

APPENDIX E

Fate and Transport Modeling Results

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Tables

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Table E-1. Physical and Chemical Properties of Inorganic SRCs in Surface and Subsurface Soil at Buildings F-15 and F-16

Analyte	K _d (L/kg)	Reference	HLC (atm·m ³ /mol)	Reference	C _w (mg/L)	SSL Type	Generic SSL (mg/kg)	Reference	SSL Type
<i>Inorganic Compounds</i>									
Antimony	4.50E+01	a	NA	-	6.00E-03	MCL	2.70E-01	a	MCL
Arsenic	2.90E+01	a	NA	-	1.00E-02	MCL	2.90E-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
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
Zinc	6.20E+01	a	NA	-	6.00E+00	RSL	3.70E+02	a	Risk

^aU.S. Environmental Protection Agency regional screening levels 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/kg = Milligrams per kilogram.

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 at Buildings F-15 and F-16

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
<i>Explosives</i>									
Nitrocellulose	1.00E+01	a	3.29E-23	a	6.00E+04	RSL	1.30E+04	a	Risk
Nitroglycerin	1.16E+02	a	8.66E-08	a	2.00E-03	RSL	8.50E-04	a	Risk
<i>Semi-volatile Organic Compounds</i>									
2-Methylnaphthalene	2.48E+03	a	5.18E-04	a	3.60E-02	RSL	1.90E-01	a	Risk
Acenaphthene	5.03E+03	a	1.84E-04	a	5.30E-01	RSL	5.50E+00	a	Risk
Acenaphthylene ^c	7.40E+03	b	1.84E-04	a	5.30E-01	RSL	5.50E+00	a	Risk
Anthracene	1.64E+04	a	5.56E-05	a	1.80E+00	RSL	5.80E+01	a	Risk
Benz(<i>a</i>)anthracene	1.77E+05	a	1.20E-05	a	1.20E-05	RSL	4.25E-03	a	Risk
Benzo(<i>a</i>)pyrene	5.87E+05	a	4.57E-07	a	2.00E-04	MCL	2.40E-01	a	MCL
Benzo(<i>b</i>)fluoranthene	5.99E+05	a	6.57E-07	a	3.40E-05	RSL	4.10E-02	a	Risk
Benzo(<i>ghi</i>)perylene ^d	1.07E+07	b	1.40E-07	b	1.20E-01	RSL	1.30E+01	a	Risk
Benzo(<i>k</i>)fluoranthene	5.87E+05	a	5.84E-07	a	3.40E-04	RSL	4.00E-01	a	Risk
Bis(2-ethylhexyl)phthalate	1.20E+05	a	2.70E-07	a	6.00E-03	MCL	1.40E+00	a	MCL
Carbazole	NA	-	NA	-	NA	-	NA	-	-
Chrysene	1.81E+05	a	5.23E-06	a	3.40E-03	RSL	1.20E+00	a	Risk
Dibenz(<i>a,h</i>)anthracene	1.91E+06	a	1.41E-07	a	3.40E-06	RSL	1.30E-02	a	Risk
Dibenzofuran	9.16E+03	a	2.13E-04	a	7.90E-03	RSL	1.50E-01	a	Risk
Fluoranthene	5.55E+04	a	8.86E-06	a	8.00E-01	RSL	8.90E+01	a	Risk
Fluorene	9.16E+03	a	9.62E-05	a	2.90E-01	RSL	5.40E+00	a	Risk
Indeno(1,2,3- <i>cd</i>)pyrene	1.95E+06	a	3.48E-07	a	3.40E-05	RSL	1.30E-01	a	Risk
Naphthalene	1.54E+03	a	4.40E-04	a	1.70E-04	RSL	5.40E-04	a	Risk
Phenanthrene ^d	1.82E+04	b	3.93E-05	b	1.20E-01	RSL	1.30E+01	a	Risk
Pyrene	5.43E+04	a	1.19E-05	a	1.20E-01	RSL	1.30E+01	a	Risk
<i>Volatile Organic Compounds</i>									
Chloroform	3.18E+01	a	3.67E-03	a	2.20E-04	RSL	2.20E-02	a	MCL

Table E-2. Physical and Chemical Properties of Organic SRCs in Surface and Subsurface Soil at Buildings F-15 and F-16 (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
<i>Pesticides/PCBs</i>									
4,4'-DDE	1.18E+05	a	4.16E-05	a	4.60E-05	RSL	1.10E-02	a	Risk
4,4'-DDT	1.69E+05	a	8.32E-06	a	2.30E-04	RSL	7.70E-02	a	Risk
PCB-1260	3.50E+05	a	3.36E-04	a	7.80E-06	RSL	5.50E-03	a	Risk

^a U.S. Environmental Protection Agency (USEPA) RSL generic tables June 2015; found at: <http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

^bUSEPA 1994. Risk Reduction Engineering Laboratory Treatability Database, Version 5.0. Office of Research and Development. Cincinnati, Ohio.

^cAcenaphthene C_w and generic SSL were used as a surrogate for acenaphthylene.

^dPyrene C_w and generic SSL were used as a surrogate for benzo(*ghi*)perylene and phenanthrene.

C_w = Target groundwater concentration (either MCL or RSL).

DDE = Dichlorodiphenyldichloroethylene.

DDT = Dichlorodiphenyltrichloroethane.

HLC = Henry's Law Constant.

K_{oc} = Organic carbon partition coefficient.

L/kg = Liters per kilogram.

MCL = Maximum contaminant level.

mg/L = Milligrams per liter.

mg/kg = Milligrams per kilogram.

NA = Not available.

PCB = Polychlorinated biphenyl.

RSL = Regional screening level (USEPA 2015)

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 Buildings F-15 and F-16

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Samples > SSL/Total Samples	Sample ID at Maximum Concentration	Date Collected
Building F-15									
<i>Inorganic Chemicals</i>									
Antimony	7440-36-0	1.4	0.27	MCL	Yes	Exceeds SSL	4/ 19	FWC_{ss}-007-0001-SO	12/2/09
Arsenic	7440-38-2	20	0.29	MCL	Yes	Exceeds SSL	23/ 23	F15_{ss}-011M-SO	10/28/04
Barium	7440-39-3	118	82	MCL	Yes	Exceeds SSL	12/ 23	F15_{sb}-031-5406-SO	03/02/10
Beryllium	7440-41-7	1.4	3.2	MCL	No	Below SSL	0/ 23	F15 _{ss} -011M-SO	10/28/04
Cadmium	7440-43-9	1.03	0.38	MCL	Yes	Exceeds SSL	2/ 23	F15_{ss}-012M-0500-SO	11/04/09
Chromium	7440-47-3	58.4	180,000	MCL	No	Below SSL	0/ 23	FWC _{ss} -007-0001-SO	12/2/09
Cobalt	7440-48-4	25	0.27	Risk	Yes	Exceeds SSL	23/ 23	F15_{sb}-031-5406-SO	03/02/10
Copper	7440-50-8	38.4	46	MCL	No	Below SSL	0/ 23	F15 _{ss} -036M-5427-SO	02/24/10
Lead	7439-92-1	58	14	MCL	Yes	Exceeds SSL	16/ 23	F15_{ss}-011M-SO	10/28/04
Mercury	7439-97-6	0.072	0.1	MCL	No	Below SSL	0/ 23	F15 _{ss} -036M-5427-SO	02/24/10
Nickel	7440-02-0	55	26	Risk	Yes	Exceeds SSL	10/ 23	F15_{ss}-035M-5428-SO	02/24/10
Silver	7440-22-4	0.069	0.8	Risk	No	Below SSL	0/ 22	F15 _{sb} -031-5406-SO	03/02/10
Thallium	7440-28-0	0.59	0.14	MCL	Yes	Exceeds SSL	13/ 23	F15_{ss}-011M-SO	10/28/04
Zinc	7440-66-6	110	370	Risk	No	Below SSL	0/ 23	F15 _{ss} -001M-SO	10/28/04
<i>Explosives</i>									
Nitrocellulose	9004-70-0	0.93	13,000	Risk	No	Below SSL	0/ 4	F15 _{ss} -006M-SO	10/28/04
<i>Semi-volatile Organic Compounds</i>									
2-Methylnaphthalene	91-57-6	0.098	0.19	Risk	No	Below SSL	0/ 4	FWC _{ss} -007-0001-SO	12/2/09
Acenaphthene	83-32-9	0.08	5.5	Risk	No	Below SSL	0/ 13	F15 _{ss} -036M-5427-SO	02/24/10
Acenaphthylene	208-96-8	0.022	5.5	Risk	No	Below SSL	0/ 13	F15 _{ss} -036M-5427-SO	02/24/10
Anthracene	120-12-7	0.13	58	Risk	No	Below SSL	0/ 13	F15 _{ss} -036M-5427-SO	02/24/10
Benz(a)anthracene	56-55-3	0.49	0.00425	Risk	Yes	Exceeds SSL	5/ 13	F15_{ss}-036M-5427-SO	02/24/10
Benzo(a)pyrene	50-32-8	0.48	0.24	MCL	Yes	Exceeds SSL	1/ 13	F15_{ss}-036M-5427-SO	02/24/10
Benzo(b)fluoranthene	205-99-2	0.69	0.041	Risk	Yes	Exceeds SSL	2/ 13	F15_{ss}-036M-5427-SO	02/24/10
Benzo(<i>ghi</i>)perylene	191-24-2	0.33	13	Risk	No	Below SSL	0/ 13	F15 _{ss} -036M-5427-SO	02/24/10
Benzo(<i>k</i>)fluoranthene	207-08-9	0.26	0.4	Risk	No	Below SSL	0/ 13	F15 _{ss} -036M-5427-SO	02/24/10
Bis(2-ethylhexyl)phthalate	117-81-7	0.028	1.4	MCL	No	Below SSL	0/ 4	F15 _{sb} -031-5407-SO	03/02/10
Chrysene	218-01-9	0.54	1.2	Risk	No	Below SSL	0/ 13	F15 _{ss} -036M-5427-SO	02/24/10

