Attachment 1: Summary of Screening Thresholds and TRVs

Table 1. Summary of Aquatic Benthic Invertebrate Sediment Thresholds

Sediment COI	Sediment Threshold				Source of Selected Sediment Thresholds
	TEC[a]	TEL[b]	PEC[a]	PEL[b]	
Metals (mg/kg dw)					
Arsenic	9.79	**5.9**	33	**17**	Smith et al. (1996)
Cadmium	0.99	**0.596**	4.98	**3.53**	Smith et al. (1996)
Chromium	43.4	**37.3**	111	**90**	Smith et al. (1996)
Copper	**31.6**	35.7	**149**	197	MacDonald et al. (2000)
Lead	35.8	**35**	128	**91.3**	Smith et al. (1996)
Mercury	0.18	**0.174**	1.06	**0.486**	Smith et al. (1996)
Nickel	22.7	**18**	48.6	**36**	Smith et al. (1996)
Zinc	**121**	123	459	**315**	MacDonald et al. (2000); Smith et al. (1996)
PAHs (µg/kg dw)					
Anthracene	**57.2**	na	**845**	na	MacDonald et al. (2000)
Benzo(a)anthracene	108	**31.7**	1,050	**385**	Smith et al. (1996)
Benzo(a)pyrene	150	**31.9**	1,450	**782**	Smith et al. (1996)
Chrysene	166	**57.1**	1,290	**862**	Smith et al. (1996)
Dibenzo(a,h)anthracene	**33**	na	na	na	MacDonald et al. (2000)
Fluoranthene	423	**111**	**2,230**	2,355	Smith et al. (1996); MacDonald et al. (2000)
Fluorene	**77.4**	na	**536**	na	MacDonald et al. (2000)
Naphthalene	**176**	na	**561**	na	MacDonald et al. (2000)
Phenanthrene	204	**41.9**	1,170	**515**	Smith et al. (1996)
Pyrene	195	**53**	1,520	**875**	Smith et al. (1996)
Total PAHs	**1,610**	na	**22,800**	na	MacDonald et al. (2000)
PCBs(µg/kg dw)					
Total PCBs	59.8	**34.1**	676	**277**	Smith et al. (1996)
Pesticides (µg/kg dw)					
2,4'-DDD	4.88	**3.54**	28	**8.51**	Smith et al. (1996)
4,4'-DDD	4.88	**3.54**	28	**8.51**	Smith et al. (1996)
4,4'-DDE	3.16	**1.42**	31.3	**6.75**	Smith et al. (1996)
Total DDTs	**5.28**	7	**572**	4,450	MacDonald et al. (2000)
Chlordane	**3.24**	4.5	17.6	**8.9**	MacDonald et al. (2000); Smith et al. (1996)
Dieldrin	**1.9**	2.85	61.8	**6.67**	MacDonald et al. (2000); Smith et al. (1996)
Endrin	**2.22**	na	207	**62.4**	MacDonald et al. (2000); Smith et al. (1996)
Lindane (gamma-BHC)	2.37	**0.94**	4.99	**1.38**	Smith et al. (1996)
Heptachlor epoxide	2.47	**0.6**	16	**2.74**	Smith et al. (1996)

[a] TECs and PECs reported by MacDonald et al. (2000).

[b] TELs and PELs reported by Smith et al. (1996).

BHC – benzene hexachloride
COI – contaminant of interest
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
na – not available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
SSL – soil screening level
SVOC – semivolatile organic compound
TEC – threshold effects concentration
TEL – threshold effects level

Bold indicates selected soil thresholds (i.e., the lower of the TEC and TEL and the lower of the PEC and PEL).

Table 2. Summary of Surface Water Thresholds

Water COI	Water Threshold		Source
	Chronic	Acute	
Metals (µg/L)			
Arsenic (dissolved)	150	340	EPA AWQC (EPA 2009)
Barium (total)	4	110	Tier II (Suter and Tsao 1996)
Copper (dissolved)	1.3[a]	1.6[a]	EPA AWQC (EPA 2009)
VOCs (µg/L)			
Acetone	1,500	28,000	Tier II (Suter and Tsao 1996)

[a] AWQC values were hardness-adjusted based on the average Force Lake hardness (10.7 mg/L $CaCO_3$).

AWQC – ambient water quality criteria
COI – contaminant of interest
EPA – US Environmental Protection Agency
VOC – volatile organic compound

Table 3. Summary of Terrestrial Invertebrate Soil Thresholds

Soil COI	Soil Threshold Source			Source of Selected Soil Threshold
	EPA Eco-SSL[a]	ORNL[b]	DEQ 2001[c]	
Metals (mg/kg dw)				
Aluminum	na	na	**600**	DEQ (2001)
Antimony	**78**	na	na	Ecological-SSL (EPA 2005a)
Arsenic	na	**60**	**60**	DEQ (2001); Efroymson et al. (1997)
Barium	**330**	na	3,000	Ecological-SSL (EPA 2005b)
Beryllium	**40**	na	na	Ecological -SSL (EPA 2005c)
Cadmium	140	**20**	**20**	DEQ (2001); Efroymson et al. (1997)
Chromium	na	**0.4**[d]	**0.4**[d]	DEQ (2001); Efroymson et al. (1997)
Cobalt	na	na	**1,000**	DEQ (2001)
Copper	80	**50**	**50**	DEQ (2001); Efroymson et al. (1997)
Lead	1,700	**500**	**500**	DEQ (2001); Efroymson et al. (1997)
Manganese	450	na	**100**	DEQ (2001)
Mercury	na	**0.1**[e]	**0.1**[e]	DEQ (2001); Efroymson et al. (1997)
Nickel	280	**200**	**200**	DEQ (2001); Efroymson et al. (1997)
Selenium	**4.1**	70	70	Ecological-SSL (EPA 2007c)
Silver	na	na	**50**	DEQ (2001)
Zinc	**120**	200	200	Ecological-SSL (EPA 2007d)
PAHs (µg/kg dw)				
Total LPAHs	**29,000**	na	na	Ecological-SSL (EPA 2007b)
Total HPAHs	**18,000**	na	na	Ecological-SSL (EPA 2007b)
Other SVOCs (µg/kg dw)				
1,4-Dichlorobenzene	na	**20,000**	**20,000**	DEQ (2001); Efroymson et al. (1997)
Hexachlorobenzene	na	na	**1,000,000**	DEQ (2001)
Pentachlorophenol	31,000	6,000	**4,000**	DEQ (2001)

Table 3. Summary of Terrestrial Invertebrate Soil Thresholds

Soil COI	Soil Threshold Source			Source of Selected Soil Threshold
	EPA Eco-SSL[a]	ORNL[b]	DEQ 2001[c]	
Phenol	na	**30,000**	**30,000**	DEQ (2001); Efroymson et al. (1997)

[a] Based on EPA Ecological SSL for soil invertebrates (EPA 2007a).

[b] Based on ORNL soil thresholds for earthworms (Efroymson et al 1997).

[c] Based on DEQ soil thresholds for invertebrates (DEQ 2001).

[d] The soil TRV for chromium (0.4 mg/kg dw) as reported in DEQ (2001) and Efroymson et al. (1997) was determined from the LOEC of 2 mg/kg dw using a safety factor of 5. Per consultation with EPA, safety factor-adjusted TRVs are not recommended for use in the Harbor Oil baseline ERA; therefore the non-adjusted LOEC of 2 mg/kg dw was selected for evaluation in the baseline ERA.

[e] The soil TRV for mercury (0.1 mg/kg dw) as reported in DEQ (2001) and Efroymson et al. (1997) was determined from the LOEC of 0.5 mg/kg dw using a safety factor of 5. Per consultation with EPA, safety factor-adjusted TRVs are not recommended for use in the Harbor Oil baseline ERA; therefore the non-adjusted LOEC of 0.5 mg/kg dw was selected for evaluation in the baseline ERA.

COI – contaminant of interest
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
HPAH - high-molecular-weight polycyclic aromatic hydrocarbon
LPAH - low-molecular-weight polycyclic aromatic hydrocarbon
na – not available
ORNL – Oak Ridge National Laboratory
PAH – polycyclic aromatic hydrocarbon
SSL – soil screening level
SVOC – semivolatile organic compound

Bold indicates selected soil threshold.

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Mercury	mercuric chloride	guppy	200	nv	sediment and water	20 days	survival	no effect on survival	Kudo and Mortimer (1979)
Mercury	methylmercury	golden shiner	**230**	nv	food	90 days	survival	predator avoidance	Webber and Haines (2003)
Mercury	methyl-mercuric chloride	mummichog	200	**470**	water	42 days	survival	male survival	Matta et al. (2001)
Mercury	mercuric chloride	fathead minnow	0.8	1,310	food	60 days	growth	body weight	Snarski and Olson (1982)
Mercury	methyl-mercuric chloride	rainbow trout (fingerling)	2,280	nv	water	24 days	growth	body weight	Phillips and Buhler (1978)
Mercury	methylmercury	brook trout	2,700	3,400	water	756 days	reproduction	reduced number of viable eggs produced	McKim et al. (1976)
Mercury	mercuric chloride	fathead minnow	2,750	4,180	water	60 days	survival	mortality	Snarski and Olson (1982)
Mercury	mercuric chloride	fathead minnow	2,840	4,470	water	287 days	reproduction	reproduction	Snarski and Olson (1982)
Mercury	methylmercury	rainbow trout (juvenile)	5,000	nv	water	84 days	growth, survival	no effect on growth or survival	Lock (1975)
Mercury	methylmercury	goldfish	nv	5,600	water	2 days	survival	mortality	Heisinger et al. (1979)
Mercury	methyl-mercuric chloride	rainbow trout (fingerling)	5,670	nv	water	24 days	growth	no effect on growth	Phillips and Buhler (1978)
Mercury	methyl-mercuric chloride	bluegill (juvenile)	nv	6,500	water	12.5 days	survival	mortality	Cember et al. 1978
Mercury	methyl-mercuric chloride	rainbow trout (fingerling)	8,630	nv	water	24 days	growth	no effect on growth	Phillips and Buhler (1978)
Mercury	unspecified	brook trout	9,400	nv	water	756 days	growth, survival	reduced juvenile weight	McKim et al. (1976)
Mercury	methylmercury	rainbow trout (fingerling)	nv	10,000	food	84 days	growth	reduced growth and final body weight (after 84 days)	Rodgers and Beamish (1982)
Mercury	methylmercury	fathead minnow	10,900	nv	water	336 days	growth, survival	no effect on growth or survival	Olson et al. (1975)
Mercury	methyl-mercuric chloride	mummichog	1,100	11,000	food	42 days	reproduction	F1 fertilization success	Matta et al. (2001)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Mercury	methyl-mercuric chloride	rainbow trout	12,000	nv	water	75 days	growth, survival	body weight	Niimi and Lowe-Jinde (1984)
Mercury	methyl-mercuric chloride	mummichog	12,000	nv	food	42 days	reproduction	F1 hatchability, survival, fecundity, F2 larval survival	Matta et al. (2001)
Mercury	methyl-mercuric chloride	mummichog	12,000	nv	food	42 days	reproduction	fecundity, fertilization success, offspring weight, female survival	Matta et al. (2001)
Mercury	unspecified	rainbow trout (fingerling)	29,000	nv		84 days	survival	no effect on survival	Rodgers and Beamish (1982)
Total PCBs	Aroclor 1260	common barbel	**104**[a]	**520**	maternal exposure	50 days	reproduction	reduced fecundity	Hugla and Thome (1999)
Total PCBs	Aroclor 1254	juvenile Chinook salmon	980	nv	food	4 weeks	growth, survival	no effect on growth or survival	Powell et al. (2003)
Total PCBs	Aroclor 1260	common barbel	520	2,640	maternal exposure	75 days	reproduction	lack of spawning in first reproductive season; egg and larval mortality	Hugla and Thome (1999)
Total PCBs	Aroclor 1254	rainbow trout	8,000	nv	food	32 weeks	growth, survival	no effect on growth or survival	Lieb et al. (1974)
Total PCBs	Aroclor 1254	sheepshead minnow	1,900	9,300	maternal exposure water	28 days	reproduction	decreased fry survival in the first week after hatch	Hansen et al. (1974a)
Total PCBs	Aroclor 1254	pinfish	nv	14,000	water	20 days	survival	reduced survival	Hansen et al. (1971)
Total PCBs	Aroclor 1242	channel catfish	nv	14,300	food	20 weeks	growth	40% reduction in body weight gain	Hansen et al. (1976)
Total PCBs	Aroclor 1268	mummichog	15,000	nv	food	6 weeks	reproduction, survival	no effect on fertilization, hatching, or larval survival	Matta et al. (2001)
Total PCBs	Clophen A50	*Phoxinus phoxinus* (minnow)	nv	25,000	food	45 days; observation for 355 additional days	reproduction	increased fry mortality; delayed spawning	Bengtsson (1980)

