APPENDIX E

Fate and Transport Modeling Results

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Table E-1. Physical and Chemical Properties of Inorganic SRCs in Surface and Subsurface Soil and Sediment at Load Line 5

Analyte	K_d (L/kg)	Reference	HLC (atm-m^3/mol)	Reference	C_w (mg/L)	SSL Type	Generic SSL	Reference	SSL Type
Inorganic Chemicals									
Aluminum	1.50E+03	a	NA	-	2.00E+01	RSL	3.00E+04	a	Risk
Antimony	4.50E+01	a	NA	-	6.00E-03	MCL	2.70E-01	a	MCL
Barium	4.10E+01	a	NA	-	2.00E+00	MCL	8.20E+01	a	MCL
Beryllium	7.90E+02	a	NA	-	4.00E-03	MCL	3.20E+00	a	MCL
Cadmium	7.50E+01	a	NA	-	5.00E-03	MCL	3.80E-01	a	MCL
Chromium	1.90E+01	a	NA	-	1.00E-01	MCL	1.80E+05	a	MCL
Cobalt	4.50E+01	a	NA	-	6.00E-03	RSL	2.70E-01	a	Risk
Copper	3.50E+01	a	NA	-	1.30E+00	MCL	4.60E+01	a	MCL
Lead	9.00E+02	a	NA	-	1.50E-02	MCL	1.40E+01	a	MCL
Manganese	6.50E+01	a	NA	-	4.30E-01	RSL	2.80E+01	a	Risk
Mercury	5.20E+01	a	1.14E-02	a	2.00E-03	MCL	1.00E-01	a	MCL
Nickel	6.50E+01	a	NA	-	3.90E-01	RSL	2.60E+01	a	Risk
Selenium	5.00E+00	a	NA	-	5.00E-02	MCL	2.60E-01	a	MCL
Silver	8.30E+00	a	NA	-	9.40E-02	RSL	8.00E-01	a	Risk
Thallium	7.10E+01	a	NA	-	2.00E-03	MCL	1.40E-01	a	MCL
Vanadium	1.00E+03	a	NA	-	8.60E-02	RSL	8.60E+01	a	Risk
Zinc	6.20E+01	a	NA	-	6.00E+00	RSL	3.70E+02	a	Risk
Anions									
Nitrate	NA	-	NA	-	NA	-	NA	-	-

[a] U.S. Environmental Protection Agency RSL generic tables June 2015; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.
C_w = Target groundwater concentration (either MCL or RSL).
HLC = Henry's Law Constant.
K_d = Distribution coefficient.
L/kg = Liters per kilogram.
MCL = Maximum contaminant level.
mg/L = Milligrams per liter.
NA = Not applicable.
RSL = Regional screening level.
SRC = Site-related contaminant.
SSL = Soil screening level.

Table E-2. Physical and Chemical Properties of Organic SRCs in Surface and Subsurface Soil and Sediment at Load Line 5

Analyte	K_{oc} (L/kg)	Reference	HLC (atm-m^3/mol)	Reference	C_w (mg/L)	SSL Type	Generic SSL (mg/kg)	Reference	SSL Type
Explosives									
4-Nitrotoluene	3.63E+02	c	5.63E-06	c	4.20E-03	RSL	3.90E-03	c	Risk
HMX	5.32E+02	c	8.67E-10	c	1.00E+00	RSL	1.30E+00	c	Risk
Nitrocellulose	1.00E+01	c	3.29E-23	c	6.00E+04	RSL	1.30E+04	c	Risk
Tetryl	4.61E+03	c	2.71E-09	c	3.90E-02	RSL	3.70E-01	c	Risk
Semi-volatile Organic Compounds									
2-Methylnaphthalene	2.48E+03	c	5.18E-04	c	3.60E-02	RSL	1.90E-01	c	Risk
Acenaphthene	5.03E+03	c	1.84E-04	c	5.30E-01	RSL	5.50E+00	c	Risk
Anthracene	1.64E+04	c	5.56E-05	c	1.80E+00	RSL	5.80E+01	c	Risk
Benz(*a*)anthracene	1.77E+05	c	1.20E-05	c	1.20E-05	RSL	4.25E-03	c	Risk
Benzenemethanol	2.15E+01	c	3.37E-07	c	2.00E+00	RSL	4.80E-01	c	Risk
Benzo(*a*)pyrene	5.87E+05	c	4.57E-07	c	2.00E-04	MCL	2.40E-01	c	MCL
Benzo(*b*)fluoranthene	5.99E+05	c	6.57E-07	c	3.40E-05	RSL	4.10E-02	c	Risk
Benzo(*ghi*)perylene[a]	1.07E+07	d	1.40E-07	d	1.20E-01	RSL	1.30E+01	c	Risk
Benzo(*k*)fluoranthene	5.87E+05	c	5.84E-07	c	3.40E-04	RSL	4.00E-01	c	Risk
Bis(2-ethylhexyl)phthalate	1.20E+05	c	2.70E-07	c	6.00E-03	MCL	1.40E+00	c	MCL
Carbazole	NA	-	NA	-	NA	-	NA	-	-
Chrysene	1.81E+05	c	5.23E-06	c	3.40E-03	RSL	1.20E+00	c	Risk
Di-n-butyl phthalate	1.16E+03	c	1.81E-06	c	9.00E-01	RSL	2.30E+00	c	Risk
Dibenz(*a*,*h*)anthracene	1.91E+06	c	1.41E-07	c	3.40E-06	RSL	1.30E-02	c	Risk
Dibenzofuran	9.16E+03	c	2.13E-04	c	7.90E-03	RSL	1.50E-01	c	Risk
Fluoranthene	5.55E+04	c	8.86E-06	c	8.00E-01	RSL	8.90E+01	c	Risk
Fluorene	9.16E+03	c	9.62E-05	c	2.90E-01	RSL	5.40E+00	c	Risk
Hexachlorobenzene	6.20E+03	c	1.70E-03	c	1.00E-03	MCL	1.30E-02	c	MCL
Indeno(1,2,3-*cd*)pyrene	1.95E+06	c	3.48E-07	c	3.40E-05	RSL	1.30E-01	c	Risk
Naphthalene	1.54E+03	c	4.40E-04	c	1.70E-04	RSL	5.40E-04	c	Risk
Phenanthrene[b]	1.82E+04	d	3.93E-05	d	1.20E-01	RSL	1.30E+01	c	Risk
Phenol	1.87E+02	c	3.33E-07	c	5.80E+00	RSL	3.30E+00	c	Risk
Pyrene	5.43E+04	c	1.19E-05	c	1.20E-01	RSL	1.30E+01	c	Risk

Table E-2. Physical and Chemical Properties of Organic SRCs in Surface and Subsurface Soil at Load Line 5 (continued)

Analyte	K_{oc} (L/kg)	Reference	HLC (atm-m^3/mol)	Reference	C_w (mg/L)	SSL Type	Generic SSL (mg/kg)	Reference	SSL Type
Pesticide/PCB									
beta-BHC	2.81E+03	c	5.14E-06	c	2.50E-05	RSL	1.40E-04	c	Risk
PCB-1254	1.31E+05	c	2.83E-04	c	7.80E-06	RSL	2.00E-03	c	Risk

[a] Pyrene C_w and generic SSL was used as a surrogate for benzo(*ghi*)perylene.
[b] Pyrene C_w and generic SSL was used as a surrogate for phenanthrene.
[c] U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.
[d] USEPA 1994. Risk Reduction Engineering Laboratory Treatability Database, Ver. 5.0, Office of Research and Development, Cincinnati, Ohio.
BHC = Beta-hexachlorocyclohexane.
C_w = Target groundwater concentration (either MCL or RSL).
HLC = Henry's Law Constant.
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocane.
K_{oc} = Organic carbon partition coefficient.
L/kg = Liters per kilogram.
MCL = Maximum contaminant level.
mg/kg = Milligrams per kilogram.
mg/L = Milligram per liter.
NA = Not applicable.
PCB = Polychlorinated biphenyl.
RSL = Regional screening level.
SRC = Site-related contaminant.
SSL = Soil screening level.

Table E-3. HELP Model Parameters for Developing Water Balance Estimates

Layer	Layer Type	Thickness (inch)	Effective K (cm/sec)
1	1--Vertical Percolation Layer	60	2.50E-05
2	3--Barrier Soil Liner	84	8.20E-06

Evapotranspiration and Weather Data	
Station Latitude =	41.24
Maximum Leaf Area Index =	3.5
Start of Growing Season (Julian Date) =	120
End of Growing Season (Julian Date) =	290
Evaporative Zone Depth (inch) =	20 (Fair)

General Design and Evaporative Zone Data	
Fraction of Area Allowing Runoff (%) =	100
Default Soil Database Texture =	Silty Clay
Vegetative Cover =	Poor Stand of Grass
Surface Slope (%) =	4
Slope Length (ft) =	500
SCS Runoff Curve Number =	93

Precipitation Data
Synthetically Generated Using Cleveland, Ohio, Coefficients

Temperature Data
Synthetically Generated Using Cleveland, Ohio, Coefficients

Solar Radiation Data
Synthetically Generated Using Cleveland, Ohio, Coefficients

cm/sec = Centimeters per second.
ft = Feet.
HELP = Hydrologic evaluation of landfill performance.
K = Hydraulic conductivity.
SCS = Soil conservation service.

