005, Table C-1-10

Equation 71

HI Total hazard index for all COPCs from inhalation, ingestion, and dermal exposure pathways [unitless]

$$HI = \sum_{z} HI_{inh(z)} + \sum_{x} HI_{ing(x)} + \sum_{y} HI_{dermal(y)}$$

R68

For residential population:
z = inhalation of ambient air ambient
x = soil, dw, & produce
y = soil dc, swdc

For farming population:
z = ambient
x = soil, dw, produce, beef, milk, goat, egg, & chicken
y = soil dc, swdc

For fishing population:
z = ambient
x = soil, dw, produce, & fish
y = soil dc, swdc

For Native American population:
z = ambient, sweat lodge
x = soil, dw, vegetation, milk, egg, fish, game, & fowl
y = soil dc, swdc, & sldc

For worker population:
z = ambient
x = soil, dw, produce
y = soil dc, swdc

For military population:
z = ambient
x = soil, dw, produce
y = soil dc, swdc

Reference: Adapted from EPA 2005, Table C-1-10

Equation 72

RfD_{inh} Inhalation reference dose [mg/kg-day]

$$RfD_{inh} = \frac{RfC \cdot 20m^3 / day}{70kg}$$

Reference: EPA 2005, Table C-2-2

Equation 73

$LECR_{inh(z)}$ Lifetime excess cancer risk for COPC from inhalation pathway z (ambient air, sweat lodge vapor/mist) [unitless]

$$LECR_{inh(z)} = LADI_{inh(z)} \cdot CSF_{inh}$$

R61

Reference: Adapted from EPA 2005, Table C-2-1

Equation 74

$LECR_{ing(x)}$ Lifetime excess cancer risk for COPC from ingestion pathway x (soil, dw, native vegetation, produce, beef, milk, chicken, eggs, goat, game fish, game, fowl) [unitless]

$$LECR_{ing(x)} = LADI_{ing(x)} \cdot CSF_o$$

R61

Reference: Adapted from EPA 2005, Table C-1-7

Equation 75

$LECR_{dermal(y)}$ Lifetime excess cancer risk for COPC from dermal pathway y (soil, surface water, sweat lodge vapor/mist) [unitless]

$$LECR_{dermal(y)} = LADD_{dermal(y)} \cdot CSF_d$$

R61

Reference: Adapted from EPA 2005, Table C-1-7

Equation 76

$PLECR_{inh}$ or $PLECR_{ing}$ or $PLECR_{dermal}$ Lifetime excess cancer risk for all COPCs *i* across pathway [unitless]

For inhalation pathway

$$PLECR_{inh} = \sum_i LECR_{inh(z)(i)}$$

R63

For ingestion pathways

$$PLECR_{ing} = \sum_i LECR_{ing(x)(i)}$$

R63

For dermal pathways

$$PLECR_{dermal} = \sum_i LECR_{dermal(y)(i)}$$

R63

Reference: Adapted from EPA 2005, Table C-1-9

Equation 77

LECR Total lifetime excess cancer risk for all COPCs from inhalation, ingestion, and dermal exposure pathways [unitless]

$$LECR = \sum_{z} PLECR_{inh(z)} + \sum_{x} PLECR_{ing(x)} + \sum_{y} PLECR_{dermal(y)}$$

R64

For residential population:
z = inhalation of ambient air ambient
x = soil, dw, & produce
y = soil dc, swdc

For farming population:
z = ambient
x = soil, dw, produce, beef, milk, goat, egg, & chicken
y = soil dc, swdc

For fishing population:
z = ambient
x = soil, dw, produce, & fish
y = soil dc, swdc

For Native American population:
z = ambient, sweat lodge
x = soil, dw, vegetation, milk, egg, fish, game, & fowl
y = soil dc, swdc, & sldc

For worker population:
z = ambient
x = soil, dw, produce
y = soil dc, swdc

For military population:
z = ambient
x = soil, dw, produce
y = soil dc, swdc

Reference: Adapted from EPA 2005, Table C-1-9

Equation 78

CSF_{inh} Inhalation cancer slope factor [(mg/kg-day)$^{-1}$]

$$CSF_{inh} = \frac{URF \cdot 70kg \cdot 1E+03\mu g/mg}{20m^3/day}$$

Reference: EPA 2005, Table C-2-1

Equation 79

AHQ Acute hazard quotient from inhalation of COPC [unitless]

$$AHQ = \frac{C_{a(acute)} \cdot 0.001}{ARC}$$

R69

Reference: Adapted from EPA 2005, Table C-4-1

Equation 80

AHI Acute hazard index for all COPCs *i* from inhalation [unitless]

$$AHI = \sum_i AHQ_{(i)}$$

R70

Reference: Adapted from EPA 2005, Table C-1-10

Equation 81

ADD_{infant} Average daily dose for infant exposed to impacted maternal milk [pg COPC/kg BW-day]

$$ADD_{infant} = \frac{C_{milkfat} \cdot f_3 \cdot f_4 \cdot IR_{milk} \cdot ED}{BW \cdot AT_{infant}}$$

R57A

Reference: EPA 2005, Table C-3-2

Section F-8. References

EPA. 1989. Risk Assessment Guidance for Superfund (RAGS) Volume 1 Human Health Evaluation Manual (Part A). EPA/540/1-89/002. Office of Emergency and Remedial Response, Washington, D.C.: December 1989.

EPA 2004. Risk Assessment Guidance for Superfund (RAGS) Volume 1 Human Health Evaluation Manual (Part E: Supplemental Guidance for Dermal Risk Assessment)(Final). EPA/540/R/99/005. Office of Superfund Remediation and Technology Innovation, Washington, D.C.: July 2004.

EPA 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA530-R-05-006). US Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.: September 2005.

ODEQ 2004. Final Post-Trial Burn Risk Assessment Work Plan for the Umatilla Chemical Agent Disposal Facility, Hermiston, Oregon. Prepared by Ecology & Environment, Inc. for the Oregon Department of Environmental Quality (ODEQ), Portland, OR: August 2004.