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Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Total PCBs	Aroclor 1254	spot	27,000	46,000	water	20 days	survival	reduced survival	Hansen et al. (1971)
Total PCBs	Aroclor 1248, 1260 mixture	fathead minnow	25,000	50,000	water	30 days	growth	reduced weight of second-generation fish at 30 days	DeFoe et al. (1978)
Total PCBs	Aroclor 1254	brook trout (embryos)	31,000	71,000	water	128 days (10 days prior to hatch and 118 days after)	growth	reduced fry growth	Mauck et al. (1978)
Total PCBs	Aroclor 1016	sheepshead minnow	110,000	nv	water	4 weeks	reproduction	no effect on fertilization success, survival of embryos, or fry survival	Hansen et al. (1975)
Total PCBs	Aroclor 1016	pinfish	nv	106,000	water	33 days	survival	50% mortality	Hansen et al. (1974b)
Total PCBs	Aroclor 1254: 1260 mixture	rainbow trout (juvenile)	120,000	nv	water	90 days	survival	no effect on survival	Mayer et al. (1985)
Total PCBs	Aroclor 1254: 1260 mixture	rainbow trout (juvenile)	70,000	120,000	water	90 days	growth	reduced growth	Mayer et al. (1985)
Total PCBs	Aroclor 1254	brook trout (embryos)	71,000	125,000	water	128 days (10 days prior to hatch and 118 days after)	survival	reduced fry survival	Mauck et al. (1978)
Total PCBs	Aroclor 1016	sheepshead minnow (fry)	57,000	200,000	water	4 weeks	survival	reduced fry survival	Hansen et al. (1975)
Total PCBs	Clophen A50	goldfish	nv	250,000	water	21 days	survival	reduced survival	Hattula and Karlog (1972)
Total PCBs	Aroclor 1254	fathead minnow	nv	429,000 (female)	water	8 months	reproduction	reduced spawning	Nebeker et al. (1974)
Total PCBs	Aroclor 1242, 1254, or 1260	fathead minnow	nv	1,860 – 749,000	water	100 to 300 hours		range of lethal body burdens (concentration associated with mortality of individuals)	van Wezel et al. (1995)
Total DDTs	DDT mixture	golden shiner	25	nv	food	6-15 days	survival	no effect on survival	Courtney and Reed (1971)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Total DDTs	DDT mixture	cutthroat trout	**1,800**	**1,800**	water	612 days (mortality observed at 111 days)	survival	mortality	Allison et al. (1964)
Total DDTs	Total DDT	brook trout (juvenile)	1,920	nv	food	120 days	survival	no effect on survival	Macek and Korn (1970)
Total DDTs	Total DDT	cutthroat trout	1,200	2,000	water	20 mo (mortality observed at 4 mo)	survival	survival	Allison et al. (1963)
Total DDTs	Total DDT	brook trout	nv	2,800 - 3,000	food	156 days	reproduction	offspring (sac-fry and embryo) mortality	Macek (1968b)
Total DDTs	Total DDT	chinook salmon	620	3,650	food	40 days	survival		Buhler et al. (1969)
Total DDTs	Total DDT	rainbow trout	4,670	nv	food	140 days	growth, survival	survival, growth	Macek et al. (1970)
Total DDTs	Total DDT	killifish	nv	5,200	water	24 hrs	survival	25% mortality at 24 hrs	Crawford and Guarino (1976)
Total DDTs	DDT mixture	cutthroat trout	3,900	5,500	food	612 days	survival	survival	Allison et al. (1964)
Total DDTs	DDT mixture	pinfish	nv	5,600	food	21 days	survival	35% mortality at 21 days	Butler (1969)
Total DDTs	DDT mixture	pinfish	nv	7,890	food	2 days	survival	63.5% mortality	Butler (1969)
Total DDTs	Total DDT	brook trout (fry)	7,600	nv	food	156 days	growth, survival	survival, growth	Macek (1968b)
Total DDTs	Total DDT	brook trout	11,200	nv	food	31 wks	growth	increased growth	Macek (1968a)
Total DDTs	Total DDT	chinook salmon	11,400	12,100	food	40 days	survival	survival	Buhler et al. (1969)
Total DDTs	Total DDT	brook trout	nv	20,200 - 45,800	food	26 wks	survival	reduced survival during stress (starvation)	Macek (1968a)
Total DDTs	Total DDT	green sunfish/ pumpkin-seed	nv	24,000	water	90 days	survival	survival	Hamelink et al. (1971)
Total DDTs	DDT mixture	Atlantic menhaden	24,000	nv	food	48 (109)[a]	growth	growth	Warlen et al. (1977)
Total DDTs	Total DDT	mosquito fish	nv	26,500	water	16 days	survival	survival	Pillai et al. (1977)
Total DDTs	Total DDT	fathead minnow	40,000	nv	food and water	266 days	survival	survival	Jarvinen et al. (1976, 1977)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Total DDTs	Total DDT	sailfin molly	51,400	92,700	water	21 days	growth, survival	survival, growth	Benton et al. (1994)
Total DDTs	Total DDT	coho salmon	16,600	69,600	food	60 days	survival	survival	Buhler et al. (1969)
Total DDTs	Total DDT	goldfish	130,000	200,000	food and water	38 to 58 days	survival	survival	Rhead and Perkins (1984)

[a] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

DDT – dichlorodiphenyltrichloroethane
LOAEL – lowest-observed-effect concentration
NOAEL – no-observed-effect concentration
nv – no value
PCB – polychlorinated biphenyl
TRV – toxicity reference value
ww – wet weight

BOLD represents selected NOAEL and LOAEL TRVs.

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	nv	**0.50**	food (prepared diet)	24 days	growth	body weight	Cockell et al. (1991)
Arsenic	sodium arsenite	rainbow trout (juvenile)	**0.40**	0.60	food (prepared diet)	8 weeks	growth	body weight	Oladimeji et al. (1984)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	0.12	0.62	food (prepared diet)	16 days	growth	body weight	Cockell et al. (1991)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	0.63	nv	food (prepared diet)	24 days	growth	body weight	Cockell et al. (1991)
Arsenic	disodium arsenate	rainbow trout (juvenile)	nv	1.0	food (prepared diet)	4 weeks	growth	body weight	Cockell and Bettger (1993)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	0.55	1.0	food (prepared diet)	12 weeks	growth	body weight	Cockell et al. (1992)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	nv	1.4	food (prepared diet)	8 weeks	growth	body weight	Cockell et al. (1992)
Arsenic	arsenic trioxide	rainbow trout (juvenile)	nv	1.7	food (prepared diet)	8 weeks	growth	body weight	Cockell and Hilton (1988)
Arsenic	disodium arsenate heptahydrate	striped bass (juvenile)	0.52	1.9	food (prepared diet)	6 weeks	growth	body weight	Blazer et al. (1997)
Arsenic	disodium arsenate	rainbow trout (juvenile)	nv	2.9	food (prepared diet)	8 weeks	growth	body weight	Cockell and Hilton (1988)
Cadmium	cadmium nitrate	rockfish (juvenile)	**0.0020**[b,c]	**0.010**[c]	food (prepared diet)	60 days	growth	reduced body weight and length, growth rate, and condition factor	Kim et al. (2004); Kang et al. (2005)
Cadmium	cadmium chloride	guppy (adult)	1.2	nv	food (midge larvae)	2 months	reproduction	no effect on number of live fry, fry survival, or premature release of embryos	Hatakeyama and Yasuno (1987)
Cadmium	cadmium chloride	guppy (60 days old)	1.6	nv	food (midge larvae)	30 days	growth	no effect on body weight	Hatakeyama and Yasuno (1987)
Cadmium	cadmium nitrate	rockfish	2.5	nv	food (prepared diet)	60 days	survival	no effect on survival	Kim et al. (2004)
Cadmium	cadmium chloride	guppy (30 days old)	**3.2**[d]	**4.6**[d]	food (midge larvae)	7 months	reproduction	reduced cumulative number of fry produced	Hatakeyama and Yasuno (1987)
Cadmium	cadmium chloride	rainbow trout	4.1	nv	food (brine shrimp) and water	60 days	survival	no effect on survival	Mount et al. (1994)

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Cadmium	cadmium nitrate	rainbow trout	5.9	nv	food (prepared diet)	15 to 30 days	survival, growth	no effect on specific growth rate, survival	Baldisserotto et al. (2005)
Cadmium	cadmium chloride	guppy	1.0	nv	food (M*oina macrocoipa*)	10 to 30 days	growth	no effect on growth	Hatakeyama and Yasuno (1982)
Cadmium	cadmium nitrate	rainbow trout	9.4	nv	food (prepared diet)	28 days	survival, growth	no effect on growth rate or survival	Franklin et al. (2005)
Cadmium	cadmium chloride	guppy (30 days old)	nv	9.4	food (midge larvae)	7 months	survival, growth	reduced female growth and survival	Hatakeyama and Yasuno (1987)
Cadmium	cadmium nitrate	rainbow trout (juvenile)	16	28	food (prepared diet)	36 days	survival	reduced survival	Szebedinsky et al. (2001)
Cadmium	cadmium sulfate	rainbow trout (juvenile)	nv	68	food (prepared diet)	28 days	survival	reduced survival	Handy (1992)
Chromium	chromium (III)	grey mullet	**9.42**	nv	food and sediment	8 weeks	growth	body weight	Walsh et al. (1994)
Copper	copper sulfate	channel catfish (fingerling)	0.24	0.48	food (prepared diet)	16 weeks	growth	reduced growth	Murai et al. (1981)
Copper	copper sulfate	rockfish (juvenile)	**1.0**	**2.0**	food (prepared diet)	60 days	growth	reduced growth rate	Kang et al. (2005)
Copper	copper sulphate	rainbow trout	2.2	nv	food (prepared diet)	32 days	survival	no effect on survival	Handy (1992)
Copper	copper sulphate pentahydrate	rainbow trout	6.8	nv	food (prepared diet)	16 weeks	growth	no effect on growth	Lanno et al. (1985b)
Copper	copper sulfate	rainbow trout	13	nv	food (prepared diet)	42 days	growth	no effect on growth	Miller et al. (1993)
Copper	copper sulphate pentahydrate	Atlantic salmon (parr)	17	nv	food (prepared diet)	4 weeks	growth	no effect on body weight, length, or condition factor	Berntssen et al. (1999b)
Copper	copper sulphate pentahydrate	rainbow trout	17	nv	food (prepared diet)	24 weeks	survival, growth	no effect on growth or survival	Lanno et al. (1985b)
Copper	copper sulphate pentahydrate	rainbow trout	18	nv	food (prepared diet)	8 weeks	survival	no effect on survival	Lanno et al. (1985b)

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Copper	copper sulphate pentahydrate	rainbow trout	nv	18	food (prepared diet)	8 weeks	growth	reduced growth	Lanno et al. (1985b)
Copper	copper sulphate pentahydrate	rainbow trout	nv	20	food (prepared diet) and water	16 weeks	growth	reduced growth	Lanno et al. (1985a)
Copper	copper sulfate pentahydrate	Atlantic salmon (fry)	14	20	food (prepared diet)	3 months	growth	reduced growth	Lundebye et al. (1999)
Copper	copper sulphate	Atlantic salmon	20	28	food (prepared diet)	3 months	growth	reduced growth	Berntssen et al. (1999a)
Copper	copper sulphate pentahydrate	rainbow trout	42	nv	food (prepared diet)	28 days	survival, growth	no effect on growth or survival	Kamunde et al. (2001)
Copper	copper chloride	rainbow trout (fry)	26	50	food (brine shrimp) and water	60 days	survival	reduced survival	Mount et al. (1994)
Copper	copper chloride	rainbow trout (fry)	60	nv	food (brine shrimp) and water	60 days	growth	no effect on body weight and length	Mount et al. (1994)
Copper	copper sulphate pentahydrate	grey mullet	nv	60	food (prepared diet)	67 days	growth	reduced growth	Baker et al. (1998)
Copper	copper sulphate	rainbow trout	69	nv	food (prepared diet)	28 days	survival	no effect on survival	Handy (1993)
Lead	lead nitrate	rainbow trout	12.6	nv	food (brine shrimp)	60 days	survival, growth	no effect on body weight and length; 100% survival	Mount et al. (1994)
Lead	unspecified	rainbow trout	**134**	nv	food (prepared diet)	191 days	growth	no effect on growth	Goettl et al. (1976)
Silver	silver sulfide	rainbow trout	**70**	nv	food (prepared diet)	58 days	growth	reduced body weight	Galvez and Wood (1999)
Vanadium	sodium orthovanadate	rainbow trout (juvenile)	**0.039[e]**	**0.19**	food (prepared diet)	12 weeks	growth	reduced body weight	Hilton and Bettger (1988)
Zinc	unspecified	rainbow trout	**19**	**38**	food (prepared diet)	6 weeks	growth	reduced growth	Takeda and Shimma (1977)

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Zinc	zinc chloride	rainbow trout	114	nv	food (brine shrimp)	60 days	survival, growth	no effect on body weight and length; 97% survival	Mount et al. (1994)
Benzo(a)pyrene	benzo(a)pyrene	English sole (juvenile)	**0.66**	**1.4**	food (worms)	10 to 12 days	growth	reduced daily growth rate	Rice et al. (2000)
Benzo(a)pyrene	benzo(a)pyrene	rainbow trout (juvenile)	nv	3.7	food (prepared diet)	53 days	survival, growth	reduced body weight; no effect on survival	Hendricks et al. (1985)
Benzo(a)pyrene	benzo(a)pyrene	rainbow trout (juvenile)	1.9	19	food (prepared diet)	18 months	growth	reduced body weight	Hart and Heddle (1991)
Benzo(a)pyrene	benzo(a)pyrene	grouper	13	nv	food (prepared diet)	4 weeks	survival, growth	no effect on survival or growth (body weight and total length)	Wu et al. (2003)
Total PAHs	PAH mixture	English sole	nv	0.12	food (worms contaminated with field sediment)	10-12 days	growth	reduced daily growth rate	Rice et al. (2000)
Total PAHs	PAH mixture	Chinook salmon (juvenile)	5.0	nv	food (prepared diet)	7 weeks	survival, growth	no effect on body weight, length, or condition factor	Palm et al. (2003)
Total PAHs	PAH mixture	Chinook salmon (juvenile)	5.0	nv	food (prepared diet)	4 weeks[c]	survival	no impact to disease resistance	Palm et al. (2003)
Total PAHs	PAH mixture	Chinook salmon (juvenile)	**6.1**	**18**	food (prepared diet)	53 days	growth	reduced body weight (as dry body weight)	Meador et al. (2006)

[a] NOAEL and LOAEL TRVs, expressed as a dietary dose (mg/kg bw/day), were calculated from literature studies based on body weight, ingestion rate, and dietary concentrations.
[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.
[c] Selected NOAEL and LOAEL for the screening-level risk assessment.
[d] Selected NOAEL and LOAEL for the baseline risk evaluation.
[e] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

bw – body weight
nv – no value
PAH – polycyclic aromatic hydrocarbon
LOAEL – lowest-observed-effect concentration
NOAEL – no-observed-effect concentration
TRV – toxicity reference value

BOLD identifies the selected NOAEL and LOAEL TRVs.