Table E-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for Load Line 5

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type (mg/kg)	Initial CMCOPC (Yes/No)	CMCOPC Justification	Samples >SSL/ Total Samples	Sample ID at Maximum Concentration	Date Collected
Inorganic Chemicals									
Aluminum	7429-90-5	1.89E+04	3.00E+04	Risk	No	Below SSL	0/ 73	LL5sb-056-5166-SO	3/3/2010
Barium	**7440-39-3**	**2.20E+02**	**8.20E+01**	**MCL**	**Yes**	**Exceeds SSL**	**12/ 73**	**LL5ss-005M-SO**	**11/19/2004**
Beryllium	**7440-41-7**	**4.20E+00**	**3.20E+00**	**MCL**	**Yes**	**Exceeds SSL**	**1/ 73**	**LL5ss-005M-SO**	**11/19/2004**
Cadmium	**7440-43-9**	**3.00E+00**	**3.80E-01**	**MCL**	**Yes**	**Exceeds SSL**	**18/ 73**	**LL5ss-019M-SO**	**11/12/2004**
Chromium	7440-47-3	8.67E+01	1.80E+05	MCL	No	Below SSL	0/ 73	LL5ss-038M-SO	8/12/2007
Cobalt	**7440-48-4**	**1.33E+01**	**2.70E-01**	**Risk**	**Yes**	**Exceeds SSL**	**73/ 73**	**LL5ss-068M-5050-SO**	**3/3/2010**
Copper	**7440-50-8**	**4.90E+01**	**4.60E+01**	**MCL**	**Yes**	**Exceeds SSL**	**1/ 73**	**LL5ss-001M-SO**	**11/12/2004**
Lead	**7439-92-1**	**1.70E+02**	**1.40E+01**	**MCL**	**Yes**	**Exceeds SSL**	**61/ 73**	**LL5ss-005M-SO**	**11/19/2004**
Manganese	**7439-96-5**	**3.10E+03**	**2.80E+01**	**Risk**	**Yes**	**Exceeds SSL**	**73/ 73**	**LL5ss-005M-SO**	**11/19/2004**
Mercury	**7439-97-6**	**3.00E+00**	**1.00E-01**	**MCL**	**Yes**	**Exceeds SSL**	**7/ 73**	**LL5ss-012M-SO**	**11/15/2004**
Nickel	**7440-02-0**	**3.30E+01**	**2.60E+01**	**Risk**	**Yes**	**Exceeds SSL**	**16/ 73**	**LL5ss-028M-SO**	**11/15/2004**
Selenium	**7782-49-2**	**1.80E+00**	**2.60E-01**	**MCL**	**Yes**	**Exceeds SSL**	**54/ 73**	**LL5ss-005M-SO**	**11/19/2004**
Silver	7440-22-4	7.50E-02	8.00E-01	Risk	No	Below SSL	0/ 73	LL5sb-054-5158-SO	3/8/2010
Thallium	**7440-28-0**	**2.80E-01**	**1.40E-01**	**MCL**	**Yes**	**Exceeds SSL**	**29/ 73**	**LL5ss-017M-SO**	**11/15/2004**
Zinc	7440-66-6	1.40E+02	3.70E+02	Risk	No	Below SSL	0/ 73	LL5ss-005M-SO	11/19/2004
Anions									
Nitrate	14797-55-8	3.20E+01	NA	NA	No	No SSL	0/ 29	LL5ss-019M-SO	11/12/2004
Explosives									
4-Nitrotoluene	**99-99-0**	**7.00E-02**	**3.90E-03**	**Risk**	**Yes**	**Exceeds SSL**	**1/ 73**	**LL5ss-021M-SO**	**11/19/2004**
HMX	2691-41-0	1.20E-02	1.30E+00	Risk	No	Below SSL	0/ 73	LL5ss-071M-5053-SO	3/8/2010
Nitrocellulose	9004-70-0	3.10E+00	1.30E+04	Risk	No	Below SSL	0/ 10	LL5ss-033M-SO	8/12/2007
Tetryl	479-45-8	1.70E-02	3.70E-01	Risk	No	Below SSL	0/ 73	LL5ss-077M-5059-SO	3/8/2010
Semi-volatile Organic Compounds									
2-Methylnaphthalene	91-57-6	1.10E-01	1.90E-01	Risk	No	Below SSL	0/ 11	LL5ss-005M-SO	11/19/2004
Acenaphthene	83-32-9	3.80E-02	5.50E+00	Risk	No	Below SSL	0/ 35	LL5ss-064M-5046-SO	3/3/2010
Anthracene	120-12-7	1.60E-01	5.80E+01	Risk	No	Below SSL	0/ 35	LL5ss-069M-5051-SO	3/3/2010
Benz(a)anthracene	**56-55-3**	**1.40E+00**	**4.25E-03**	**Risk**	**Yes**	**Exceeds SSL**	**19/ 35**	**LL5ss-042M-SO**	**8/9/2007**

Table E-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for Load Line 5 (continued)

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type (mg/kg)	Initial CMCOPC (Yes/No)	CMCOPC Justification	Samples >SSL/ Total Samples	Sample ID at Maximum Concentration	Date Collected
Benzenemethanol	**100-51-6**	**1.30E+00**	**4.80E-01**	**Risk**	**Yes**	**Exceeds SSL**	**1/ 8**	**LL5ss-005M-SO**	**11/19/2004**
Benzo(a)pyrene	**50-32-8**	**5.30E-01**	**2.40E-01**	**MCL**	**Yes**	**Exceeds SSL**	**2/ 35**	**LL5ss-064M-5046-SO**	**3/3/2010**
Benzo(b)fluoranthene	**205-99-2**	**7.80E-01**	**4.10E-02**	**Risk**	**Yes**	**Exceeds SSL**	**13/ 35**	**LL5ss-064M-5046-SO**	**3/3/2010**
Benzo(ghi)perylene[a]	191-24-2	2.80E-01	1.30E+01	Risk	No	Below SSL	0/ 35	LL5ss-064M-5046-SO	3/3/2010
Benzo(k)fluoranthene	207-08-9	4.00E-01	4.00E-01	Risk	No	Below SSL	0/ 35	LL5ss-064M-5046-SO	3/3/2010
Bis(2-ethylhexyl)phthalate	117-81-7	1.30E-01	1.40E+00	MCL	No	Below SSL	0/ 11	LL5ss-069M-5051-SO	3/3/2010
Carbazole	86-74-8	3.80E-02	NA	NA	No	No SSL	0/ 11	LL5ss-012M-SO	11/15/2004
Chrysene	**218-01-9**	**1.40E+00**	**1.20E+00**	**Risk**	**Yes**	**Exceeds SSL**	**1/ 35**	**LL5ss-042M-SO**	**8/9/2007**
Di-n-butyl phthalate	84-74-2	2.20E-02	2.30E+00	Risk	No	Below SSL	0/ 11	LL5ss-072M-5054-SO	3/8/2010
Dibenz(a,h)anthracene	**53-70-3**	**9.20E-02**	**1.30E-02**	**Risk**	**Yes**	**Exceeds SSL**	**4/ 35**	**LL5ss-064M-5046-SO**	**3/3/2010**
Dibenzofuran	132-64-9	3.90E-02	1.50E-01	Risk	No	Below SSL	0/ 11	LL5ss-005M-SO	11/19/2004
Fluoranthene	206-44-0	3.30E+00	8.90E+01	Risk	No	Below SSL	0/ 35	LL5ss-042M-SO	8/9/2007
Fluorene	86-73-7	3.10E-02	5.40E+00	Risk	No	Below SSL	0/ 35	LL5ss-064M-5046-SO	3/3/2010
Indeno(1,2,3-cd)pyrene	**193-39-5**	**2.70E-01**	**1.30E-01**	**Risk**	**Yes**	**Exceeds SSL**	**2/ 35**	**LL5ss-069M-5051-SO**	**3/3/2010**
Naphthalene	**91-20-3**	**9.50E-02**	**5.40E-04**	**Risk**	**Yes**	**Exceeds SSL**	**15/ 35**	**LL5ss-005M-SO**	**11/19/2004**
Phenanthrene[a]	85-01-8	1.60E+00	1.30E+01	Risk	No	Below SSL	0/ 35	LL5ss-042M-SO	8/9/2007
Phenol	108-95-2	4.60E-02	3.30E+00	Risk	No	Below SSL	0/ 11	LL5ss-018M-SO	11/19/2004
Pyrene	129-00-0	2.50E+00	1.30E+01	Risk	No	Below SSL	0/ 35	LL5ss-042M-SO	8/9/2007
Pesticide/PCB									
beta-BHC	**319-85-7**	**1.80E-03**	**1.40E-04**	**Risk**	**Yes**	**Exceeds SSL**	**1/ 11**	**LL5ss-072M-5054-SO**	**3/8/2010**
PCB-1254	**11097-69-1**	**3.80E-02**	**2.00E-03**	**Risk**	**Yes**	**Exceeds SSL**	**1/ 11**	**LL5ss-005M-SO**	**11/19/2004**

[a]Pyrene was used as a surrogate for benzo(*ghi*)perylene and phenanthrene.
BHC = Beta-hexachlorocyclohexane.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant migration chemical of potential concern.
GSSL = Generic soil screening level.
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
ID = Identification.
MCL = Maximum contaminant level.
mg/kg = Milligrams per kilogram.
NA = Not available.
PCB = Polychlorinated biphenyl.
SRC = Site-related contaminant
SSL = Soil screening level.
Bold = SRCs that exceed the GSSL

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Table E-5. DAF Calculations for Load Line 5

$$DAF = 1 + \frac{(K \times i \times d)}{(q \times L)}$$

$$d = \sqrt{0.0112 \times L^2} + d_a \times \left[1 - \exp\left(\frac{-L \times q}{K \times i \times d_a}\right)\right]$$

Parameter	Symbol	Value	Unit	Note
Former Production Area				
DAF	DAF	1.02	unitless	Calculated from DAF equation shown above
Aquifer hydraulic conductivity	K	7.57E+01	m/year	Average of slug test results (MKM 2007)
Horizontal hydraulic gradient	i	2.46E-04	m/m	Determined from Figure 3-1
Percolation rate	q	9.40E-02	m/year	Developed from HELP model from Cleveland, Ohio, weather data
Source length parallel to groundwater flow	L	60.4	m	Determined from Figure 3-1
Mixing zone depth	d	6	m	Determined from the lower value between above equation for "d" (d = 12.39 m) and d_a
Aquifer thickness	d_a	6	m	Facility-wide assumption for the unconsolidated aquifer presented in the Load Line 1 investigation (USACE 2003)

MKM (MKM Engineers, Inc.) 2007. Final Characterization of 14 AOCs at Ravenna Army Ammunition Plant: Characterization of Load Line 5. March 2007.