Table E-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for Buildings F-15 and F-16 (continued)

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Samples > SSL/Total Samples	Sample ID at Maximum Concentration	Date Collected
Dibenz(a,h)anthracene	53-70-3	0.089	0.013	Risk	Yes	Exceeds SSL	1/ 13	F15ss-036M-5427-SO	02/24/10
Dibenzofuran	132-64-9	0.017	0.15	Risk	No	Below SSL	0/ 4	F15ss-006M-SO	10/28/04
Fluoranthene	206-44-0	1.2	89	Risk	No	Below SSL	0/ 13	F15ss-036M-5427-SO	02/24/10
Fluorene	86-73-7	0.062	5.4	Risk	No	Below SSL	0/ 13	F15ss-036M-5427-SO	02/24/10
Indeno(1,2,3-cd)pyrene	193-39-5	0.3	0.13	Risk	Yes	Exceeds SSL	1/ 13	F15ss-036M-5427-SO	02/24/10
Naphthalene	91-20-3	0.13	0.00054	Risk	Yes	Exceeds SSL	5/ 13	F15ss-035M-5428-SO	02/24/10
Phenanthrene	85-01-8	0.71	13	Risk	No	Below SSL	0/ 13	F15ss-036M-5427-SO	02/24/10
Pyrene	129-00-0	0.85	13	Risk	No	Below SSL	0/ 13	F15ss-036M-5427-SO	02/24/10
Building F-16									
<i>Inorganic Chemicals</i>									
Antimony	7440-36-0	1.5	0.27	MCL	Yes	Exceeds SSL	4/ 15	FWC_{ss}-008-0001-SO	12/2/09
Arsenic	7440-38-2	24.3	0.29	MCL	Yes	Exceeds SSL	16/ 16	F16sb-021-5419-SO	03/02/10
Barium	7440-39-3	200	82	MCL	Yes	Exceeds SSL	7/ 16	F16ss-007M-SO	11/03/04
Beryllium	7440-41-7	2.9	3.2	MCL	No	Below SSL	0/ 16	F16ss-007M-SO	11/03/04
Cadmium	7440-43-9	2.5	0.38	MCL	Yes	Exceeds SSL	2/ 16	F16ss-007M-SO	11/03/04
Chromium	7440-47-3	65.3	180,000	MCL	No	Below SSL	0/ 16	F16ss-027M-5432-SO	02/24/10
Cobalt	7440-48-4	12	0.27	Risk	Yes	Exceeds SSL	16/ 16	F16ss-006M-SO	10/28/04
Copper	7440-50-8	200	46	MCL	Yes	Exceeds SSL	1/ 16	F16ss-002M-SO	11/03/04
Lead	7439-92-1	120	14	MCL	Yes	Exceeds SSL	10/ 16	F16ss-007M-SO	11/03/04
Mercury	7439-97-6	0.05	0.1	MCL	No	Below SSL	0/ 16	F16ss-001M-SO	11/03/04
Nickel	7440-02-0	39.6	26	Risk	Yes	Exceeds SSL	5/ 16	F16ss-026M-5431-SO	02/24/10
Selenium	7782-49-2	1.7	0.26	MCL	Yes	Exceeds SSL	10/ 16	F16ss-007M-SO	11/03/04
Silver	7440-22-4	0.048	0.8	Risk	No	Below SSL	0/ 15	F16ss-027M-5432-SO	02/24/10
Thallium	7440-28-0	0.33	0.14	MCL	Yes	Exceeds SSL	4/ 16	F16ss-005M-SO	11/03/04
Zinc	7440-66-6	130	370	Risk	No	Below SSL	0/ 16	F16ss-007M-SO	11/03/04

Table E-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for Buildings F-15 and F-16 (continued)

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Samples > SSL/Total Samples	Sample ID at Maximum Concentration	Date Collected
<i>Explosives</i>									
Nitrocellulose	9004-70-0	2.1	13,000	Risk	No	Below SSL	0/ 3	F16ss-005M-SO	11/03/04
Nitroglycerin	55-63-0	0.52	0.00085	Risk	Yes	Exceeds SSL	1/ 10	F16ss-005M-SO	11/03/04
<i>Semi-volatile Organic Compounds</i>									
2-Methylnaphthalene	91-57-6	1	0.19	Risk	Yes	Exceeds SSL	1/ 3	F16ss-005M-SO	11/03/04
Acenaphthene	83-32-9	0.2	5.5	Risk	No	Below SSL	0/ 9	F16sb-022-5423-SO	03/02/10
Anthracene	120-12-7	0.053	58	Risk	No	Below SSL	0/ 9	F16ss-005M-SO	11/03/04
Benz(a)anthracene	56-55-3	0.14	0.00425	Risk	Yes	Exceeds SSL	4/ 10	F16ss-005M-SO	11/03/04
Benzo(a)pyrene	50-32-8	0.11	0.24	MCL	No	Below SSL	0/ 10	F16ss-005M-SO	11/03/04
Benzo(b)fluoranthene	205-99-2	0.13	0.041	Risk	Yes	Exceeds SSL	3/ 10	F16ss-005M-SO	11/03/04
Benzo(ghi)perylene	191-24-2	0.095	13	Risk	No	Below SSL	0/ 9	F16ss-005M-SO	11/03/04
Benzo(k)fluoranthene	207-08-9	0.1	0.4	Risk	No	Below SSL	0/ 9	F16ss-005M-SO	11/03/04
Bis(2-ethylhexyl)phthalate	117-81-7	0.13	1.4	MCL	No	Below SSL	0/ 3	F16ss-005M-SO	11/03/04
Carbazole	86-74-8	0.038	NA	NA	No	No SSL	0/ 3	F16ss-005M-SO	11/03/04
Chrysene	218-01-9	0.2	1.2	Risk	No	Below SSL	0/ 10	F16ss-005M-SO	11/03/04
Dibenzofuran	132-64-9	0.26	0.15	Risk	Yes	Exceeds SSL	1/ 3	F16ss-005M-SO	11/03/04
Fluoranthene	206-44-0	0.26	89	Risk	No	Below SSL	0/ 10	F16ss-005M-SO	11/03/04
Fluorene	86-73-7	0.16	5.4	Risk	No	Below SSL	0/ 9	F16sb-022-5423-SO	03/02/10
Indeno(1,2,3-cd)pyrene	193-39-5	0.073	0.13	Risk	No	Below SSL	0/ 9	F16ss-005M-SO	11/03/04
Naphthalene	91-20-3	0.73	0.00054	Risk	Yes	Exceeds SSL	5/ 9	F16ss-005M-SO	11/03/04
Phenanthrene	85-01-8	0.66	13	Risk	No	Below SSL	0/ 9	F16sb-022-5423-SO	03/02/10
Pyrene	129-00-0	0.3	13	Risk	No	Below SSL	0/ 10	F16ss-005M-SO	11/03/04
<i>Volatile Organic Compounds</i>									
Chloroform	67-66-3	0.00068	0.022	MCL	No	Below SSL	0/ 2	F16ss-026M-5431-SO	02/24/10

