APPENDIX A
INDICATOR HAZARDOUS SUBSTANCES SCREENING
PASCO LANDFILL NPL SITE

Prepared for

Industrial Waste Area Generator Group III

Prepared by

Anchor QEA, LLC

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August 2017

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MEMORANDUM

To:	Project File	**Date:**	September 25, 2013
From:	Halah Voges, Anchor QEA, LLC	**Project:**	100722-01.01
Re:	Indicator Hazardous Substances Screening		

Indicator Hazardous Substances (IHS) analysis is the process of identifying those site contaminants that pose the largest threat to human health and the environment. The process for selection of IHSs is discussed in Washington Administrative Code (WAC) 172-340-703. An IHS analysis was previously conducted by the Washington State Department of Ecology (Ecology) in 2007 and became the basis for development of the 2007 draft cleanup levels for the Pasco Sanitary Landfill National Priorities List (NPL) Site (Site).

The process was refined in discussions between the Site potentially liable persons and Ecology as presented by Ecology in the February 8, 2012 letter on general guidance on IHS selection and cleanup level development. The process was further refined in response to comments from Ecology on the December 2012 draft of the Pasco Landfill NPL Site Focused Feasibility Study Work Plan.

The analysis presented herein follows a similar multi-tier process developed by Ecology in 2007. The analysis includes the following:

- Identification of the frequency of detection of hazardous substances in Site ground water based on:
  - Data from the Site remedial investigations (RI) and monitoring through 2012 for compounds that may be affected by the landfill gas (LFG) control system at the Municipal Solid Waste Landfill or the soil vapor extraction (SVE) system at Zone A of the Industrial waste area
  - Data from the interim action (IA) performance evaluations from 2002 through 2012 for those compounds considered to be not substantially affected by the LFG control and SVE systems

- Maximum concentration in each set of data
- Screening for maximum concentrations relative to ground water Method B formula values or maximum concentration levels in Ecology's Cleanup Levels and Risk Calculations (CLARC) database. Those compounds detected at monitoring well MW-54I were also screened against relevant surface water criteria in the CLARC database.

The results of the IHS analysis are presented in Table 1. The table contains compounds that have been detected in Site ground water in either the RI or IA monitoring periods and have maximum concentration levels or Model Toxics Control Act (MTCA) Method B values given in the CLARC database.

Compounds carried forward as IHSs had a frequency of detection of at least 5 percent and at least one exceedance of a screening level. Compounds with a frequency of detection between 2 and 5 percent were also examined.

TABLE

Table 1
Screening for Ground Water Indicator Hazardous Substances

Chemical Type	Compound	Screening Level[1] (µg/L)				Number of Samples	Number of Detections	Frequency of Detection (%)	Maximum Concentration	Number of Exceedances	Potential Chemical of Concern
		Ground Water		Surface Water							
		Level	Criteria	Level	Criteria						
PAHs (Not affected by interim actions except for capping, therefore screened against ground water monitoring data from 2002-2012)											
	1-Methylnaphthalene	1.5				26	0	0.0		0	No
	2-Methylnaphthalene	32				228	0	0.0		0	No
	Acenaphthene	960				228	0	0.0		0	No
	Anthracene	4800				228	0	0.0		0	No
	Benzo(a)anthracene	0.12				265	2	0.8	0.051	0	No
	Benzo(a)pyrene	0.012				269	1	0.4	0.044	1	No
	Benzo(b)fluoranthene	0.12				150	1	0.7	0.046	0	No
	Benzo(k)fluoranthene	1.2				150	3	2.0	0.045	0	No
	Chrysene	12				265	2	0.8	0.056	0	No
	Dibenzo(a,h)anthracene	0.012				265	4	1.5	0.048	4	No
	Fluoranthene	640				228	0	0.0		0	No
	Fluorene	640				228	0	0.0		0	No
	Indeno(1,2,3-c,d)pyrene	0.12				265	7	2.6	0.057	0	No
	Naphthalene	160				3813	61	1.6	36	0	No
	Pyrene	480				228	0	0.0		0	No
SVOCs (Not affected by interim actions except for capping, therefore screened against ground water monitoring data from 2002-2012)											
	1,2,4-Trichlorobenzene	1.5				3813	23	0.6	6	19	No
	1,2-Dichlorobenzene	720				3813	107	2.8	15	0	No
	2,2'-Oxybis (1-chloropropane)	0.63				115	0	0.0		0	No
	2,3,4,6-Tetrachlorophenol	480				26	0	0.0		0	No
	2,4,5-Trichlorophenol	800				228	0	0.0		0	No
	2,4,6-Trichlorophenol	4.0				228	0	0.0		0	No
	2,4-Dichlorophenol	24				228	0	0.0		0	No
	2,4-Dimethylphenol	160				228	0	0.0		0	No
	2,4-Dinitrophenol	32				228	0	0.0		0	No
	2,4-Dinitrotoluene	32				228	0	0.0		0	No
	2,6-Dinitrotoluene	16				228	0	0.0		0	No
	2-Chloronaphthalene	640				228	0	0.0		0	No
	2-Chlorophenol	40				228	0	0.0		0	No
	2-Methylphenol (o-Cresol)	400				228	1	0.4	19	0	No
	2-Nitroaniline	160				228	0	0.0		0	No
	3,3'-Dichlorobenzidine	0.19				202	0	0.0		0	No
	4-Chloroaniline	0.22				228	0	0.0		0	No
	Aniline	7.7				228	0	0.0		0	No
	Azobenzene	0.80				26	0	0.0		0	No
	Benzoic acid	64000				228	2	0.9	30.5	0	No
	Benzyl alcohol	800				228	1	0.4	12.2	0	No
	bis(2-Chloroethyl)ether	0.040				254	0	0.0		0	No
	Bis(2-ethylhexyl) phthalate	6.3				228	1	0.4	138	1	No
	Butylbenzyl phthalate	46				228	0	0.0		0	No
	Dibenzofuran	16				228	0	0.0		0	No
	Diethyl phthalate	12800				228	0	0.0		0	No
	Di-n-butyl phthalate	1600				228	0	0.0		0	No
	Hexachlorobenzene	0.055				254	0	0.0		0	No
	Hexachlorocyclopentadiene	48				228	0	0.0		0	No
	Hexachloroethane	3.1				228	0	0.0		0	No
	Isophorone	46				228	0	0.0		0	No
	Nitrobenzene	16				228	0	0.0		0	No
	N-Nitrosodimethylamine	0.00086				26	0	0.0		0	No
	Pentachlorophenol	0.22				350	0	0.0		0	No
	Phenol	2400				228	0	0.0		0	No
	Pyridine	8.0				26	0	0.0		0	No