USACE (U.S. Army Corps of Engineers) 2003. Phase II Remedial Investigation Report for the Load Line 1 at the Ravenna Army Ammunition Plant, Ravenna, Ohio. June 2003.

DAF = Dilution attenuation factor.

HELP = Hydrologic evaluation of landfill performance.

Table E-6. Initial CMCOPCs Based on Comparison of the SRC's Maximum Concentration to SSSL at Load Line 5

Analyte	CAS Number	Maximum Concentration (mg/kg)	SSSL (mg/kg)	Initial CMCOPC (Yes/No)	CMCOPC Justification	Sample ID at Maximum Concentration	Date Collected
Inorganic Chemicals							
Barium	**7440-39-3**	**2.20E+02**	**8.36E+01**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Beryllium	**7440-41-7**	**4.20E+00**	**3.26E+00**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Cadmium	**7440-43-9**	**3.00E+00**	**3.88E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-019M-SO**	**11/12/2004**
Cobalt	**7440-48-4**	**1.33E+01**	**2.75E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-068M-5050-SO**	**3/3/2010**
Copper	**7440-50-8**	**4.90E+01**	**4.69E+01**	**Yes**	**Exceeds SSSL**	**LL5ss-001M-SO**	**11/12/2004**
Lead	**7439-92-1**	**1.70E+02**	**1.43E+01**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Manganese	**7439-96-5**	**3.10E+03**	**2.86E+01**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Mercury	**7439-97-6**	**3.00E+00**	**1.02E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-012M-SO**	**11/15/2004**
Nickel	**7440-02-0**	**3.30E+01**	**2.65E+01**	**Yes**	**Exceeds SSSL**	**LL5ss-028M-SO**	**11/15/2004**
Selenium	**7782-49-2**	**1.80E+00**	**2.65E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Thallium	**7440-28-0**	**2.80E-01**	**1.43E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-017M-SO**	**11/15/2004**
Explosives							
4-Nitrotoluene	**99-99-0**	**7.00E-02**	**3.98E-03**	**Yes**	**Exceeds SSSL**	**LL5ss-021M-SO**	**11/19/2004**
Semi-volatile Organic Compounds							
Benz(a)anthracene	**56-55-3**	**1.40E+00**	**4.34E-03**	**Yes**	**Exceeds SSSL**	**LL5ss-042M-SO**	**8/9/2007**
Benzenemethanol	**100-51-6**	**1.30E+00**	**4.90E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Benzo(a)pyrene	**50-32-8**	**5.30E-01**	**2.45E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-064M-5046-SO**	**3/3/2010**
Benzo(b)fluoranthene	**205-99-2**	**7.80E-01**	**4.18E-02**	**Yes**	**Exceeds SSSL**	**LL5ss-064M-5046-SO**	**3/3/2010**
Chrysene	**218-01-9**	**1.40E+00**	**1.22E+00**	**Yes**	**Exceeds SSSL**	**LL5ss-042M-SO**	**8/9/2007**
Dibenz(a,h)anthracene	**53-70-3**	**9.20E-02**	**1.33E-02**	**Yes**	**Exceeds SSSL**	**LL5ss-064M-5046-SO**	**3/3/2010**
Indeno(1,2,3-cd)pyrene	**193-39-5**	**2.70E-01**	**1.33E-01**	**Yes**	**Exceeds SSSL**	**LL5ss-069M-5051-SO**	**3/3/2010**
Naphthalene	**91-20-3**	**9.50E-02**	**5.51E-04**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**
Pesticide/PCB							
beta-BHC	**319-85-7**	**1.80E-03**	**1.43E-04**	**Yes**	**Exceeds SSSL**	**LL5ss-072M-5054-SO**	**3/8/2010**
PCB-1254	**11097-69-1**	**3.80E-02**	**2.04E-03**	**Yes**	**Exceeds SSSL**	**LL5ss-005M-SO**	**11/19/2004**

BHC = Beta-hexachlorocyclohexane.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant migration chemical of potential concern.
ID = Identification.
PCB = Polychlorinated biphenyl.
mg/kg = Milligrams per kilogram.
SRC = Site-related contaminant.
SSSL = Site-specific soil screening level.
Bold = SRCs that exceed the SSSL.

Table E-7. Initial CMCOPCs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years at Load Line 5

$$R = 1 + \frac{\rho_b K_d}{\theta_w} \qquad T = L_z \theta_w R / q$$

Parameter	Symbol	Value	Unit	Note
Percolation rate	q	0.31	ft/year	Developed from HELP model from Cleveland, Ohio, weather data
Soil-water distribution coefficient	K_d	chemical-specific	L/kg	See footnotes below for references
Organic carbon distribution coefficient	K_{oc}	chemical-specific	L/kg	See footnotes below for references
Fraction organic carbon	f_{oc}	0.0012	unitless	From PBA08 RI geotechnical samples Load Lines 7, 10, and 11
Water-filled soil porosity	θ_w	0.311	unitless	
Bulk density (dry)	ρ_b	1.70	gm/cm^3	
Leaching zone	Lz	7.0 to 16.0	ft	Distance from last layer of soil contamination greater than background concentration to top of water table
Retardation factor	R	chemical-specific	unitless	Calculated by equation shown above
Arrival time	T	chemical-specific	year	Calculated by equation shown above

Table E-7. Initial CMCOPCs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years at Load Line 5 (continued)

Analyte	Initial CMCOPC Sample ID	Sample Depth[a] (ft)	Lz[b] (ft)	K_{oc} (L/kg)	Reference	K_d (L/kg)	Reference	Retardation Factor (R)	Arrival Time (T) from Sample Max Depth to Groundwater (years)	T <1,000? from Sample Depth to Groundwater Table (Yes/No)
Inorganic Chemicals										
Barium	LL5ss-005M-SO	1.0	15.0	NA	-	4.10E+01	c	2.25E+02	3,390	No
Beryllium	LL5ss-005M-SO	1.0	15.0	NA	-	7.90E+02	c	4.32E+03	65,000	No
Cadmium	LL5ss-019M-SO	1.0	11.0	NA	-	7.50E+01	c	4.11E+02	4,540	No
Cobalt	LL5ss-068M-5050-SO	1.0	15.0	NA	-	4.50E+01	c	2.47E+02	3,720	No
Copper	LL5ss-001M-SO	1.0	13.0	NA	-	3.50E+01	c	1.92E+02	2,510	No
Lead	LL5ss-005M-SO	1.0	15.0	NA	-	9.00E+02	c	4.92E+03	74,000	No
Manganese	LL5ss-005M-SO	1.0	15.0	NA	-	6.50E+01	c	3.57E+02	5,360	No
Mercury	LL5ss-012M-SO	1.0	15.0	NA	-	5.20E+01	c	2.85E+02	4,290	No
Nickel	LL5ss-028M-SO	1.0	16.0	NA	-	6.50E+01	**c**	3.57E+02	5,720	No
Selenium	**LL5ss-005M-SO**	1.0	**15.0**	**NA**	**-**	**5.00E+00**	**c**	**2.84E+01**	**426**	**Yes**
Thallium	LL5ss-017M-SO	1.0	13.0	NA	-	7.10E+01	c	3.89E+02	5,070	No
Explosives										
4-Nitrotoluene	**LL5ss-021M-SO**	**1.0**	**6.0**	**3.63E+02**	**c**	**4.52E-01**	**d**	**3.47E+00**	**21**	**Yes**
Semi-volatile Organic Compounds										
Benz(a)anthracene	LL5ss-042M-SO	1.0	11.0	1.77E+05	c	2.20E+02	d	1.20E+03	13,300	No
Benzenemethanol	**LL5ss-005M-SO**	**1.0**	**15.0**	**2.15E+01**	c	**2.67E-02**	d	**1.15E+00**	**17**	**Yes**
Benzo(a)pyrene	LL5ss-064M-5046-SO	1.0	13.0	5.87E+05	c	7.31E+02	d	4.00E+03	52,100	No
Benzo(b)fluoranthene	LL5ss-064M-5046-SO	1.0	13.0	5.99E+05	c	7.46E+02	d	4.08E+03	53,100	No
Chrysene	LL5ss-042M-SO	1.0	11.0	1.81E+05	c	2.25E+02	d	1.23E+03	13,600	No
Dibenz(a,h)anthracene	LL5ss-064M-5046-SO	1.0	13.0	1.91E+06	c	2.38E+03	d	1.30E+04	169,000	No
Indeno(1,2,3-cd)pyrene	LL5ss-069M-5051-SO	1.0	13.0	1.95E+06	c	2.43E+03	d	1.33E+04	173,000	No
Naphthalene	**LL5ss-005M-SO**	**1.0**	**15.0**	**1.54E+03**	**c**	**1.92E+00**	**d**	**1.15E+01**	**173**	**Yes**

Table E-7. Initial CMCOPCs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years at Load Line 5 (continued)

