APPENDIX G

Fate and Transport Modeling Results

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ACRONYMS AND ABBREVIATIONS

amsl	Above Mean Sea Level
AOC	Area of Concern
AT123D	Analytical Transient 1-, 2-, 3-Dimensional
B2EHP	bis(2-Ethylhexyl)phthalate
bgs	Below Ground Surface
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMCOC	Contaminant Migration Chemical of Concern
CMCOPC	Contaminant Migration Chemical of Potential Concern
COI	Chemical of Interest
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DNB	Dinitrobenzene
DNT	Dinitrotoluene
ERA	Ecological Risk Assessment
f_{oc}	Fraction Organic Carbon
FS	Feasibility Study
FWCUG	Facility-wide Cleanup Goal
GAC	Granular Activated Carbon
GSSL	Generic Soil Screening Level
HELP	Hydrologic Evaluation of Landfill Performance
HHRA	Human Health Risk Assessment
HLC	Henry's Law Constant
HQ	Hazard Quotient
ISM	Incremental Sample Method
K_d	Partitioning Coefficient
K_{oc}	Organic Carbon Partition Coefficient
K_{ow}	Octanol-water Partition Coefficient
MCL	Maximum Containment Level
PBA	Performance-Based Acquisition
PCB	Polychlorinated Biphenyl
R	Retardation Factor
RDX	Hexahydro-1,3,5-Trinitro-1,3,5-Triazine
Redox	Oxidation-Reduction
RI	Remedial Investigation
RSL	Regional Screening Level
RVAAP	Ravenna Army Ammunition Plant
SAP	Sampling and Analysis Plan
SRC	Site-related Contaminant
SSL	Soil Screening Level
SSSL	Site-specific Soil Screening Level
SVOC	Semi-volatile Organic Compound

ACRONYMS AND ABBREVIATIONS (continued)

TNB	Trinitrobenzene
TNT	Trinitrotoluene
TR	Target Risk
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compound
WOE	Weight-of-Evidence

G.0 FATE AND TRANSPORT MODELING RESULTS

Contaminant fate and transport modeling assesses the potential for chemicals of interest (COIs) to leach from surface soil and subsurface soil (defined as soil leaching COIs) at Load Lines 1 through 4 and 12 and impact groundwater beneath the sources and downgradient receptor locations. The analyses also evaluate the potential for site-related contaminants (SRCs) to leach from sediment sources at Load Lines 1 through 4 and impact groundwater beneath the sources and downgradient receptor locations. Modeling results were included in the decision-making process to determine whether performing remedial actions may be necessary to protect groundwater resources. Surface water exposure pathways are evaluated in the human health risk assessment (HHRA) and ecological risk assessment (ERA) presented in the Human Health and Ecological Risk sections of the Feasibility Study (FS) Addendum, respectively. A summary of the principles of contaminant fate and transport are presented in this appendix along with the results of the modeling.

Section G.1 describes physical and chemical properties of the soil leaching COIs for Load Lines 1 through 4 and 12 and the sediment SRCs at the four areas of concern (AOCs) (Load Lines 1 through 4). Section G.2 presents a conceptual model for contaminant fate and transport that considers AOC topography, hydrogeology, contaminant sources, and release mechanisms. Section G.3 presents the soil screening analysis to identify the remaining COIs that have the potential to migrate from the overlying soil to the water table beneath the source. Section G.4 presents the sediment screening analysis to identify sediment contaminant migration chemicals of potential concern (CMCOPCs) with the potential to migrate from sediment to groundwater. Section G.5 describes fate and transport modeling of final COIs/CMCOPCs and presents contaminant migration chemicals of concern (CMCOCs). Section G.6 provides a list of the remaining final COIs/CMCOCs and a qualitative assessment of the results and considerations of the limitations and assumptions. Section G.8 presents a summary and conclusions of the fate and transport analysis.