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Chemical Type	Compound	Screening Level[1] (µg/L)				Number of Samples	Number of Detections	Frequency of Detection (%)	Maximum Concentration	Number of Exceedances	Potential Chemical of Concern
		Ground Water		Surface Water							
		Level	Criteria	Level	Criteria						
VOCs (Screened against RI data and ground water monitoring)											
	1,1,1,2-Tetrachloroethane	1.7				4857	1	0.0	0.11	0	No
	1,1,1-Trichloroethane	200	MCL			4927	710	14.4	950	25	Yes
	1,1,2,2-Tetrachloroethane	0.22				4945	5	0.1	0.251	1	No
	1,1,2-Trichloroethane	5.0	MCL			4901	169	3.4	9	4	Yes
	1,1,2-Trichlorotrifluoroethane	240000				44	15	34.1	1440	0	No
	1,1-Dichloroethane	1600				4930	1521	30.9	830	0	No
	1,1-Dichloroethene			0.057	Human health - 40 CFR 131	6249	1065	17.0	250	845	Yes
	1,2,3-Trichloropropane	0.0015				4857	2	0.0	6.6	2	No
	1,2-Dibromo-3-chloropropane	0.055				4860	0	0.0		0	No
	1,2-Dibromoethane (Ethylene dibromide)	0.022				4921	1	0.0	0.021	0	No
	1,2-Dichloroethane			0.38	Human health - 40 CFR 131	5329	1493	28.0	460	1220	Yes
	1,2-Dichloroethene	72				41	7	17.1	170	3	No
	1,2-Dichloroethene, cis-	16				4887	2046	41.9	3200	648	Yes
	1,2-Dichloroethene, trans-	160				4889	145	3.0	110	0	No
	1,3,5-Trimethylbenzene (Mesitylene)	80				4316	105	2.4	63	0	No
	1,4-Dioxane	0.44				11	0	0.0		0	No
	2-Butanone (MEK)	4800				4915	52	1.1	38000	2	No
	2-Chlorotoluene	160				4315	1	0.0	2	0	No
	Acetone	7200				4901	118	2.4	20000	1	Yes
	Acrolein	4				918	0	0.0		0	No
	Acrylonitrile	0.081				919	7	0.8	0.85	3	No
	Benzene	5.0	MCL			5386	292	5.4	51	86	Yes
	Bromodichloromethane	0.71				4901	0	0.0		0	No
	Bromoform (Tribromomethane)	5.5				4901	2	0.0	0.807	0	No
	Bromomethane (Methyl Bromide)	11.2				4901	2	0.0	1.7	0	No
	Carbon disulfide	800				4901	67	1.4	22	0	No
	Carbon tetrachloride	0.63				4945	34	0.7	83	15	No
	Chlorobenzene	160				4908	44	0.9	5	0	No
	Chloroform	80				4901	460	9.4	86	1	Yes
	Dibromochloromethane	0.52				4899	2	0.0	16	2	No
	Dibromomethane	80				4858	1	0.0	13	0	No
	Dichlorodifluoromethane	1600				1412	83	5.9	103	0	No
	Methylene chloride	5.0	MCL			4901	237	4.8	360	103	Yes
	Ethylbenzene	800				4904	149	3.0	2070	1	Yes
	Hexachlorobutadiene	0.56				4811	2	0.0	1	1	No
	Isopropylbenzene (Cumene)	800				4316	59	1.4	11	0	No
	m,p-Xylene	1600				1447	20	1.4	880	0	No
	Methyl isobutyl ketone (MIBK)	640				4915	48	1.0	1300	2	No
	m-Xylene	1600				47	1	2.1	8	0	No
	n-Propylbenzene	800				4316	80	1.9	26	0	No
	o-Xylene	1600				4877	203	4.2	540	0	No
	p-Xylene	1600				44	1	2.3	4	0	No
	Styrene	1600				4901	19	0.4	46	0	No
	Tetrachloroethene (PCE)			0.69	Human health - Clean Water Act	5544	1743	31.4	74	969	Yes
	Toluene	640				4919	225	4.6	3400	38	Yes
	Total xylenes	1600				3424	141	4.1	1500	0	No
	Trichloroethene (TCE)			2.5	Human health - Clean Water Act	5520	2392	43.3	280	937	Yes
	Trichlorofluoromethane	2400				4860	111	2.3	47	0	No
	Vinyl acetate	8000				1534	1	0.1	0.054	0	No
	Vinyl chloride	0.29	Method B carcingen adjusted for MCL			6267	693	11.1	31	209	Yes

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Screening for Ground Water Indicator Hazardous Substances