Analyte	Initial CMCOPC Sample ID	Sample Depth[a] (ft)	Lz[b] (ft)	K_{oc} (L/kg)	Reference	K_d (L/kg)	Reference	Retardation Factor (R)	Arrival Time (T) from Sample Max Depth to Groundwater (years)	T <1,000? from Sample Depth to Groundwater Table (Yes/No)
Pesticide/PCB										
beta-BHC	**LL5ss-072M-5054-SO**	1.0	**14.0**	**2.81E+03**	-	**3.49E+00**	c	**2.01E+01**	**282**	**Yes**
PCB-1254	LL5ss-005M-SO	1.0	15.0	1.31E+05	-	1.62E+02	c	8.92E+02	13,400	No

[a] The maximum depth of an initial CMCOPC (based on the maximum depth that an analyte is detected above facility-wide background).
[b] Based on each average depth to water from ground surface and depth of soil sample.
[c] U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.
[d] K_d value for organic chemicals calculated by multiplying the organic carbon partition coefficient by fraction organic carbon of 0.0012 (average PBA08 RI geotechnical data from Load Lines 7, 10, and 11).
[e] USEPA 1994. Risk Reduction Engineering Laboratory Treatability Database, Ver. 5.0, Office of Research and Development, Cincinnati, Ohio.
CMCOPC = Contaminant migration chemical of potential concern.
HELP = Hydrologic evaluation of landfill performance.
ID = Identification.
ft = Feet.
gm/cm^3 = Grams per cubic centimeter.
K_d = Distribution coefficient.
L/kg = Liters per kilogram.
Lz = Leaching zone.
NA = Not applicable.
PBA08 RI = Performance Based Acquisition 2008 Remedial Investigation.
PCB = Polychlorinated biphenyl.
BHC = Beta-hexachlorocyclohexane.
Bold = Initial CMCOPCs that exceed the 1,000-year travel time screen.

Table E-8. Results for SRCs in Sediment at Load Line 5

Analyte	CAS Number	Background Criteria (mg/kg)[a]	Maximum Sediment Concentration (mg/kg)	Sediment Sample ID	K_{oc} (L/kg)	Reference	K_d (L/kg)	Reference	Maximum Groundwater Concentration (mg/L)[b]	DAF[c]	Maximum Groundwater Concentration (mg/L)/DAF	MCL or RSL (mg/L)	MCL or RSL?	CMCOPC (Yes/No)
Inorganic Chemicals														
Aluminum	7429-90-5	1.39E+04	1.49E+04	LL5sd-078-5797-SD	NA	-	1.50E+03	e	9.93E+00	77	1.29E-01	2.00E+01	RSL	No
Antimony	7440-36-0	0.00E+00	1.50E-01	LL5sd-078-5797-SD	NA	-	4.50E+01	e	3.33E-03	1	3.33E-03	6.00E-03	MCL	No
Beryllium	7440-41-7	3.80E-01	7.40E-01	LL5sd-078-5797-SD	NA	-	7.90E+02	e	9.37E-04	1	9.37E-04	4.00E-03	MCL	No
Cadmium	7440-43-9	0.00E+00	2.40E-01	LL5sd-078-5797-SD	NA	-	7.50E+01	e	3.20E-03	1	3.20E-03	5.00E-03	MCL	No
Mercury	7439-97-6	5.90E-02	7.50E-02	LL5sd-078-5797-SD	NA	-	5.20E+01	e	1.44E-03	1	1.44E-03	2.00E-03	MCL	No
Silver	7440-22-4	0.00E+00	9.40E-02	LL5sd-086-5872-SD	NA	-	8.30E+00	e	1.13E-02	1	1.13E-02	9.40E-02	RSL	No
Vanadium	7440-62-2	2.61E+01	2.68E+01	LL5sd-078-5797-SD	NA	-	1.00E+03	e	2.68E-02	50	5.36E-04	8.60E-02	RSL	No
Explosives														
Nitrocellulose	9004-70-0	None	2.10E+00	LL5sd-086-5872-SD	1.00E+01	e	1.24E-02	f	1.69E+02	1	1.69E+02	6.00E+04	RSL	No
Semi-volatile Organic Compounds														
Benzo(a)pyrene	50-32-8	None	1.30E-02	LL5sd-078-5797-SD	5.87E+05	e	7.05E+02	f	1.84E-05	1	1.84E-05	2.00E-04	MCL	No
Benzo(b)fluoranthene	205-99-2	None	2.10E-02	LL5sd-078-5797-SD	5.99E+05	e	7.19E+02	f	2.92E-05	1	2.92E-05	3.40E-05	RSL	No
Chrysene	218-01-9	None	1.60E-02	LL5sd-078-5797-SD	1.81E+05	e	2.17E+02	f	7.39E-05	1	7.39E-05	3.40E-03	RSL	No
Fluoranthene	206-44-0	None	2.40E-02	LL5sd-078-5797-SD	5.55E+04	e	6.65E+01	f	3.61E-04	1	3.61E-04	8.00E-01	RSL	No
Hexachlorobenzene	**118-74-1**	**None**	**3.90E-02**	**LL5sd-086-5872-SD**	**6.20E+03**	**e**	**7.71E+00**	**f**	**5.06E-03**	**1**	**5.06E-03**	**1.00E-03**	**MCL**	**Yes**
Phenanthrene[d]	85-01-8	None	9.70E-03	LL5sd-086-5872-SD	1.82E+04	g	2.18E+01	f	4.44E-04	1	4.44E-04	1.20E-01	RSL	No
Pyrene	129-00-0	None	1.80E-02	LL5sd-078-5797-SD	5.43E+04	e	6.52E+01	f	2.76E-04	1	2.76E-04	1.20E-01	RSL	No

[a] Background criteria for sediment from final facility-wide background values for the Ravenna Army Ammunition Plant, published in the Final *Phase II Remedial Investigation Report for Winklepeck Burning Grounds at Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2001).
[b] Maximum groundwater concentration = maximum sediment concentration divided by the distribution coefficient.
[c] An exposure unit-specific DAF was calculated based on the sediment and co-located surface water concentrations and the lowest calculated DAF for each exposure unit (i.e., 1 for sodium) was used for analytes that did not have an exposure unit-specific DAF.
[d] Pyrene RSL was used as a surrogate for phenanthrene.
[e] U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.
[f] K_d value for organic chemicals calculated by multiplying K_{oc} by fraction organic carbon of 0.0012 (average geotechnical data from Load Lines 7, 10, and 11).
[g] USEPA 1994. Risk Reduction Engineering Laboratory Treatability Database, Ver. 5.0, Office of Research and Development, Cincinnati, Ohio.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant migration chemical of potential concern.
DAF = Dilution attenuation factor.
ID = Identification.
K_d = Distribution coefficient.
K_{oc} = Organic carbon distribution coefficient.
L/kg = Liters per kilogram.
MCL = Maximum contaminant level.
mg/kg = Milligrams per kilogram.
mg/L = Milligrams per liter.
NA = Not applicable.
RSL = Regional screening level.
SRC = Site-related contaminant.
Bold = Final CMCOPC to be modeled with Analytical Transient 1-, 2-, 3-Dimensional model.

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Table E-9. Climatic Data from SESOIL for Load Line 5

Month	Air Temp (°C)	Cloud Cover	Humidity	Albedo	Evapotranspiration[a] (cm/day)	Precipitation (cm)	Duration (days)	Storms per Month	Model Days in Month
October	12	0.60	0.70	0.17	0.00	6.46	0.42	5.33	30.4
November	5.22	0.70	0.75	0.24	0.00	7.4	0.53	6.67	30.4
December	-1.06	0.80	0.75	0.31	0.00	7.06	0.57	6.14	30.4
January	-2.94	0.80	0.80	0.3	0.00	7.06	0.61	5.69	30.4
February	-2.33	0.70	0.75	0.32	0.00	5.76	0.53	5.09	30.4
March	2.33	0.70	0.70	0.29	0.00	8.26	0.55	7.14	30.4
April	9.11	0.70	0.70	0.19	0.00	8.83	0.48	7.4	30.4
May	14.61	0.60	0.70	0.16	0.00	8.46	0.45	7.15	30.4
June	19.89	0.60	0.70	0.16	0.00	9.07	0.36	6.57	30.4
July	21.89	0.50	0.70	0.16	0.00	9.8	0.3	6.06	30.4
August	21.11	0.55	0.70	0.16	0.00	8.14	0.3	6.06	30.4
September	17.67	0.55	0.70	0.16	0.00	7.85	0.4	5.44	30.4

[a] Data calculated in SESOIL model; 0.00 indicates evapotranspiration is calculated from other climatic data -1996 data from Youngstown, Ohio, Weather Service Office - Airport Station.

cm/day = Centimeters per day.

SESOIL = Seasonal Soil Compartment.