Table F-1. HHRA Parameter Definitions

Parameters are arranged alphabetically, with Greek letters grouped at the top and numbers at the end of the table. Subscripts are subordinate; for example, A_w comes before ADD_{infant}.

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
λ_z	Dimensionless viscous sublayer thickness [unitless]	EPL-Specific	Volume 3, Appendix B	41, 42
μ_a	Viscosity of air corresponding to water temperature [g/cm-s]	EPL-Specific	Volume 3, Appendix B	42
μ_w	Viscosity of water corresponding to water temperature [g/cm-s]	EPL-Specific	Volume 3, Appendix B	41
Θ	Temperature correction factor [unitless]	EPL-Specific	Volume 3, Appendix B	40
Θ_{bs}	Bed sediment porosity [L pore water/L sediment or unitless]	EPL-Specific	Volume 3, Appendix B	29, 45
Θ_{sw}	Soil volumetric water content [mL water/cm^3 soil]	EPL-Specific	Volume 3, Appendix B	8, 9, 13, 38, 39
Θ_v	Soil void fraction [cm^3/cm^3]	Calculated	Volume 3, Appendix B	12, 13
ρ_a	Density of air [g/cm^3]	EPL-Specific	Volume 3, Appendix B	19, 41, 42
ρ_s	Solids particle density [g/cm^3]	EPL-Specific	Volume 3, Appendix B	13
ρ_w	Density of water [g/cm^3]	EPL-Specific	Volume 3, Appendix B	41
π	*Pi* is the ratio of the circumference of a circle to its diameter [unitless] *Π = 3.14159265358979323846…*	Constant	--	51, 54, 55, 56
τ_{event}	Lag time per dermal contact event for COPC in population [hr/event]	Calculated	Volume 3, Appendices L, M, N, O, & P	51, 52, 53
a	Empirical intercept coefficient [unitless]	EPL-Specific	Volume 3, Appendix B	44
$A_{beef(nw)}$	Highest annual average COPC concentration in beef [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	21
$A_{beef(tw)}$	Average COPC concentration in beef over the exposure duration [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	21
$A_{chicken(nw)}$	Highest annual average COPC concentration in chicken meat [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	25
$A_{chicken(tw)}$	Average COPC concentration in chicken meat over the exposure duration [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	25

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	**Equations**
$A_{egg(nw)}$	Highest annual average COPC concentration in eggs [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	24
$A_{egg(tw)}$	Average COPC concentration in eggs over the exposure duration [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	24
A_I	Impervious watershed area receiving COPC deposition [m^2]	EPL-Specific	Volume 3, Appendix B	37, 38, 39
$A_{k(nw)}$	Highest annual average COPC concentration in animal tissue *k* (beef, milk, goat, egg, chicken, game, fowl) [mg COPC/kg FW tissue]	Calculated	**Volume 3, Appendix I**	**64**
$A_{k(tw)}$	Average COPC concentration in animal tissue *k* (beef, milk, goat, egg, chicken, game, fowl) over the exposure duration [mg COPC/kg FW tissue]	Calculated	**Volume 3, Appendix I**	**64**
A_L	Total watershed area receiving COPC deposition [m^2]	EPL-Specific	Volume 3, Appendix B	38, 39, 44, 49
$A_{milk(nw)}$	Highest annual average COPC concentration in cow's milk [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	22
$A_{milk(tw)}$	Average COPC concentration in cow's milk over the exposure duration [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	22
$A_{goat(nw)}$	Highest annual average COPC concentration in goat [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	23
$A_{goat(tw)}$	Average COPC concentration in goat over the exposure duration [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix I	23
A_w	Water body surface area [m^2]	EPL-Specific	Volume 3, Appendix B	26, 35, 36, 49
$ABSd$	Dermal absorption fraction from soil to skin [unitless]	COPC-specific	Volume 3, Appendix C	50
ADD_{dermal}	Average daily COPC intake from dermal contact with soil, surface water, or sweat lodge vapor/mist [mg COPC/kg BW-d]	Calculated	**Volume 3, Appendices L, M, N, O, & P**	**66**
$ADD_{dermal(y)}$	Average daily COPC intake from dermal pathway y (soil, surface water, or sweat lodge vapor/mist) [mg COPC/kg BW-d]	Calculated	**Volume 3, Appendices L, M, N, O, & P**	**58, 69**
ADD_{infant}	Average daily dose for infant exposed to impacted maternal milk [pg COPC/kg BW-day]	Calculated	**Volume 3, Appendices L, M, N, O, & P**	**81**
ADI_{dw}	Average daily COPC intake from drinking water ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	62
$ADI_{gamefish}$	Average daily COPC intake from game fish ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices N & O	65

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
$ADI_{ing(x)}$	Average daily COPC intake from ingestion pathway x [soil ingestion (soil), drinking water ingestion (dw), native vegetation ingestion (vegetation), produce ingestion (produce), beef ingestion (beef), cow's milk ingestion (milk), goat meat ingestion (goat), egg ingestion (egg), chicken meat ingestion (chicken), game fish ingestion (fish), wild game ingestion (game), wild fowl ingestion (fowl)] [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	58, 68
ADI_{inh}	Average daily COPC intake from inhalation of ambient air [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	59
$ADI_{inh(sl)}$	Average daily COPC intake from inhalation of sweat lodge vapor/mist [mg COPC/kg BW-day]	Calculated	Volume 3, Appendix O	60
$ADI_{inh(z)}$	Average daily COPC intake from inhalation of z (ambient air or sweat lodge vapor/mist) [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	58, 67
ADI_k	Average daily COPC intake from animal tissue *k* (beef, milk, goat, egg, chicken, game, fowl) ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendix M & O	64
$ADI_{produce}$	Average daily COPC intake from native vegetation or produce ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	63
ADI_{soil}	Average daily COPC intake from soil ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	61
AF	Adherence factor of soil to skin during soil activity in population [mg/cm^2-event]	Population-Specific	Volume 3, Appendix D	50
AHI	Acute hazard index for all COPCs *i* from inhalation [unitless]	Calculated	Volume 3, Appendix Q	80
AHQ	Acute hazard quotient from inhalation of COPC [unitless]	Calculated	Volume 3, Appendix Q	79, 80
ARC	Acute reference concentration [mg/m^3]	COPC-Specific	Volume 3, Appendix C	79
AT_{cancer}	Carcinogenic averaging time [yrs]	Population-Specific	Volume 3, Appendix D	59 – 66
AT_{infant}	Averaging time for infant [yr]	Population-Specific	Volume 3, Appendix D	81
$AT_{noncancer}$	Noncancer averaging time [yrs]	Population-Specific	Volume 3, Appendix D	59 – 66
b	Empirical slope coefficient [unitless]	EPL-Specific	Volume 3, Appendix B	44