Chemical Type	Compound	Screening Level[1] (µg/L)				Number of Samples	Number of Detections	Frequency of Detection (%)	Maximum Concentration	Number of Exceedances	Potential Chemical of Concern
		Ground Water		Surface Water							
		Level	Criteria	Level	Criteria						
Pesticides/Herbicides (Not affected by interim actions except for capping, therefore screened against ground water monitoring data from 2002-2012)											
	2,2-Dichloropropionic acid (Dalapon)	240				162	0	0.0		0	No
	2,4-D (2,4-Dichlorophenoxyacetic acid)	160				162	0	0.0		0	No
	2,4-DB (2,4-D derivative)	128				162	0	0.0		0	No
	Dicamba	480				162	0	0.0		0	No
	MCPA	8				162	0	0.0		0	No
	Mecoprop (MCPP)	16				166	0	0.0		0	No
Chromium (Not affected by interim actions except for capping, therefore screened against ground water monitoring data from 2002-2012)											
	Chromium	100				816	656	80.4	785	17	Yes
	Chromium VI	48				267	15	5.6	23	0	No

Notes:
1) MTCA Method B Standard Formula Values were used except as noted
MCL: Maximum Concentration Limit

Compounds with frequency of detection between 2 and 5 percent and at least one exceedance of the screening level

Compounds with frequency of detection greater than 5 percent and at least one exceedance of the screening level

APPENDIX A, ATTACHMENT A
ADDENDUM TO THE INDICATOR HAZARDOUS SUBSTANCES SCREENING

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MEMORANDUM

To:	Project File	**Date:**	August 2017
From:	Michael Riley, Anchor QEA, LLC	**Project:**	100722-01.07
Re:	Addendum to the Indicator Hazardous Substances Screening		

An Indicator Hazardous Substances (IHS) analysis was conducted for the Draft Focused Feasibility Study (FFS) to identify the site contaminants that pose the largest threat to human health and the environment. In comments on the Draft FFS, the Washington State Department of Ecology (Ecology) requested that the IHS analysis include reporting limits of various data sets and analytes and identify the percentage of reported non-detect values that exceeded current Model Toxics Control Act (MTCA) Method B cleanup levels (Ecology Comment 124, last sentence, and Comment 125). This addendum to the IHS analysis has been prepared in response to those comments.

As is well known in the environmental field, laboratory methods have improved substantially over the years, achieving lower detection limits and higher accuracy over time. Similarly, MTCA Method B levels have changed over time, with many levels substantially lower than those in place during initial U.S. Environmental Protection Agency (EPA) ground water investigations in the 1980s and the site remedial investigations in the 1990s.

In 2008, to provide a more robust and defensible determination of ground water quality relative to MTCA Method B levels, the potentially liable persons (PLPs) in cooperation with Ecology implemented analytical methods with detection limits lower than MTCA Method B values for the site chemicals of concern. The laboratory methods and reporting limits were further refined in 2012 and 2017.

To address Ecology's comments regarding the IHS analysis and detection limits, ground water monitoring laboratory detection limits in use since 2008 are tabulated in Table 1 and show that for the greater majority of compounds, reporting limits are below MTCA Method B ground water cleanup levels as well as the draft cleanup levels presented in the FFS. This provides the public with information on current ground water monitoring and

analytical methods and assurance that these methods can identify exceedances of MTCA Method B levels and therefore are protective of human health and the environment.

TABLE

Table 4
Analytical Methods, Analytes, and Reporting Limits

Analyte	Reporting Limit (µg/L)			MTCA Method B or dCUL (µg/L)
	2008	2012	2017	
VOCs - EPA Method 8260 SIM				
1,1-Dichloroethene	0.05	0.020	0.020	0.057
1,1,2,2-Tetrachloroethane[1]	1.0	0.220	0.200	0.219
1,2-Dibromo 3-chloropropane[1]	5.0	0.100	0.100	0.055
1,2-Dibromoethane[1]	1.0	0.024	0.020	0.022
1,2-Dichloroethane	0.02	0.014	0.020	0.38
1,2,3-Trichloropropane[1]	1.0	0.020	0.020	0.001
Benzene	0.02	0.028	0.028	0.79
Tetrachloroethylene	0.02	0.050	0.200	0.69
Trichloroethene	0.02	0.053	0.053	2.5
Vinyl Chloride	0.02	0.032	0.032	0.069
VOCs - EPA Method 8260				
1,1-Dichloroethane	1.0	2.0	2.0	7.675
1,1,1-Trichloroethane	1.0	2.0	2.0	200
1,1,1,2-Tetrachloroethane	1.0	1.68	1.68	1.683
1,1,2-Trichloroethane	1.0	0.77	0.77	0.77
1,2-Dichlorobenzene	1.0	2.0	2.0	720
1,2-Dichloropropane	1.0	0.64	0.64	1.215
1,2,4-Trichlorobenzene	1.0	2.0	2.0	1.509
1,3,5-Trimethylbenzene	1.0	2.0	2.0	80
1,4-Dichlorobenzene	1.0	1.82	1.82	8.102
Acetone	10	25	25	7200
Acrylonitrile	1.0	10	10	0.08
Bromodichloromethane	1.0	0.71	0.71	0.71
Bromoform	1.0	2.0	2.0	5.54
Bromomethane	2.0	2.0	2.0	11.20
Carbon Disulfide	1.0	2.0	2.0	800
Carbon Tetrachloride	1.0	0.34	0.34	0.63
Chlorobenzene	1.0	2.0	2.0	160
Chloroform	1.0	2.0	2.0	1.41
cis-1,2-Dichloroethene	1.0	2.0	2.0	16
Dibromochloromethane	1.0	0.52	0.52	0.52
Dichlorodifluoromethane (CFC-12)	1.0	2.0	2.0	1600
Ethylbenzene	1.0	2.0	2.0	800
Hexachlorobutadiene	1.0	0.56	0.56	0.56
Isopropylbenzene (cumene)	1.0	2.0	2.0	800
m,p-Xylene	2.0	4.0	4.0	1600
Methyl T-Butyl Ether	1.0	2.0	2.0	24.31
Methylene Chloride	5.0	5.0	5.0	5.0