G.1 PHYSICAL AND CHEMICAL PROPERTIES OF SITE-RELATED CONTAMINANTS

This evaluation of contaminant fate and transport presents not only those chemicals identified as COIs for evaluation of the potential for leaching from soil to groundwater that were identified in the Sampling and Analysis Plan (SAP) Addendum (USACE 2016), but also presents chemicals that were identified as sediment SRCs and are evaluated as part of this FS Addendum. The list of surface and subsurface soil COIs and sediment SRCs are summarized below:

- **Surface and Subsurface Soil Leaching COIs**
    - **Load Line 1:** Seven explosives: 1,3-dinitrobenzene (DNB); 2,4-dinitrotoluene (DNT); 2,6-DNT; nitrobenzene; hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); 1,3,5-trinitrobenzene (TNB); and 2,4,6-trinitrotoluene (TNT).
    - **Load Line 2:** Two explosives: 2,4-DNT and RDX.
    - **Load Line 3:** Three explosives: 2,6-DNT; 2,4,6-TNT; and RDX.
    - **Load Line 4:** One explosive: RDX.

  - **Load Line 12:** Eight explosives: 1,3-DNB; 2,4-DNT; 2,6-DNT; nitrate-nitrite; nitrobenzene; 3-nitrotoluene; 4-nitrotoluene; and RDX.
- **Sediment SRCs**
  - **Load Line 1:** Fourteen inorganic chemicals: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, thallium and vanadium; and five organic chemicals: benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, fluoranthene, and acetone.
  - **Load Line 2:** Fourteen inorganic chemicals: aluminum, antimony, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, vanadium nitrate/nitrite and ammonia; and 29 organic chemicals: TNT; 2,4-DNT; 4-amino-2,6-DNT; nitrocellulose; acenaphthene; acenaphthylene; anthracene; benz(a)anthracene; benzo(a)pyrene; benzo(b)fluoranthene; benzo(g,h,i)perylene; benzo(k)fluoranthene; bis(2-ethylhexyl)phthalate; carbazole; chrysene; di-n-butyl phthalate; dibenz(a,h)anthracene; fluoranthene; fluorine; indeno(1,2,3-cd)pyrene; naphthalene; phenanthrene; pyrene; 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; endrin ketone; and beta-BHC.
  - **Load Line 3:** Ten inorganic chemicals: antimony, beryllium, cadmium, chromium, cobalt, copper, lead, nickel, silver and zinc; and three organic chemicals: TNT; 4-amino-2,6-DNT; and polychlorinated biphenyl (PCB)-1254.
  - **Load Line 4:** Sixteen inorganic chemicals: aluminum, antimony, barium, beryllium, cadmium, chromium, hexavalent chromium, cobalt, copper, lead, mercury, nickel, thallium, vanadium nitrate/nitrite, and ammonia; and five organic chemicals: di-n-butyl-phthalate, PCB-1248, 2-butanone, acetone, and toluene.

Chemicals released into the environment are susceptible to several degradation pathways, including hydrolysis, oxidation-reduction (redox), isomerization, photolysis, photo-oxidation, biotransformation, and biodegradation. Transformed products resulting from these processes may behave differently than their parent chemical in the environment.

The migration of chemicals is governed by their physical and chemical properties and the surface and subsurface media through which chemicals are transferred. In general, chemicals and structures with similar physical and chemical characteristics will show similar patterns of transformation, transport, or attenuation in the environment. Solubility, vapor pressure data, chemical partitioning coefficients, degradation rates, and Henry's Law Constant (HLC) provide information that can be used to evaluate contaminant mobility in the environment. Partitioning coefficients are used to assess relative affinities of chemicals for solution or solid phase adsorption. However, the synergistic effects of multiple migrating chemicals and complexity of soil/water interactions, including pH and redox potential, grain size, and clay mineral variability, are typically unknown.

The physical properties of the chemicals defined as the soil leaching COIs and SRCs in sediment are summarized in Tables G-1 and G-2. These properties are used to assess the anticipated behavior of each chemical under environmental conditions. The physical properties of the chemicals defined as soil leaching COIs and sediment SRCs are summarized in Sections G.1.1 through G.1.5.