Table E-10. Physical and Chemical Properties of Initial CMCOPCs Selected for SESOIL Modeling for Load Line 5

Initial CMCOPC	Molecular Weight	Solubility (mg/L)	Reference	K_d (L/kg)[a]	Reference	Diffusion Coefficient in Air (cm^2/sec)	Reference	Biodegradation Rate (1/day)	Sample Location	Application Area (cm^2)
Inorganic Chemicals										
Selenium	79.0	0.00E+00	b	5.00E+00	b	NA	NA	NA	LL5ss-005M-SO	1.10E+06
Explosives										
4-Nitrotoluene	137.1	4.42E+02	b	4.52E-01	a	5.7E-02	b	NA	LL5ss-021M-SO	4.67E+06
Semi-volatile Organic Compounds										
Benzenemethanol	108.1	4.29E+04	b	2.67E-02	a	7.3E-02	b	NA	LL5ss-005M-SO	1.10E+06
Naphthalene	128.2	3.10E+01	b	1.92E+00	a	6.0E-02	b	NA	LL5ss-005M-SO	1.10E+06
Pesticide/PCB										
beta-BHC	290.8	2.40E-01	b	3.49E+00	a	2.8E-02	b	NA	LL5ss-072M-5054-SO	1.59E+08

[a] K_d value for organic chemicals calculated by multiplying the organic carbon partition coefficient by fraction organic carbon of 0.0012 (average geotechnical data from Load Lines 7, 10, and 11).
[b] U.S. Environmental Protection Agency RSL generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.
BHC = Beta-hexachlorocyclohexane.
CMCOPC = Contaminant migration chemical of potential concern.
cm^2/sec = Centimeters per second.
K_d = Distribution coefficient.
L/kg = Liters per kilogram.
mg/L = Milligrams per liter.
NA = Not applicable.
PCB = Polychlorinated biphenyl.
SESOIL = Seasonal Soil Compartment.

Table E-11. Load Application Data for SESOIL Model at Load Line 5

16 ft Thick Vadose Zone for Selenium

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Selenium	4	1	4	4	1	1.8	Contaminant Loading
					2	0.84	
					3	0.84	
					4	0.84	
		2	9	3	1	0.79	
					2	0.71	
					3	0.71	
		3	2.5	2	1	0.0	Leaching
					2	0.0	
		4	0.5	1	1	0.0	

7 ft Thick Vadose Zone for 4-Nitrotoluene

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
4-Nitrotoluene	4	1	1	2	1	0.070	Contaminant Loading
					2	0.070	
		2	3	4	1	0.0	Leaching
					2	0.0	
					3	0.0	
					4	0.0	
		3	2.5	2	1	0.0	
					2	0.0	
		4	0.5	1	1	0.0	

16 ft Thick Vadose Zone for Benzenemethanol

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Benzenemethanol	4	1	1	2	1	1.3	Contaminant Loading
					2	1.3	
		2	7	4	1	0.0	Leaching
					2	0.0	
					3	0.0	
					4	0.0	
		3	7.5	2	1	0.0	
					2	0.0	
		4	0.5	1	1	0.0	

Table E-11. Load Application Data for SESOIL Model at Load Line 5 (continued)

16 ft Thick Vadose Zone for Naphthalene

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Naphthalene	4	1	1	2	1	0.095	Contaminant Loading
					2	0.095	
		2	7	4	1	0.0	Leaching
					2	0.0	
					3	0.0	
					4	0.0	
		3	7.5	2	1	0.0	
					2	0.0	
		4	0.5	1	1	0.0	

15 ft Thick Vadose Zone for beta-BHC

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
beta-BHC	4	1	1	2	1	0.0018	Contaminant Loading
					2	0.0018	
		2	7	4	1	0.0	Leaching
					2	0.0	
					3	0.0	
					4	0.0	
		3	6.5	2	1	0.0	
					2	0.0	
		4	0.5	1	1	0.0	

BHC = Beta-hexachlorocyclohexane.
ft = Feet.
mg/kg = Milligrams per kilogram.
SESOIL = Seasonal Soil Compartment.

Table E-12. Physical and Chemical Properties of Final CMCOPCs Selected for AT123D Modeling at Load Line 5

Analyte	K_d (L/kg)[a]	Source	Retardation Factor (R)	Source	Diffusion Coefficient in Water (cm^2/sec)	Source	Biodegradation Rate (1/day)	Source
Final CMCOPCs in Soil								
Inorganic Chemicals								
Selenium	5.00E+00	c	2.84E+01	b	NA	NA	0.00E+00	NA
Explosives								
4-Nitrotoluene	4.52E-01	a	3.47E+00	b	8.41E-06	c	0.00E+00	NA
Semi-volatile Organic Compounds								
Naphthalene	1.92E+00	a	1.15E+01	b	8.38E-06	c	0.00E+00	NA
Pesticide/PCB								
beta-BHC	3.49E+00	a	2.01E+01	b	7.40E-06	c	0.00E+00	NA
Final CMCOPCs in Sediment								
Semi-volatile Organic Compounds								
Hexachlorobenzene	7.44E+00	a	4.32E+01	b	6.59E-06	c	0.00E+00	NA

[a] K_d value for organic chemicals calculated by multiplying the organic carbon partition coefficient by fraction organic carbon of 0.0012 (average geotechnical data from Load Lines 7, 10, and 11).
[b] R value calculated from equation in Table E-7.
[c] U.S. Environmental Protection Agency regional screening level generic tables June 2015; found at: < http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.
AT123D = Analytical Transient 1-, 2-, 3-Dimensional model.
BHC = Beta-hexachlorocyclohexane.
cm^2/sec = Square centimeters per second.
CMCOPC = Contaminant migration chemical of potential concern.
K_d = Distribution coefficient.
L/kg = Liters per kilogram.
NA = Not applicable.
PCB = Polychlorinated biphenyl.

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Figures

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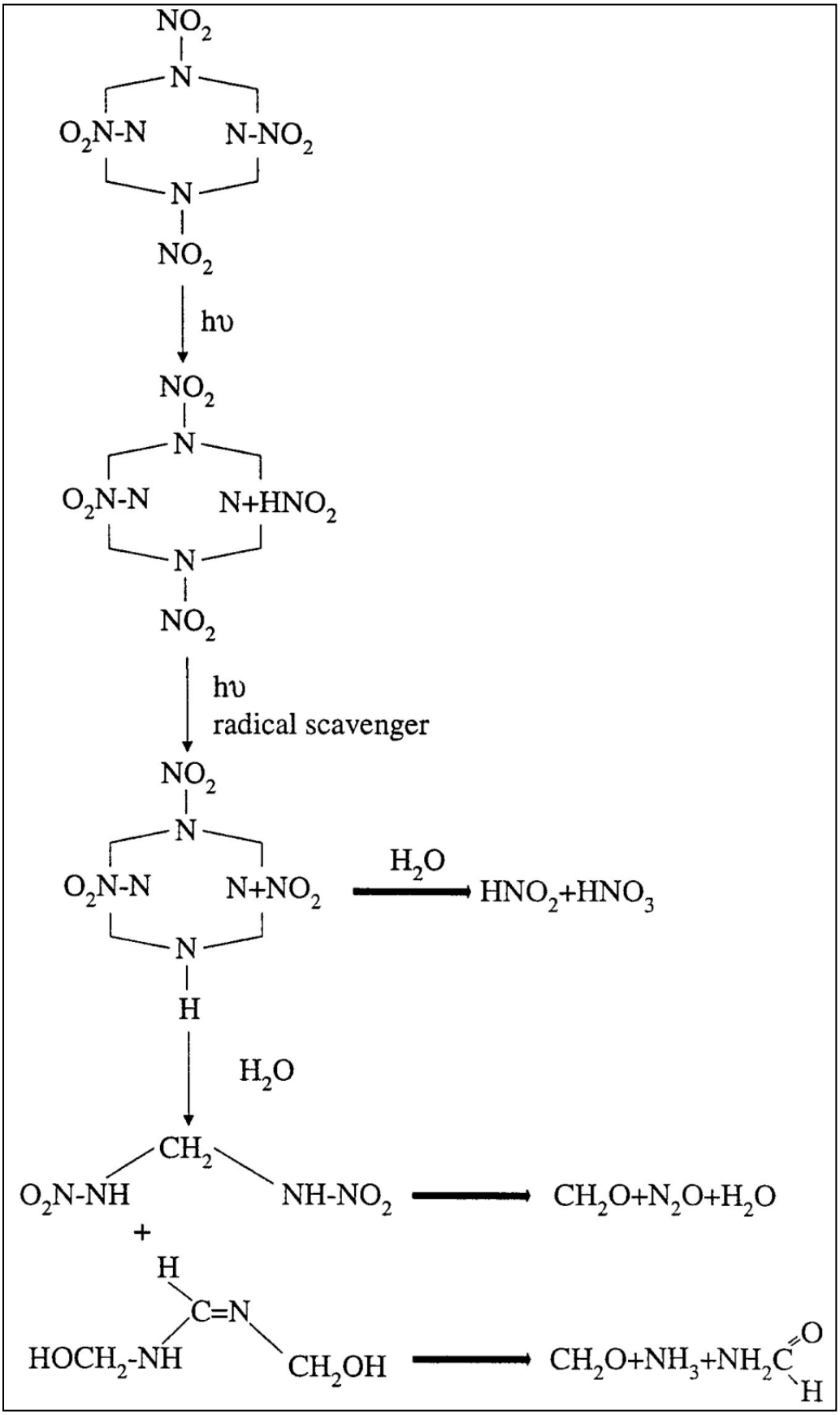