Table 4
Analytical Methods, Analytes, and Reporting Limits

Analyte	Reporting Limit (µg/L)			MTCA Method B or dCUL (µg/L)
	2008	2012	2017	
n-Butylbenzene	1.0	2.0	2.0	400
n-Propyl Benzene	1.0	2.0	2.0	800
Naphthalene	1.0	2.0	2.0	160
o-Xylene	1.0	2.0	2.0	1600
s-Butyl Benzene	1.0	2.0	2.0	800
Styrene	1.0	1.46	1.46	1600
T-Butyl Benzene	1.0	2.0	2.0	800
Toluene	1.0	2.0	2.0	615
Trichlorofluoromethane (CFC-11)	1.0	2.0	2.0	2400
SVOCs - EPA Method 8270 SIM[2]				
Benzo[A]Anthracene	10	0.02	0.02	0.12
Benzo[A]Pyrene	10	0.0288	0.0288	0.01
Benzo[B]Fluoranthene	10	0.03	0.03	0.12
Benzo[K]Fluoranthene	10	0.0212	0.0212	1.20
Bis(2-Chloroethyl)Ether	10	0.04	0.04	0.04
Chrysene	10	0.02	0.02	11.99
Dibenz[A,H]Anthracene	10	0.02	0.02	0.01
Hexachlorobenzene	10	0.05	0.05	0.05
Hexachlorobutadiene	10	0.56	0.56	0.56
Indeno[1,2,3-Cd]Pyrene	10	0.02	0.02	0.12
Pentachlorophenol	10	0.5	0.5	0.22
SVOCs - EPA Method 8270				
1-Methylnaphthalene	10	2.0	0.02	1.51
1,2-Dichlorobenzene	10	2.0	2.0	720
1,2,4-Trichlorobenzene	10	2.0	2.0	1.51
1,4-Dichlorobenzene	10	1.82	1.82	8.10
2-Chlorophenol	10	2.0	2.0	40
2-Methylnaphthalene	10	2.0	2.0	32
2-Nitroaniline	10	2.0	2.0	160
2,3,4,6-Tetrachlorophenol	10	2.0	2.0	480
2,4-Dichlorophenol	10	2.0	2.0	24
2,4-Dimethylphenol	10	2.0	2.0	160
2,4-Dinitrophenol	20	10	10	32
2,4-Dinitrotoluene	10	2.0	2.0	0.28
2,4,5-Trichlorophenol	10	2.0	2.0	800
2,4,6-Trichlorophenol	10	2.0	2.0	3.98
2,6-Dinitrotoluene	10	2.0	2.0	0.06
Acenaphthene	10	2.0	2.0	960
Aniline	10	5.0	5.0	7.68
Anthracene	10	2.0	2.0	4800

Table 4
Analytical Methods, Analytes, and Reporting Limits

Analyte	Reporting Limit (µg/L)			MTCA Method B or dCUL (µg/L)
	2008	2012	2017	
Azobenzene	10	2.0	2.0	0.80
Benzoic Acid	20	10	10	64000
Benzyl Alcohol	10	2.0	2.0	800
Bis(2-Ethylhexyl)Phthalate	50	2.0	2.0	6.25
Butylbenzylphthalate	10	2.0	2.0	46.05
Di-N-Octylphthalate	10	2.0	2.0	160
Dibenzofuran	10	2.0	2.0	16
Diethylphthalate	10	2.0	2.0	12800
Fluoranthene	10	2.0	2.0	640
Fluorene	10	2.0	2.0	640
Hexachlorocyclopentadiene	10	5.0	5.0	48
Hexachloroethane	10	2.0	2.0	1.09
Isophorone	10	2.0	2.0	46.05
N-Nitroso-Di-N-Propylamine	10	5.0	5.0	0.01
N-Nitrosodimethylamine	10	2.0	2.0	0.0009
N-Nitrosodiphenylamine	10	2.0	2.0	17.86
Naphthalene	10	2.0	2.0	160
Nitrobenzene	10	2.0	2.0	16
Phenol	10	2.0	2.0	2400
Pyrene	10	2.0	2.0	480
Pyridine	10	5.0	5.0	8
Herbicides - EPA Method 8151A				
4-(2,4-Dichlorophenoxy)butyric acid	1.0	0.04	0.04	128
Dicamba	0.10	0.04	0.04	480
Dinoseb	0.05	0.04	0.04	16
Pentachlorophenol[2]	10	0.04	0.08	0.219
Metals - EPA Method 6020 (ICP-MS)				
Total Chromium (Cr)	0.3	0.59	2.0	100
Chromium - EPA Method 7196				
Hexavalent Chromium	3.0	10	10	48

Notes:

1. Chemical analyzed by EPA Method 8260 prior to 2012.

2. Chemical analyzed by EPA Method 8270 prior to 2012.

µg/L = micrograms per liter

dCUL = Draft Cleanup Levels

EPA = U.S. Environmental Protection Agency

MTCA = Model Toxics Control Act

APPENDIX B
SITE WORKER DIRECT CONTACT RISK EVALUATION
PASCO LANDFILL NPL SITE

Prepared for

Industrial Waste Area Generator Group III

Prepared by

Anchor QEA, LLC

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August 2017

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MEMORANDUM

To:	Project File	**Date:**	August 26, 2013
From:	Dan Hennessey, Anchor QEA	**Project:**	100722-01.03
Re:	MTCA Evaluation of Potential Risks to Industrial Workers from Direct Contact Soil Exposure at Non-capped Areas of the Pasco Landfill		

Potential risk to industrial maintenance workers exposed to non-cap soil at the Pasco Landfill site were evaluated for the following chemicals of concern (COCs), which were previously established as the primary risk drivers:

- 1,1,1-Trichloroethane
- 1,1-Dichloroethene
- 1,2-Dichloroethane
- cis-1,2-Dichloroethene
- Benzene
- Dichloromethane (methylene chloride)
- Tetrachloroethene (PCE)
- Toluene
- Trichloroethene (TCE)
- Vinyl chloride

Soil sample data were obtained from the project database maintained by Environmental Partners, Inc. (EPI). Samples were identified for locations outside of established cap areas to assess potential exposure to site-workers via direct contact with soil outside of engineered caps. The Model Toxics Control Act (MTCA) soil point of compliance for industrial exposure scenarios is 15 feet below ground surface (bgs) (Washington Administrative Code [WAC] 173-34-745). Therefore, the database was queried to select samples identified as having been collected from intervals between 0 and 15 feet bgs. The maximum soil concentrations of the COCs were selected to represent the potential worst-case exposure scenario.