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
B	Dimensionless ratio of the permeability coefficient of a substance through the stratum corneum relative to its permeability coefficient across the viable epidermis [unitless]	COPC-Specific	Volume 3, Appendix C	51
Ba_{beef}	Biotransfer factor for beef [day/kg FW tissue]	COPC-specific	Volume 3, Appendix C	21
$Ba_{chicken}$	Biotransfer factor for chicken meat [day/kg FW tissue]	COPC-specific	Volume 3, Appendix C	25
Ba_{egg}	Biotransfer factor for eggs [day/kg FW tissue]	COPC-specific	Volume 3, Appendix C	24
Ba_{milk}	Biotransfer factor for cow's milk [day/kg FW tissue]	COPC-specific	Volume 3, Appendix C	22
Ba_{goat}	Biotransfer factor for goat [day/kg FW tissue]	COPC-specific	Volume 3, Appendix C	23
$BAF_{gamefish}$	Bioaccumulation factor for COPC in game fish [L/kg FW tissue]	COPC-specific	Volume 3, Appendix C	31
$BCF_{gamefish}$	Bioconcentration factor for COPC in game fish [L/kg FW tissue]	COPC-specific	Volume 3, Appendix C	30
BD	Soil bulk density [g soil/cm^3 soil]	EPL-Specific	Volume 3, Appendix B	5, 6, 8, 9, 11,13, 38, 39
Br_x *indexed as:* Br_{ag} Br_{forage} Br_{grain}	Plant-soil bioconcentration factor for above ground exposed plant (native vegetation, exposed produce, or forage) and protected plant (native vegetation, protected produce or grain) [(mg COPC/kg DW plant)/(mg COPC/kg soil) or unitless]	COPC-Specific	Volume 3, Appendix C	16, 20
Bs	Soil bioavailability factor [unitless]	COPC-Specific	Volume 3, Appendix C	21 - 25
BSAF	Biota-to-sediment accumulation factor [(mg COPC/kg lipid tissue)/(mg COPC/kg sediment) or unitless]	COPC-specific	Volume 3, Appendix C	32
Bv_x *indexed as:* Bv_{ag} Bv_{forage}	Air-to-plant biotransfer factor for above ground exposed plant (native vegetation, exposed produce, or forage) [(mg COPC/g DW plant)/(mg COPC/g air) or unitless]	COPC-Specific	Volume 3, Appendix C	19
BW	Body weight [kg]	Population-Specific	Volume 3, Appendix D	59 – 62, 66, 81
c	Second lag time correlation coefficient (Flynn's data) for dermal contact with surface water [unitless]	COPC-Specific	Volume 3, Appendix C	53
C	USLE cover management factor [unitless]	EPL-Specific	Volume 3, Appendix B	43

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
$C_{a(chronic)}$	Chronic air concentration [µg/m^3]	Calculated	Volume 3, Appendix F	1, 59
$C_{a(acute)}$	Acute air concentration [µg/m^3]	Calculated	Volume 3, Appendix F	2, 79
$C_{a(sl)(nw)}$	Highest annual average sweat lodge air concentration [mg/m^3]	Calculated	Volume 3, Appendix F	55, 60
$C_{a(sl)(tw)}$	Average sweat lodge air concentration over the exposure duration [mg/m^3]	Calculated	Volume 3, Appendix F	55, 60
C_{BS}	Bed sediment concentration [g/cm^3]	EPL-Specific	Volume 3, Appendix B	29, 45, 49
C_d	Drag coefficient [unitless]	EPL-Specific	Volume 3, Appendix B	41, 42
$C_{dw(nw)}$	Highest annual average dissolved phase COPC concentration in water body [mg COPC/L water]	Calculated	Volume 3, Appendix J	28, 30, 31, 62
$C_{dw(tw)}$	Average dissolved phase COPC concentration in water body over the exposure duration [mg COPC/L water]	Calculated	Volume 3, Appendix J	28, 30, 31, 62
$C_{gamefish(nw)}$	Highest annual average COPC concentration in game fish [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix J	30, 31, 32, 65
$C_{gamefish(tw)}$	Average COPC concentration in game fish over the exposure duration [mg COPC/kg FW tissue]	Calculated	Volume 3, Appendix J	30, 31, 32, 65
$C_{milkfat}$	Dioxin-like compounds' concentration in maternal milk [pg COPC/kg milkfat]	Calculated	Volume 3, Appendix K	57, 81
$C_{sb(nw)}$	Highest annual average COPC concentration sorbed to bed sediment [mg COPC/kg bed sediment]	Calculated	Volume 3, Appendix J	29, 32
$C_{sb(tw)}$	Average COPC concentration sorbed to bed sediment over the exposure duration [mg COPC/kg bed sediment]	Calculated	Volume 3, Appendix J	29, 32
$C_{wctot(nw)}$	Highest annual average COPC concentration in water column [mg COPC/L water]	Calculated	Volume 3, Appendix J	27, 28, 51, 54, 55
$C_{wctot(nw)}$	Average COPC concentration in water column over the exposure duration [mg COPC/L water]	Calculated	Volume 3, Appendix J	27, 28, 51, 54, 55
$C_{wtot(nw)}$	Highest annual average COPC concentration in water body (including water column & bed sediment) [mg COPC/L water or g COPC/m^3 water]	Calculated	Volume 3, Appendix J	26, 27, 29
$C_{wtot(tw)}$	Average COPC concentration in water body (including water column & bed sediment) over the exposure duration [mg COPC/L water or g COPC/m^3 water]	Calculated	Volume 3, Appendix J	26, 27, 29