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Metals									
Aluminum	aluminum citrate	Japanese quail	90	nv	food	65 days and through reproduction	reproduction, growth	body weight	Wolff and Phillips (1990)
Aluminum	aluminum sulfate	ring dove	**157**	nv	food	4 months	reproduction, growth	adult growth, fertility, hatchability, egg permeability	Carriere et al. (1986)
Arsenic	sodium arsenate	mallard	6.1	nv	food	10 weeks	growth, survival	female	Camardese et al. (1990)
Arsenic	sodium arsenate	mallard	**10**	**40**	food	115-128 days	reproduction	delayed egg laying; depressed egg weight and shell thinning; decrease offspring body weight and production	Stanley et al. (1994)
Arsenic	sodium arsenite	mallard - young	25	50	food	154 days	survival	survival	USFWS (1964)
Cadmium	cadmium chloride	mallard young (females)	**1.5**	nv	food	12 weeks	growth	body weight	Cain et al. (1983)
Cadmium	cadmium sulfate	leghorn hen	0.73	2.9	food	48 weeks	reproduction	egg production, shell thickness	Leach et al. (1979)
Cadmium	cadmium chloride	Japanese quail (chicks)	nv	**4.0**	food	6 weeks	growth	male body weight	Richardson et al. (1974)
Cadmium	cadmium chloride	mallard	19	nv	food	90 days	survival	no effect on survival	White and Finley (1978a)
Cadmium	cadmium chloride	mallard	20	nv	food	30-90 days	survival, growth	body weight, adult survival	White and Finley (1978b)
Cadmium	cadmium chloride	mallard	1.5	20	food	30-90 days	reproduction	egg production	White and Finley (1978b)
Cadmium	cadmium chloride	leghorn chicks	nv	24	food	21 days	growth	male body weight	Freeland and Cousins (1973)
Cadmium	cadmium chloride	leghorn chicks	nv	40	food	20 days	growth	male body weight	Pritzl et al. (1974)
Cadmium	cadmium chloride	mallard	16	47	food	42 days	growth	body weight	DiGiulio and Scanlon (1984)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Chromium	copper sulfate	white leghorn layers (hens)	0.10	nv	food	28 days	reproduction	egg weight and shell thickness	Lien et al. (2004)
Chromium	chromium potassium sulfate	black duck	**1.0**	**5.0**	food	10 months (and critical lifestage)	reproduction	duckling survival	Haseltine et al. (unpublished)
Chromium	sodium chromate	Nochols chicks	7.7	nv	food	22 days	growth, survival	male adult survival, male body weight	Romoser et al. (1961)
Cobalt	cobalt chloride	broiler chicks	**2.31[b]**	**23.1**	food	14 days	growth	body weight, survival	Diaz et al. (1994)
Copper	copper sulfate, copper amino acid complex	broiler chicks	2.1	nv	food	17 days	growth, survival	body weight, survival	Dozier et al. (2003)
Copper	copper sulfate (hydrous)	hisex-brown hens	11.2	nv	food	90 days	reproduction, survival	damaged egg ratio, egg weight and survival	Balevi & Coskun (2004)
Copper	copper sulfate	chicks, day-old	16	**29**	food	25 days	growth	growth	Smith (1969)
Copper	copper sulfate	chicks	**21**	41	food	4 weeks	growth	growth and gizzard erosion	Poupoulis and Jensen (1976)
Copper	copper chloride	chicks	nv	66	food	8-22 days	growth	body weight	Persia et al. (2004)
Copper	copper oxide	chicks	47	62	food	10 weeks	growth/ survival	growth, survival	Mehring et al. (1960)
Copper	copper sulfate	white leghorn layers (hens)	15	nv	food	28 days	reproduction	egg weight and shell thickness	Lien et al. (2004)
Lead	lead nitrate	mallards, first-year	2.5	nv	food	12 weeks	survival	survival	Finley et al. (1976)
Lead	metallic lead powder	American kestrel	**5.82**	nv	food	5-7 months	survival/ reproduction	survival, fertility, egg production, eggshell thinning	Pattee (1984)
Lead	lead acetate	Japanese quail	2.0	**20**	food	12 weeks	reproduction	egg hatchability	Edens et al. (1976)
Lead	lead acetate	Japanese quail (chicks)	5.5	28	food	6 weeks	growth	body weight	Morgan et al. (1975)
Mercury	methylmercury chloride	great egret, one day old	**0.018[c]**	**0.091**	food	14 weeks	growth	growth	Spalding et al. (2000)
Mercury	methylmercury chloride	mallard	0.50	nv	food	>60 days	reproduction	eggshell thickness	Heinz (1980)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Mercury	methylmercury chloride	Japanese quail (chicks at hatching)	nv	0.9	food	5 days	survival	hatchling survival (16%)	Hill and Soares (1987)
Mercury	methylmercury chloride	zebra finch	0.72	1.4	food	76 days	survival	survival	Scheuhammer (1988)
Mercury	methylmercury chloride	northern bobwhite, 12 day old	0.43	1.6	food	6 weeks	survival	survival	Spann et al. (1986)
Mercury	mercuric chloride	Japanese quail, one day old	0.80	1.6	food	10 weeks	reproduction	eggshell thickness	Stoewsand et al. (1971)
Mercury	dimethyl mercury	American kestrel	5.24	nv	food	3 months	survival	eggshell thickness	Peakall and Lincer (1972)
Mercury	mercuric chloride	Japanese quail (chicks at hatching)	nv	62	food	5 days	survival	hatchling survival (12%)	Hill and Soares (1987)
Nickel	nickel sulfate	broiler chicks	15	nv	food	4 weeks	growth	body weight gain	Weber and Reid (1968)
Nickel	nickel sulfate	broiler chicks	nv	33	food	4 weeks	growth	reduced body weight	Weber and Reid (1968)
Nickel	nickel acetate	broiler chicks	17	nv	food	4 weeks	growth	body weight gain	Weber and Reid (1968)
Nickel	nickel acetate	broiler chicks	nv	38	food	4 weeks	growth	reduced body weight	Weber and Reid (1968)
Nickel	nickel sulfate	mallard	**77**	**107**	food	90 days	survival, growth	survival, body weight	Cain and Pafford (1981)
Nickel	nickel sulfate	mallard	132	nv	food	90 days	survival, growth, reproduction	adult survival; body weight; hatchling weight	Eastin and O'Shea (1981)
Selenium	sodium selenite, sel-plex 50	broiler chicks	0.025	nv	food	~40 days	growth, survival	body weight	Choct et al. (2004)
Selenium	seleno-methionine	mallard	0.42	**0.82**	food	~100 days	reproduction	offspring growth/survival	Heinz et al. (1989)
Selenium	sodium selenite Na_2SeO_3	mallard	**0.50**	1.0	food	4 weeks before laying to 3 wks after hatching	reproduction	embryo abnormalities	Heinz et al. (1987)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Selenium	sodium selenite	mallard	1.0	2.5	food	4 weeks before laying to 3 wks after hatching	growth	adult growth	Heinz et al. (1987)
Selenium	seleno-methionine	mallard	1.6	nv	food	~100 days	survival, growth	body weight; adult survival	Heinz et al. (1989)
Selenium	seleno-methionine	screech owl	1.0	3.2	food	~ 3 months	growth, reproduction	body weight, hatching success, 5 days survival, clutch size, egg size and mass	Wiemeyer and Hoffman (1996)
Selenium	sodium selenite	mallard	4.6	10	food	42 days	survival		Heinz et al. (1988)
Selenium	sodium selenite	mallard	2.1	4.6	food	42 days	growth	body weight	Heinz et al. (1988)
Selenium	sodium selenite	mallard	2.5	10	food	4 weeks before laying to 3 wks after hatching	survival	adult survival	Heinz et al. (1987)
Vanadium	ammonium metavanadate	white leghorn hens	**1.2**	**2.3**	food	4 weeks	growth	body weight	Ousterhout and Berg (1981)
Vanadium	vanadium sulfate	mallard	11.4	nv	food	12 weeks	growth, survival	body weight, survival	White and Dieter (1978)
Zinc	copper sulfate, copper amino acid complex	broiler chicks	17	nv	food	17 days	growth, survival	body weight, survival	Dozier et al. (2003)
Zinc	zinc oxide, zinc sulfate, or zinc carbonate	white rock chicks	**82**	**124**	food	5 weeks	growth	growth	Roberson and Schaible (1960)
Zinc	zinc sulfate	white leghorn hens	133	nv	food and supplements	44 weeks	reproduction	egg hatchability	Stahl et al. (1990)
Zinc	zinc carbonate	mallard (7 wks old)	nv	300	food	60 days	survival	survival, leg paralysis	Gasaway and Buss (1972)
Zinc	zinc acetate	Hubbard broiler chicks	330	659	food	5 weeks	growth/ survival	survival, reduced growth	Oh et al. (1979)
Zinc	zinc chloride	chicks	nv	344	food	8-22 days	growth	body weight	Persia et al. (2004)
PAHs									
Benzo(a)pyrene	benzo(a)pyrene	pigeons	**0.28[c]**	**1.4**	weekly intramuscular injection	5 months	reproduction	fertility, ovarian appearance	Hough et al. (1993)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Benzo(a)pyrene	benzo(a)pyrene	white rock chicken	33	nv	food	30 days	growth	body weight gain	Rigdon and Neal (1963)
Total PAHs	aromatic hydrocarbon mixture including individual PAHs	mallard	**8**	**40**	food	7 months	growth	little change in body weight	Patton and Dieter (1980)
Total PAHs	petroleum hydrocarbon mixture including PAHs)	mallard	400	nv	food	7 months	survival	survival	Patton and Dieter (1980)
Phthalates									
BEHP	BEHP	ringed turtle-dove	1.45	nv	food	4 weeks	reproduction	eggshell thickness	Peakall (1974)
BEHP	BEHP	European starling	67.8	nv	food	30 days	growth	growth, food consumption	O'Shea and Stafford (1980)
BEHP	BEHP	chicken	**65.8[c]**	**329**	food	230 days	reproduction	cessation of egg laying, abnormal ovaries	Ishida et al. (1982)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	**1.1**	nv	food	90 days	reproduction, survival	hatchability, survival	Vos et al. (1971)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	1.2	nv	food	90 days	growth	body weight	Schwetz et al. (1974)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	nv	**1.2**	food	90 days	reproduction	chicks hatched and survival	Schwetz et al. (1974)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	nv	4.5	food	90 days	reproduction	hatchability	Vos et al. (1971)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	nv	5	food	90 days	survival	no effect on survival	Vos et al. (1971)
Pentachlorophenol	pentachloro-phenol	chicks	**22**	**63**	food	8 weeks	growth	body weight	Prescott et al. (1982)
PCBs									
Total PCBs	Aroclor 1248	American kestrel	nv	0.35	food	5.5 months	reproduction	eggshell weight and thickness	Lowe and Stendell (1991)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Total PCBs	Aroclor 1248	screech owl	**0.49**	nv	food	2 generations	reproduction	eggshell thickness, egg production, hatching success, fledging success	McLane and Hughes (1980)
Total PCBs	Aroclor 1242	Japanese quail	nv	0.60	food	45 days	reproduction	eggshell thinning	Hill et al. (1976)
Total PCBs	Aroclor 1254	ringed turtle-dove	nv	**1.4**	food	2 generations	reproduction	hatching success in second generation	Peakall et al. (1972); Peakall and Peakall (1973)
Total PCBs	Aroclor 1254	mallard	2.5	nv	food	~ 1 month	reproduction	Reproductive success	Custer and Heinz (1980)
Total PCBs	Aroclor 1254	mallard	3.9	nv	food	4 months	reproduction	egg production, eggshell thinning	Risebrough and Anderson (1975)
Total PCBs	1:1:1 ratio of Aroclor 1248:1254:1260	American kestrel	nv	5 to 7	food	100 days until eggs hatched	reproduction	egg laying in second generation (exposed in ovo); also some effect on clutch size and fledgling success	Fernie et al. (2000; 2001)
Total PCBs	1:1:1 ratio of Aroclor 1248:1254:1260	American kestrel	nv	5 to 7	food	1 mo prior to pairing until anticipated egg hatching	reproduction	cracked eggs, embryo abnormalities;	Fernie et al. (2003b)
Total PCBs	1:1:1 ratio of Aroclor 1248:1254:1260	American kestrel	nv	7	food	100 days	reproduction	offspring survival and offspring body weight	Fernie et al. (2003a)
Total PCBs	Aroclor 1242	mallard	nv	15	food	12 weeks	reproduction	hatchability, embryo survival, egg viability, embryo abnormalities	Haseltine and Prouty (1980)
Pesticides									
DDTs[d]	p,p'-DDT	quail	nv	0.15	food	26 wks+12 days	reproduction	eggshell thickness	Stickel and Rhodes (1970)
DDTs[d]	p,p'-DDT	mallard	0.19	nv	food	11 months	reproduction	eggshell weight and thickness	Davison and Sell (1974)
DDTs[d]	DDE	barn owls	**0.064**[c]	**0.32**	food	2 years (2 nestings)	reproduction	eggshell breakage/ thickness; nestling survival	Mendenhall et al. (1983)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
DDTs[d]	DDE	American kestrel	nv	0.35	food	14 days	reproduction	eggshell thinning, egg permeability	Peakall et al. (1973)
DDTs[d]	technical DDD	mallard	nv	0.90	food	2 years	reproduction	hatchling survival, production	Heath et al. (1969)
DDTs[d]	p,p'-DDE	mallard	nv	0.90	food	2 years	reproduction	% cracked, hatchling survival/production, shell thickness, embryonation	Heath et al. (1969)
DDTs[d]	p,p-DDE	black duck	nv	1.0	food	7 months	reproduction	shell thickness, egg weight, hatchability, duckling survival	Longcore and Samson (1973)
DDTs[d]	DDE	mallard	nv	1.0	food	30 days	reproduction	eggshell thinning	Kolaja (1977)
DDTs[d]	DDT	mallard	nv	1.0	food	30 days	reproduction	eggshell thinning	Kolaja (1977)
DDTs[d]	p,p' DDE	American kestrel	nv	1.0	food	1 year (2 clutches)	reproduction	eggshell thickness	Wiemeyer and Porter (1970); Porter and Wiemeyer (1972)
gamma- HCH	gamma- HCH	domestic mallard	**1.6**	**3.6**	oral intubation	8 weeks	reproduction	eggshell thickness, size, quality; clutch size	Chakravarty and Lahiri (1986); Chakravarty et al. (1986)
gamma- HCH	gamma- HCH	domestic mallard	20	nv	oral intubation	8 weeks	survival, growth	survival, body weight	Chakravarty et al. (1986)
Methoxychlor	technical methoxychlor	zebra finch (chicks at 5-11 days old)	**34.6**	**346**	oral gavage	1 weeks	reproduction	number of eggs hatched, broken/missing eggs	Gee et al. (2004)
Methoxychlor	methoxychlor	zebra finch chicks	**34.6**	**346**	oral gavage	1 weeks	survival	survival	Millam et al. (2002)
Methoxychlor	technical methoxychlor	four species	831	nv	food	5 days	survival	survival	Hill et al. (1975); Heath et al. (1972)
VOCs									
Acetone	acetone	four species	**6,647**	nv	food	5 days	survival	survival	Hill et al. (1975)

[a] NOAEL and LOAEL TRVs, expressed as a dietary dose (mg/kg bw/day), were calculated from literature studies based on body weight, ingestion rate, and dietary concentrations.

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 10.