The maximum soil concentrations compared to MTCA Method C soil direct contact cleanup levels (WAC 173-340-745) queried from the Washington State Department of Ecology's (Ecology's) Cleanup Levels and Risk Calculation (CLARC) database (https://fortress.wa.gov/ecy/clarc/). Input parameters for the MTCA Method C soil direct contact cleanup levels are as follows:

- 70 kilograms (kg) average body weight (MTCA default value)
- 20 years' exposure duration (MTCA industrial exposure default value)
- 75 years' carcinogenic averaging time (MTCA default value)
- 20 years' non-carcinogenic averaging time (MTCA industrial exposure default value)
- 50 grams per day soil ingestion rate (MTCA industrial exposure default value)

The cancer potency factors and reference doses used were MTCA default values as reported by CLARC. The cleanup levels for the carcinogenic compounds, 1,2-dichloroethane, benzene, methylene chloride, PCE, and TCE, were based on a risk level of 1 in 1,000,000 ($1x10^{-6}$) excess lifetime cancer risk (ELCR). The non-carcinogenic cleanup levels were based on a hazard quotient (HQ) of 1. The site-specific ECLR or HQ associated with the maximum COC concentrations in site soils were calculated by applying the proportion of the MTCA Method C soil direct cleanup level and the maximum concentration to the MTCA risk levels. The corresponding site-specific ECLR and HQs are presented in Table 1.

Comparison of MTCA Method C soil direct contact cleanup levels to the maximum concentrations in the non-cap soil samples found that potential risk to industrial workers from this pathway is insignificant (Table 1). For all COCs, ECLRs were more than four orders of magnitude below the $1x10^{-6}$ risk threshold and the HQs were more than six orders of magnitude below the risk threshold of one. Therefore, direct contact exposure to site soils outside of the cap areas is unlikely to contribute any significant risk to site workers.

Table 1
Summary of Risk Screening Results for Soil Direct Contact Exposure to Industrial Workers at Non-capped Areas of the Pasco Landfill Site

Chemical of Concern (µg/kg)	Soil Method C Carcinogen Direct Contact Cleanup Level	Soil Method C Non-carcinogen Direct Contact Cleanup Level	Maximum Concentration or Detection Limit in Soil Samples 0 to 15 feet bgs	Excess Lifetime Cancer Risk (ELCR)	Non-Carcinogen Hazard Quotient (HQ)
1,1,1-Trichloroethane		7,000,000,000	10	NA	1E-09
1,1-Dichloroethene		175,000,000	10	NA	6E-08
1,2-Dichloroethane	1,442,308	70,000,000	10	6.93E-12	1E-07
1,2-Dichloroethene, cis-		7,000,000	10	NA	1E-06
Benzene	2,386,364	14,000,000	10	4.19E-12	7E-07
Dichloromethane (methylene chloride)	17,500,000	210,000,000	110	6.29E-12	5E-07
Tetrachloroethene (PCE)	62,500,000	21,000,000	10	1.60E-13	5E-07
Toluene		280,000,000	10	NA	4E-08
Trichloroethene (TCE)	2,800,000	1,750,000	10	3.57E-12	6E-06
Vinyl chloride		10,500,000	11	NA	1E-06

Notes:
µg/kg = microgram per kilogram
bgs = below ground surface

APPENDIX C
THREE-PHASE PARTITIONING ANALYSIS OF SITE SOILS
PASCO LANDFILL NPL SITE

Prepared for

Industrial Waste Area Generator Group III

Prepared by

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August 2017

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MEMORANDUM

To:	Halah Voges and Michael Riley Anchor QEA, LLC	**Date:**	August 31, 2017
From:	Sylian Rodriguez and Casey Janisch, Anchor QEA, LLC	**Project:**	Pasco Landfill NPL Site, 100722-01.07
Re:	Three-phase Partitioning Analysis of Site Soils		

INTRODUCTION

This appendix presents an analysis of contaminant migration in vadose zone soils at the Pasco Landfill Site (Site). The analysis is based on Washington Administrative Code (WAC) 17-340-747, Deriving Soil Concentrations for Groundwater Protection, to develop soil cleanup levels that are protective of ground water. The analysis uses the variable parameter three-phase partitioning model (WAC 173-340-747(5)). The approach is a soil to ground water partitioning analysis and transport due to infiltration based on local precipitation. As an infiltration-based model, this analysis applies to all areas of the Site that are not currently under lined covers. The variable parameter model is used to represent some Site-specific conditions, consistent with the Model Toxics Control Act (MTCA) as described below.

VARIABLE PARAMETER THREE-PHASE PARTITIONING MODEL

The general equation for this analysis is equation 747-1[1]:

$$C_s = C_w\,(UCF)DF\left(K_d + \frac{\theta_w+\theta_a H_{cc}}{\rho_b}\right) \qquad (1)$$

Where:

Cs = is the concentration of a compound in soil (micrograms per kilogram [µg/kg])

Cw = is the concentration of the compound in water (micrograms per liter [µg/L])

[1] Units are given in WAC 173-340-747(5). However, other units can be used as long as the units are internally consistent in an equation. For instance, equations that yield a dimensionless number can be in either English or SI units as long as the result is dimensionless.