Figure E-1. HMX Biotransformation Pathway

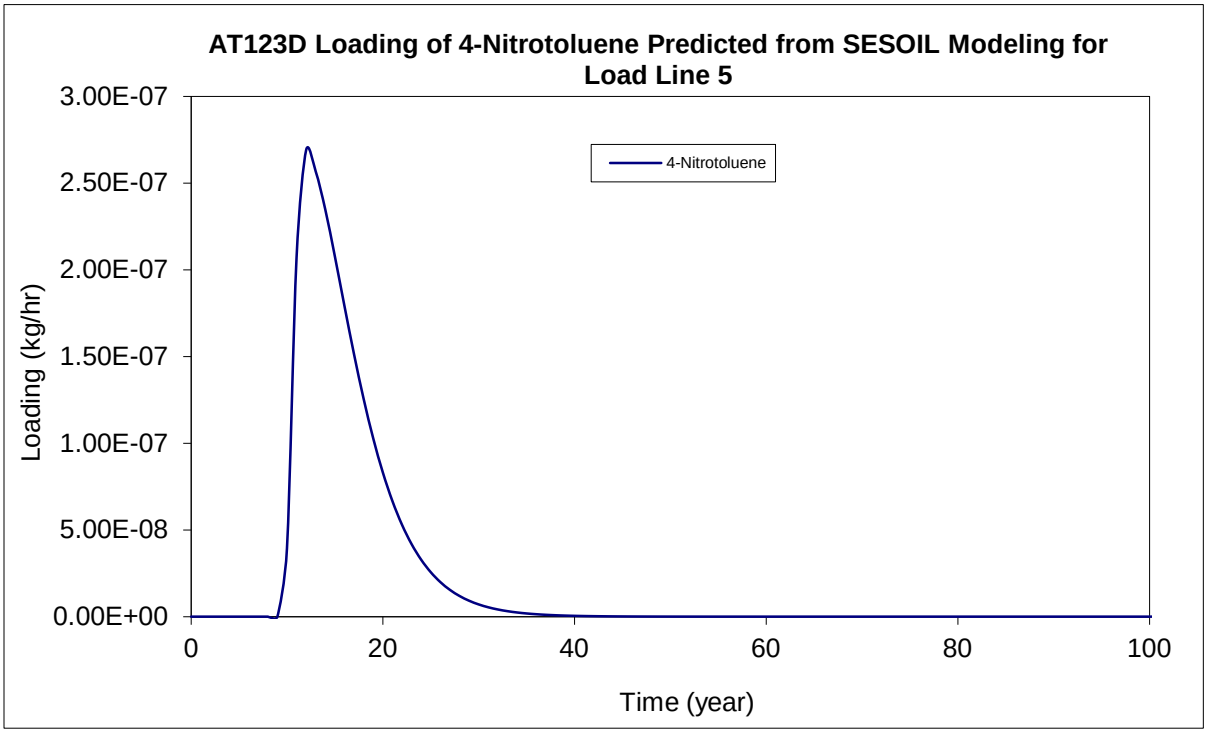

Figure E-2. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 5 – 4-Nitrotoluene

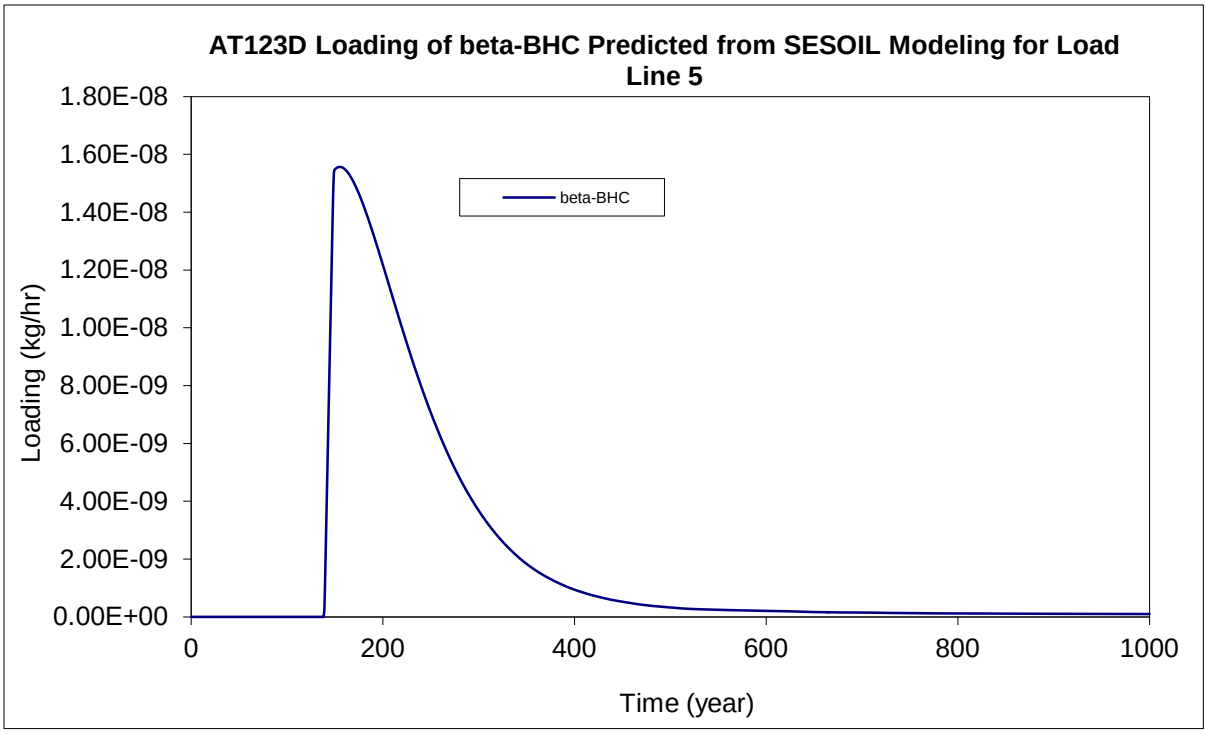

Figure E-3. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 5 – beta-BHC

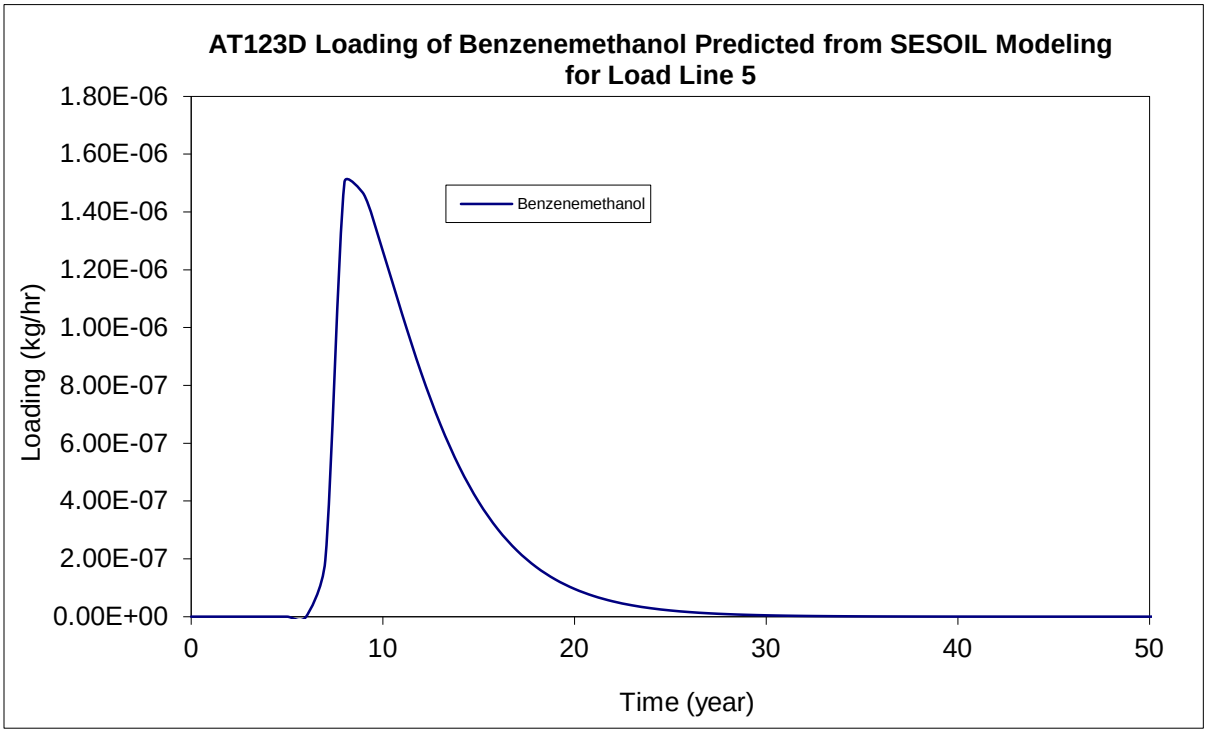

Figure E-4. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 5 – Benzenemethanol