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
Chp	Unitized hourly air concentration from particle phase [µg-s/g-m^3]. Depending upon the substance Fv, this is based on particle-mass or particle-bound approach.	Air-Modeled	Volume 3, Appendix F	2
Chv	Unitized hourly air concentration from vapor phase [µg-s/g-m^3]	Air-Modeled	Volume 3, Appendix F	2
CR_{age}	Consumption rate of above ground exposed plant (exposed produce) [kg DW plant/kg BW-day]	Population-Specific	Volume 3, Appendix D	63
CR_{agp}	Consumption rate of above ground protected plant (protected produce) [kg DW plant/kg BW-day]	Population-Specific	Volume 3, Appendix D	63
CR_{bg}	Consumption rate of below ground produce [kg DW plant/kg BW-day]	Population-Specific	Volume 3, Appendix D	63
CR_{dw}	Consumption rate of drinking water [L/day]	Population-Specific	Volume 3, Appendix D	62
$CR_{gamefish}$	Consumption rate of game fish [kg FW tissue/kg BW-day]	Population-Specific	Volume 3, Appendix D	65
CR_k	Consumption rate of animal tissue *k* (beef, milk, goat, egg, chicken, game, fowl) [kg FW tissue/kg BW-day]	Population-Specific	Volume 3, Appendix D	64
CR_{soil}	Consumption rate of soil [kg/day]	Population-Specific	Volume 3, Appendix D	61
$Cs_{nw} = Cs_{tD}$	Highest annual average COPC concentration in soil [mg COPC/kg soil]	Calculated	Volume 3, Appendix G	3, 4, 61
$Cs_{tw(long)}$	Average COPC concentration in soil over exposure durations greater than tD [mg COPC/kg soil]	Calculated	Volume 3, Appendix G	4, 61
$Cs_{tw(short)}$	Average COPC concentration in soil over exposure durations less than or equal to tD [mg COPC/kg soil]	Calculated	Volume 3, Appendix G	4, 61
Cs_x	Highest annual average COPC concentration in soil (Cs_{nw}) or Average COPC concentration in soil over the exposure duration (Cs_{tw}), whichever is applicable, at 1 or 20 cm mixing depth [mg COPC/kg soil]	Calculated	Volume 3, Appendix G	3, 4, 16, 17, 20, 21, 22, 23, 24, 25, 38, 39, 50
CSF_d	Dermal cancer slope factor [(mg/kg-day)$^{-1}$]	COPC-specific	Volume 3, Appendix C	75
CSF_{inh}	Inhalation cancer slope factor [(mg/kg-day)$^{-1}$]	COPC-specific	Volume 3, Appendix C	73, 78

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
CSF_o	Oral cancer slope factor [(mg/kg-day)$^{-1}$]	COPC-specific	Volume 3, Appendix C	74
Cyp	Unitized yearly average air concentration from particle phase [µg-s/g-m^3]. Depending upon the substance Fv, this is based on particle-mass or particle-bound approach.	Air-Modeled	Volume 3, Appendix F	1
Cyv	Unitized yearly average air concentration from vapor phase [µg-s/g-m^3]	Air-Modeled	Volume 3, Appendix F	1, 19
$Cywv$	Unitized yearly (water body or watershed) average air concentration from vapor phase [µg-s/g-m^3]	Air-Modeled	Volume 3, Appendix F	36
d	First lag time correlation coefficient (Flynn's data) for dermal contact with surface water [unitless]	COPC-Specific	Volume 3, Appendix C	53
$DAevent_{sl(nw)}$	Highest annual average dermally absorbed dose per event for sweat lodge [mg/cm^2-event]	Calculated	Volume 3, Appendix O	54
$DAevent_{sl(tw)}$	Average dermally absorbed dose per event for sweat lodge over the exposure duration [mg/cm^2-event]	Calculated	Volume 3, Appendix O	54
$DAevent_{soil(nw)}$	Highest annual average dermally absorbed dose per event for soil contact [mg/cm^2-event]	Calculated	Volume 3, Appendices L, M, N, O, & P	50
$DAevent_{soil(tw)}$	Average dermally absorbed dose per event for soil contact over the exposure duration [mg/cm^2-event]	Calculated	Volume 3, Appendices L, M, N, O, & P	50
$DAevent_{sw(nw)}$	Highest annual average dermally absorbed dose per event for surface water contact [mg/cm^2-event]	Calculated	Volume 3, Appendices L, M, N, O, & P	51
$DAevent_{sw(tw)}$	Average dermally absorbed dose per event for surface water contact over the exposure duration [mg/cm^2-event]	Calculated	Volume 3, Appendices L, M, N, O, & P	51
$DAevent_{x(nw)}$	Highest annual average dermally absorbed dose per event from x (soil, surface water, sweat lodge vapor/mist) contact [mg/cm^2-event]	Calculated	Volume 3, Appendices L, M, N, O, & P	66
$DAevent_{x(tw)}$	Average dermally absorbed dose per event from x (soil, surface water, sweat lodge vapor/mist) contact over the exposure duration [mg/cm^2-event]	Calculated	Volume 3, Appendices L, M, N, O, & P	66
D_a	Diffusivity of COPC in air [cm^2/s]	COPC-Specific	Volume 3, Appendix C	12, 42
d_{bs}	Depth of upper benthic sediment layer [m]	EPL-Specific	Volume 3, Appendix B	26, 27, 29, 41, 45, 48, 49