UCF = is a conversion factor (1 in the present case as Cs and Cw have the same units for mass)
DF = is a dilution factor that is computed by Equation 747-3
Kd = is the soil-water partitioning partition coefficient, computed from Equation 747-2 (liters per kilogram [L/kg])
θw = is the water-filled porosity of the soil
θa = is the air-filled porosity of the soil
Hcc = is the Henry's law constant
Rb = is the soil dry bulk density (kg/L)

The soil-water partitioning coefficient (K_d) is computed from Equation 747-2 for hydrophobic organic compounds using Site-specific data for organic carbon (f_{oc}) in undisturbed Site soils:

$$K_d = K_{oc} * f_{oc} \quad (2)$$

Where:

Koc = is the organic carbon-water partitioning coefficient and is taken from Ecology's Cleanup Levels and Risk Calculations (CLARC) database. If no value was provided in CLARC, literature values were used in the computation (Mackay et al. 2000)

f_{oc} is the soil fraction of organic carbon from background testing, as a percentage

The dilution factor (DF) is computed from Equation 747-3:

$$DF = (Q_p + Q_a)/Q_p \quad (3)$$

Where:

Qp = is the flow rate of infiltrating water
Qa = is the flow rate of ground water flow

Parameters for the DF equation are provided by Equations 747-4 and 747-5.

$$Q_a = K * A * I \quad (4)$$

and

$$Q_p = L * W * Inf \quad (5)$$

Where:

K = is the hydraulic conductivity of the underlying aquifer
A = is the aquifer mixing zone
I = is the ground water gradient under the source area
L = is the length of the source area in the direction of ground water flow
W = is the width of the source area
Inf = is the annual infiltration rate

The hydraulic conductivity, the ground water gradient, and length of the source area are taken from Site-specific information. The aquifer mixing zone, width of the source area, and infiltration rate are prescribed in WAC 173-340-747(5). The aquifer mixing zone is stipulated to not exceed 5 meters. The width of the source zone is taken as 1 unit of length, which is a conservative assumption as it does not allow for dispersion along the edges of the aquifer mixing zone. The default infiltration rate for Eastern Washington is set at 25 percent of the average annual precipitation. This assumes no cap over the source area, which is consistent with the stipulation that the analysis should not consider surface caps, but it is not applicable to any areas where lined caps currently exist and are expected to remain in place with long-term cover replacement, as stipulated by Ecology.

Table 1 summarizes input parameter values and data sources for use in Equations 747-1 through 747-5.

ANALYSIS AND RESULT

Equation 747-1 is used to predict the concentration of a contaminant in soil that is protective of cleanup levels in ground water. In the present case, MTCA Method B formula values in CLARC for ground water were used to predict a corresponding concentration in soil. The soil concentrations were then compared to data from historical Site investigations and the results were expressed as an exceedance ratio. Values greater than 1 indicate Site soil concentrations that exceed soil concentrations predicted to be protective of ground water.

The analysis compares the maximum and average concentrations found in soils beneath the Site during the past investigations (EPI 2008, EPI 2011, AMEC 2012, etc.) to the soil concentrations predicted to be protective of ground water. Using the maximum value would predict a conservatively high concentration in ground water as the analysis assumes the concentration is found throughout the footprint of the Site.

The present analysis includes metals, volatile organic compounds (VOCs), pesticides, herbicides, polychlorinated biphenyls (PCBs), semivolatile organic compounds (SVOCs), and dioxins and furans. In addition, the analysis focused on compounds that had a frequency of detection of at least 5 percent. This resulted in 12 metals, 4 VOCs, 4 herbicides, 3 SVOCs, and 1 equivalent dioxin being included in the analysis. The equivalent dioxin is the summation of all dioxin and furan concentrations using Toxicity Equivalency Factors per MTCA regulation for mixtures of dioxins and furans (WAC 173-340-708(8)(d)). The input parameters and results of this analysis are presented in Tables 2a, 2b, and 2c.

The analysis showed that three compounds are expected to affect ground water at the average soil concentrations measured in the Site investigations. Using the maximum concentration as a conservative indicator of potential ground water impacts, one metal and two VOCs had exceedance ratios greater than 1. The highest exceedance ratio was calculated for arsenic using its maximum concentration. Methylene chloride and cis-1,2-dichloroethene (1,2-DCE) also had exceedance ratios greater than 1 when using their maximum concentrations, but much lower than for arsenic. However, the maximum concentration was approximately seven times greater for methylene chloride, three times greater for 1,2-DCE, and two times greater for arsenic than the average concentration for these compounds, indicating that using the maximum concentration is overly conservative. When using the average concentration, only arsenic and methylene chloride had an exceedance ratio greater than 1.

CONCLUSIONS

The three-phase partitioning analysis indicates that pesticides, herbicides, PAHs, PCBs, SVOCs, and dioxins and furans in soils beneath the Site are not likely to adversely affect ground water under uncapped conditions. Based on Site investigations, one metal and two VOCs resulted to have an exceedance ratio greater than 1 if the maximum concentration is

used, and only two compounds resulted in having exceedance ratios greater than 1 at the average concentrations. Based on this analysis, arsenic and methylene chloride could be included in the list of chemicals of concern (COC) for the Draft Final Focused Feasibility Study (FFS). However, as presented in the Draft Final FFS, methylene chloride is already a COC based on detected concentrations in ground water. Arsenic has not been identified with a defined waste source at the Site and the mean concentration of 7.3 mg/kg is below the natural background for eastern Washington (Ecology 1994); based on these conditions, it should not be included among Site COCs. Consequently, arsenic should not be considered a Site COC based on protection of ground water.

REFERENCES

AMEC, 2012. Soil Sampling Technical Memorandum, Additional Soil Sampling at Zone B of the Pasco Sanitary Landfill Site. Pasco, Washington. August 16, 2012.