G.1.1 Chemical Factors Affecting Fate and Transport

The water solubility of a chemical is a measure of the saturated concentration of the chemical in water at a given temperature and pressure. The tendency for a chemical to be transported by groundwater is directly related to its solubility and inversely related to its tendencies to adsorb to soil and volatilize from water (OGE 1988). Chemicals with high water solubilities tend to desorb from soil, are less likely to volatilize from water, and are susceptible to biodegradation. The water solubility of a chemical varies with temperature, pH, and the presence of other dissolved chemicals (including organic carbon and humic acids).

The octanol-water partition coefficient (K_{ow}) can be used to estimate the tendency for a chemical to partition between environmental phases of different polarity. The K_{ow} is a laboratory-determined ratio of the concentration of a chemical in the n-octanol phase of a two-phase system to the concentration in the water phase. Chemicals with log K_{ow} values less than 1 are highly hydrophilic, while chemicals with log K_{ow} values greater than 4 will partition to soil particles (Lyman et al. 1990).

Vapor pressure is a measure of the pressure at which a chemical and its vapor are in equilibrium. The value can be used to determine the extent to which a chemical would travel in air, as well as the rate of volatilization from soil and solution (OGE 1988). In general, chemicals with vapor pressures lower than 10^{-7} mm mercury will not be present in the atmosphere or air spaces in soil in significant amounts, while chemicals with vapor pressures higher than 10^{-2} mm mercury will exist primarily in the air (Dragun 1988).

The HLC value for a chemical is a measure of the ratio of the chemical's vapor pressure to its aqueous solubility. The HLC value can be used to make general predictions about a chemical's tendency to volatilize from water. Chemicals with HLC values less than 10^{-7} atm-m^3/mol will generally volatilize slowly, while chemicals with an HLC greater than 10^{-3} atm-m^3/mol will volatilize rapidly (Lyman et al. 1990).

G.1.2 Biodegradation

Organic chemicals with differing chemical structures will biodegrade at different rates. Primary biodegradation consists of any biologically induced structural change in an organic chemical. Complete biodegradation is the biologically mediated degradation of an organic chemical into carbon dioxide, water, oxygen, and other metabolic inorganic products (Dragun 1988). The first order biodegradation rate of an organic chemical is proportional to the concentration:

$$-dC/dt = kC \qquad \text{(Equation G-1)}$$

Where:

C = concentration
t = time
k = biodegradation rate constant = ln 2 / $t_{1/2}$
$t_{1/2}$ = biodegradation half-life.

The biodegradation half-life is the time necessary for half of the chemical to degrade. The biodegradation rate of an organic chemical generally depends on the presence and population size of soil microorganisms that are capable of degrading the chemical.

G.1.3 Inorganic Chemicals

Inorganic chemicals detected in soil and sediment samples are associated with the aqueous phase and leachable metal ions on soil particles. The transport of this material from unsaturated soil to the underlying water table is controlled by the physical processes of precipitation percolation, chemical interaction with the soil, and downward transport of metal ions by continued percolation. The chemistry of inorganic chemical interactions with percolating precipitation and varying soil conditions is complex and includes numerous chemical transformations that may result in altered oxidation states, including ion exchange, adsorption, precipitation, or complexation. The chemical reactions, which are affected by environmental conditions (pH, redox conditions, type and amount of organic matter, clay content, and the presence of hydrous oxides), may act to enhance or reduce the mobility and toxicity of metal ions. In general, these reactions are reversible and add to the variability commonly observed in distributions of inorganic chemicals in soil.

The chemical form of an inorganic chemical determines its solubility and mobility in the environment; however, chemical speciation is complex and difficult to delineate in routine laboratory analysis. Inorganic chemicals in soil are commonly found in several forms, including dissolved concentrations in soil pore water, metal ions occupying exchange sites on inorganic soil constituents (i.e., adsorbed to inorganic soil constituents), metal ions associated with insoluble organic matter, precipitated inorganic chemicals as pure or mixed solids, and metal ions present in the structure of primary or secondary minerals.