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
D_w	Diffusivity of COPC in water [cm^2/s]	COPC-specific	Volume 3, Appendix C	41
d_{wc}	Depth of water column [m]	EPL-Specific	Volume 3, Appendix B	26, 27, 29, 41, 45, 48,
Ds	Deposition term [mg COPC/kg soil-yr]	Calculated	Volume 3, Appendix G	3, 4, 5, 6
Dydp	Unitized yearly average dry deposition from particle phase [s/m^2-yr]. Depending upon the substance Fv, this is based on particle-mass or particle-bound approach.	Air-Modeled	Volume 3, Appendix F	5, 18
Dydv	Unitized yearly dry deposition from vapor phase [s/m^2-yr].	Air-Modeled	Volume 3, Appendix F	5
Dydwp	Unitized yearly (water body or watershed) average dry deposition from particle phase [s/m^2-yr]. Depending upon the substance Fv, this is based on particle-mass or particle-bound approach.	Air-Modeled	Volume 3, Appendix F	6, 35, 37
Dydwv	Unitized yearly (water body or watershed) dry deposition from vapor phase [s/m^2-yr].	Air-Modeled	Volume 3, Appendix F	6, 35, 37
Dywp	Unitized yearly average wet deposition from particle phase [s/m^2-yr]. Depending upon the substance Fv, this is based on particle-mass or particle-bound approach.	Air-Modeled	Volume 3, Appendix F	5, 18
Dywv	Unitized yearly average wet deposition from vapor phase [s/m^2-yr]	Air-Modeled	Volume 3, Appendix F	5
Dywwp	Unitized yearly (water body or watershed) average wet deposition from particle phase [s/m^2-yr]. Depending upon the substance Fv, this is based on particle-mass or particle-bound approach.	Air-Modeled	Volume 3, Appendix F	6, 35, 37
Dywwv	Unitized yearly (water body or watershed) average wet deposition from vapor phase [s/m^2-yr]	Air-Modeled	Volume 3, Appendix F	6, 35, 37
E_v	Average annual evapotranspiration [cm/yr]	EPL-Specific	Volume 3, Appendix B	9
ED	Exposure duration [yrs]	Population-Specific	Volume 3, Appendix D	4, 15, 34, 59 – 66, 81
EF	Exposure frequency [days/yr]	Population-Specific	Volume 3, Appendix D	59 – 66

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
ER	Soil enrichment ratio [unitless]	COPC-specific	Volume 3, Appendix C	39
ET	Exposure time [hrs/day]	Population-Specific	Volume 3, Appendix D	54, 59, 60
EV	Exposure event frequency [events/day]	Population-Specific	Volume 3, Appendix D	66
f_1	Fraction of ingested dioxin that is stored in fat [unitless]	COPC-Specific	Volume 3, Appendix C	57
f_2	Fraction of mother's weight that is fat [unitless]	Population-Specific	Volume 3, Appendix D	57
f_3	Fraction of maternal milk that is fat [unitless]	Biota-Specific	Volume 3, Appendix D	81
f_4	Fraction of ingested COPC that is absorbed [unitless]	COPC-Specific	Volume 3, Appendix C	81
FA	Fraction of substance absorbed from dermal contact with water [unitless]	COPC-Specific	Volume 3, Appendix C	51
F_{age}	Fraction of above ground exposed plant (forage) grown on impacted soil & ingested by animal [unitless]	Biota-Specific	Volume 3, Appendix B	21, 22, 23
F_{agp}	Fraction of above ground protected plant (grain) grown on impacted soil & ingested by animal [unitless]	Biota-Specific	Volume 3, Appendix B	21, 22, 24, 25
f_{bs}	Fraction of total water body COPC concentration in benthic sediment [unitless]	Calculated	Volume 3, Appendix J	29, 46, 47
F_{dw}	Fraction of drinking water that is impacted [unitless]	Population-Specific	Volume 3, Appendix B	62
$F_{gamefish}$	Fraction of gamefish that is impacted [unitless]	Population-Specific	Volume 3, Appendix B	65
F_k	Fraction of animal tissue *k* (beef, milk, goat, egg, chicken, game, fowl) that is impacted [unitless]	Population-Specific	Volume 3, Appendix B	64
f_{lipid}	Fish lipid content [unitless]	Biota-Specific	Volume 3, Appendix B	32
$F_{produce}$	Fraction of produce that is impacted [unitless]	Population-Specific	Volume 3, Appendix B	63
F_{soil}	Fraction of soil that is impacted [unitless]	Population-Specific	Volume 3, Appendix B	61

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
Fv	Fraction of COPC air concentration in vapor phase [unitless]	COPC-Specific	Volume 3, Appendix C	1, 2, 5, 6, 18, 19, 35, 36, 37
Fw	Fraction of COPC wet deposition that adheres to plant surfaces [unitless]	COPC-Specific	Volume 3, Appendix C	18
f_{wc}	Fraction of total water body COPC concentration in the water column [unitless]	Calculated	Volume 3, Appendix J	26, 27, 45, 46, 47
h	Half-life of dioxin in adults [days]	COPC-Specific	Volume 3, Appendix C	57
H	Henry's Law constant [atm-m^3/mol]	COPC-Specific	Volume 3, Appendix C	11, 36, 40
HI	Total hazard index for all COPCs from inhalation, ingestion, and dermal exposure pathways [unitless]	Calculated	Volume 3, Appendices L, M, N, O, P, & Q	71
HI_{dermal}	Hazard index for all COPCs *i* across dermal pathway [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	70, 71
HI_{ing}	Hazard index for all COPCs *i* across ingestion pathway [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	70, 71
HI_{inh}	Hazard index for all COPCs *i* across inhalation pathway [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	70, 71
$HQ_{dermal(y)}$	Hazard quotient for COPC from dermal pathway y (soil, surface water, sweat lodge vapor/mist) [unitless]	Calculated	Volume3, Appendices L, M, N, O, & P	69, 70
$HQ_{ing(x)}$	Hazard quotient for COPC from ingestion pathway *x* (soil, dw, native vegetation, produce, beef, milk, goat, egg, chicken, fish, game, fowl) [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	68, 70
$HQ_{inh(z)}$	Hazard quotient for COPC from inhalation pathway z (ambient air and sweat lodge vapor/mist) [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	67, 70
I	Average annual irrigation [cm/yr]	EPL-Specific	Volume 3, Appendix B	9
IR	Inhalation rate [m^3/hr]	Population-Specific	Volume 3, Appendix D	59
IR_{milk}	Ingestion rate of maternal milk by the infant [kg/day]	Population-Specific	Volume 3, Appendix D	81
IR_{sl}	Inhalation rate of sweat lodge vapor/mist [m^3/hr]	Population-Specific	Volume 3, Appendix D	60
k	von Karman's constant [unitless]	EPL-Specific	Volume 3, Appendix B	41, 42
K	USLE erodibility factor [tons/acre]	Site-Specific	Volume 3, Appendix B	43
k_b	Benthic burial rate constant [(yr)$^{-1}$]	Calculated	Volume 3, Appendix J	47, 49
K_G	Gas phase COPC transfer coefficient [m/yr]	Calculated	Volume 3, Appendix J	40, 42