[c] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

[d] Only the results of the nine studies with the lowest reported effects concentrations for any form of DDT are presented.

bw – body weight
LOAEL – lowest-observed-effect concentration
BEHP – bis(2-ethylhexyl)phthalate
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCH – hexachlorocyclohexane
BOLD represents selected NOAEL and LOAEL TRVs**.**

NOAEL – no-observed-effect concentration
nv – no value
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
VOC – volatile organic compound

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Metals									
Aluminum	aluminum chloride	mouse	**34.3**	nv	food	multiple generations	reproduction	body weight, number of litters, number of offspring per litter	Ondreicka et al. (1966)
Aluminum	aluminum lactate	mouse	nv	**75.8**	food	gestation	growth	maternal and offspring body weight and length	Golub et al. (1987)
Aluminum	aluminum lactate	mouse	**137**	nv	food	8 weeks	growth	body weight and length	Golub and Keen (1999)
Antimony	antimony trioxide	rat	**1,489**	nv	food	90 days	growth, survival	body weight	Hext et al. (1999)
Arsenic	sodium arsenite	rat	**2.6**	**5.4**	food	2 years	growth	female body weight	Byron et al. (1967)
Cadmium	cadmium chloride	beagle dog	0.88	nv	food	3 months	growth	female body weight	Loeser and Lorke (1977b)
Cadmium	cadmium chloride	rat	3.0	nv	food	3 months	survival, growth	adult survival, growth	Loeser and Lorke (1977a)
Cadmium	cadmium chloride	rat	**3.5**	**13**	food	10 days (pregnancy)	growth	maternal body weight	Machemer and Lorke (1981)
Cadmium	cadmium chloride	rat	13	nv	food	10 days	survival, reproduction	adult survival; fertility, fetus weight/survival/ malformations	Machemer and Lorke (1981)
Cadmium	cadmium chloride	shrew	115	nv	food	12 weeks	growth	female body weight	Dodds-Smith et al. (1992)
Cadmium	cadmium chloride	shrew	nv	115	food	12 weeks	growth	male body weight	Dodds-Smith et al. (1992)
Cadmium	unspecified chemical form	rat	nv	189	food	12 weeks	growth, reproduction	pup birth weight; adult body weight	Pond and Walker (1975)
Chromium	chromium picolinate	rat	0.14	nv	food	12 weeks	growth	body weight and growth rate	Hasten et al. (1997)
Chromium	chromium(III) chloride/ chromium picolinate	rat	8.3	nv	food	20 weeks	growth, survival	no effect on growth, survival	Anderson et al. (1997)
Chromium	chromic oxide green	rat	1,292	nv	food	90 days	growth, reproduction	body weight, litter size, pregnancy rate, pup malformation	Ivankovic and Preussman (1975)
Chromium	chromic oxide green	rat	**1,466**	nv	food	2 years	growth, survival	body weight	Ivankovic and Preussman (1975)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Cobalt	cobalt chloride	rat	**0.1**[b]	**1.0**	diet	4 weeks	growth	body weight	Chetty et al. (1979)
Cobalt	cobalt sulfate	guinea pig	nv	1.4	diet	5 weeks	survival	no effect on survival	Mohiuddin et al. (1970)
Cobalt	cobalt sulfate	guinea pig	1.4	nv	diet	5 weeks	growth	no effect on body weight	Mohiuddin et al. (1970)
Cobalt	cobalt chloride	hooded rat	1.9	10	diet	3 days	growth	body weight	Wellman et al. (1984)
Copper	copper sulfate	mink	**18**	**26**	food	357 days	reproduction	kit survival, litter mass	Aulerich et al. (1982)
Copper	copper sulfate	mink	43	nv	food	153-657 days	growth	body weight	Aulerich et al. (1982)
Copper	copper sulfate	rat	137	nv	food	13 weeks	survival	no effect on survival	NTP (1993)
Copper	copper sulfate	rat	67	137	food	13 weeks	growth	body weight	NTP (1993)
Copper	copper sulfate	rat	93	197	food	2 weeks	growth	body weight	NTP (1993)
Copper	copper chloride	shrew	267	nv	food	weanlings for 12 weeks	survival, growth	body weight	Dodds-Smith et al. (1992)
Copper	copper sulfate	rat	305	nv	food	2 weeks	survival	no effect on survival	NTP (1993)
Copper	copper sulfate	mouse	467	nv	food	13 weeks	survival	no effect on survival	NTP (1993)
Copper	copper sulfate	mouse	227	467	food	13 weeks	growth	body weight	NTP (1993)
Copper	copper sulfate	mouse	749	nv	food	2 weeks	survival, growth	no effect on survival or growth	NTP (1993)
Lead	lead acetate	mouse	7.35	nv	food	second and third generation through puberty	reproduction	no effect on litter size	Iavicoli et al. (2006)
Lead	lead acetate	rat	**11**	**90**	food	2 years	growth	offspring weight and kidney damage	Azar et al. (1973)
Mercury	methylmercuric chloride	rat	**0.0017**[c]	**0.0084**	food	3 generations	growth	reduced growth	Verschuuren et al. (1976)
Mercury	methylmercuric chloride	rat	0.19	nv	food	3 generations	survival, reproduction	no effect on survival or reproduction	Verschuuren et al. (1976)
Mercury	methylmercuric chloride	mink	0.16	0.25	food	93 days	growth, survival	reduced growth; 40% mortality	Wobeser et al. (1976)

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Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Mercury	methyl-mercury	mink	nv	0.64	food	2 months	growth, survival	reduced growth; 100% mortality	Aulerich et al. (1974)
Nickel	nickel chloride	rat	20	nv	food	14 days + 61 days untreated	growth	body weight	Nation et al. (1985)
Nickel	unspecified chemical form	rat	nv	**20**	food	3 generations	reproduction	increased number of stillborns in F1 generation	Ambrose et al. (1976)
Nickel	nickel sulfate	rat	**8.4**	87	food	2 years	growth	body weight	Ambrose et al. (1976)
Nickel	nickel acetate	mouse	nv	169	food	4 weeks	growth	body weight	Weber and Reid (1969)
Nickel	nickel acetate	mouse	210	313	food	weanling thru reproduction	reproduction	number of pups weaned	Weber and Reid (1969)
Nickel	nickel sulfate	rat	230	nv	food	2 years	survival	no effect on survival	Ambrose et al. (1976)
Nickel	nickel sulfate	beagle dog	2500	nv	food	2 years	survival	no effect on survival	Ambrose et al. (1976)
Selenium	sodium selenite	rat	**0.055**	**0.080**	food	6 weeks	growth	body weight	Halverson et al. (1966)
Selenium	sodium selenite	rat	0.13	0.14	food	6 weeks	survival	survival	Halverson et al. (1966)
Selenium	L-seleno-methionine	rat	nv	0.16	food	110 days	growth	body weight	Behne et al. (1992)
Selenium	selenite	rat	0.16	nv	food	110 days	growth	body weight	Behne et al. (1992)
Selenium	Na_2SeO_3, Nano-Se, or organic selenium	rat	0.17	0.28	food	13 weeks	growth	body weight	Jia et al. (2005)
Selenium	selenomethionine	hamster	0.36	0.76	food	21 days	growth	body weight	Julius et al. (1983)
Selenium	Na_2SeO_3	hamster	nv	3.4	food	21 days	growth	body weight	Julius et al. (1983)
Selenium	Na_2SeO_3	hamster	nv	5.8	food	21 days	survival	female survival	Julius et al. (1983)
Vanadium	sodium meta-vanadate	rat	**0.27[b]**	**2.7**	food	10 weeks	growth	body weight	Adachi et al. (2000)
Vanadium	sodium meta-vanadate	rat	nv	6.5	food	reproduction period	growth, reproduction	maternal body weight, offspring body weight gain and survival	Elfant and Keen (1987)
Zinc	zinc oxide	rat	**160**	**320**	food	gestation	reproduction	fetal growth, number of resorptions	Schlicker and Cox (1968)

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Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Zinc	zinc oxide	ferret	149	433	food	2 weeks – 6 months	growth	reduced body weight	Straube et al. (1980)
Zinc	zinc carbonate	rat	400	799	food	gestation	growth	body weight	Sutton and Nelson (1937)
PAHs									
2-methylnaphthalene	2-methyl-naphthalene	mouse	**54**	**114**	food	81 weeks	growth	body weight	Murata et al. (1997)
Benzo(a)pyrene	benzo(a)pyrene	mouse	**2.0[c]**	**10**	gavage	gestation (10 days)	reproduction	pup body weight, testes weight	MacKenzie and Angevine (1981)
Benzo(a)pyrene	benzo(a)pyrene	mouse	33.3	nv	food	up to 115 days	survival	survival	Neal and Rigdon (1967)
Naphthalene	naphthalene	mouse	**133**	nv	gavage	90 days	survival, growth	body weight, adult survival	Shopp et al. (1984)
Naphthalene	naphthalene	mouse	nv	**300**	gavage	8 days of pregnancy	survival, reproduction	maternal survival; litter size	Plasterer et al. (1985)
Phthalates									
BEHP	BEHP	mouse	**44**	**91**	food	17 days (pregnancy)	reproduction	fetal abnormalities increased	Tyl et al. (1988)
BEHP	BEHP	guinea pig	93	nv	food	1 year	survival, growth	life expectancy, body weight	Carpenter et al. (1953)
BEHP	BEHP	mouse	14	136	food	>24 weeks (2 generations)	reproduction	number of litters, viability	Lamb et al. (1987)
BEHP	BEHP	mouse	70	190	food	18 days (pregnancy)	reproduction	fetal death	Shiota et al. (1980)
BEHP	BEHP	mouse	91	191	food	17 days (pregnancy)	growth	maternal body weight	Tyl et al. (1988)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	**250**	**750**	food	multi-generational (2 generations)	growth, reproduction	body weight, reduced no. live pups/litter and no. implantations, reduced offspring body weight, delayed onset of puberty	Tyl et al. (2004)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	831	nv	food	14 days	growth	male body weight	Agarwal et al. (1985)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	nv	845	food	11 days (pregnancy)	reproduction	maternal weight; post-implantation embryo loss	Ema et al. (1994)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	991	nv	food	20 days (pregnancy)	survival	maternal mortalities	Ema et al. (1992a; 1992b)

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Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Butyl benzyl phthalate	butyl benzyl phthalate	rat	nv	991	food	20 days (pregnancy)	reproduction	fetal death, fetal weight, malformations and resorptions	Ema et al. (1992a)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	nv	1325	food	14 days	growth	male body weight	Agarwal et al. (1985)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	1570	nv	food	14 days	survival	male survival	Agarwal et al. (1985)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	**16**[c]	**80**	food	~24 weeks (2 gen)	reproduction	fertility, pup weight, pup viability, mating	Wine et al. (1997)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	641	nv	food	~24 weeks (2 gen)	survival		Wine et al. (1997)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	320	641	food	~24 weeks (2 gen)	growth	body weight	Wine et al. (1997)
Di-n-butyl phthalate	di-n-butyl phthalate	mouse	660	nv	food	18 days (pregnancy)	growth	maternal weight	Shiota et al. (1980)
Di-n-butyl phthalate	di-n-butyl phthalate	mouse	350	660	food	18 days (pregnancy)	reproduction	decrease in male fetal weight	Shiota et al. (1980)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	200	999	food	1 year	survival		Smith (1953)
Other SVOCs									
Benzoic acid	benzoic acid	rat	**80**	nv	diet	18 months	survival, growth	body weight, survival	Ignat'ev 1965 (as cited in IRIS (EPA 2006))
Benzoic acid	benzoic acid	rat	50	**750**	diet	long-term	growth	body weight	Marquardt 1980 (as cited in IRIS (EPA 2006))
Benzoic acid	sodium benzoate	hamster	300	nv	diet		survival, reproduction	no maternal toxicity or fetal toxicity	FDRL 1972 (as cited in IRIS (EPA 2006))
Biphenyl	biphenyl	rat	50	250	diet	3-generation	survival	longevity	Ambrose et al. 1960 (as cited in IRIS (EPA 2006))
Hexachlorobenzene	hexachloro-benzene	mink, ferret	**0.026**[c]	**0.13**	food	331 days	reproduction	birth weight	Bleavins et al. (1984)
Hexachlorobenzene	hexachloro-benzene	rat	nv	0.80	food	4 generation	reproduction	weanling weight	Grant et al. (1977)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Hexachlorobenzene	hexachloro-benzene	rat	1.28	nv	food	>120 days	reproduction, behavior	number of pups and weights	Lilienthal et al. (1996)
Hexachlorobenzene	hexachloro-benzene	rat	3.2	nv	food	2 generation	survival, growth		Arnold et al. (1985)
Hexachlorobenzene	hexachloro-benzene	rat	0.64	3.2	food	2 generation	reproduction	decreased viability	Arnold et al. (1985)
Hexachlorobenzene	hexachloro-benzene	rat	nv	4.8	food	~200 d days	reproduction	pup survival	Kitchin et al. (1982)
Hexachlorobenzene	hexachloro-benzene	rat	11	nv	food	> 100 days	survival, growth		Kitchin et al. (1982)
Hexachlorobenzene	hexachloro-benzene	mink, ferret	3.2	16	food	331 days	survival		Bleavins et al. (1984)
Hexachlorobenzene	hexachloro-benzene	rat	13	26	food	4 generation	survival		Grant et al. (1977)
Phenol	phenol	rat	**60**	**120**	gavage	gestational days 6 - 15	growth	maternal body weight	Argus Research Laboratories 1997 (as cited in IRIS (EPA 2006))
Phenol	phenol	rat	**60**	**120**	gavage	not specified	reproduction	decreased fetal body weight	Charles River Laboratories 1988 and NTP 1983a (as cited in IRIS (EPA 2006))
Phenol	phenol	mouse	140	280	gavage	gestational days 6 - 15	survival, growth	survival and reduced body weight	NTP 1983b (as cited in IRIS (EPA 2006))
PCBs									
Total PCBs	Clophen A50	mink	**0.045**[d,e]	**0.089**[e]	food	18 months	reproduction	kit growth	Brunström et al. (2001)
Total PCBs	Aroclor 1254	mink	nv	0.13	food	6 months	reproduction	reduced kit growth rate	Wren et al. (1987)
Total PCBs	Aroclor 1254	mink	nv	0.22	food	4 and 9 months prior to giving birth	reproduction	number of offspring per female, decrease in pup body weight	Ringer (1983)
Total PCBs	Aroclor 1254	mink	0.13	0.26	food	4 months	reproduction	Number of kits born alive (0% at 4 weeks)	Aulerich and Ringer (1977)
Total PCBs	Aroclor 1254	mink	nv	0.39	food	88-102 days	reproduction	number of kits whelped and born alive (0%)	Aulerich et al. (1985)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Total PCBs	mixture composition not reported	mink	nv	0.51	food	66 days	reproduction	number of kits born alive	Jensen et al. (1977)
Total PCBs	Aroclor 1242	mink	nv	0.65	food	8 months	reproduction	reproductive failure	Bleavins et al. (1980)
Total PCBs	Aroclor 1254	mouse	**0.13**[b,f]	**1.3**[f]	food	7.5 to 18 months	reproduction	offspring survival, offspring body weight	Linzey (1987, 1988)
Total PCBs	Aroclor 1254	mink	nv	1.31	food	4 weeks	weight gain in adults	weight gain in adults	Hornshaw et al. (1986)
Total PCBs	Aroclor 1254	mink	nv	1.64	food	3 months	reproduction	all whelps stillborn	Kihlstrom et al. (1992)
Total PCBs	Aroclor 1254	mink	1.2	1.8	food	28 days	growth	female growth	Aulerich et al. (1986)
Total PCBs	Clophen A50	mink	nv	2.0	food	3 months	reproduction	all whelps stillborn	Kihlstrom et al. (1992)
Total PCBs	Aroclor 1254	mink	1.5	2.4	food	28 days	growth	male and female growth	Aulerich et al. (1986)
Total PCBs	Aroclor 1016	mink	nv	2.6	food	8 months	reproduction/survival	birth weight and growth rate of kits, and 25 % adult female survival	Bleavins et al. (1980)
Total PCBs	Aroclor 1254	rat	3.7	7.5	food	10 days during gestation	reproduction	offspring body weight	Spencer (1982)
Organochlorine Pesticides									
beta-HCH	beta-HCH	rat	**5.7**	**31**	food	13 weeks	growth, survival	body weight, survival	Van Velsen et al. (1986)
beta-HCH	beta-HCH	rat	64	nv	food	2 weeks	growth	body weight	Srinivasan et al. (1991)
DDT	o,p'-DDT	rat	0.24	nv	food	2 generation	reproduction	litter size and weight and uterine involution	Duby et al. (1971)
DDT	p,p'-DDT	mouse	0.6	nv	food	5 generation	survival, growth, reproduction	adult survival, growth, number of pregnancies, number of births, litter size, pup growth/survival	Tarjan and Kemeny (1969)
DDT	p,p'- DDT	rat	1.0	nv	food	2 generation	reproduction	litter size and weight and uterine involution	Duby et al. (1971)
Total DDT	technical DDT	rat	**1.2**	nv	food	2 generations	reproduction	litter size and weight and uterine involution	Duby et al. (1971)