Table E-4. Initial CMCOPCs Based on Maximum Concentration of SRCs Compared to GSSL for Buildings F-15 and F-16 (continued)

Analyte	CAS Number	Maximum Concentration (mg/kg)	GSSL (mg/kg)	GSSL Type	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Samples > SSL/Total Samples	Sample ID at Maximum Concentration	Date Collected
<i>Pesticides/PCBs</i>									
4,4'-DDE	72-55-9	0.012	0.011	Risk	Yes	Exceeds SSL	1/ 2	F16ss-005M-SO	11/03/04
4,4'-DDT	50-29-3	0.019	0.077	Risk	No	Below SSL	0/ 2	F16ss-005M-SO	11/03/04
PCB-1260	11096-82-5	0.12	0.0055	Risk	Yes	Exceeds SSL	1/ 2	F16ss-005M-SO	11/03/04

CAS = Chemical Abstract Service.

CMCOPC = Contaminant migration chemical of potential concern.

DDE = Dichlorodiphenyldichloroethylene.

DDT = Dichlorodiphenyltrichloroethane.

GSSL = Generic soil screening level.

ID = Identifier.

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.

Table E-5. DAF Calculation for Buildings F-15 and F-16

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

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

Parameter	Symbol	Value	Unit	Note
Building F-15				
DAF	DAF	2.97	unitless	Calculated from DAF equation shown above
Aquifer hydraulic conductivity	K	1.31E+02	m/year	Geometric mean from RVAAP range in MKM (2007)
Horizontal hydraulic gradient	i	7.40E-03	m/m	Determined from EQM 2010
Percolation rate	q	9.40E-02	m/year	Developed from HELP model from Cleveland, Ohio, weather data
Source length parallel to groundwater flow	L	16.7	m	Based on average area for all ISM areas for Building F-15
Mixing zone depth	d	3.19	m	Determined from the lower value between above equation for “d” (d = 3.19 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)
Building F-16				
DAF	DAF	2.95	unitless	Calculated from DAF equation shown above
Aquifer hydraulic conductivity	K	1.31E+02	m/year	Geometric mean from RVAAP range in MKM (2007)
Horizontal hydraulic gradient	i	7.40E-03	m/m	Determined from EQM 2010
Percolation rate	q	9.40E-02	m/year	Developed from HELP model from Cleveland, Ohio, weather data
Source length parallel to groundwater flow	L	19.2	m	Based on average area for all ISM areas for Building F-16
Mixing zone depth	d	3.63	m	Determined from the lower value between above equation for “d” (d = 3.63 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)

EQM (Environmental Quality Management, Inc.) 2010. *Facility-wide Groundwater Monitoring Program Report on the January 2010 Sampling Event*. Final. July 2010.

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

USACE (U.S. Army Corp 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.

ISM = Incremental sampling methodology.

m = Meter.

RVAAP = Ravenna Army Ammunition Plant.

Table E-6. Initial CMCOPCs Based on Comparison of the SRCs Maximum Concentration at Buildings F-15 and F-16

Analyte	CAS Number	Maximum Concentration (mg/kg)	SSSL (mg/kg)	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Sample ID at Maximum Concentration	Date Collected
Building F-15 with a DAF = 2.97							
<i>Inorganic Chemicals</i>							
Antimony	7440-36-0	1.40E+00	8.02E-01	Yes	Exceeds SSSL	FWC_{ss}-007-0001-SO	12/2/09
Arsenic	7440-38-2	2.00E+01	8.61E-01	Yes	Exceeds SSSL	F15_{ss}-011M-SO	10/28/04
Barium	7440-39-3	1.18E+02	2.44E+02	No	Below SSSL	F15 _{sb} -031-5406-SO	03/02/10
Cadmium	7440-43-9	1.03E+00	1.13E+00	No	Below SSSL	F15 _{ss} -012M-0500-SO	11/04/09
Cobalt	7440-48-4	2.50E+01	8.02E-01	Yes	Exceeds SSSL	F15_{sb}-031-5406-SO	03/02/10
Lead	7439-92-1	5.80E+01	4.16E+01	Yes	Exceeds SSSL	F15_{ss}-011M-SO	10/28/04
Nickel	7440-02-0	5.50E+01	7.72E+01	No	Below SSSL	F15 _{ss} -035M-5428-SO	02/24/10
Thallium	7440-28-0	5.90E-01	4.16E-01	Yes	Exceeds SSSL	F15_{ss}-011M-SO	10/28/04
<i>Semi-volatile Organic Compounds</i>							
Benz(a)anthracene	56-55-3	4.90E-01	1.26E-02	Yes	Exceeds SSSL	F15_{ss}-036M-5427-SO	02/24/10
Benzo(a)pyrene	50-32-8	4.80E-01	7.13E-01	No	Below SSSL	F15 _{ss} -036M-5427-SO	02/24/10
Benzo(b)fluoranthene	205-99-2	6.90E-01	1.22E-01	Yes	Exceeds SSSL	F15_{ss}-036M-5427-SO	02/24/10
Dibenz(a,h)anthracene	53-70-3	8.90E-02	3.86E-02	Yes	Exceeds SSSL	F15_{ss}-036M-5427-SO	02/24/10
Indeno(1,2,3- <i>cd</i>)pyrene	193-39-5	3.00E-01	3.86E-01	No	Below SSSL	F15 _{ss} -036M-5427-SO	02/24/10
Naphthalene	91-20-3	1.30E-01	1.60E-03	Yes	Exceeds SSSL	F15_{ss}-035M-5428-SO	02/24/10

Table E-6. Initial CMCOPCs Based on Comparison of the SRC's Maximum Concentration at Buildings F-15 and F-16 (continued)

Analyte	CAS Number	Maximum Concentration (mg/kg)	SSSL (mg/kg)	Initial CMCOPC? (Yes/No)	CMCOPC Justification	Sample ID at Maximum Concentration	Date Collected
Building F-16 with a DAF = 2.95							
<i>Inorganic Chemicals</i>							
Antimony	7440-36-0	1.50E+00	7.97E-01	Yes	Exceeds SSSL	FWC_{ss}-008-0001-SO	12/2/09
Arsenic	7440-38-2	2.43E+01	8.56E-01	Yes	Exceeds SSSL	F16sb-021-5419-SO	03/02/10
Barium	7440-39-3	2.00E+02	2.42E+02	No	Below SSSL	F16 _{ss} -007M-SO	11/03/04
Cadmium	7440-43-9	2.50E+00	1.12E+00	Yes	Exceeds SSSL	F16_{ss}-007M-SO	11/03/04
Cobalt	7440-48-4	1.20E+01	7.97E-01	Yes	Exceeds SSSL	F16_{ss}-006M-SO	10/28/04
Copper	7440-50-8	2.00E+02	1.36E+02	Yes	Exceeds SSSL	F16_{ss}-002M-SO	11/03/04
Lead	7439-92-1	1.20E+02	4.13E+01	Yes	Exceeds SSSL	F16_{ss}-007M-SO	11/03/04
Nickel	7440-02-0	3.96E+01	7.67E+01	No	Below SSSL	F16 _{ss} -026M-5431-SO	2/24/10
Selenium	7782-49-2	1.70E+00	7.67E-01	Yes	Exceeds SSSL	F16_{ss}-007M-SO	11/03/04
Thallium	7440-28-0	3.30E-01	4.13E-01	No	Below SSSL	F16 _{ss} -005M-SO	11/03/04
<i>Explosives</i>							
Nitroglycerin	55-63-0	5.20E-01	2.51E-03	Yes	Exceeds SSSL	F16_{ss}-005M-SO	11/03/04
<i>Semi-volatile Organic Compounds</i>							
2-Methylnaphthalene	91-57-6	1.00E+00	5.61E-01	Yes	Exceeds SSSL	F16_{ss}-005M-SO	11/03/04
Benz(a)anthracene	56-55-3	1.40E-01	1.25E-02	Yes	Exceeds SSSL	F16_{ss}-005M-SO	11/03/04
Benzo(b)fluoranthene	205-99-2	1.30E-01	1.21E-01	Yes	Exceeds SSSL	F16_{ss}-005M-SO	11/03/04
Dibenzofuran	132-64-9	2.60E-01	4.43E-01	No	Below SSSL	F16 _{ss} -005M-SO	11/03/04
Naphthalene	91-20-3	7.30E-01	1.59E-03	Yes	Exceeds SSSL	F16_{ss}-005M-SO	11/03/04
<i>Pesticides/PCBs</i>							
4,4'-DDE	72-55-9	1.20E-02	3.25E-02	No	Below SSSL	F16 _{ss} -005M-SO	11/03/04
PCB-1260	11096-82-5	1.20E-01	1.62E-02	Yes	Exceeds SSSL	F16_{ss}-005M-SO	11/03/04

CAS = Chemical Abstract Service.