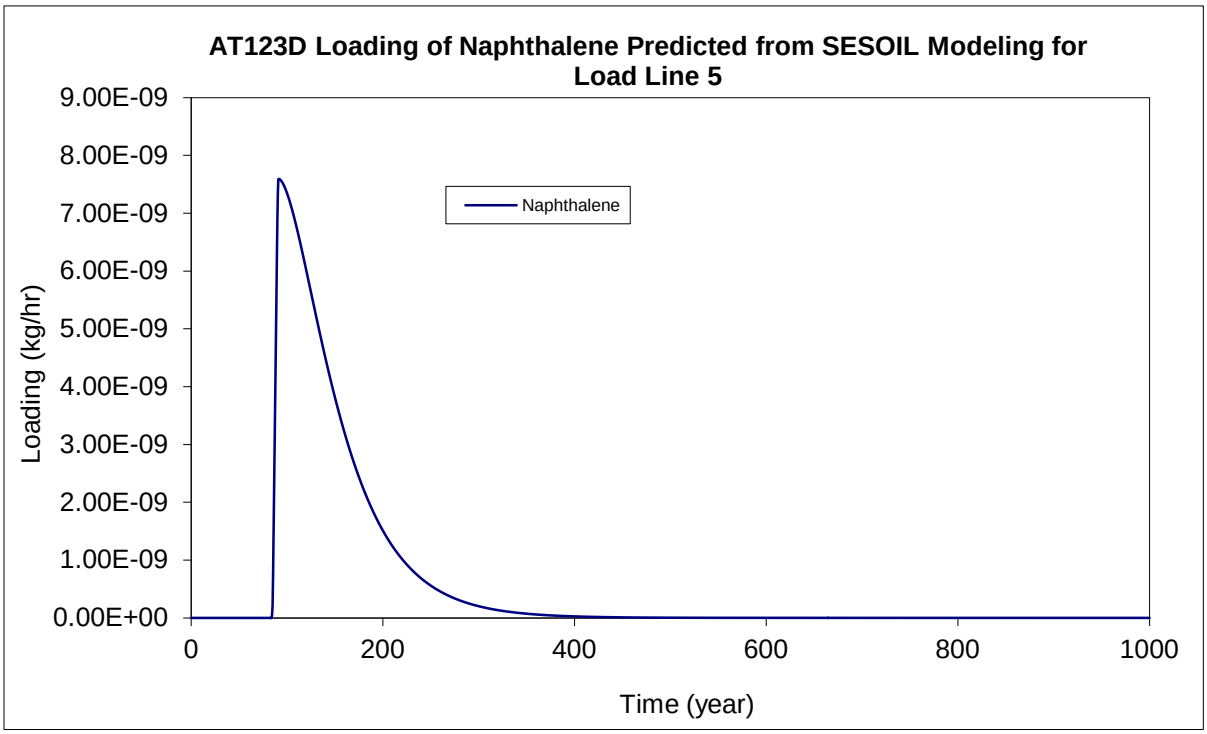

Figure E-5. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 5 – Naphthalene

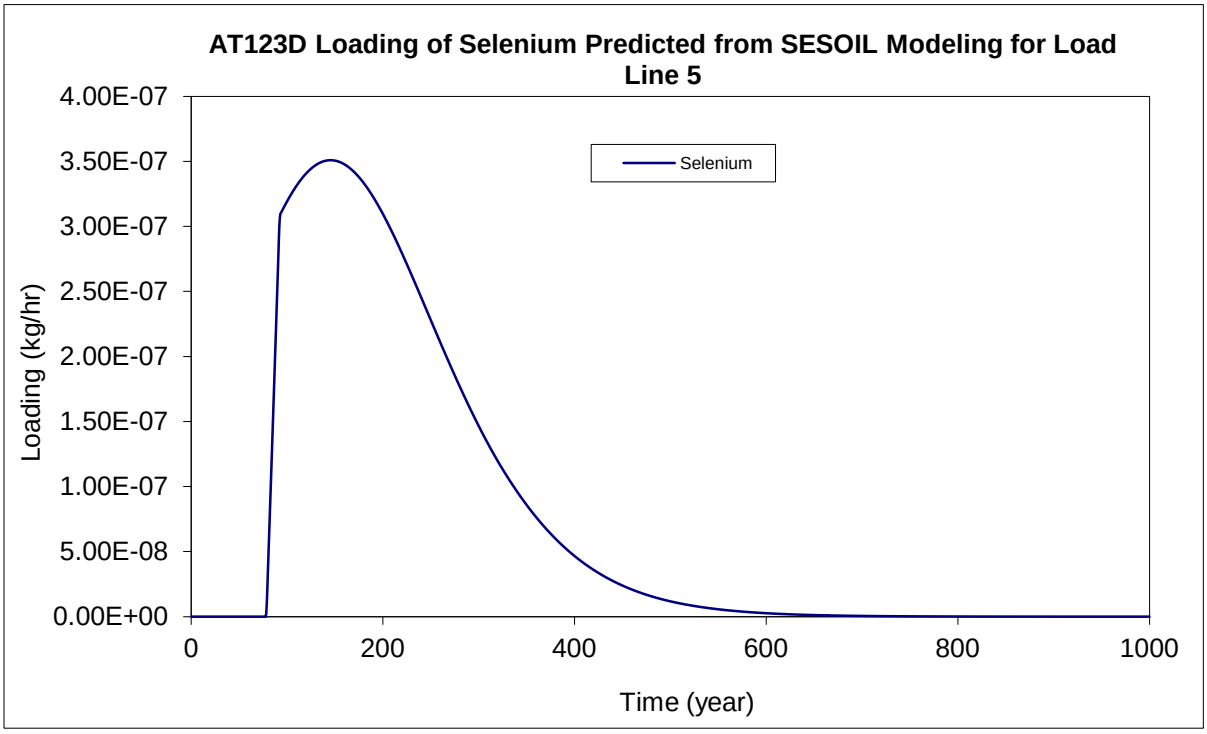

Figure E-6. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 5 – Selenium

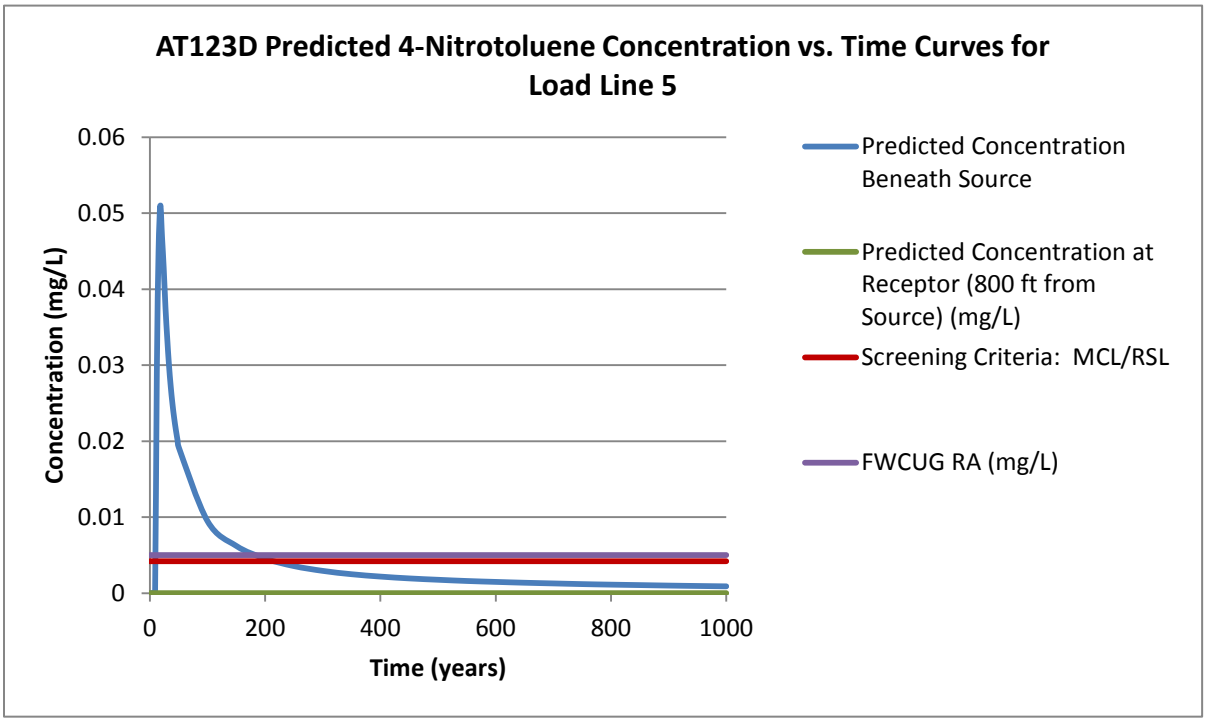

Figure E-7. Predicted Concentration of 4-Nitrotoluene in Groundwater based on AT123D Modeling at Load Line 5 from Soil

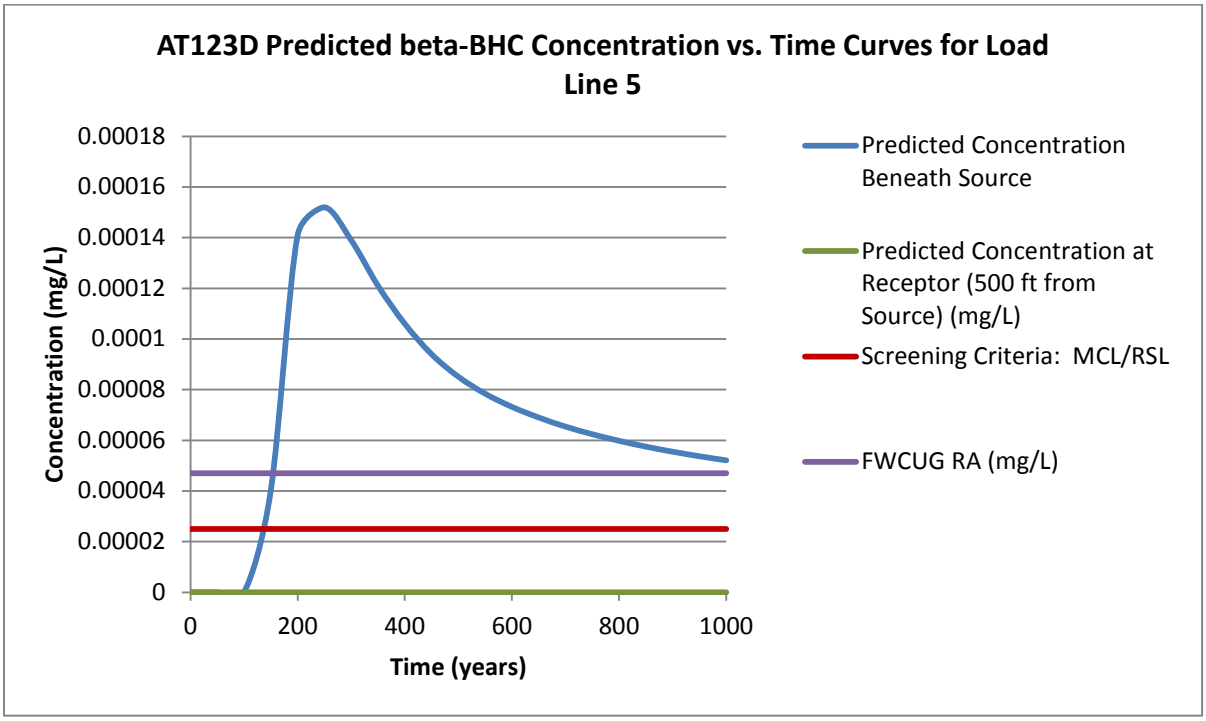

Figure E-8. Predicted Concentration of beta-BHC in Groundwater based on AT123D Modeling at Load Line 5 from Soil