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
K_L	Liquid phase COPC transfer coefficient [m/yr]	Calculated	Volume 3, Appendix J	40, 41
K_t	Gas phase mass transfer coefficient [cm/s]	Calculated	Volume 3, Appendix G	10, 12
k_{wt}	Overall total water body dissipation rate constant [$(yr)^{-1}$]	Calculated	Volume 3, Appendix J	26, 47
k_v	Water column volatilization rate constant [yr^{-1}]	Calculated	Volume 3, Appendix J	47, 48
K_v	Overall COPC transfer rate coefficient [m/yr]	Calculated	Volume 3, Appendix J	36, 40, 48
Kd_{bs}	Bed sediment-sediment pore water partition coefficient [L water/kg bed sediment or cm^3 water/g bed sediment]	COPC-specific	Volume 3, Appendix C	29, 45
Kd_s	Soil-water partition coefficient [L water/kg soil or cm^3 water/g soil]	COPC-specific	Volume 3, Appendix C	8, 9, 11, 17, 38, 39
Kd_{sw}	Suspended sediments-surface water partition coefficient [L water/kg suspended sediment or cm^3 water/kg suspended sediment]	COPC-specific	Volume 3, Appendix C	28, 45, 48
Ke	Equilibrium coefficient [s/yr-cm]	Calculated	Volume 3, Appendix G	10, 11
kp	Plant surface loss coefficient [$(yr)^{-1}$]	Biota-Specific	Volume 3, Appendix B	18
Kpv	Dermal permeability coefficient of substance in vapor [cm/hr]	COPC-Specific	Volume 3, Appendix C	54
Kpw	Dermal permeability coefficient of substance in water [cm/hr]	COPC-Specific	Volume 3, Appendix C	51, 54
ks	COPC soil loss constant due to all processes [$(yr)^{-1}$]	Calculated	Volume 3, Appendix G	3, 4, 7
kse	COPC soil loss constant due to erosion [$(yr)^{-1}$]	COPC-Specific	Volume 3, Appendix C	7
ksg	COPC soil loss constant due to biotic & abiotic degradation [$(yr)^{-1}$]	COPC-Specific	Volume 3, Appendix C	7
ksl	COPC soil loss constant due to leaching [$(yr)^{-1}$]	Calculated	Volume 3, Appendix G	7, 9
ksr	COPC soil loss constant due to surface runoff [$(yr)^{-1}$]	Calculated	Volume 3, Appendix G	7, 8
ksv	COPC soil loss constant due to volatilization [$(yr)^{-1}$]	Calculated	Volume 3, Appendix G	7, 10
L_{DEP}	COPC load to water body due to (wet & dry) particle phase & wet vapor phase direct deposition [g/yr]	Calculated	Volume 3, Appendix J	33, 34, 35
L_{dif}	COPC load to water body due to dry vapor phase diffusion [g/yr]	Calculated	Volume 3, Appendix J	33, 34, 36
$L_{E(nw)}$	Highest annual average COPC load to water body due to soil erosion [g/yr]	Calculated	Volume 3, Appendix J	33, 39

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
$L_{E(tw)}$	Average COPC load to water body due to soil erosion over the exposure duration [g/yr]	Calculated	Volume 3, Appendix J	34, 39
$L_{R(nw)}$	Highest annual average COPC load to water body due to runoff from pervious surfaces [g/yr]	Calculated	Volume 3, Appendix J	33, 38
$L_{R(tw)}$	Average COPC load to water body due to runoff from pervious surfaces over the exposure duration [g/yr]	Calculated	Volume 3, Appendix J	34, 38
L_{RI}	COPC load to water body due to runoff from impervious surfaces [g/yr]	Calculated	Volume 3, Appendix J	33, 34, 37
$L_{T(nw)}$	Highest annual average COPC load to water body [g/yr]	Calculated	Volume 3, Appendix J	26, 33
$L_{T(tw)}$	Average COPC load to water body over the exposure duration [g/yr]	Calculated	Volume 3, Appendix J	26, 34
$LADD_{dermal}$	Lifetime average daily COPC intake from dermal contact with soil, surface water, or sweat lodge vapor/mist [mg COPC/kg BW-d]	Calculated	Volume 3, Appendices L, M, N, O, & P	66
$LADD_{dermal(y)}$	Lifetime average daily COPC intake from dermal pathway y (soil, surface water, or sweat lodge vapor/mist) [mg COPC/kg BW-d]	Calculated	Volume 3, Appendices L, M, N, O, & P	75
$LADI_{dw}$	Lifetime average daily COPC intake from drinking water ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	62
$LADI_{gamefish}$	Lifetime average daily COPC intake from gamefish ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendix N & O	65
$LADI_{ing(x)}$	Lifetime average daily COPC intake from ingestion pathway x [soil, dw, vegetation, produce, beef, milk, goat, egg, chicken, fish, game, fowl] [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	74
$LADI_{inh}$	Lifetime average daily COPC intake from inhalation of ambient air [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	59
$LADI_{inh(sl)}$	Lifetime average daily COPC intake from inhalation of sweat lodge vapor/mist [mg COPC/kg BW-d]	Calculated	Volume 3, Appendix O	60
$LADI_{inh(z)}$	Lifetime average daily COPC intake from inhalation of z (ambient air or sweat lodge vapor/mist) [mg COPC/kg BW-d]	Calculated	Volume 3, Appendices L, M, N, O, & P	73
$LADI_{k}$	Lifetime average daily COPC intake from animal tissue *k* (beef, milk, goat, egg, chicken, game, fowl) ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendix M & O	64
$LADI_{produce}$	Lifetime average daily COPC intake from native vegetation or produce ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	63