CMCOPC = Contaminant migration chemical of potential concern.

DAF = Dilution attenuation factor.

DDE = Dichlorodiphenyldichloroethylene.

ID = Identifier.

mg/kg = Milligrams per kilogram.

PCB = Polychlorinated biphenyl.

SRC = Site-related contaminant.

SSSL = Site-specific soil screening level; generic SSL multiplied by the DAF.

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 Buildings F-15 and F-16

$$R = 1 + \frac{\rho_b K_d}{\theta_w}$$

$$T = L_z \theta_w R / q$$

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}	0.0010	unitless	Average from the PBA08 RI geotechnical samples F16SB-023-5425-SO and F16SB-023-5425-SO
Water-filled soil porosity	θ _w	0.26	unitless	
Bulk density (dry)	ρ _b	1.79	gm/cm ³	
Leaching zone	L _z	0.25–12.5	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 Buildings F-15 and F-16 (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)
Building F-15										
<i>Inorganic Chemicals</i>										
Antimony	FWC _{ss} -007-0001-SO	0-0.5	12.5	NA	-	4.50E+01	c	3.11E+02	3,260	No
Arsenic	F15 _{ss} -011M-SO	0-1	12	NA	-	2.90E+01	c	2.01E+02	2,020	No
Cobalt	F15 _{sb} -031-5406-SO	1-4	9	NA	-	4.50E+01	c	3.11E+02	2,350	No
Lead	F15 _{ss} -011M-SO	0-1	12	NA	-	9.00E+02	c	6.20E+03	62,400	No
Thallium	F15 _{ss} -011M-SO	0-1	12	NA	-	7.10E+01	c	4.90E+02	4,930	No
<i>Semi-volatile Organic Compounds</i>										
Benz(<i>a</i>)anthracene	F15 _{ss} -036M-5427-SO	0-1	12	1.77E+05	c	1.77E+02	d	1.22E+03	12,300	No
Benzo(<i>b</i>)fluoranthene	F15 _{ss} -036M-5427-SO	0-1	12	5.99E+05	c	5.99E+02	d	4.13E+03	41,500	No
Dibenz(<i>a,h</i>)anthracene	F15 _{ss} -036M-5427-SO	0-1	12	1.91E+06	c	1.91E+03	d	1.32E+04	132,000	No
Naphthalene	F15_{ss}-035M-5428-SO	0-1	12	1.54E+03	c	1.54E+00	d	1.16E+01	117	Yes
Building F-16										
<i>Inorganic Chemicals</i>										
Antimony	FWC _{ss} -008-0001-SO	0-0.5	7.5	NA	-	4.50E+01	c	3.11E+02	1,960	No
Arsenic	F16 _{sb} -021-5419-SO	4-7	6	NA	-	2.90E+01	c	2.01E+02	1,010	No
Cadmium	F16 _{ss} -007M-SO	0-0.5	12.5	NA	-	7.50E+01	c	5.17E+02	5,420	No
Cobalt	F16 _{ss} -006M-SO	0-1	10	NA	-	4.50E+01	c	3.11E+02	2,610	No
Copper	F16 _{ss} -002M-SO	0-0.5	10.5	NA	-	3.50E+01	c	2.42E+02	2,130	No
Lead	F16 _{ss} -007M-SO	0-0.5	12.5	NA	-	9.00E+02	c	6.20E+03	65,000	No
Selenium	F16_{ss}-007M-SO	0-0.5	12.5	NA	-	5.00E+00	c	3.54E+01	371	Yes
<i>Explosives</i>										
Nitroglycerin	F16_{ss}-005M-SO	0-0.5	10.5	1.16E+02	c	1.16E-01	d	1.80E+00	16	Yes

Table E-7. Initial CMCOPCs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years at Buildings F-15 and F-16 (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)
<i>Semi-volatile Organic Compounds</i>										
2-Methylnaphthalene	F16ss-026M-5431-SO	0 - 1	10.0	2.48E+03	c	2.48E+00	d	1.81E+01	151	Yes
Benz(a)anthracene	F16ss-005M-SO	0 - 0.5	10.5	1.77E+05	c	1.77E+02	d	1.22E+03	10,700	No
Naphthalene	F16sb-021-5420-SO	7 - 13	0.25	1.54E+03	c	1.54E+00	d	1.16E+01	2.4	Yes
<i>Pesticides/PCBs</i>										
PCB-1260	F16ss-005M-SO	0 - 0.5	10.5	3.50E+05	c	3.50E+02	d	2.41E+03	21,200	No

^aThe maximum depth of an initial CMCOPC (based on the maximum depth that an analyte is detected above facility-wide background).

^bBased on each average depth to water from ground surface and depth of soil sample.

^cU.S. Environmental Protection Agency regional screening levels generic tables June 2015; found at: <http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

^dK_d value for organic chemicals calculated by multiplying K_{oc} by mass fraction of the organic carbon soil (f_{oc}) of 0.0010 (average from the PBA08 RI geotechnical samples F16SB-023-5425-SO and F16SB-023-5425_SO).

CMCOPC = Contaminant migration chemical of potential concern.

ft = Feet.

gm/cm³ = Grams per cubic centimeter.

HELP = Hydrologic Evaluation of Landfill Performance.

ID = Identification.

K_{oc} = Organic carbon partition coefficient.

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.

Bold = Initial CMCOPCs that exceed the 1,000-year travel time screen.

Table E-8. Climatic Data from SESOIL for Buildings F-15 and F-16

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

^aData 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 = Centimeter.

SESOIL = Seasonal Soil Compartment (model).

Table E-9. Physical and Chemical Properties of Initial CMCOPCs Selected for SESOIL Modeling for Buildings F-15 and F-16

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)
Building F-15										
<i>Semi-volatile Organic Compounds</i>										
Naphthalene	128.2	3.10E+01	b	1.54E+00	b	6.0E-02	b	NA	F15ss-035M-5428-SO	2.16E+06
Building F-16										
<i>Inorganic Chemicals</i>										
Selenium	79.0	0.00E+00	b	5.00E+00	b	NA	NA	NA	F16ss-007M-SO	2.31E+06
<i>Explosives</i>										
Nitroglycerin	227.1	1.38E+03	b	1.16E-01	b	2.90E-02	b	NA	F16ss-005M-SO	2.44E+06
<i>Semi-volatile Organic Compounds</i>										
2-Methylnaphthalene	142.2	2.46E+01	b	2.48E+00	b	5.24E-02	b	NA	F16ss-005M-SO	2.44E+06
Naphthalene	128.2	3.10E+01	b	1.54E+00	b	6.0E-02	b	NA	F16ss-005M-SO	2.44E+06

^aK_d value for organic chemicals calculated by multiplying organic carbon partition coefficient by fraction organic carbon of 0.0010 (average from the Performance-based Acquisition 2008 Remedial Investigation geotechnical samples F16SB-023-5425-SO and F16SB-023-5425-SO).

^b U.S. Environmental Protection Agency regional screening levels generic tables June 2015; found at: <http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

cm²/sec = Cubic centimeters per second.

CMCOPC = Contaminant migration chemical of potential concern.

K_d = Distribution coefficient.