The dissolved (aqueous) fraction and its equilibrium sorbed fraction are important when considering the migration potential of inorganic chemicals through soil. Of the inorganic chemicals that are likely to form, chlorides, nitrates, and nitrites are commonly the most soluble. Sulfate, carbonate, and hydroxides generally have low to moderate solubility. Soluble chemicals are transported in aqueous forms subject to attenuation, whereas less soluble chemicals remain as a precipitate and limit the overall dissolution of metal ions. The solubility of the metal ions is also regulated by ambient chemical conditions, including pH and redox.

The attenuation of metal ions in the environment can be estimated numerically using the retardation factor (R), dispersion in higher flow systems (high conductivity environments), and diffusion in low conductivity environments. R defines the extent to which the velocity of the contaminant is slowed, which is largely derived from the K_d. R is calculated using the following equation:

$$R = 1 + (K_d \rho_b)/ \theta_w \qquad \text{(Equation G-2)}$$

Where:

ρ_b = the soil bulk dry density (g/cm^3)
θ_w = soil moisture content (dimensionless).

Metal ion concentrations in the environment do not attenuate by natural or biological degradation because of low volatility and solubility of the ions. Inorganic chemicals may be biotransformed or bioconcentrated through microbial activity.

G.1.4 Organic Chemicals

Organic chemicals, such as semi-volatile organic compounds (SVOCs) or volatile organic compounds (VOCs), may be transformed or degraded in the environment by processes including hydrolysis, redox, photolysis, volatilization, biodegradation, or biotransformation. The half-life of organic chemicals in transport media can vary from minutes to years, depending on environmental conditions and chemical structures. Some types of organic chemicals are very stable, and degradation rates can be very slow. Organic degradation may either enhance (by producing more toxic byproducts) or reduce (reducing concentrations) the toxicity of a chemical in the environment.

G.1.5 Explosives-related Chemicals

Several explosive compounds were identified as soil leaching COIs at Load Lines 1 through 4 and 12 and sediment SRCs at Load Lines 1 through 4. Microbiological and photochemical transformation may affect the fate and transport of explosive compounds in the environment. For example, based on the results of culture studies involving the removal of TNT by activated sludge microorganisms, it has been concluded that TNT undergoes biotransformation but not biodegradation (USABRDL 1989). Biotransformation of TNT occurs with the reduction of the nitro groups by microbial reduction, typically under anaerobic conditions. Beneficial bacteria in these reactions include *Pseudomonas, Escherichia, Bacillus, Citrobacter, Enterobacter, Klebseilla, Veillonella,* and *Clostridium* (USACHPPM 2000). It has been found that anaerobic metabolism occurs in two stages (Funk et al. 1993). The first stage is the reductive stage in which TNT is reduced to its amino derivatives. In the second stage, degradation to non-aromatic products begins after the reduction of the third nitro group.

The biotransformation rate of TNT has been found to be rapid at most sites (ERDC 2007) and may be increased with the presence of carbon (USACHPPM 2000). Fungi and photolysis also can biotransform TNT. The predominant transformation products 1,3,5-TNB; 4,6-dinitroanthranil; 2,4,6-trinitrobezadehyde; and 2,4,6-trinitrobenzonitrite are due to photolysis of TNT (USACHPPM 2000). The biotransformation pathway for TNT is shown in Figure G-1 (Kaplan and Kaplan 1982).

The biotransformation of 2,4-DNT has been systematically studied in laboratory cell cultures. The biotransformation pathway for 2,4-DNT is shown in Figure G-2 (McCormick et al. 1978). The reduction products include the amino and azoxy derivatives as observed with TNT biotransformation. The biotransformation of 2,6-DNT has been systematically studied in laboratory cell cultures. The biotransformation pathway for 2,6-DNT is shown in Figure G-3 (Singh et al. 2015). The reduction products include the amino and azoxy derivatives as observed with TNT biotransformation. As with TNT and DNT, the principal mode of microbial transformation of the nitroaromatic chemicals TNB and 1,3-DNB is reduction of nitro groups to form amino groups. TNB is a photolytic product of TNT but will not undergo further photolysis. TNB will also resist hydrolysis. TNB primarily breaks down through microbial degradation (USACHPPM 2001).