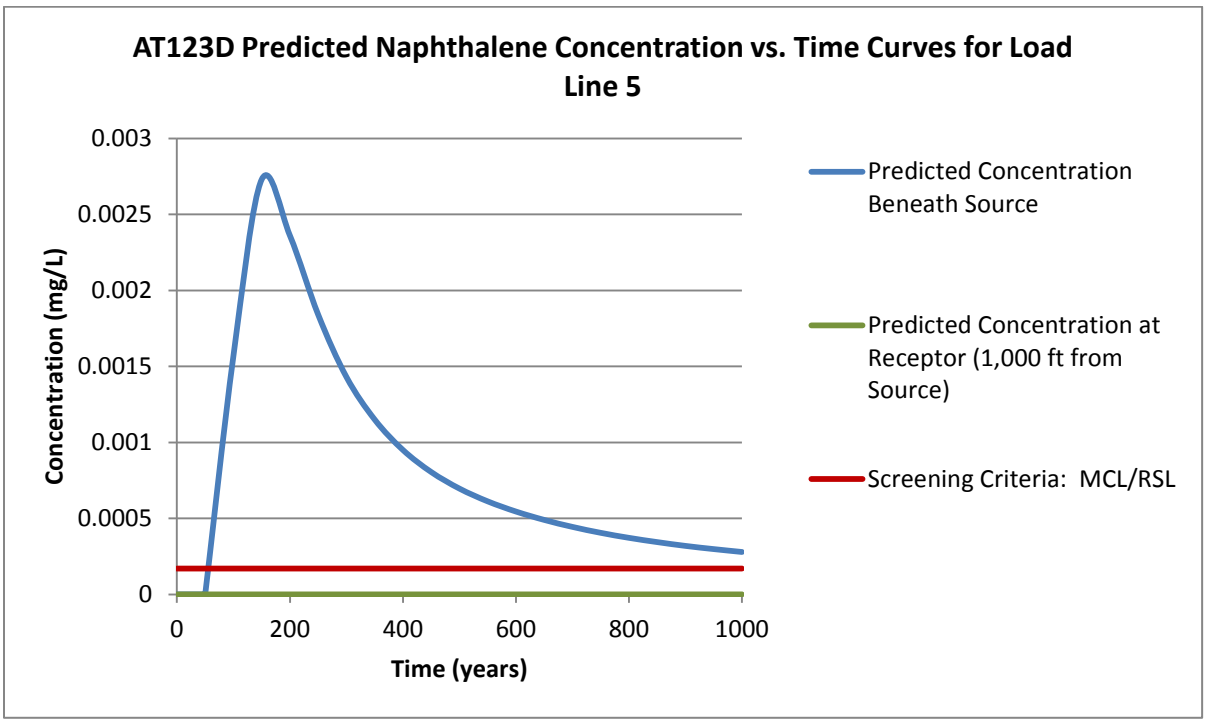

Figure E-9. Predicted Concentration of Naphthalene in Groundwater based on AT123D Modeling at Load Line 5 from Soil

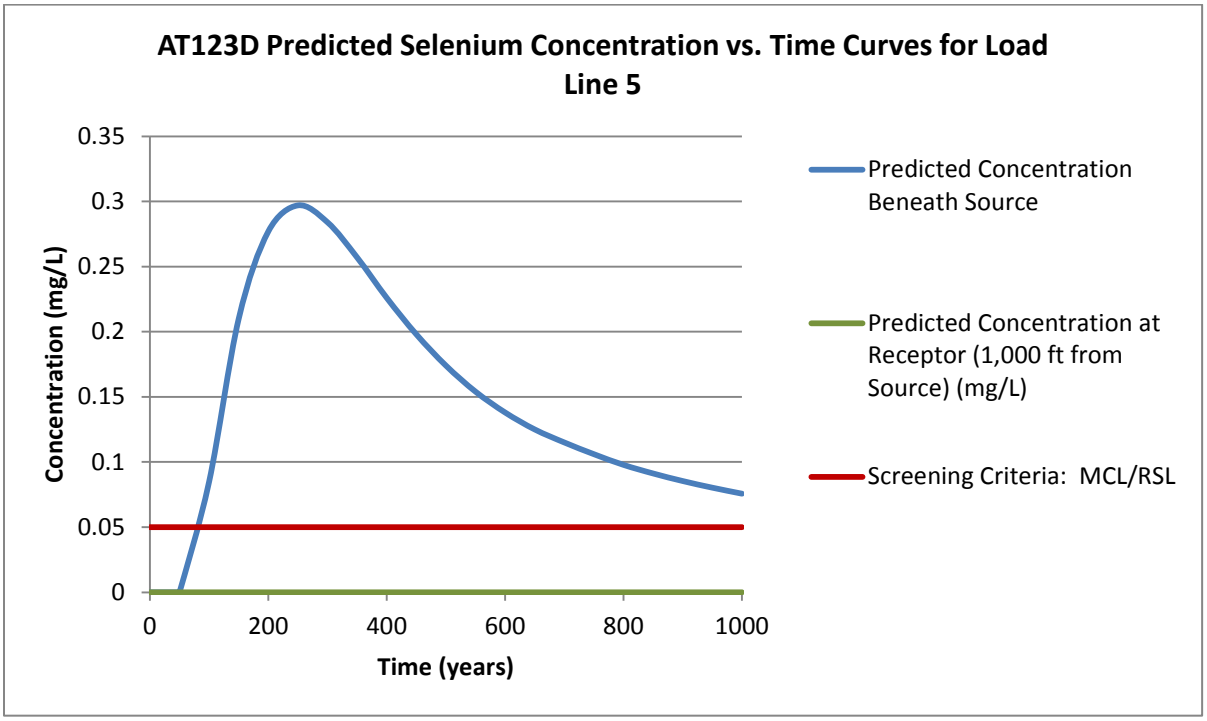

Figure E-10. Predicted Concentration of Selenium in Groundwater based on AT123D Modeling at Load Line 5 from Soil

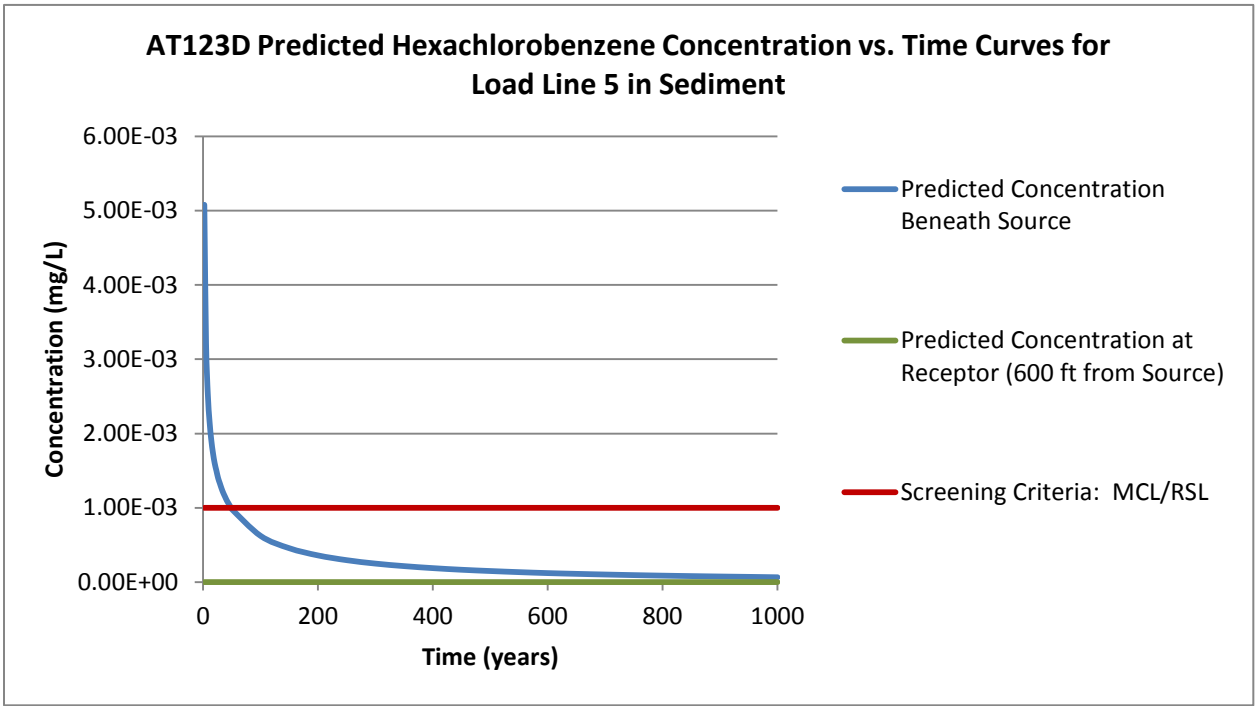

Figure E-11. Predicted Concentration of Selenium in Groundwater based on AT123D Modeling at Load Line 5 from Sediment