L/kg = Liters per kilogram.

mg/L = Milligrams per liter.

NA = Not applicable.

SESOIL = Seasonal Soil Compartment (model).

Table E-10. Load Application Data for SESOIL Model at Buildings F-15 and F-16

13-ft-thick Vadose Zone for Naphthalene at Building F-15

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	0.13	Contaminant Loading
					2	0.13	
		2	6	4	1	0	Leaching
					2	0	
					3	0	
					4	0	
		3	5.5	2	1	0	
					2	0	
		4	0.5	1	1	0	

13-ft-thick Vadose Zone for Selenium at Building F-16

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Selenium	4	1	1	2	1	1.7	Contaminant Loading
					2	1.2	
		2	6	4	1	1.1	
					2	1.1	
					3	1	
					4	1	
		3	6	2	1	0.67	
					2	0.67	
		4	0.25	1	1	0	Leaching

11-ft-thick Vadose Zone for Nitroglycerin at Building F-16

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Nitroglycerin	4	1	1	2	1	0.52	Contaminant Loading
					2	0	
		2	5	4	1	0	Leaching
					2	0	
					3	0	
					4	0	
		3	4.5	2	1	0	
					2	0	
		4	0.5	1	1	0	

Table E-10. Load Application Data for SESOIL Model at Buildings F-15 and F-16 (continued)

11-ft-thick Vadose Zone for 2-Methylnaphthalene at Building F-16

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
2-Methylnaphthalene	4	1	1	2	1	1	Contaminant Loading
					2	0	
	4	2	5	4	1	0	Leaching
					2	0	
					3	0	
					4	0	
		3	4.5	2	1	0	
					2	0	
	4	0.5	1	1	0		

11-ft-thick Vadose Zone for Naphthalene at Building F-16

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	0.73	Contaminant Loading
					2	0	
	4	2	5	4	1	0	Leaching
					2	0	
					3	0	
					4	0	
		3	4.5	2	1	0	
					2	0	
	4	0.5	1	1	0		

ft = Feet.

mg/kg = Milligrams per kilogram.

SESOIL = Seasonal Soil Compartment

Table E-11. Physical and Chemical Properties of Final CMCOPCs Selected for AT123D Modeling at Buildings F-15 and F-16

Analyte	K _d (L/kg) ^a	Source	Retardation Factor (R)	Source	Diffusion Coefficient in Water (cm ² /sec)	Source	Biodegradation Rate (1/day)	Source
Building F-15								
<i>Semi-volatile Organic Compounds</i>								
Naphthalene	1.54E+00	b	1.16E+01	c	8.38E-06	b	0.00E+00	NA
Building F-16								
<i>Inorganic Compounds</i>								
Selenium	5.00E+00	b	3.54E+01	c	NA	NA	0.00E+00	NA
<i>Explosives</i>								
Nitroglycerin	1.16E-01	b	1.80E+00	c	7.74E-06	b	0.00E+00	NA
<i>Semi-volatile Organic Compounds</i>								
Naphthalene	1.54E+00	b	1.16E+01	c	8.38E-06	b	0.00E+00	NA

^aK_d value for organic chemicals calculated by multiplying organic carbon partition coefficient by fraction organic carbon of 0.0010 (average from the Performance-based Acquisition 2008 Remedial Investigation geotechnical samples F16SB-023-5425-SO and F16SB-023-5425-SO).

^bU.S. Environmental Protection Agency regional screening levels generic tables June 2015; found at: <http://www2.epa.gov/risk/risk-based-screening-table-generic-tables>.

^cR value calculated from equation in Table E-7.

AT123D = Analytical Transient 1-,2-,3-Dimensional (model).

cm²/sec = square centimeters per second.

CMCOPC = Contaminant migration chemical of potential concern.

K_d = Distribution coefficient.

L/kg = Liters per kilogram.

NA = Not applicable.

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Figures

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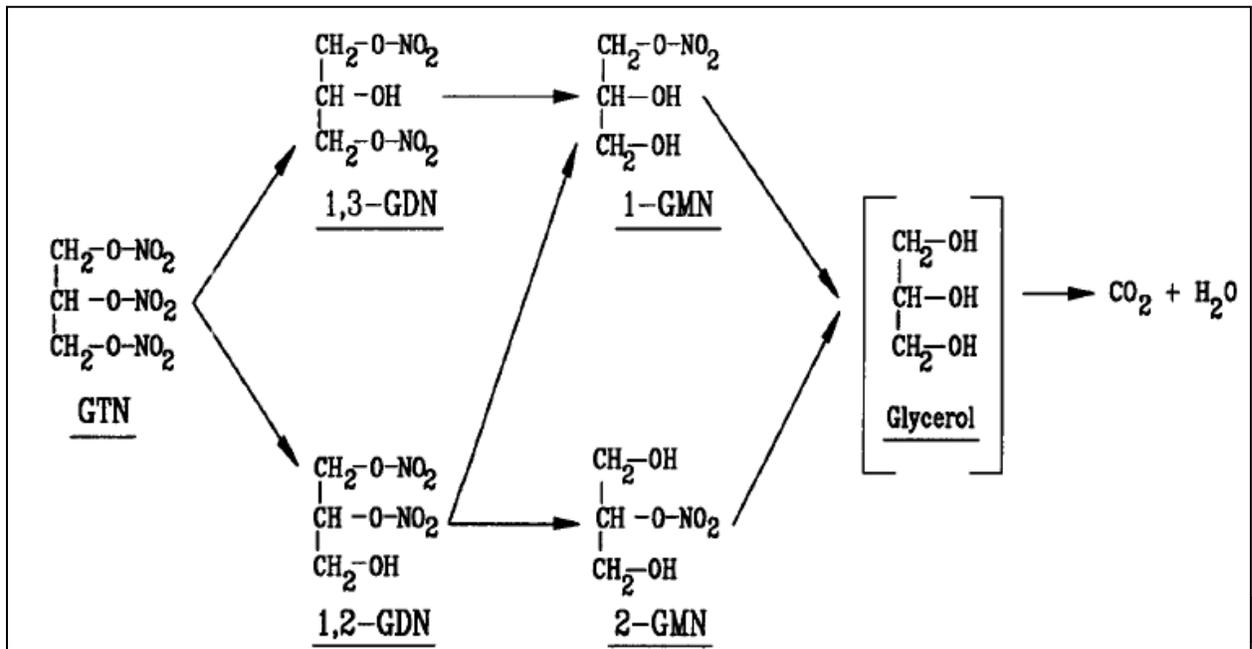


Figure E-1. Nitrolycerin (GTN) Biodegradation Pathway (from Christodoulatos et al. 1997)