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Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Total DDT	form not specified, likely DDT mixture	mouse	1.3	nv	food	120 days	survival	no effect on survival	Ware and Good (1967)
Total DDT	form not specified, likely DDT mixture	mouse	nv	**1.3**	food	120 days	reproduction	litter size	Ware and Good (1967)
Total DDT	technical DDT	rat	1.6	nv	food	23 months	growth, survival, reproduction	adult survival, growth, viable litter size, reproductive life-span	Ottoboni (1972)
Total DDT	technical DDT	rat	nv	2.0	food	7.5 weeks	reproduction	fertility	Nickerson and Sniffen (1973)
Total DDT	form not specified, likely DDT mixture	rat	0.8	4.0	food	2 years	reproduction	number of young surviving to weaning (63% vs. 87% lower dose and 88% in control)	Fitzhugh (1948)
Total DDT	technical DDT	rat	6.7	13.4	food	36 weeks	reproduction	litter size, mating and reproductive success	Jonsson et al. (1976)
DDT	p,p'-DDT	rat	1.6	16	food	6 months	reproduction	offspring growth	Clement and Okey (1974)
Total DDT	form not specified, likely DDT mixture	white lab mouse	nv	37	food	F0 mating, gestation and weaning+F1 breeding	survival	no effect on survival	Cannon and Holcomb (1968)
Total DDT	technical DDT	Oldfield mouse	2.4	nv	food	15 months	survival, reproduction	adult survival, litter size, litters per pair	Wolfe et al. (1979)
DDT	o,p'-DDT	rat	4.0	nv	food	18-23 weeks	reproduction	offspring survival, fertility, fecundy, growth	Wrenn et al. (1971)
Total DDT	technical DDT	mouse	9.2	46	food	6 generation	survival, reproduction	lifespan, pup survival	Turusov et al. (1973)
Total DDT	technical DDT	rat	13	nv	food	37 weeks	survival	no effect on survival	Jonsson et al. (1976)
Total DDT	technical DDT (DDD, DDE, DDT)	rat	16	nv	food	3 generation	survival, growth, reproduction	adult survival, growth, fertility, viability, stillbirths, litter size, abnormalities, pup survival	Ottoboni (1969)
DDT	p,p'-DDT	mouse	18	nv	food	2 years	survival	no effect on survival	Thorpe and Walker (1973)
Total DDT	pp'-DDT, '-DDD, -DDE	rat	21	nv	food	6 weeks	growth, survival	survival, body weight (males only)	Banerjee et al. (1996)

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Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Methoxychlor	methoxychlor	rat	nv	**56**	food	gestation day 0 to postnatal day 22 (adult); postnatal day 28 to 100 (young)	growth, reproduction	body weight; offspring growth rate, litter size, sex development of offspring	You et al. (2002)
Methoxychlor	methoxychlor	rat	**17**	86	food	gestation day 15, postnatal day 10	reproduction, growth	maternal body weight, offspring body weight, delayed onset of puberty	Masutomi et al. (2003)
Methoxychlor	technical methoxychlor	rat	nv	80	food	parents treated, weanlings treated 8 weeks thru mating	reproduction	% mated, % littered	Harris et al. (1974)
Methoxychlor	technical methoxychlor	rat	nv	168	food	pre-mating thru weaning	reproduction	% mated, litter production and size	Harris et al. (1974)
VOCs									
Acetone	acetone, 99% pure	rat	**1,650**	**3,259**	drinking water	2 or 13 weeks	growth	body weight	Dietz et al. (1991)
Ethylbenzene	ethylbenzene	rat	**250**	**750**	gavage	13 weeks	growth	reduced body weight	Mellert et al. (2007)

[a] NOAEL and LOAEL TRVs, expressed as a dietary dose (mg/kg bw/day), were calculated from literature studies based on body weight, ingestion rate, and dietary concentrations.

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 10.

[c] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

[d] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 2.

[e] Selected NOAEL and LOAEL for the screening-level risk assessment.

[f] Selected NOAEL and LOAEL for the baseline risk evaluation.

bw – body weight
LOAEL – lowest-observed-effect concentration
BEHP – bis(2-ethylhexyl)phthalate
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCH – hexachlorocyclohexane
NOAEL – no-observed-effect concentration
nv – no value
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
SVOC - semivolatile organic compound
VOC – volatile organic compound

BOLD represents selected NOAEL and LOAEL TRVs.

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ATTACHMENT 2: METHODS FOR ESTIMATING TISSUE CONCENTRATIONS

Tissue data were not collected from the Harbor Oil Superfund Study Area for chemistry analysis. In order to conduct the ecological risk assessment (ERA), chemical concentrations in various tissue types were estimated from abiotic concentrations. Estimated tissue concentrations were used to assess risks to fish via fish tissue residues and to assess risks to various ecological receptors via dietary exposures.

Aquatic species (i.e., benthic invertebrates and fish) tissue concentrations were estimated from sediment using biota-sediment accumulation factors (BSAFs), and terrestrial species (i.e., terrestrial plants, invertebrates [earthworms] and small mammals) concentrations were estimated from soil using bioaccumulation factors (BAFs). BSAFs and BAFs represent the steady-state relationship between chemical concentrations in sediment or soil and tissue. Other assumptions (i.e., tissue-specific moisture and lipid content, sediment organic carbon [OC] content) were also used to calculate biota tissue-residue concentrations.

Equations 1 and 2 present how BSAFs are commonly derived as a ratio for inorganic (metals) and organic compounds, respectively.

$$BSAF = \frac{C_{tiss,dw}}{C_{sed,dw}} \qquad \textbf{Equation 1}$$

Where:

BSAF	ratio	chemical - and species-specific biota-sediment accumulation factor
$C_{tiss,dw}$	mg/kg dw	dry weight concentration in tissue
$C_{sed,dw}$	mg/kg dw	dry weight concentration in sediment

$$BSAF = \frac{C_{tissue} / Lipid_{tiss}}{C_{sed} / OC_{sed}} \qquad \textbf{Equation 2}$$

Where:

BSAF	ratio	chemical - and species-specific biota-sediment accumulation factor
$C_{tiss,ww}$	mg/kg ww	wet weight concentration in tissue
$Lipid_{tiss}$	fraction	lipid content in tissue (expressed as a fraction)
$C_{sed,dw}$	mg/kg dw	dry weight concentration in sediment
OC_{sed}	fraction	organic carbon content in sediment (expressed as a fraction)

Aquatic benthic invertebrate and fish tissue concentrations (C_{tiss}) used in the ERA were derived from Force Lake surface sediment concentrations (C_{sed}) by algebraically rearranging Equations 1 and 2 and using literature-based BSAFs and generic assumptions regarding moisture content and lipid content (Table 1).

Moisture content was needed to convert BSAF-estimated dry weight tissue concentrations (for metals) into wet weight tissue concentrations. For organic compounds, Force Lake sediment concentrations were OC-normalized using the sample-specific total organic carbon (TOC) value (Table 2), and tissue concentrations were converted from lipid-normalized concentrations to wet weight concentrations using an average receptor-specific lipid content.

Table 1. Assumptions Used to Estimate Tissue Concentrations Using BSAFs

Parameter	Assumption	Source
Sediment total organic carbon	see Table 2	Force Lake data
Moisture content – benthic invertebrates	79%	EPA (1993)
Moisture content – fish	72%	EPA (1993)
Lipid content – benthic invertebrates	1.2%	EPA (2008)[a]
Lipid content – fish	3.7%	EPA (2008)[b]
Lipid content – pumpkinseed	3.1%	EPA (2008)[c]
Lipid content – brown bullhead	2.6%	EPA (2008)[d]

[a] Average reported lipid content for all benthic invertebrates.
[b] Average reported lipid content for pumpkinseed, carp, and brown bullhead.
[c] Average reported lipid content for pumpkinseed.
[d] Average reported lipid content for brown bullhead.

BSAF – biota-sediment accumulation factor EPA – US Environmental Protection Agency

Table 2. TOC Data Used to Estimate Organic Compound Concentrations in Fish Tissue

Surface Sediment Sampling Location	TOC (%)
SE-01	6.71
SE-02	5.1
SE-03	6.54
SE-04	10.4
SE-05	6.02
SE-06	10.6
SE-07	13.1
SE-08	3.02
SE-09	8.44
SE-10	7.07
SE-11	1.34

TOC – total organic carbon

For metals, the following equation was used to estimate dry weight aquatic benthic invertebrate and fish tissue concentrations on a sample-by-sample basis:

$$C_{tiss,dw} = C_{sed,dw} \times BSAF \qquad \textbf{Equation 3}$$

Where:

$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
$C_{sed,\ dw}$	mg/kg dw	sample-specific dry weight Force Lake sediment concentration
BSAF	ratio	chemical and receptor-specific biota-sediment accumulation factor

Metal dry weight tissue concentrations were then converted into wet weight tissue concentrations using the following equation and percent moisture assumptions:

$$C_{tiss,ww} = C_{tiss,dw} \times (1 - M_{tiss}) \qquad \textbf{Equation 4}$$

Where:

$C_{tiss,ww}$	mg/kg ww	sample- and receptor-specific estimated wet weight tissue concentration
$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
M_{tiss}	fraction	receptor-specific moisture content in tissue (expressed as a fraction); M_{tiss} = 0.79 for aquatic benthic invertebrates, and M_{tiss} = 0.72 for fish (Table 1)

For organic compounds, the following equation and assumptions were used to derive wet weight aquatic benthic invertebrate and fish tissue concentrations:

$$C_{tiss,ww} = \left[\frac{C_{sed,dw}}{OC_{sed}} \times BSAF\right] \times Lipid_{tiss} \qquad \textbf{Equation 5}$$

Where:

$C_{tiss,ww}$	mg/kg ww	sample- and receptor-specific estimated wet weight tissue concentration
$C_{sed,\ dw}$	mg/kg dw	sample-specific dry weight Force Lake sediment concentration
OC_{sed}	fraction	sample-specific TOC in sediment (expressed as a fraction)
BSAF	ratio	chemical and receptor-specific biota-sediment accumulation factor
$Lipid_{tiss}$	fraction	receptor-specific lipid content in tissue (expressed as a fraction); $Lipid_{tiss}$ = 0.012 for aquatic benthic invertebrates, $Lipid_{tiss}$ = 0.031 for pumpkinseed, and $Lipid_{tiss}$ = 0.026 for brown bullhead (Table 1)

Equation 6 presents how BAFs are commonly derived as a ratio for both inorganic (metals) and organic compounds.

$$BAF = \frac{C_{tissue}}{C_{soil}} \qquad \textbf{Equation 6}$$

Where:

BAF	ratio	chemical - and species-specific bioaccumulation factor
$C_{tiss,dw}$	mg/kg dw	dry weight concentration in tissue
$C_{sed,dw}$	mg/kg dw	dry weight concentration in soil

Terrestrial plant, terrestrial invertebrate (earthworms), and small mammal tissue concentrations (C_{tiss}) used in the ERA were derived from wetland surface soil concentrations (C_{sed}) by algebraically rearranging Equation 6 and using literature-based BAFs and generic assumptions regarding moisture content (Table 3). Moisture content was needed to convert BAF-estimated dry weight tissue concentrations into wet weight tissue concentrations.

Table 3. Assumptions Used to Estimate Tissue Concentrations Using BAFs

Parameter	Assumption	Source
Moisture content – terrestrial plants	79%	EPA (1993)
Moisture content – terrestrial invertebrates	71%[a]	EPA (1993)
Moisture content – small terrestrial mammals	68%	EPA (1993)

[a] Moisture content was based on the average earthworm percent moisture.

BAF – bioaccumulation factor EPA – US Environmental Protection Agency

The following equation and assumptions were used to estimate dry weight terrestrial species tissue concentrations on a sample-by-sample basis:

$$C_{tiss,dw} = C_{soil,dw} \times BAF \qquad \textbf{Equation 7}$$

Where:

$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
$C_{soil,\ dw}$	mg/kg dw	sample-specific dry weight wetland soil concentration
BAF	ratio	chemical- and receptor-specific biota accumulation factor

Dry weight tissue concentrations were then converted into wet weight tissue concentrations using the following equation and percent moisture assumption:

$$C_{tiss,ww} = C_{tiss,dw} \times (1 - M_{tiss}) \qquad \textbf{Equation 8}$$

Where:

$C_{tiss,ww}$	mg/kg ww	sample- and receptor-specific estimated wet weight tissue concentration
$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
M_{tiss}	fraction	receptor-specific moisture in tissue (expressed as a fraction); M_{tiss} = 0.79 for terrestrial plants, M_{tiss} = 0.71 for terrestrial invertebrates, and M_{tiss} = 0.68 for small mammals (Table 3)

A search for benthic invertebrate and fish literature-based BSAF was conducted for all sediment contaminants of interest (COIs) (i.e., chemicals with detected concentrations in Force Lake surface sediment). BSAFs were selected from a variety of compilation sources; their availability varied depending on the chemical class and modeled species. BSAFs were selected based on the following hierarchy:

- Fish and invertebrate BSAFs for organic compounds were based on US Environmental Protection Agency's (EPA's) BSAF database (EPA 2008) when available.

- Benthic invertebrate BSAFs for inorganic chemicals (i.e., metals) were based on mean BSAFs reported by the Oak Ridge National Laboratory (ORNL) (1998).
- Fish BSAFs were derived as the mean BSAF reported in the collection of BSAFs compiled by PTI (1995a, b).
- A surrogate BSAF was used for some related chemicals (e.g., bis(2-ethylhexyl) phthalate [BEHP] was used as a surrogate for other phthalates with no BAF).
- A default value of 1 was used for all sediment COIs with no published value from the above sources. The use of this default value assumed that sediment and tissue concentrations were equal, which is a conservative assumption for chemicals that are regulated by fish or benthic invertebrates (e.g., metals) or do not accumulate (e.g., VOCs) and would therefore have BSAFs lower than 1. The default BSAF assumption of 1 could underestimate risks for bioaccumulative chemicals; however, literature-based BSAFs are available for the key known bioaccumulative chemicals, such as PCBs and DDTs.

The US Army Corps of Engineers (USACE) BSAF database (2008) was searched to obtain BSAFs; however, units for BSAFs in this database are not clearly presented (i.e., whether BSAFs for organic compounds were expressed as lipid- and OC-normalized tissue and sediment concentrations, respectively), and thus these BSAFs were not used.

A search for terrestrial plant, invertebrate (earthworm), and small mammal literature-based BAFs was conducted for all soil COIs (i.e., all chemicals with detected concentrations in wetland soil). BAFs were selected from a variety of compilation sources based on the following hierarchy:

- BAFs for terrestrial plants, terrestrial invertebrates, and small terrestrial mammals were selected from the available literature from ORNL (Bechtel Jacobs 1998; Lockheed-Martin Energy Systems 1998a, b) when available.
- The guidance for ecological soil screening levels (EPA 2007) was used to develop plant, invertebrate, and small mammals BAFs for those COIs for which no ORNL BAF was available.
- BAFs for terrestrial plants were derived from regressions reported in Travis and Arms (1988) and using chemical-specific K_{OW} values.
- A PCB BAF for small mammals was developed based on Moore et al. (2003).
- A surrogate BAF was used for some related chemicals (e.g., BEHP was used as a surrogate for other phthalates with no BAF).
- A default value of 1 was used for all soil COIs with no published value from the above sources. The use of this default value assumed that soil and tissue concentrations were equal, which is a conservative assumption for chemicals that are regulated (e.g., metals) or do not accumulate (e.g., VOCs) and would therefore have BAFs lower than 1. The default BAF assumption of 1 could underestimate risks for

bioaccumulative chemicals; however, literature-based BAFs are available for the key known bioaccumulative chemicals, such as PCBs and DDTs.