Ecology, 1994. Natural Background Soil Metals Concentrations in Washington State. By Charles San Juan, Toxics Cleanup Program, Ecology publication No. 94-115.

EPI, 2008. *Revised Final Work Plan for Additional Interim Actions – Phase I.* Prepared for IWAG Group II. Submitted to the Washington State Department of Ecology. May 2008.

EPI, 2011. Phase II Additional Interim Actions Sub-Zone A Investigation and Downgradient Well Installation Report. Volume 1 of 2. September 30, 2011.

Mackay, D., S. Wan-Ying, and M. Kuo-Ching, 2000. Physical-Chemical Properties and Environmental Fate Handbook. Chapman & Hall/CRCnetBASE.

TABLES

Table 1

Summary of Input Parameters for the Three-phase Partitioning Model

Parameter	Description	Value Used	Units	Basis for Value Used
C_s	Concentration in soil	Varies	µg/kg	Maximum and average concentrations from Site investigations
UCF	Unit conversion factor	1	dimensionless	Concentration data for soil and water are both in micrograms
DF	Dilution factor	Computed	dimensionless	See parameters listed below for dilution factor calculation
K_d	Soil-water partitioning coefficient	Computed	L/kg	$K_d = K_{oc} * f_{oc}$
K_{oc}	Organic carbon-water partitioning coefficient	Varies	L/kg	Compound specific. Default values from the database or literature values if not in CLARC
f_{oc}	Soil fraction of organic carbon	0.011	dimensionless	Average of organic carbon data from Site background boring GB-1 for organic carbon measure at 440°C
θ_w	Water-filled porosity	0.30	dimensionless	Default value for unsaturated soils
θ_a	Air-filled porosity	0.13	dimensionless	Default value for unsaturated soils
H_{cc}	Henry's law constant		dimensionless	Compound specific. Default values from the CLARC database or zero if not provided
ρ_b	Soil dry bulk density	1.5	kg/L	Default value
Dilution Factor Parameters				
K	Hydraulic conductivity	1,200	feet/day	Phase II RI, Table 3.1
A	Aquifer mixing zone	16	feet	Default value of 5 meters
I	Ground water gradient	0.005	dimensionless	Average gradient across Site from water level contours in quarterly reports
L	Length of source area	5,600	feet	Longest distance across Site in the direction of ground water flow
W	Width of source area	1	foot	Default value
Inf	Annual average infiltration rate	0.16	feet/year	Default value based on infiltration as 25 percent of annual precipitation. Annual precipitation of 7.5 inches from the Phase II RI

Notes:
µg/kg = micrograms per kilogram
CLARC = Cleanup Levels and Risk Calculations
kg/L = kilograms per liter
L/kg = liters per kilogram
RI = Remedial Investigation

Table 2a
Input Coefficients for Three-phase Partitioning Analysis

				Ecology CLARC Database Parameters			
Analyte Type	**Chemical**	**K_d**	**Henry's Law Term**	**Henrys Law Constant, H_{cc} (unitless)**	**K_{oc} (Soil Organic Carbon-Water Partitioning Coefficient) (L/kg)**	**Ground Water, Method B, Carcinogen, Standard Formula Value (µg/L)**	**Ground Water, Method B, Non-carcinogen, Standard Formula Value (µg/L)**
MET	Antimony	45	-	0	-	Not Researched	6.4
MET	Arsenic	29	-	0	-	5.83E-02	4.8
MET	Barium	41	-	0	-	Not Researched	3200
MET	Beryllium	790	-	0	-	Not Researched	32
MET	Cadmium	67	-	0	-	Not Researched	8
MET	Chromium	19	-	0	-	Not Researched	50
MET	Copper	22	-	0	-	Not Researched	640
MET	Lead	10000	-	0	-	Not Researched	15
MET	Mercury	52	-	4.70E-01	-	Not Researched	2
MET	Nickel	65	-	0	-	Not Researched	320
MET	Silver	8	-	0	-	Not Researched	80
MET	Zinc	62	-	0	-	Not Researched	4800
VOC	1,2-Dichloroethene, cis-	0.39	0.2167	1.67E-01	3.55E+01	Not Researched	16
VOC	Acetone	0.01	0.200159	1.59E-03	5.75E-01	Not Researched	7200
VOC	Dichloromethane (Methylene chloride)	0.11	0.20898	8.98E-02	1.00E+01	2.19E+01	48
VOC	Toluene	1.54	0.2272	2.72E-01	1.40E+02	Not Researched	640
HERB	Mephanac (MCPA)	1.80	0.200027533	2.75E-04	1.64E+02	Not Researched	8
HERB	2,4-D (2,4-Dichlorophenoxyacetic acid)	0.46	0.200051154	5.12E-04	4.17E+01	Not Researched	160
HERB	2,4-DB (2,4-D derivative)	1.83	-	0	1.66E+02	Not Researched	160
HERB	Dichloroprop	1.07	0.2000269	2.69E-04	9.74E+01	Not Researched	160
SVOC	Bis(2-ethylhexyl) phthalate	1222.35	0.200000418	4.18E-06	1.11E+05	6.25	320
SVOC	Di-n-butyl phthalate	17.24	0.200000004	3.85E-08	1.57E+03	Not Researched	1600
SVOC	Butylbenzyl phthalate	151.21	0.20000517	5.17E-05	1.37E+04	46.1	3200
DIOX	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	13932.84	0.469146364	2.69E+00	1.27E+06	6.73077E-07	0.0000112

Notes:

Green-highlighted cells indicate that the MTCA Method A value was used as no Method B value was available in the CLARC database.

Blue-highlighted cells indicate no value was available in the Ecology CLARC database. Values were derived instead from averaged value in Mackay et al. (2000).