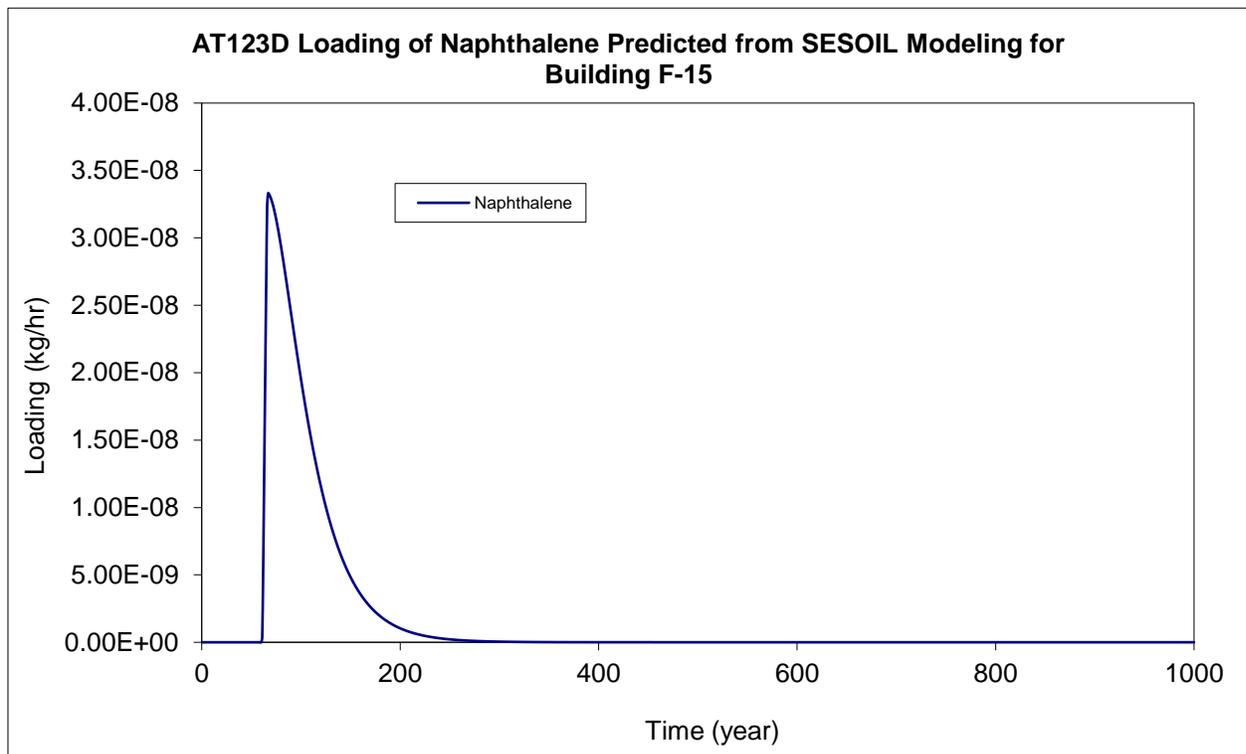


Figure E-2. Predicted Contaminant Mass Loading for AT123D Modeling at Building F-15 – Naphthalene

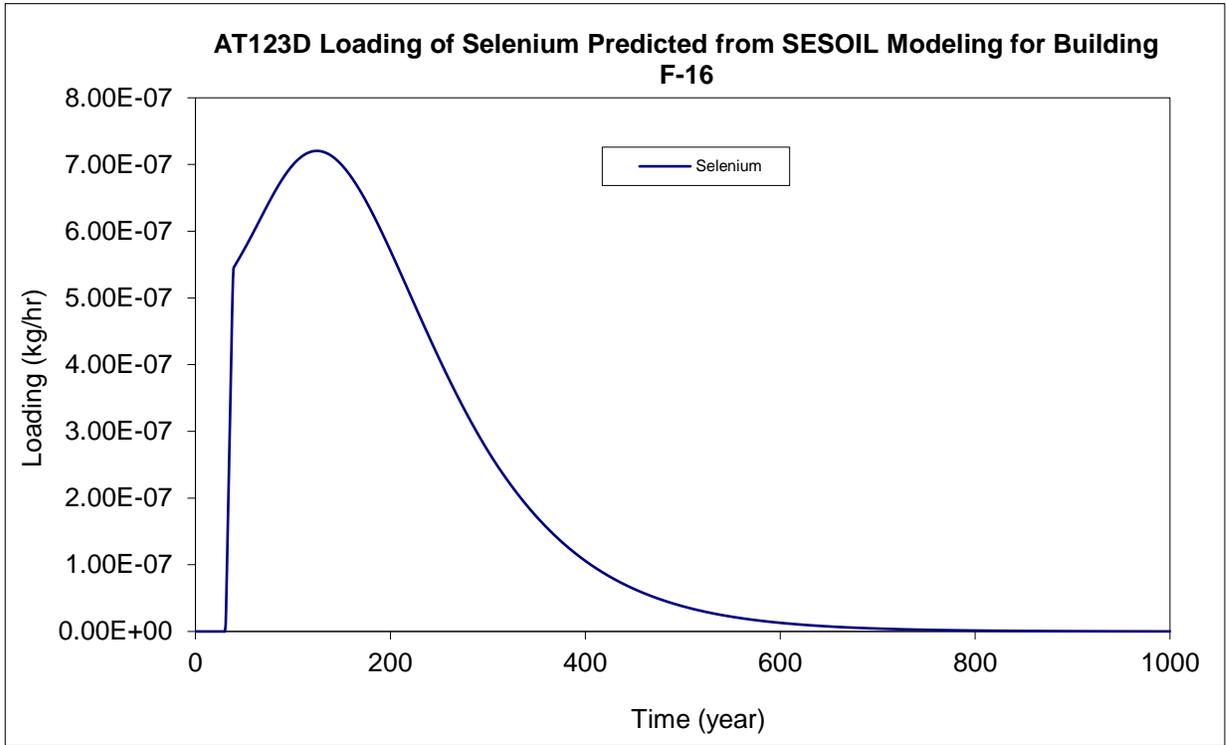


Figure E-3. Predicted Contaminant Mass Loading for AT123D Modeling at Building F-16 – Selenium

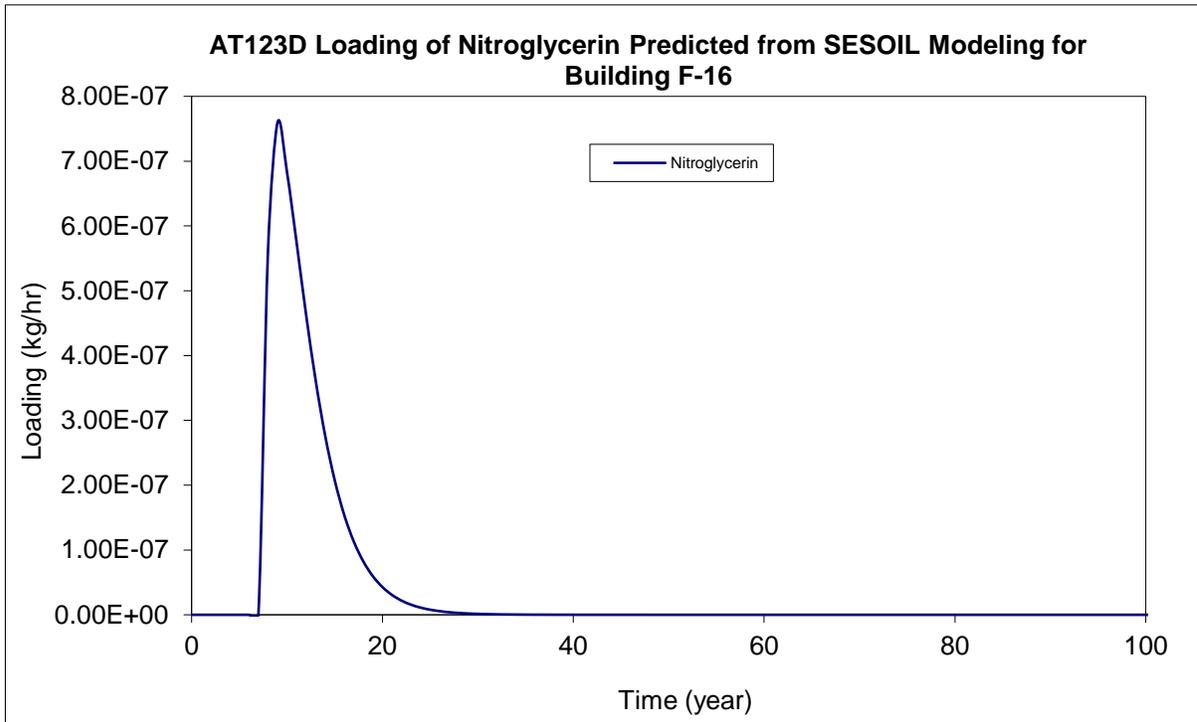


Figure E-4. Predicted Contaminant Mass Loading for AT123D Modeling at Building F-16 – Nitroglycerin