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
$LADI_{soil}$	Lifetime average daily COPC intake from soil ingestion [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	61
LECR	Total lifetime excess cancer risk for all COPCs from inhalation, ingestion, and dermal exposure pathways [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	77
$LECR_{dermal(y)}$	Lifetime excess cancer risk for COPC from dermal pathway y (soil, surface water, sweat lodge vapor/mist) [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	75, 76
$LECR_{ing(x)}$	Lifetime excess cancer risk for COPC from ingestion pathway x (soil, dw, vegetation, produce, beef, milk, goat, egg, chicken, fish, game, fowl) [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	74, 76
$LECR_{inh(z)}$	Lifetime excess cancer risk for COPC from inhalation pathway z (ambient air, sweat lodge vapor/mist) [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	73, 76
LS	USLE length-slope factor [unitless]	EPL-Specific	Volume 3, Appendix B	43
lsc	Apparent thickness of stratum corneum in population [cm]	Population-Specific	Volume 3, Appendix D	52
m_{nw}	Highest annual average maternal daily intake of dioxin-like compounds [mg COPC/kg BW-day]	Calculated	Volume 3, Appendices L, M, N, O, & P	57, 58
MF	Metabolism factor [unitless]	COPC-Specific	Volume 3, Appendix C	21, 22, 23
MW	Molecular weight [g/mole]	COPC-Specific	Volume 3, Appendix C	52
NVws	Volume of surface water from exposure point location that is needed to produce 100 percent saturation in a sweat lodge [L]	Calculated	Volume 3, Appendix F	55, 56
OC_{sed}	Fraction of organic carbon in bottom sediment [unitless]	EPL-Specific	Volume 3, Appendix B	32
P	Average annual precipitation [cm/yr]	Site-Specific	Volume 3, Appendix B	9
$P_{age(nw)}$	Highest annual average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	14, 63
$P_{age(tw)}$	Average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	15, 63
$P_{age(x)}$	Highest annual average COPC concentration in above ground exposed plant (forage) ingested by animal or Average COPC concentration in above ground exposed plant (forage) ingested by animal over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	21, 22, 23,

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
$P_{agp(nw)}$	Highest annual average COPC concentration in above ground protected plant (native vegetation, protected produce or grain) [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	16, 63
$P_{agp(tw)}$	Average COPC concentration in above ground protected plant (native vegetation, protected produce or grain) over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	16, 63
$P_{agp(x)}$	Highest annual average COPC concentration in above ground protected plant (grain) ingested by animal or Average COPC concentration in above ground protected plant (grain) ingested by animal over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	21, 22, 24, 25
$P_{bg(nw)}$	Highest annual average COPC concentration in below ground native vegetation or produce [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	17, 63
$P_{bg(tw)}$	Average COPC concentration in below ground native vegetation or produce over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	17, 63
Pd_{age}	COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to direct deposition [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	14, 15, 18
PF	USLE supporting practice factor [unitless]	EPL-Specific	Volume 3, Appendix B	43
$PLECR_{dermal}$	Lifetime excess cancer risk for all COPCs *i* across dermal pathway [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	76, 77
$PLECR_{ing}$	Lifetime excess cancer risk for all COPCs *i* across ingestion pathway [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	76, 77
$PLECR_{inh}$	Lifetime excess cancer risk for all COPCs *i* across inhalation pathway [unitless]	Calculated	Volume 3, Appendices L, M, N, O, & P	76, 77
$Pr_{age(nw)}$	Highest annual average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to root uptake [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	14, 20
$Pr_{age(tw)}$	Average COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to root uptake over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	15, 20
$Pr_{agp(nw)}$	Highest annual average COPC concentration in above ground protected plant (native vegetation, protected produce or grain) due to root uptake [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	16

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
$Pr_{agp(tw)}$	Average COPC concentration in above ground protected plant (native vegetation, protected produce or grain) due to root uptake over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	16
$Pr_{bg(nw)}$	Highest annual average COPC concentration in below ground native vegetation or produce due to root uptake [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	17
$Pr_{bg(tw)}$	Average COPC concentration in below ground native vegetation or produce due to root uptake over the exposure duration [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	17
Pv_{age}	COPC concentration in above ground exposed plant (native vegetation, exposed produce, or forage) due to air-to-plant transfer [mg COPC/kg DW]	Calculated	Volume 3, Appendix H	14, 15, 19
Q	COPC emission rate [g/s], annual or hourly average	COPC-Specific	Volume 2 (year); Volume 3, Appendix F (hour)	1, 2
Q_{ops}	COPC emission rate adjusted for the assumed or actual number of annual hours of operation [g/s]	COPC-Specific	Volume 3, Appendix F	1, 5, 6, 18, 19, 35, 36, 37
Qp_{age}	Quantity of above ground exposed plant (forage) ingested by animal per day [kg DW/day]	Biota-Specific	Volume 3, Appendix B	21, 22, 23,
Qp_{agp}	Quantity of above ground protected plant (grain) ingested by animal per day [kg DW/day]	Biota - Specific	Volume 3, Appendix B	21, 22, 24, 25
Qs	Quantity of soil ingested by animal per day, [kg/day]	Biota - Specific	Volume 3, Appendix B	21 - 25
R	Universal gas constant [atm-m^3/mol-K]	EPL-Specific	Volume 3, Appendix B	11, 36, 40
RCF	Root concentration factor [(µg COPC/g DW plant)/(µg COPC/mL soil water) or unitless]	COPC-Specific	Volume 3, Appendix C	17
RF	USLE rainfall (or erosivity) factor [(yr)$^{-1}$]	EPL-Specific	Volume 3, Appendix B	43
RfC	Reference concentration [mg/m^3]	COPC-specific	Volume 3, Appendix C	72
RfD_d	Dermal reference dose [mg/kg-day]	COPC-specific	Volume 3, Appendix C	69
RfD_{inh}	Inhalation reference dose [mg/kg-day]	COPC-specific	Volume 3, Appendix C	67, 72
RfD_o	Oral reference dose [mg/kg-day]	COPC-specific	Volume 3, Appendix C	68
RO	Average annual surface runoff from pervious areas [cm/yr]	EPL-Specific	Volume 3, Appendix B	8, 9, 38