Tables 4 and 5 present the aquatic invertebrate and fish BSAFs used in the ERA. Tables 6 through 8 present the terrestrial plant, earthworm, and small mammal BAFs that were used in the ERA. Table 9 presents the K_{OW} values that were used to derive some terrestrial plant BAFs.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Metals (dw/dw)		
Aluminum	1	No invertebrate BSAF was available from the literature; default value was used.
Antimony	1	No invertebrate BSAF was available from the literature; default value was used.
Arsenic	0.240	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 49 BSAFs ranging from 0.018 to 0.889 compiled from multiple sources; median BSAF was 0.127.
Barium	1	No invertebrate BSAF was available from the literature; default value was used.
Beryllium	1	No invertebrate BSAF was available from the literature; default value was used.
Cadmium	3.438	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 88 BSAFs ranging from 0.049 to 41.55 compiled from multiple sources; median BSAF was 0.614.
Chromium	0.206	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 26 BSAFs ranging from 0.015 to 1.101 compiled from multiple sources; median BSAF was1.108.
Cobalt	1	No invertebrate BSAF was available from the literature; default value was used.
Copper	2.14	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 74 BSAFs ranging from 0.032 to 16.63 compiled from multiple sources; median BSAF was1.647.
Lead	0.331	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 83 BSAFs ranging from 0.004 to 7.08 compiled from multiple sources; median BSAF was 0.066.
Mercury	1.204	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 13 BSAFs ranging from 0.286 to 2.868 compiled from multiple sources; median BSAF was 1.081.
Nickel	1.313	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 16 BSAFs ranging from 0.397 to 5.746 compiled from multiple sources; median BSAF was 0.818.
Selenium	1	No invertebrate BSAF was available from the literature; default value was used.
Vanadium	1	No invertebrate BSAF was available from the literature; default value was used.
Zinc	3.473	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 84 BSAFs ranging from 0.026 to 14.512 compiled from multiple sources; median BSAF was 2.33
PAHs (lipid/OC)		
2-Methylnaphthalene	3.194	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 17 BSAFs ranging from 0.00369 to 29.42.
Acenaphthene	0.252	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 42 BSAFs ranging from 0.00048 to 1.43.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Acenaphthylene	0.508	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 52 BSAFs ranging from 0.00105 to 5.07.
Anthracene	0.659	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 63 BSAFs ranging from 0.00030 to 23.7.
Benzo(a)anthracene	0.545	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 66 BSAFs ranging from 0.00014 to 11.8.
Benzo(a)pyrene	0.383	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 64 BSAFs ranging from 0.00016 to 9.51.
Benzo(b)fluoranthene	1.45	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 8 BSAFs ranging from 0.00144 to 8.03.
Benzo(g,h,i)perylene	0.691	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 55 BSAFs ranging from 0.00013 to 16.8.
Benzo(k)fluoranthene	2.09	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 6 BSAFs ranging from 0.00226 to 11.0.
Chrysene	0.554	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 43 BSAFs ranging from 0.00713 to 7.30.
Dibenzo(a,h)anthracene	1.89	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 28 BSAFs ranging from 0.00004 to 37.1.
Fluoranthene	0.431	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 70 BSAFs ranging from 0.00044 to 4.54.
Fluorene	0.628	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 56 BSAFs ranging from 0.00053 to 10.7.
Indeno(1,2,3-cd)pyrene	1.02	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 47 BSAFs ranging from 0.00006 to 19.6.
Naphthalene	0.588	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 22 BSAFs ranging from 0.00043 to 3.15.
Phenanthrene	0.496	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 65 BSAFs ranging from 0.00016 to 8.86.
Pyrene	0.318	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 70 BSAFs ranging from 0.00037 to 3.33.
Total PAHs	0.924	Based on the mean of the average BSAFs for individual PAHs reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrates; individual PAH BSAFs ranged from 0.00004 to 37.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
PCBs (lipid/OC)		
Total PCBs	2.57	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 155 BSAFs ranging from 0.00715 to 27.9.
Phthalates (lipid/OC)		
BEHP	7.75	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 3 BSAFs ranging from 0.81 to 14.0.
Butyl benzyl phthalate	7.75	Based on the BEHP BSAF.
Di-n-butyl phthalate	7.75	Based on the BEHP BSAF.
Other SVOCs (lipid/OC)		
Hexachlorobenzene	1	No invertebrate BSAF was available from the literature; default value was used.
Phenol	1	No invertebrate BSAF was available from the literature; default value was used.
Pentachlorophenol	1	No invertebrate BSAF was available from the literature; default value was used.
Pesticides (lipid/OC)		
2,4'-DDD	4.32	Based on the 4,4'-DDD BSAF.
4,4'-DDD	4.32	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 19 BSAFs ranging from 0.0343 to 45.0.
4,4'-DDE	5.94	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 74 BSAFs ranging from 0.393 to 48.5.
Total DDTs	5.21	Based on the weighted average BSAF for the three DDT components detected in Force Lake: 16% 2,4′-DDD (mean BSAF of 4.32 from EPA (2008)), 29% 4,4′-DDD (mean BSAF of 4.32 from EPA (2008)), and 55% 4,4'-DDE (mean BSAF of 5.94 from EPA (2008)); DDT metabolite BSAFs ranged from 0.034 to 49.
delta-BHC	1	No invertebrate BSAF was available from the literature; default value was used.
Methoxychlor	1	No invertebrate BSAF was available from the literature; default value was used.
Ethylbenzene	1	No invertebrate BSAF was available from the literature; default value was used.
VOCs (lipid/OC)		
Acetone	1	No invertebrate BSAF was available from the literature; default value was used.
Carbon disulfide	1	No invertebrate BSAF was available from the literature; default value was used.
Methyl ethyl ketone	1	No invertebrate BSAF was available from the literature; default value was used.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Toluene	1	No invertebrate BSAF was available from the literature; default value was used.
Acetone	1	No invertebrate BSAF was available from the literature; default value was used.

[a] All metal BSAFs are expressed as the ratio of tissue concentration (in dry weight) over sediment concentration (in dry weight); all BSAFs for organic compounds are expressed as the ratio of tissue concentration (as a lipid-normalized concentration) over sediment concentration (as an OC-normalized concentration).

BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
BSAF – biota-sediment accumulation factor
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
OC – organic carbon
ORNL – Oak Ridge National Laboratory
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 5. Fish BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Metals (dw/dw)		
Aluminum	1	No fish BSAF was available from the literature; default value was used.
Arsenic	0.12	This was the only fish BSAF presented in PTI (1995b).
Barium	1	No fish BSAF was available from the literature; default value was used.
Cadmium	0.785	Based on the mean BSAF reported by PTI (1995b); mean was based on 9 BSAFs ranging from 0.043 to 2.0 compiled from one location.
Chromium	0.043	This was the only fish BSAF presented in PTI (1995b).
Cobalt	1	No fish BSAF was available from the literature; default value was used.
Copper	1	No fish BSAF was available from the literature; default value was used.
Lead	0.180	Based on the mean BSAF reported by PTI (1995b); mean was based on 9 BSAFs ranging from 0.028 to 0.43 compiled from one location.
Mercury	0.38	Only fish BSAF value presented in PTI (1995b)
Nickel	1	No fish BSAF was available from the literature; default value was used.
Vanadium	1	No fish BSAF was available from the literature; default value was used.
Zinc	1.83	Based on the mean BSAF reported by PTI (1995b); mean was based on 10 BSAFs ranging from 0.13 to 5.0 compiled from two locations.
PAHs (lipid/OC)		
2-Methylnaphthalene	0.147	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 14 BSAFs ranging from 0.0109 to 0.972.
Acenaphthene	0.0313	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 11 BSAFs ranging from 0.00484 to 0.0602.
Acenaphthylene	0.0138	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 11 BSAFs ranging from 0.00032 to 0.0287.
Anthracene	0.0078	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 15 BSAFs ranging from 0.00020 to 0.0148.
Benzo(a)anthracene	0.0135	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 8 BSAFs ranging from 0.00030 to 0.0941.
Benzo(a)pyrene	0.0021	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 4 BSAFs ranging from 0.00023 to 0.0040.

Table 5. Fish BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Benzo(b)fluoranthene	0.0025	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 5 BSAFs ranging from 0.00022 to 0.0043.
Benzo(g,h,i)perylene	0.0250	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 3 BSAFs ranging from 0.00118 to 0.0699.
Benzo(k)fluoranthene	0.0023	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 5 BSAFs ranging from 0.00021 to 0.0041.
Chrysene	0.0100	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 8 BSAFs ranging from 0.00032 to 0.0636.
Dibenzo(a,h)anthracene	0.0022	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 5 BSAFs ranging from 0.00031 to 0.0043.
Dibenzofuran	0.0259	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 12 BSAFs ranging from 0.00211 to 0.0496.
Fluoranthene	0.0056	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 15 BSAFs ranging from 0.00008 to 0.0383.
Fluorene	0.0626	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 16 BSAFs ranging from 0.00058 to 0.5256.
Indeno(1,2,3-cd)pyrene	0.0144	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 6 BSAFs ranging from 0.00021 to 0.0756.
Naphthalene	0.135	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 11 BSAFs ranging from 0.0123 to 0.813.
Phenanthrene	0.0237	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 17 BSAFs ranging from 0.00021 to 0.161.
Pyrene	0.0158	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 8 BSAFs ranging from 0.00025 to 0.0638.
Total PAHs	0.0300	Based on the mean of average BSAFs for individual PAHs reported in EPA's BSAF database (EPA 2008) for all fish species.

Table 5. Fish BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
PCBs (lipid/OC)		
Total PCBs	6.45	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 285 BSAFs ranging from 0.00375 to 258.
Other SVOCs (lipid/OC)		
Pentachlorophenol	1	No fish BSAF was available from the literature; default value was used.
Pesticides (lipid/OC)		
2,4'-DDD	0.045	Based on the geometric mean BSAF reported by PTI (1995a).
4,4'-DDD	0.83	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008).;
4,4'-DDE	5.00	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008).
Total DDTs	3.0	Based on the weighted average BSAFs for the three DDT components detected in Force Lake:16% 2,4′-DDD (geometric mean BSAF of 0.045 from PTI (1995a)), 29% 4,4′-DDD (mean BSAF of 0.83 from EPA (2008)), and 55%4,4'-DDE (mean BSAF of 5.00 from EPA (2008))
VOCs (lipid/OC)		
Acetone	1	No fish BSAF was available from the literature; default value was used.
Carbon disulfide	1	No fish BSAF was available from the literature; default value was used.
Methyl ethyl ketone	1	No fish BSAF was available from the literature; default value was used.
Toluene	1	No fish BSAF was available from the literature; default value was used.

[a] All metal BSAFs are expressed as the ratio of tissue concentration (in dry weight) over sediment concentration (in dry weight); all BSAFs for organic compounds are expressed as the ratio of tissue concentration (as a lipid-normalized concentration) over sediment concentration (as an OC-normalized concentration).

BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
BSAF – biota sediment accumulation factor
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 6. Terrestrial Plant BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source of and Details on Selected Value
Metals		
Aluminum	1.0	No plant BAF was available from the literature; default value was used.
Antimony	$C_{plant} = e^{(0.938*LN(Csoil)-3.233)}$	Based on the BAF reported in EPA (2007).
Arsenic	0.454	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 122 BAFs ranging from 0.00006 to 9.074 compiled from multiple sources; median BAF was 0.0375.
Cadmium	1.359	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 207 BAFs ranging from 0.0087 to 22.879 compiled from multiple sources; median BAF was 0.586.
Chromium	0.041	Based on the BAF reported in EPA (2007).
Cobalt	0.0075	Based on the BAF reported in EPA (2007).
Copper	0.341	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 180 BAFs ranging from 0.0011 to 7.4 compiled from multiple sources; median BAF was 0.124.
Lead	0.245	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 189 BAFs ranging from 0.00011 to 10.601 compiled from multiple sources; median BAF was 0.0389.
Mercury	1.481	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 145 BAFs ranging from 0.00145 to 12.23 compiled from multiple sources; median BAF was 0.652.
Nickel	0.749	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 111 BAFs ranging from 0.00217 to 22.214 compiled from multiple sources; median BAF was 0.018.
Selenium	2.253	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 158 BAFs ranging from 0.02 to 77compiled from multiple sources; median BAF was 0.672.
Vanadium	0.00485	The plant BAF of 0.00485 was based EPA (2007). The variability in vanadium BAFs from the literature is unknown.
Zinc	1.021	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 220 BAFs ranging from 0.00855 to 34.286 compiled from multiple sources; median BAF was 0.366.
PAHs		
2-Methylnaphthalene	12.2	Based on the naphthalene BAF.
Benzo(a)pyrene	$C_{plant} = e^{(0.975*LN(Csoil)-2.0615)}$	Based on the BAF reported in EPA (2007).
Naphthalene	12.2	Based on the BAF reported in EPA (2007).
Total PAHs	6.15	Based on the average BAF of the two individual PAHs[a] with BAFs (benzo[a]pyrene and naphthalene) reported in EPA (2007); the benzo(a)pyrene BAF (0.103) was estimated using the maximum benzo(a)pyrene soil concentration (4,000 µg/kg dw) and the BAF equation reported by EPA (2007).
Phthalates		
BEHP	0.00179	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} =

Table 6. Terrestrial Plant BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source of and Details on Selected Value
		1.588 – (0.578 log K_{ow})[b].
Butyl benzyl phthalate	0.00179	Based on the BEHP BAF.
Di-n-butyl phthalate	0.128	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Other SVOCs		
Benzoic acid	1.0	No plant BAF was available from the literature; default value was used.
Biphenyl	1.0	No plant BAF was available from the literature; default value was used.
Hexachlorobenzene	0.0189	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Pentachlorophenol	1.0	No plant BAF was available from the literature; default value was used.
Phenol	5.55	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
PCBs		
Total PCBs	0.00519	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Pesticides		
Total DDTs	$C_{plant} = e^{(0.7524*LN(Csoil)-2.5119)}$	Based on the BAF reported in EPA (2007).
delta-BHC	0.157	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Methoxychlor	0.0585	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
VOCs		
Acetone	53.3	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Ethylbenzene	0.348	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].

[a] Average BAF of naphthalene (12.2) and benzo(a)pyrene (0.103). Benzo(a)pyrene BAF was estimated using the maximum soil concentration (4,000 mg/kg dw).