Nitrocellulose is an aliphatic nitrate ester that will gelatinize with nitroglycerin when mixed together. Nitrocellulose occurs as a fibrous solid that can act as a sorbent that will dissolve in water under highly basic conditions with high temperatures. Nitrocellulose can undergo denitrification as a degradation pathway. Degradation of nitrocellulose to non-reactive nitrocellulose has been observed under methanogenic and fungus-mediated reducing conditions (USACE 2006). Although nitrotoluenes are much more resistant to biodegradation, 4-nitrotoluene can serve as a growth substrate for bacteria and is a good candidate for bioremediation. 4-Nitrotoluene can be converted to 2-amino-4-methylphenol (6-amino-*m*-cresol) via 4-hydroxylaminotoluene in reactions catalyzed by a nitroreductase and an aminohydroxymutase (Spiess et al. 1988).

Limited information exists regarding biotransformation or biodegradation of RDX. RDX has a natural degradation rate, typically in the range of months, but may take years in more arid environments (ERDC 2007). One pilot study evaluated the treatment of pink water waste using an anaerobic fluidized-bed granular activated carbon (GAC) bioreactor (USACE 2004a). The study indicated RDX biodegrades in the presence of ethanol. Such data may be useful for evaluating potential use of enhanced bioremediation as a remedial option. Figure G-4 shows the biotransformation pathway for RDX (McCormick et al. 1981). A conservative biodegradation rate of 5.00E-04 per day was used for RDX (ANRCP 1999).

G.2 CONCEPTUAL MODEL FOR FATE AND TRANSPORT

The conceptual site model (CSM), which defines the framework for fate and transport modeling, describes conditions at the AOCs, including the contaminant sources, surficial and subsurface hydrogeologic conditions, contaminant migration and pathways, and contaminant release mechanisms.

The AOC conditions described in Sections 2.0 through 5.0 in the previous RI/FS documents (USACE 2003, 2004b, 2004c, 2004d, 2005) include contaminant source information, the surrounding geologic and hydrologic conditions, and the magnitude of SRCs and their current spatial distribution. The CSM for each AOC is based on information and data collected for historical investigations, the RI/FS reports, and informed assumptions about the AOCs. The better the information and the greater the accuracy of the assumptions, the more accurately the CSM describes the AOC, and therefore, the more reliable the fate and transport modeling predictions can be. A summary of the salient elements of the CSM that apply to fate and transport modeling for each AOC, obtained from the previous RI/FS reports, are presented in the following sections.

G.2.1 Contaminant Sources

No primary contaminant sources are located on any the five AOCs. Secondary sources (contaminated media including sediment) identified in previous investigations are further evaluated in this report.

G.2.2 Hydrogeology

A description of regional and AOC-specific geology and hydrology are provided in the RI/FS Addendum for each AOC, and are summarized below.