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
Rp	Interception fraction of the edible portion of plant [unitless]	Biota-Specific	Volume 3, Appendix B	18
rs	Radius of a sweat lodge that receives surface water from exposure point location [cm]	Population-Specific	Volume 3, Appendix D	54, 55, 56
SA	Skin surface area available for dermal contact [cm^2]	Population Specific	Volume 3, Appendix D	66
SD	Watershed sediment delivery ratio [unitless]	Calculated	Volume 3, Appendix J	39, 44, 49
t_{event}	Dermal contact event duration [hr/event]	Population-Specific	Volume 3, Appendix D	51
t^*	Time for COPC to reach steady state in population; in relation to exposure via dermal contact with water pathways [hr]	Calculated	Volume 3, Appendices L, M, N, O, & P	51, 53
T_1	Time period at beginning of deposition [yrs]	Source-Specific	Volume 3, Appendix B	4, 15, 34
T_a	Temperature of air [K]	EPL-Specific	Volume 3, Appendix B	11
T_{wk}	Water body temperature [K]	EPL-Specific	Volume 3, Appendix B	36, 40
tD	Time period over which deposition occurs [yrs]	Source-Specific	Volume 3, Appendix B	3, 4, 15, 34
Tp	Length of plant exposure to deposition per harvest of edible portion of plant [yr]	Biota-Specific	Volume 3, Appendix B	18
TSS	Total suspended solids concentration [mg/L]	EPL-Specific	Volume 3, Appendix B	28, 45, 48, 49
u	Current velocity [m/s]	EPL-Specific	Volume 3, Appendix B	41
URF	Inhalation unit risk factor [$(\mu g/m^3)^{-1}$]	COPC-specific	Volume 3, Appendix C	78
Vf_x	Average volumetric flow rate through water body [m^3/yr]	EPL-Specific	Volume 3, Appendix B	26, 49
VG_{agx} *indexed as:* VG_{ag} VG_{tp}	Empirical correction factor for above ground exposed plant (native vegetation, exposed produce, or forage) [unitless]	COPC-Specific	Volume 3, Appendix C	19
$VG_{rootveg}$	Empirical correction factor for below ground produce [unitless]	COPC-Specific	Volume 3, Appendix C	17
Vws	Volume of surface water from exposure point location that is used in a sweat lodge [L]	EPL-Specific	Volume 3, Appendix B	54, 55
W	Average annual wind speed [m/s]	EPL-Specific	Volume 3, Appendix B	41, 42
X_e	Unit soil loss due to water erosion [kg/m^2-yr]	Calculated	Volume 3, Appendix J	39, 43, 49
Yp	Yield or standing crop biomass of edible portion of plant (productivity) [kg DW/m^2]	Biota-Specific	Volume 3, Appendix B	18

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
Z_s	Soil mixing zone depth [cm]	EPL-Specific	Volume 3, Appendix B	5, 6, 8, 9, 11, 12
1E-06	[g/µg]	Units Conversion Factor	—	36
1E-06	[kg/mg]	Units Conversion Factor	—	28, 45, 48, 49, 50
1E-04		Units Conversion Factor	—	41
1E-03	[L/cm^3]	Units Conversion Factor	—	51, 54, 56
0.001	[g-kg/mg-kg]	Units Conversion Factor	—	39
0.001	[mg/µg]	Units Conversion Factor	—	59, 79
0.01	[kg-cm^2-g/mg-m^2-g]	Units Conversion Factor	—	38
0.693	Natural log of 2	Constant	—	57
1	[kg/L]	Units Conversion Factor	—	17
100	[mg-cm^2/kg-cm^2]	Units Conversion Factor	—	5, 6
365	[days/yr]	Units Conversion Factor	—	59 – 66
907.18	[kg/ton]	Units Conversion Factor	—	43
1E+03	[g/kg]	Units Conversion Factor	—	49
1000	[mg/g]	Units Conversion Factor	—	18
4047	[m^2/acre]	Units Conversion Factor	—	43
1E+06	[cm^3/m^3]	Units Conversion Factor	—	19, 55

Parameter	Definition [Units]	Type	Cross-References	
			Values/Sources	Equations
3.1536E+07	[s/yr]	Units Conversion Factor	—	11, 41, 42
1E+09	[pg/mg]	Units Conversion Factor	—	57

** Parameter types**:**
Air-Modeled = estimated COPC-specific parameter from the air dispersion model.
Biota-specific = parameter with values specific to a food item consumed by a receptor
Calculated = estimated COPC-specific parameter from the use of risk assessment equations.
EPL-Specific = exposure point location (EPL) parameter with values that may vary by attributes of the EPL.
Population-Specific = parameter with values specific to the receptor population.
COPC-Specific = parameter with values that are theoretically unique to the COPC.
Source-Specific = parameter with values specific to the source.
Units Conversion Factor = parameter used to convert units.

APPENDIX H – Ecological Risk Equations

See Appendix B and F of the 1999 EPA Screening Level Ecological Risk Assessment Protocol.