[b] Log K_{ow} values are presented in Table 6.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 7. Earthworm BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source and Details on Selected Value
Metals		
Aluminum	1	No invertebrate BAF was available from the literature; default value was used.
Antimony	1	Based on EPA (2007), where concentration in earthworm is equivalent to the concentration in soil.
Arsenic	0.258	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 53 BAFs ranging from 0.006 to 0.925 compiled from multiple sources; median BAF was 0.224.
Cadmium	17.105	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 226 BAFs ranging from 0.253 to 190 compiled from multiple sources; median BAF was 7.708.
Chromium	1.099	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 67 BAFs ranging from 0.021 to 11.416 compiled from multiple sources; median BAF was 0.306.
Cobalt	0.122	Based on the BAF reported by reported in EPA (2007).
Copper	0.754	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 197 BAFs ranging from 0.002 to 5.492 compiled from multiple sources; median BAF was 0.515.
Lead	3.342	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 245 BAFs ranging from 0 to 228.261 compiled from multiple sources; median BAF was 0.266.
Manganese	0.064	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 36 BAFs ranging from 0.012 to 0.228 compiled from multiple sources; median BAF was 0.054.
Mercury	5.231	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 30 BAFs ranging from 0.030 to 33 compiled from multiple sources; median BAF was 1.693.
Nickel	1.656	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 31 BAFs ranging from 0.033 to 7.802 compiled from multiple sources; The median BAF was 1.059.
Selenium	1.798	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 14 BAFs ranging from 0.300 to 13.733 compiled from one study; median BAF was 0.985.
Vanadium	0.042	Based on the BAF reported by reported in EPA (2007).
Zinc	5.766	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a) ; mean was based on 244 BAFs ranging from 0.025 to 49.51 compiled from multiple sources; median BAF was 3.201.
PAHs		
2-Methylnaphthalene	4.4	Based on the naphthalene BAF.
Benzo(a)pyrene	1.33	Based on the BAF reported by reported in EPA (2007).
Naphthalene	4.4	Based on the BAF reported by reported in EPA (2007).
Total PAHs	2.87	Based on the average BAF of the two individual PAHs with BAFs (benzo[a]pyrene and naphthalene) reported in EPA (2007).

Table 7. Earthworm BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source and Details on Selected Value
Phthalates		
BEHP	1	No invertebrate BAF was available from the literature; default value was used.
Butyl benzyl phthalate	1	No invertebrate BAF was available from the literature; default value was used.
Di-n-butyl phthalate	1	No invertebrate BAF was available from the literature; default value was used.
Other SVOCs		
Benzoic acid	1	No invertebrate BAF was available from the literature; default value was used.
Biphenyl	1	No invertebrate BAF was available from the literature; default value was used.
Hexachlorobenzene	1	No invertebrate BAF was available from the literature; default value was used.
Pentachlorophenol	1	No invertebrate BAF was available from the literature; default value was used.
Phenol	1	No invertebrate BAF was available from the literature; default value was used.
PCBs		
Total PCBs	8.909	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 32 BAFs ranging from 0 to 65.227 compiled from multiple sources; median BAF was 6.667.
Pesticides		
Total DDTs	11.2	Based on the BAF reported by reported in EPA (2007).
delta-BHC	1	No invertebrate BAF was available from the literature; default value was used.
Methoxychlor	1	No invertebrate BAF was available from the literature; default value was used.
VOCs		
Acetone	1	No invertebrate BAF was available from the literature; default value was used.
Ethylbenzene	1	No invertebrate BAF was available from the literature; default value was used.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 8. Small Mammal BAFs Used in the ERA

Chemical	BAF (dw/dw[a])	Source and Details on Selected Value
Metals		
Aluminum	1.0	No small mammal BAF was available from the literature; default value was used.
Arsenic	0.0063	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 72 BAFs compiled from multiple sources, ranging from 0 to 0.071; median BAF was 0.0025.
Barium	0.0696	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 14 BAFs ranging from 0.0144 to 0.253 compiled from multiple sources; median BAF was 0.0566.
Cadmium	1.9902	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 99 BAFs ranging from 0.0153 to 69.561 compiled from multiple sources; median BAF was 0.3333.
Chromium	0.1382	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 38 BAFs ranging from 0.0314 to 0.8 compiled from multiple sources; median BAF was 0.846.
Cobalt	0.0371	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 15 BAFs ranging from 0.0101 to 0.18 compiled from multiple sources; median BAF was 0.0205.
Copper	0.42	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 76 BAFs ranging from 0.0044 to 1.398 compiled from multiple sources; median BAF was 0.1963.
Lead	0.1615	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 138 BAFs ranging from 0.0031 to 2.659; compiled from multiple sources; median BAF was 0.1054.
Mercury	0.1244	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 18 BAFs ranging from 0.0183 to 1.046 compiled from multiple sources; median BAF was 0.0543.
Nickel	0.2799	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 43 BAFs ranging from 0 to 1.143 compiled from multiple sources; median BAF was 0.2488.
Selenium	0.3464	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 35 BAFs ranging from 0 to 1.754 compiled from multiple sources; median BAF was 0.1619.
Vanadium	0.0123	Based on BAF reported in EPA (2007).
Zinc	1.3352	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 103 BAFs ranging from 0.0051 to 16.364 compiled from multiple sources; median BAF was 0.7717.
PAHs		
Benzo(a)pyrene	0.001	Based on EPA (2007) which reported that uptake of PAHs is assumed to be negligible
Total PAHs	0.001	Based on EPA (2007) which reported that uptake of PAHs is assumed to be negligible.
Phthalates		
BEHP	1.0	No small mammal BAF was available from the literature; default value was used.
Butyl benzyl phthalate	1.0	No small mammal BAF was available from the literature; default value was used.
Di-n-butyl phthalate	1.0	No small mammal BAF was available from the literature; default value was used.

Table 8. Small Mammal BAFs Used in the ERA

Chemical	BAF (dw/dw[a])	Source and Details on Selected Value
Other SVOCs		
Hexachlorobenzene	1.0	No small mammal BAF was available from the literature; default value was used.
Pentachlorophenol	1.0	No small mammal BAF was available from the literature; default value was used.
Phenol		
PCBs		
Total PCBs	0.45[b]	Based on data presented in Moore et al. (2003); the small-mammal BAF (needed to estimated COPC concentrations in red-tailed hawk prey) was calculated as a weighted average of the mean reported short-tailed shrew BAF (1.2) and white-footed mouse BAF (0.2) using the following equation: BAF_{mammal} = ([BAF_{mouse} x 0.75]+[BAF_{shrew} x 0.25]).
Pesticides		
Total DDTs	C_{mammal} = ([C_{plant} x 0.75]+[C_{invert} x 0.25]) x 4.83[e]	Based on data presented in EPA (2007); EPA (2007) reported an uptake factor of 4.83 from prey concentrations to the concentration in mammal tissue. The concentration in mammals was calculated assuming 75% plant-eating mammals and 25% invertebrate-eating mammals based on the assumption that the red-tailed hawk small mammal diet is primarily plant-eating mammals (Csuti et al. 2001; EPA 1993; Marshall et al. 2003).
delta-BHC	1.0	No small mammal BAF was available from the literature; default value was used.
Methoxychlor	1.0	No small mammal BAF was available from the literature; default value was used.
VOCs		
Acetone	1.0	No small mammal BAF was available from the literature; default value was used.

[a] All BAFs are expressed as the ratio of tissue concentration (in dry weight) over soil concentration (in dry weight), except where noted.

[b] For this BAF, tissue concentration is expressed as wet weight and soil is expressed as dry weight.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 9. Log K_{ow} Values Used to Derive Plant BAFs

Chemical	Log K_{ow}[a]
BEHP	7.5
Di-n-butyl phthalate	4.29
Hexachlorobenzene	5.73
Phenol	1.46
Total PCBs	6.7[b]
delta-BHC	4.14
Methoxychlor	4.88
Acetone	-0.24
Ethylbenzene	3.54

[a] Log K_{ow} based on ATSDR (2006).

[b] Log K_{ow} based on average of PCB Aroclors 1254 and 1260.

BAF – bioaccumulation factor

BEHP – bis(2-ethylhexyl) phthalate

BHC – benzene hexachloride

PCB – polychlorinated biphenyl

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ATTACHMENT 3: EXPOSURE POINT CONCENTRATIONS

Exposure point concentrations (EPCs) in tissue and sediment were calculated in order to estimate exposure concentrations (as tissue residues or dietary doses) for fish and wildlife receptors of concern (ROCs). Sediment and soil EPCs (EPC_{sed} and EPC_{soil}) were represented by a upper confidence limit on the mean (UCL) concentration calculated using ProUCL 4.00.04 (EPA 2009), which includes provisions for handling non-detected values (EPA 2007) if sufficient data (i.e., six or more detected concentrations) are available. The UCL recommended by ProUCL was used as the EPC_{sed} or EPC_{soil} for the risk assessment, unless the UCL was greater than the maximum concentration. If the UCL was greater than the maximum concentration, then the maximum concentration was used to represent the EPC_{sed} or EPC_{soil} for the risk assessment. If sufficient data were not available to calculate a UCL using ProUCL 4.00.04, the EPC_{sed} or EPC_{soil} was set equal to one-half of the maximum reporting limit (RL) (if no detected results were available) or set equal to the maximum detect or one-half the maximum RL, whichever was greater. Tables 1 and 2 present the summary statistics and selected EPC_{sed} or EPC_{soil} values. These values were used to estimate tissue concentrations (EPC_{prey}) using biota-sediment accumulation factors (BSAFs) or bioaccumulation factors (BAFs), and receptor-specific assumptions. Details on how BSAFs, BAFs, and assumptions were selected are presented in Attachment 2.

Table 1. Wetland Soil EPCs and Summary Statistics for the Baseline ERA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	EPC_{soil}	Selected Statistic
Metals								
Aluminum	mg/kg dw	5/5	12,100	na	9,500	9,500	12,000	Maximum detect
Arsenic	mg/kg dw	71/71	53.1	na	8	8	9.3	95% H-UCL
Cadmium	mg/kg dw	63/71	4	0.4 U	1	0.9	1	95% KM (BCA) UCL
Cobalt	mg/kg dw	71/71	34.3	na	10	10	12	95% modified-t UCL
Copper	mg/kg dw	71/71	1,240 J	na	72	72	150	95% Chebyshev (Mean, Sd) UCL
Lead	mg/kg dw	71/71	320	na	60	60	78	95% H-UCL
Mercury	mg/kg dw	64/71	0.4	0.26 U	0.2	0.1	0.16	95% KM (BCA) UCL
Nickel	mg/kg dw	71/71	48	na	20	20	24	95% approximate gamma UCL
Selenium	mg/kg dw	3/71	1.1	3 U	0.8	0.5	1.5	half maximum RL
Vanadium	mg/kg dw	71/71	148	na	70	70	74	95% approximate gamma UCL
Zinc	mg/kg dw	71/71	748	na	200	200	240	95% H-UCL
PAHs								
Total PAHs	µg/kg dw	70/71	69,000	2,770 U	4,000	3,000	8,300	95% KM (Chebyshev) UCL
PCBs								
Total PCBs	µg/kg dw	46/71	4,200	990 U	500	300	680	95% KM (Chebyshev) UCL
Pesticides								
Total DDTs	µg/kg dw	70/71	46,000	130 U	3,000	3,000	8,500	97.5% KM (Chebyshev) UCL

[a] The mean value is equal to the average of all detected values and one-half of the RL for all non-detect values.

BCA – bias-corrected accelerated
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
ERA – ecological risk assessment
J-qualifier – estimated concentration
KM – Kaplan-Meier
na – not applicable
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
UCL – upper confidence limit on the mean
U-qualifier – not detected at given concentration

Table 2. Sediment EPCs and Summary Statistics for the Baseline ERA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	EPC_{sed}	Selected Statistic
Metals								
Arsenic	mg/kg dw	11/11	7	na	6	6	6.4	95% Student's-t UCL
Cadmium	mg/kg dw	8/11	2	0.7 U	2	2	2	maximum detect[b]
Cobalt	mg/kg dw	11/11	15	na	13	13	14	95% Student's-t UCL
Copper	mg/kg dw	11/11	72	na	53	53	72	maximum detect[c]
Lead	mg/kg dw	11/11	56	na	40	40	56	maximum detect[d]
Mercury	mg/kg dw	1/11	0.2 J	0.3 U	0.2	0.2	0.2	maximum detect
Nickel	mg/kg dw	11/11	31	na	24	24	27	95% Student's-t UCL
Vanadium	mg/kg dw	11/11	74	na	60	60	67	95% Student's-t UCL
Zinc	mg/kg dw	11/11	229	na	200	200	200	95% Student's-t UCL
PAHs								
Total PAHs	µg/kg dw	11/11	1,060	na	560	560	740	95% Student's-t UCL
	mg/kg OC	11/11	19.8	na	8.9	8.9	12	95% Student's-t UCL
PCBs								
Total PCBs	µg/kg dw	7/11	131	49 U	110	80	120	95% KM (percentile bootstrap) UCL
	mg/kg OC	7/11	1.83	2.5 U	1.4	1.1	1.4	95% KM (percentile bootstrap) UCL
Pesticides								
Total DDTs	µg/kg dw	11/11	250	na	160	160	200	95% Student's-t UCL
	mg/kg OC	11/11	3.7 JN	na	2.3	2.3	2.7	95% Student's-t UCL

[a] The mean value is equal to the average of all detected values and on-half of the RL for all non-detect values.
[b] All detected values were equal, and thus there were too few unique values for use in ProUCL.
[c] ProUCL recommended UCL (78) is greater than the maximum detected concentration, therefore the maximum concentration was selected as the EPC_{sed}.
[d] ProUCL recommended UCL (62) is greater than the maximum detected concentration, therefore the maximum concentration was selected as the EPC_{sed}.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
ERA – ecological risk assessment
J-qualifier – estimated concentration
N-qualifier – tentative identification
na – not applicable
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
UCL – upper confidence limit on the mean
U-qualifier – not detected at given concentration

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ATTACHMENT 4: BACKGROUND AND REFERENCE AREA CONCENTRATIONS

1.0 Introduction

US Environmental Protection Agency (EPA) guidance discusses two types of background concentrations, natural and anthropogenic. Natural background is defined as "naturally occurring substances present in the environment in forms that have not been influenced by human activity." Anthropogenic background is defined as "natural and human-made substances present in the environment as a result of human activities (not specifically related to the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] site in question)" (EPA 2002). As recommended in EPA (2002) guidance, background concentrations of contaminants of potential concern (COPCs) at the Harbor Oil Study Area (when available) are discussed in the ecological risk assessment (ERA).

This attachment discusses background concentrations for metals as available from Oregon Department of Environmental Quality (DEQ) and reference area concentrations for organic compounds. The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA. Instead, concentrations from reference areas (urban areas within the vicinity of the Study Area) are presented for comparison with Study Area concentrations.

This attachment presents the background or reference area concentrations of COPCs identified in the ERA. Sources of background or reference area concentrations for the Harbor Oil ERA include the following:

- DEQ's Memorandum from Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002): This memorandum presents regional soil background concentrations for metals, including arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc.
- DEQ's Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (DEQ 2007). This document presents regional soil and sediment background concentrations for metals, including arsenic.
- Natural Background Soils Metals Concentrations in Washington State Toxics Cleanup Program (Ecology 1994): This document presents regional soil background concentrations from Washington State for various metals, including metals not included in DEQ (2002) (e.g., aluminum and manganese).
- US Geological Survey (USGS) national background concentrations for metals (USGS 2001): For two metal COPCs (i.e., barium and vanadium), no regional background values were presented in DEQ (2002) or Ecology

(1994), so the median national soil background values reported by the USGS (2001) were used. National background values for twenty additional metals are also presented in this document.