1. Kd computed using site-specific total organic carbon of 1.1% from data at background boring location GB-1.
2. Dichloroprop Method B value based on CLARC value for 2,4-D and 2,4-DB. No value was available in the Ecology CLARC database.
3. All Dioxins and Furans were considered a single hazardous substance as TCDD per MTCA 173-340-708(8)(d)

µg/L = micrograms per liter
CLARC = Cleanup Levels and Risk Calculations
DIOX = dioxin
H_{cc} = Henry's Law constant
HERB = herbicide
K_d = soil-water partitioning coefficient
K_{oc} = organic carbon-water partitioning coefficient
L/kg = liters per kilogram
MET = metals
MTCA = Model Toxics Control Act
SVOC = semivolatile organic compound
VOC = volatile organic compound

Table 2b
Dilution Factor Calculation for Three-phase Partitioning Analysis

Site-specific Dilution Factor for Soil Protection of Groundwater Cleanup Levels (WAC 173-340-747(5)(f))							
Using Eq. 747-3:							
DF = (Qp + Qa)/Qp	=	42	Maximum Dilution Factor				
Using Eq. 747-5:							
Qp= Volume of infiltrating groundwater	=	L x W x Inf			875	ft^3/yr	
		L=	Length of source area		5,600	ft	Longest distance across Site in direction of ground water flow
		W=	Unit width		1	ft	
		Inf=	0.25 x average annual precip		0.16	ft	MTCA default: 25% of average annual precipitation (7.5 inches per year, Phase II RI report, converted to ft/year)
Using Eq. 747-4:							
Qa= Ambient Groundwater Flow	=	K x A x I =			35,837	ft^3/yr	Maximum Ground Water Flow
		K=	Hydraulic Conductivity	1200 ft/d	438,000	ft/yr	Phase II RI, Table 3.1
		A=	5m =	16 ft			Maximum MTCA mixing zone
		I=	Groundwater gradient	0.005			Jan 2010: distance of 400 ft from 354.5 to 352.5 contours
				0.0054054			Apr 2010: 370 ft from 356 to 354 contours
				0.005			Jul 2010: 400 ft from 355.5 to 353.5 contours
				0.0045455			Oct 2010: 330 ft from 354 to 352.5 contours
					0.004987715	average	

Notes:
DF = dilution factor
ft = foot
ft/yr = feet per year
ft^3/yr = cubic feet per year
MTCA = Model Toxics Control Act
Qp = flow rate of infiltrating water
Qa = flow rate of ground water flow
RI = Remedial Investigation
WAC = Washington Administrative Code

Table 2c
Three-phase Partitioning Analysis Results

						Site-specific Dilution Factor (DF=42)		
Analyte Type	**Chemical**	**Maximum Detected Concentration (µg/kg)**	**Average Detected Concentration (µg/kg)**	**Detection Ratio**	**MTCA Method B (µg/L)**	**Soil Conc Protective of Groundwater [Cs] (µg/kg)**	**Maximum Exceedance Ratio**	**Average Exceedance Ratio**
MET	Antimony	6,000	2,210	0.26	6.4	12,100	0.50	0.18
MET	Arsenic	12,600	7,300	0.80	0.0583	71.0	177	103
MET	Barium	53,400	52,200	1.00	3200	5,530,000	0.010	0.01
MET	Beryllium	210	136	0.08	32	1,060,000	0.00020	0.00
MET	Cadmium	3,800	2,040	0.97	8	22,600	0.17	0.09
MET	Chromium	21,900	6,130	1.00	50	40,300	0.54	0.15
MET	Copper	30,900	13,600	1.00	640	596,000	0.052	0.023
MET	Lead	15,000	7,870	0.95	15	6,290,000	0.0024	0.0013
MET	Mercury	960	463	0.06	2	4,380	0.22	0.11
MET	Nickel	15,100	9,230	1.00	320	875,000	0.017	0.011
MET	Silver	2,500	1,290	0.95	80	28,500	0.088	0.045
MET	Zinc	79,200	39,600	1.00	4800	12,500,000	0.0063	0.0032
VOC	1,2-Dichloroethene, cis-	660	203	0.08	16	408	1.6	0.50
VOC	Acetone	2,300	738	0.24	7200	62,400	0.037	0.012
VOC	Dichloromethane (Methylene chloride)	2,300	338	0.25	21.9	293	7.8	1.2
VOC	Toluene	1,400	96.7	0.22	640	47,500	0.029	0.0020
HERB	Mephanac (MCPA)	11	6.42	0.12	8	671	0.016	0.010
HERB	2,4-D (2,4-Dichlorophenoxyacetic acid)	17	6.37	0.06	160	4,430	0.0038	0.0014
HERB	2,4-DB (2,4-D derivative)	22	10.3	0.07	160	13,600	0.0016	0.00076
HERB	Dichloroprop	7	4.4	0.06	160	8,540	0.0008	0.00052
SVOC	Bis(2-ethylhexyl) phthalate	520	173	0.13	6.25	321,000	0.0016	0.00054
SVOC	Di-n-butyl phthalate	3,000	938	0.92	1600	1,170,000	0.0026	0.00080
SVOC	Butylbenzyl phthalate	930	458	0.10	46.1	293,000	0.0032	0.0016
DIOX	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	0.165*	0.0394*	0.46**	6.73E-07	0.393	0.42	0.10

Notes:

Yellow-highlighted cells indicate an exceedance ratio greater than 1.

* Maximum and average concentrations are the sum of all dioxin and furan concentrations multiplied by Toxicity Equivalency Factors per WAC 173-340-900 Table 708-1

** Detection Ratio based on average number of detections for all dioxins and furans.

µg/kg = micrograms per kilogram
µg/L = micrograms per liter
Cs = concentration of a compound in soil
DIOX = dioxin
HERB = herbicide
MET = metal
MTCA = Model Toxics Control Act
SVOC = semivolatile organic compound
VOC = volatile organic compound
WAC = Washington Administrative Code