G.2.2.1 Load Line 1

- Topography at Load Line 1 is moderately subdued, with elevations ranging from 297.2 to 309.6 m (975 to 1,016 ft) above mean sea level (amsl) in the production area. The topography is the result of the reworking of the original glaciated bedrock surface to accommodate the buildings and other infrastructure of Load Line 1.
- Soil cover is thin to non-existent at many locations inside the main production area at Load Line 1, except where non-native material was brought in during construction of Ravenna Army Ammunition Plant (RVAAP) or was redistributed during the demolition of buildings at the load line. Bedrock is exposed at locations throughout the production area. Consequently, contaminant leaching pathways from soil to bedrock are short or non-existent in many areas. Surface soils contain contaminants in the highest concentrations at the melt-pour buildings (Buildings CB-4 and CB-4A), Building CB-10, the former settling tanks, and near Building CA-6.
- Groundwater is present in the sandy interbeds found in glacial materials that occur south of the load line proper, at depths from about 4.26 to 4.57 m (14 to 15 ft) below ground surface (bgs). This glacial material exceeds 10.6 m (35 ft) in thickness in some locations. The water-bearing sand units may be laterally discontinuous. Groundwater in the production area of Load Line 1 occurs in the highly porous, permeable, and fractured Sharon Sandstone. Groundwater is presumed to flow generally from the west to the east across the load line, based on the site’s topography and potentiometric surface data from the 10 monitoring wells installed within the production area. Northwesterly and southeasterly flow components exist related to a potentiometric high in the central portion of the load line. The water-bearing sandstone behaves as an unconfined system.
- Surface water flow influences surface contaminant distribution and mobility at Load Line 1. Surface water from precipitation collects in storm water catch basins and unlined ditches throughout the production area. Such runoff is discharged through two exit pathways: (1) Outlets A& B, Outlet C and Charlie’s Pond, and Outlets D/E/F and Criggy’s Pond, which all drain into the unnamed tributary that exits the plant at State Route 534 northeast of the AOC; and (2) the North Area Channel that flows into Sand Creek.
- The extensive system of storm and sanitary sewers in the subsurface represents a possible preferred migration pathway for water-borne contaminants. All of these conduits are situated in trenches cut into sandstone bedrock. Leaks from the sewer pipes may have rapidly introduced contaminants from the surface soil source areas to groundwater.

G.2.2.2 Load Line 2

- Elevations across the AOC vary from approximately 301 to 307 m (990 to 1,010 ft) amsl. In general, land slopes from the center of the load line in all directions. However, the slope increases to the south of the AOC, in the direction of Kelly’s Pond. Along the axis of the AOC, slope is from the north to the south toward the pond.

- Soil cover thickness varies over Load Line 2. Hiram till and till-derived soil range from 0 to 5.49 m (0 to 18 ft) thick with an average thickness of about 1.9 m (6.3 ft) within the load line.
- Groundwater is present in the Sharon Member below the till cover. A groundwater high exists in the center of the AOC. The divide results in localized radial flow in the central portion of the AOC. A groundwater divide is inferred in the western portion of the facility. Based on available data, potential groundwater flow off of the AOC appears to occur to the north in the northern portion of the AOC and to the south in the southern portion of the AOC. A preferential path of groundwater flow is from the north to the south toward Kelly’s Pond.
- Contaminant concentrations are highest within a discrete zone (0- to 0.3-m [0- to 1-ft] surface soil interval). Contaminant leaching pathways from soil to the water table are through heterogeneous silt and clay-rich till and the sandstone with shale member. The depth to water varies from about 1 to 6 m (4 to 19 ft) bgs with an average of approximately 3 m (10 ft) bgs.

G.2.2.3 <u>Load Line 3</u>

- Elevations across the AOC vary from approximately 299 to 311 m (980 to 1,020 ft) amsl. In general, land slopes from the east to the west and north toward Cobbs Pond and the stream entering the Cobbs Pond. Along the axis of the AOC, slope is to the west and north toward Cobbs Pond.
- Soil cover thickness varies over Load Line 3. Glacial till and till-derived soil range from 1.1 to 4.6 m (3.5 to 15 ft) thick with an average thickness of about 2.1 m (7 ft) within the load line.
- Groundwater is present in the Sharon Member below the till cover. A groundwater low exists in the southern portion of the explosive handling area with flow directed to the northwest toward the stream entering the Cobbs Pond complex consistent with regional drainage patterns. Based on available data, potential groundwater flow off of the AOC appears to occur in the west and northwest directions.
- Contaminant concentrations are highest within a discrete zone (0- to 0.3-m [0- to 1-ft] surface soil interval). Contaminant leaching pathways from soil to the water table are through heterogeneous silt and clay-rich till and the sandstone with shale member. The depth to water varies from about 3 to 8 m (10 to 28 ft) bgs with an average of approximately 7 m (22 ft) bgs.