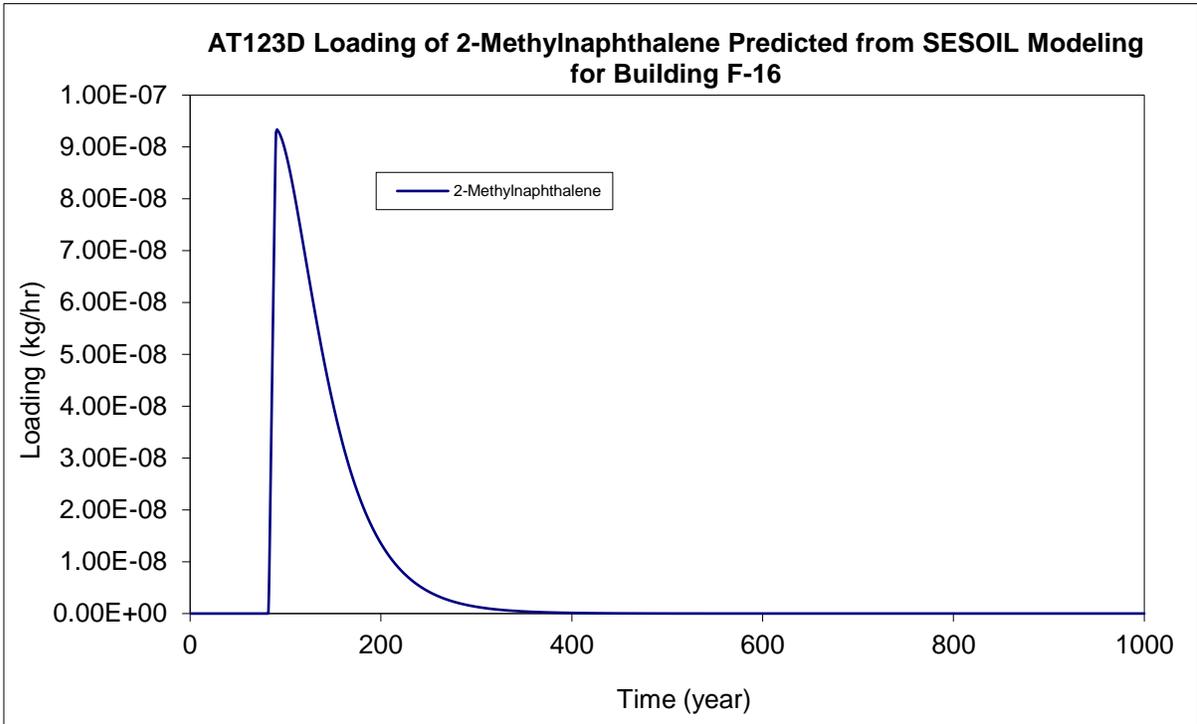


Figure E-5. Predicted Contaminant Mass Loading for AT123D Modeling at Building F-16 – 2-Methylnaphthalene

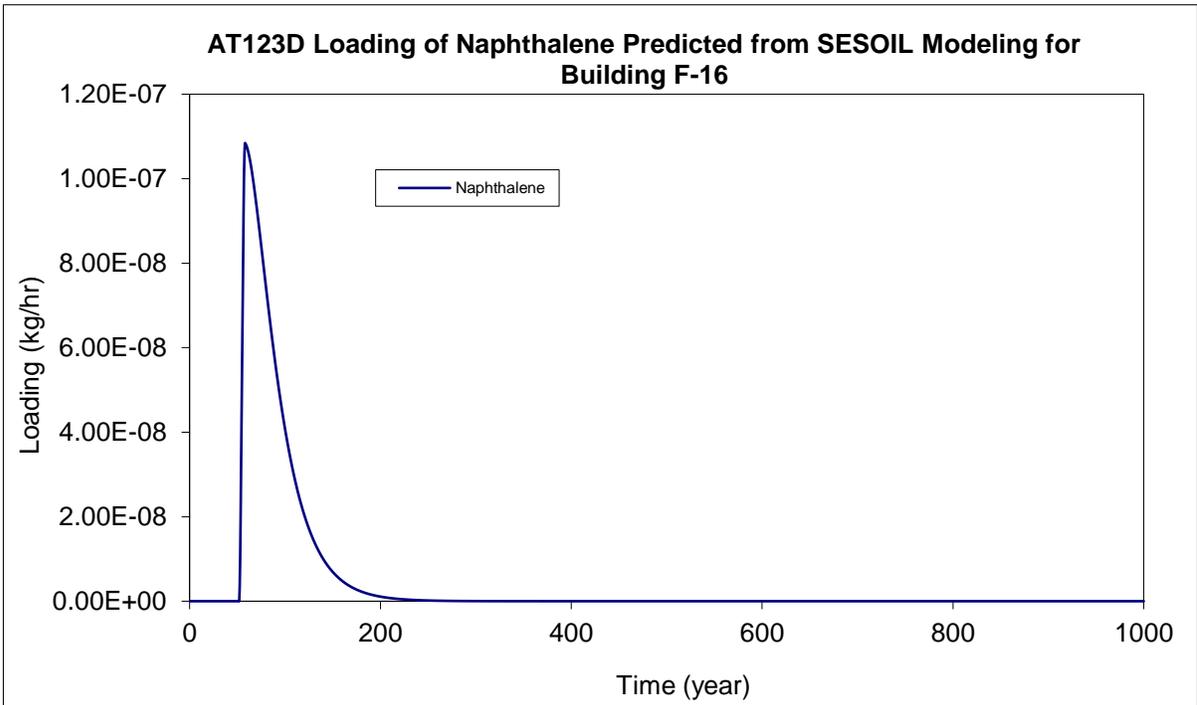


Figure E-6. Predicted Contaminant Mass Loading for AT123D Modeling at Building F-16 – Naphthalene

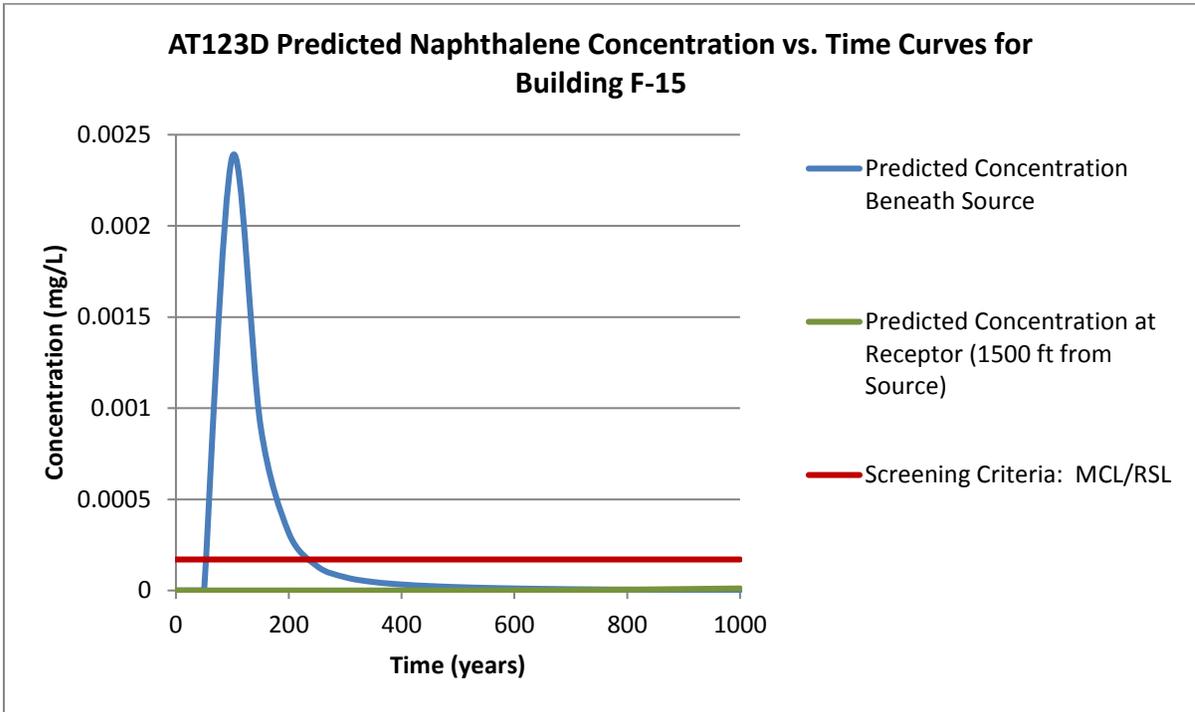


Figure E-7. Predicted Concentration of Naphthalene in Groundwater based on AT123D Modeling at Building F-15