- Radio Tower Site (URS 2000): Five samples were collected as part of a preliminary soil investigation at the Radio Tower Site across N Force Avenue from the Study Area. One of these samples was designated as a "background location" for the sampling event, but because concentrations at this location were generally similar to the other four samples, all samples from the Radio Tower Site were used to represent reference area concentrations for the ERA. Samples were analyzed for hydrocarbons, metals, pesticides, herbicides, and semi-volatile organic compounds (SVOCs).
- DEQ's Columbia Slough Sediment Project (DEQ 2005): Baseline sediment concentrations for the Columbia Slough, which drains over 30,000 acres of urban land in the City of Portland, were used to represent reference area concentrations for the ERA. These baseline maxima concentrations are calculated values meant to reflect the upper end of the range of concentrations throughout the slough (i.e., maximum concentrations excluding those associated with a particular source). These concentrations are relevant because they indicate the concentrations of chemicals present in the watershed associated with historical and current land uses (e.g., urban activities such runoff from roads, agricultural runoff). Concentrations were developed from samples taken since the early 1990s, and are available for volatile organic compounds (VOCs), phthalates, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals.

The Radio Tower Site and the Columbia Slough are shown on Figure 1 to provide information regarding the proximity of these regional sources to the Harbor Oil Study Area.

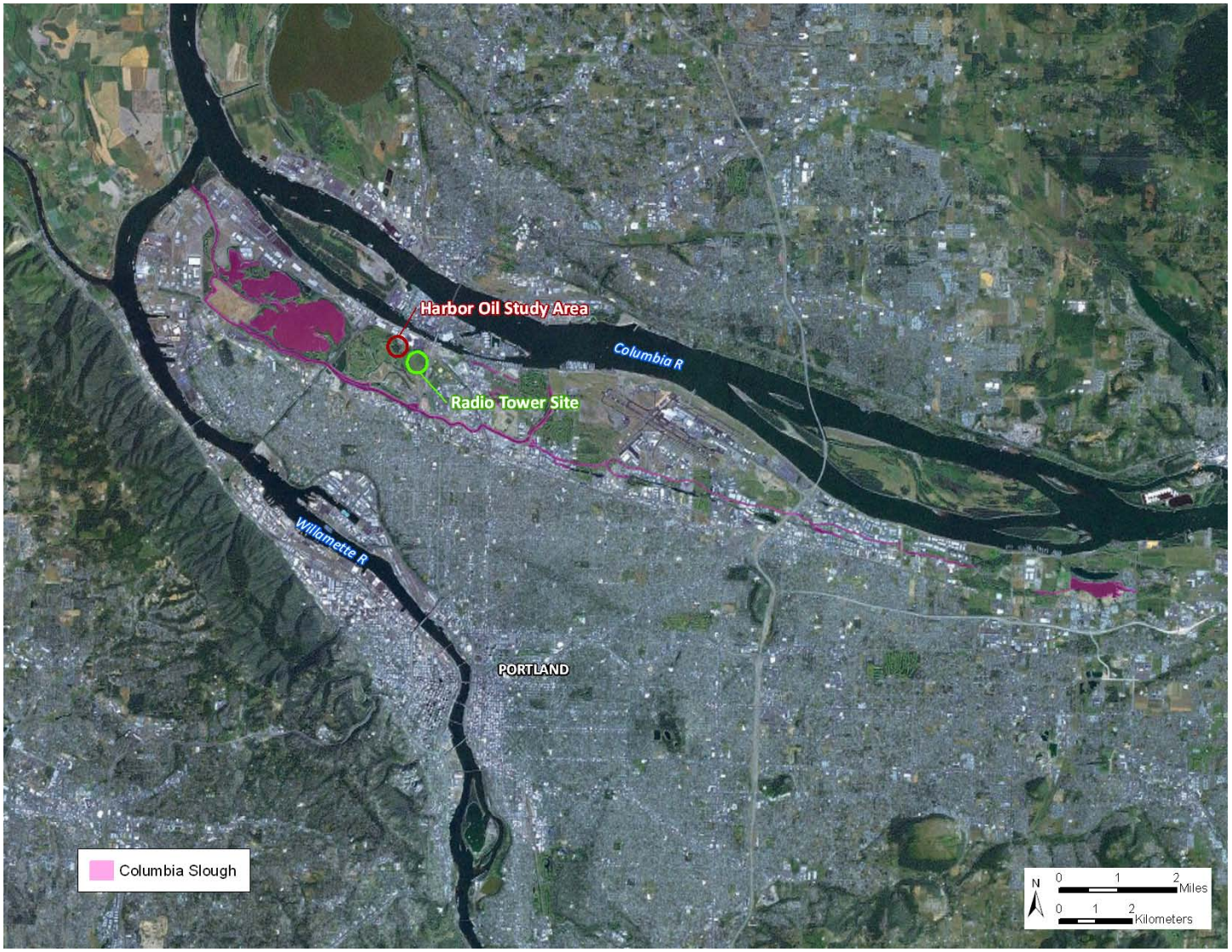

Figure 1. Locations of regional studies **used to define reference area concentrations**

Background or reference area concentrations in the ERA were used only for wildlife COPCs with lowest-observed-apparent-effects level (LOAEL) hazard quotients (HQs) greater than 1.0 and for benthic invertebrate COPCs with probably effects concentration (PEC) or probable effects level (PEL) exceedances greater than 1.0. Background or reference area concentrations of all terrestrial invertebrate COPCs were evaluated. These included 13 metals (i.e., aluminum, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, vanadium, and zinc), 6 individual PAHs (i.e., benzo[a]anthracene, benzo[a]pyrene, chrysene, fluoranthene, phenanthrene, and pyrene), total high-molecular-weight polycyclic aromatic hydrocarbons (HPAHs), total polychlorinated biphenyls (PCBs), 2,4'-dichlorodiphenyldichloroethane (DDD), 4,4'-DDD, 4,4'-dichlorodiphenyldichloroethylene (DDE), and total dichlorodiphenyltrichloroethanes (DDTs). Table 1 presents all of the selected background or reference area concentrations and sources of concentrations used in the ERA. Sections 2.0 through 5.0 present additional details on the selected background and reference area values.

Table 1. Summary of Selected Soil and Sediment Background or Reference Area Concentrations Used in the ERA

COPC	Unit (dw)	Background or Reference Area Concentration[a]		Source
		Soil	Sediment	
Metals				
Aluminum	mg/kg	37,200	37,200[b]	Ecology (1994)
Arsenic	mg/kg	7	7 – 7.9	DEQ (2002, 2007)
Barium	mg/kg	502	502[b]	USGS – 50th percentile (2001)
Cadmium	mg/kg	1	0.5 – 1	DEQ (2002, 2007)
Chromium	mg/kg	42	30	DEQ (2002)
Copper	mg/kg	36	12	DEQ (2002)
Lead	mg/kg	17	2.0 – 17	DEQ (2002, 2007)
Manganese	mg/kg	1,100	1,100[b]	Ecology (1994)
Mercury	mg/kg	0.07	0.07 – 0.2	DEQ (2002, 2007)
Nickel	mg/kg	38	20	DEQ (2002)
Selenium	mg/kg	2	0.4 – 2	DEQ (2002, 2007)
Vanadium	mg/kg	67.3	67.3[b]	USGS – 50th percentile (2001)
Zinc	mg/kg	86	53	DEQ (2002)
PAHs				
Benzo(a)anthracene	µg/kg	4.5 – 33	72 – 87	URS (2000); DEQ (2005)
Benzo(a)pyrene	µg/kg	5.3 – 39	90 – 100	URS (2000); DEQ (2005)
Chrysene	µg/kg	6.7 – 51	103 – 129	URS (2000); DEQ (2005)
Fluoranthene	µg/kg	7.3 – 53	132 – 144	URS (2000); DEQ (2005)
Phenanthrene	µg/kg	14 – 25	80 – 88	URS (2000); DEQ (2005)
Pyrene	µg/kg	8.4 – 67	196 – 196	URS (2000); DEQ (2005)
Total HPAHs	µg/kg	54 – 388	1,010 – 1,243	URS (2000); DEQ (2005)
Total PAHs	µg/kg	68 – 427	1,073 – 1,078	URS (2000); DEQ (2005)

Table 1. Summary of Selected Soil and Sediment Background or Reference Area Concentrations Used in the ERA

COPC	Unit (dw)	Background or Reference Area Concentration[a]		Source
		Soil	Sediment	
PCBs				
Total PCBs	µg/kg	23 – 24[c]	23 – 24	DEQ (2005)
Pesticides				
2,4'-DDD	µg/kg	5 – 15[d]	6.1 – 6.7	URS (2000); DEQ (2005)
4,4'-DDD	µg/kg	5 – 15[d]	6.1 – 6.7	URS (2000); DEQ (2005)
4,4'-DDE	µg/kg	5 – 110[d]	7 – 9.8	URS (2000); DEQ (2005)
Total DDTs	µg/kg	15 – 355[c]	16 – 19	URS (2000); DEQ (2005)

[a] Concentrations for metals are representative of background concentrations, and concentrations for organic compounds are representative of reference area concentrations.
[b] No sediment background value is available; sediment background value is based on soil.
[c] No soil background value is available; soil background value is based on sediment.
[d] The low end of this range is the reporting limit; the concentration was not detected.

COPC – contaminant of potential concern
dw – dry weight
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
Ecology – Washington State Department of Ecology
ERA – ecological risk assessment
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
USGS – US Geological Survey

In addition, a surface water background concentration of 9 µg/L was selected for copper based on the reported default freshwater background concentration reported by DEQ (2002).

2.0 Metals

Background metals concentrations in soil and sediment were primarily based on values reported in DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002). For mercury, the soil background value (0.07 mg/kg dw) was based on DEQ (2002). A range of sediment concentrations (0.07 to 0.2 mg/kg dw) was used to represent mercury sediment background concentrations at the Study Area based on the DEQ (2002) (regional background sediment value was 0.2 mg/kg dw), and DEQ (2007) (regional background sediment value was 0.07 mg/kg dw).

For metals that had no regional values reported in that DEQ (2002), including aluminum and manganese, background soil concentrations reported in Natural Background Soils Metals Concentrations in Washington State Toxics Cleanup Program (Ecology 1994) were used to represent soil and sediment background concentrations. For two metals COPCs, barium and vanadium, no regional background values were presented in DEQ (2002) or Ecology (1994), so the median (50th percentile) national soil background values reported in USGS national background concentrations for metals (USGS 2001) were used to

represent soil and sediment background concentrations. Based on the maps presented in USGS (2001), the Portland regional levels of barium and vanadium were actually greater than the national 50th percentile values; therefore, the selected background values for barium and vanadium are conservative background values for the Portland regional area.

3.0 PAHs

Reference area sediment PAH concentrations were available from several sources:

- A range of PAH concentrations reported for all PAH COPCs from DEQ's Columbia Slough Sediment Project (2005), which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source.
- A range of PAH concentrations reported for all individual PAH COPCs from five samples taken at the Radio Tower Site (URS 2000).

A range of PAH concentrations reported in the two above sources was used to represent reference area sediment and soil PAH concentrations at the Study Area for each PAH COPC. Table 2 presents the range of PAH COPC concentrations reported in the two sources. Specific background concentrations for PAHs have not been established by EPA or DEQ.

Table 2. Summary of PAH Reference Area Concentrations

COPC	Range of Concentrations (µg/kg dw)	
	Sediment (Columbia Slough)[a]	Soil (Radio Tower Site)[b]
Benzo(a)anthracene	72 – 87	4.5 – 33
Benzo(a)pyrene	90 – 100	5.3 – 39
Chrysene	103 – 129	6.7 – 51
Fluoranthene	132 – 144	7.3 – 53
Phenanthrene	80 – 88	14 – 25
Pyrene	196 – 196	8.4 – 67
Total HPAHs	1,010 – 1,243	54– 388[c]
Total PAHs	1,073 – 1,078	68 – 427[c]

[a] DEQ (2005).
[b] URS (2000).
[c] Non-detected values were treated as one-half the reporting limits for calculating sums.

COPC – contaminant of potential concern
DEQ – Oregon Department of Environmental Quality
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
na – not available
PAH – polycyclic aromatic hydrocarbon

4.0 PCBs

Reference area concentrations for total PCBs are available from one source, DEQ's Columbia Slough Sediment Project (2005). A range of 23 to 24 µg/kg dw (Aroclor 1254) was calculated from the data, which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source. This range was used to represent reference area sediment and soil total PCB concentrations for comparison to Harbor Oil data. Total PCBs were not analyzed in the samples collected from the Radio Tower Site. Specific background concentrations for total PCBs have not been established by EPA or DEQ.

5.0 DDTs

Reference area sediment concentrations for total DDTs were available from several sources, as noted below:

- A range of DDD, DDE, and total DDT concentrations reported DEQ's Columbia Slough Sediment Project (2005), which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source.
- A range concentrations for 4,4'-DDD, 4,4'-DDE, and total DDTs from five samples collected at the Radio Tower Site were reported in the preliminary soil investigation for that site (URS 2000). The range of total DDTs was 15 to 355 µg/kg dw. It should be noted that the maximum value (355 µg/kg dw) was substantially higher than the next highest concentration (55 µg/kg dw). However, because of the patchy nature of DDT concentrations in the region and because there was no indication that the maximum concentration was linked to a specific source, all fives samples were determined to be acceptable to represent total DDT reference area concentrations in the ERA.

A range of DDT concentrations reported in the two above sources were used to represent reference area sediment and soil DDT concentrations at the Study Area for each of the DDT COPCs: 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, and total DDTs. Table 3 presents the range of DDT COPC concentrations reported in the two sources. Specific background concentrations for DDD, DDE, or total DDTs have not been established by EPA or DEQ.

Table 3. Summary of DDT Reference Area Concentrations

COPC	Range of Concentrations (µg/kg dw)	
	Sediment (Columbia Slough)[a]	Soil (Radio Tower)[b]
2,4'-DDD	6.1 – 6.7[c]	5[d] – 15[e]
4,4'-DDD	6.1 – 6.7[c]	5[d] – 15
4,4'-DDE	7 – 9.8[f]	5[d] – 110

Table 3. Summary of DDT Reference Area Concentrations

COPC	Range of Concentrations (µg/kg dw)	
	Sediment (Columbia Slough)[a]	Soil (Radio Tower)[b]
Total DDTs	16 – 19	15[d] – 355

[a] DEQ (2005).
[b] URS (2000).
[c] Reference area concentrations for 2,4'-DDD and 4,4'-DDD are based on reported DDD concentration.
[d] The low end of this range is the reporting limit; the concentration was not detected.
[e] Reference area concentration for 2,4'-DDD is based on 4,4'-DDD reference area concentration.
[f] Reference area concentration for 4,4'-DDE is based on reported DDE concentration.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
dw – dry weight

6.0 References

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