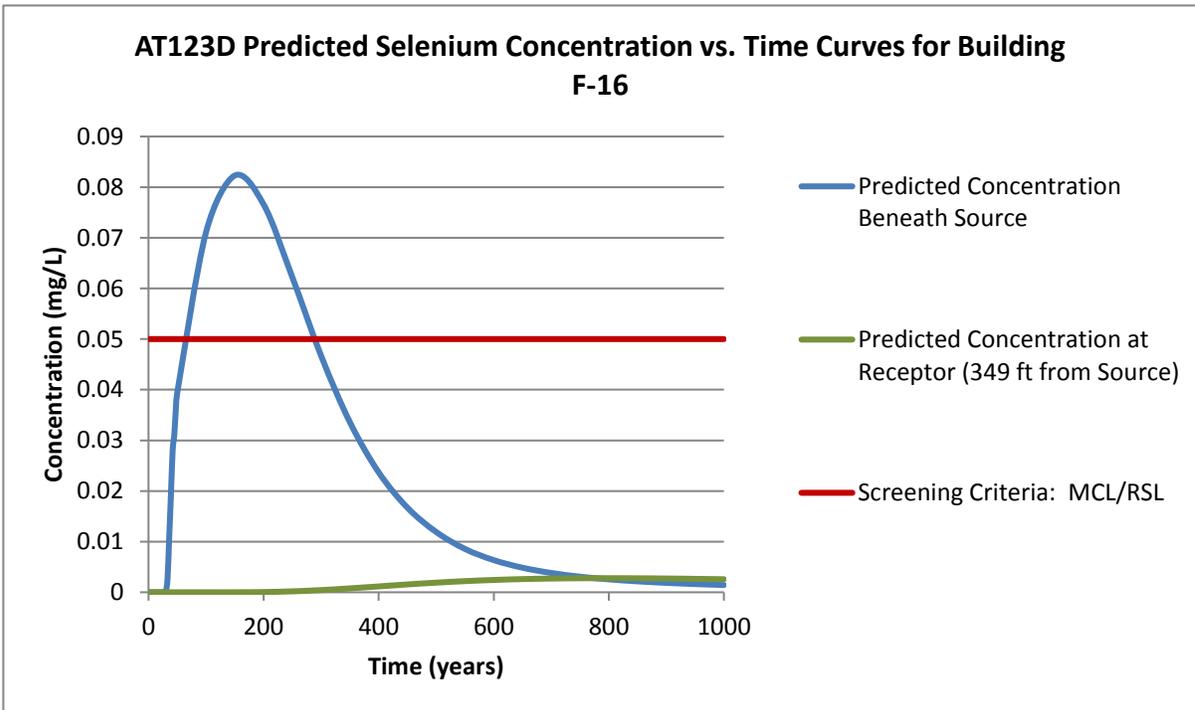


Figure E-8. Predicted Concentration of Selenium in Groundwater based on AT123D Modeling at Building F-16

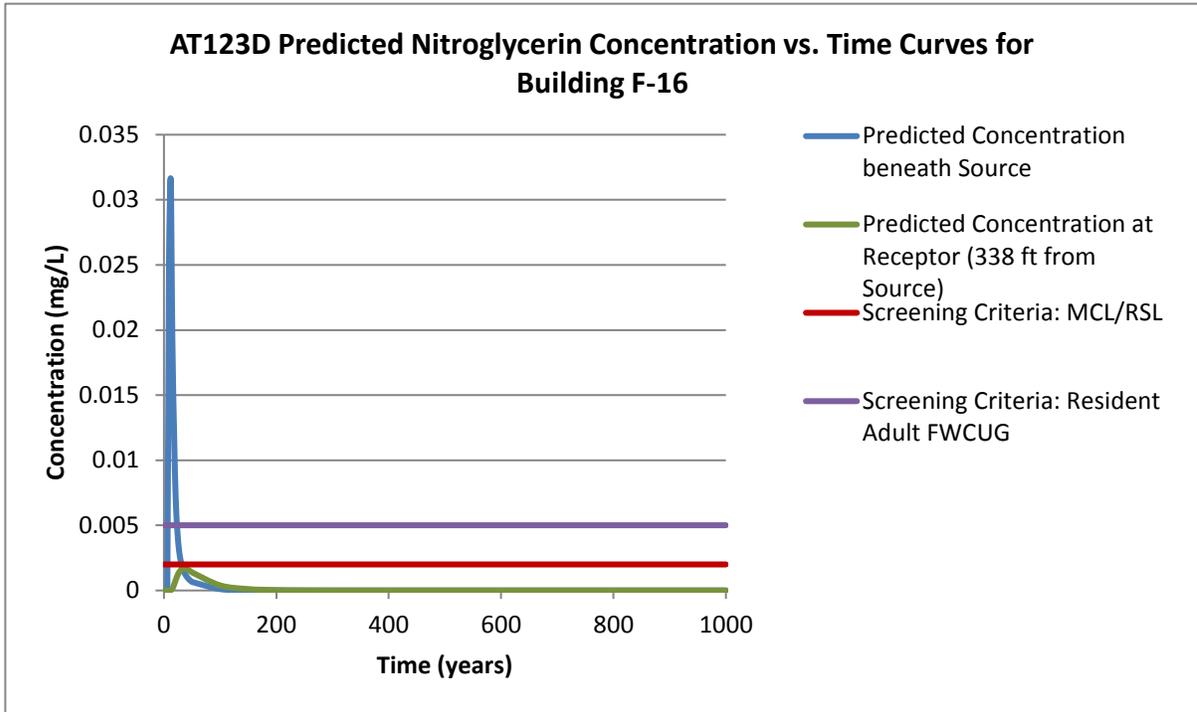


Figure E-9. Predicted Concentration of Nitroglycerin in Groundwater based on AT123D Modeling at Building F-16

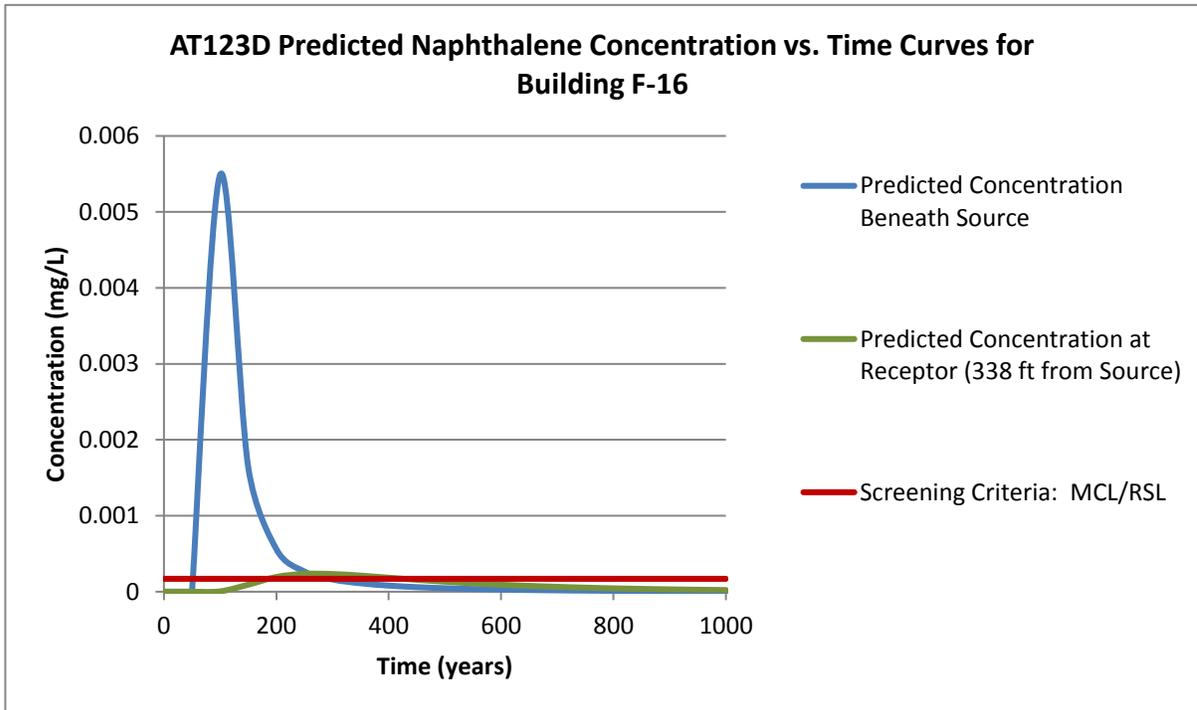


Figure E-10. Predicted Concentration of Naphthalene in Groundwater based on AT123D Modeling at Building F-16

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