G.2.2.4 <u>Load Line 4</u>

- Elevations across the AOC vary from approximately 299 to 305 m (980 to 1,000 ft) amsl. In general, the land surface slopes from the north to the south toward the settling pond and exit drainage from the settling pond.
- Soil cover composition varies across Load Line 4; silty sand, silty clay, sand, and clay layers of varying thickness were encountered. Bedrock was not encountered in any of the borings drilled during the Phase II RI; the deepest boring was drilled to depth of approximately 6.7 m (22 ft).

- The groundwater table occurs within the unconsolidated zone. A groundwater low exists in the northeastern portion of the Explosives Handling Area Aggregate. Groundwater flow is southerly, consistent with regional drainage patterns, toward the main stream and settling pond, which are presumed to represent groundwater base flow discharge points. The maximum depth to the groundwater table, within the potentiometric low area, is approximately 4 m (13 ft) bgs. Based on available data, potential groundwater flow off of the AOC appears to occur to the south.
- Contaminant concentrations are highest within a discrete zone (0- to 0.3-m [0- to 1-ft] surface soil interval). Contaminant leaching pathways from soil to the water table are through the soil cover.

G.2.2.5 <u>Load Line 12</u>

- Elevations across the AOC vary from approximately 296 to 301 m (987 to 970 ft) amsl. In general, land slopes from slightly elevated areas east and southwest of the AOC toward the main process area from either side. Along the axis of the AOC, slope is to the north toward Cobbs Pond. A low, marshy area is present on the western portion of the AOC, adjacent to Buildings 904, 905, and 906.
- Soil cover is deep inside the main production area at Load Line 12. Glacial till and till-derived soil range from 5.5 to 12.2 m (18 to 40 ft) thick. Contaminant leaching pathways from soil to the water table are through heterogeneous silt and clay-rich soil with the depth to water varying from 1.2 to 4.0 m (4 to 13 ft). Surface soil contains contaminants in the highest concentrations at footprints of the buildings that have been razed and the Team Track Area.
- Groundwater is present in the deep glacial deposits that cover the area. A groundwater low exists in the central portion of the former process area with flow directed to the northeast toward the Cobbs Pond complex consistent with regional drainage patterns. A groundwater flow divide exists in the northern quadrant of the main process area and another exists in the southeastern portion of the AOC. Steeper gradients are observed near the northern divide and at the southern AOC boundary. Based on available data, potential groundwater flow off of the AOC to the south appears to occur only in the southeastern portion of the AOC.
- Surface water drains from south to north across Load Line 12. The primary surface water conveyance across the AOC enters the site from the east through a culvert that conveys drainage from the Atlas scrapyard. This conveyance, termed the Active Area Channel, traverses Load Line 12 from west to east, flows immediately south of Building 904, and intersects the primary north-south drainage ditch between Buildings 900 and 901. The primary north-south drainage feature (Main Ditch) initiates near Building FF-19 and flows north until intersecting with the Active Area Channel. From that point, flow continues north until exiting the AOC. North of Load Line 12, surface water flows into the Upper Cobbs Pond complex.

G.2.3 Contaminant Release Mechanisms and Migration Pathways

Based on the information presented above, the following contaminant release mechanisms and migration pathways have been identified at these AOCs:

- Contaminants leaching from soil to the water table (vertical migration) and lateral transport to downgradient receptors (i.e., unnamed tributary to Sand Creek and unnamed tributary to the Mahoning River),
- Contaminated sediment transported to potential downstream receptors,
- Contaminated surface water migrating to potential downstream receptors, and
- Contaminated sediment within drainage ditches and shallow conveyances as a secondary source of leaching to the water table (vertical migration) and lateral transport to potential downgradient receptors.

The first of these pathways, which considers a primary groundwater transport pathway, is treated explicitly in this fate and transport section. Sediment and surface water exposure pathways are evaluated in the HHRA and ERA. The fourth pathway listed above, which considers a secondary groundwater transport pathway, is evaluated for Load Lines 1 through 4 using the sediment screening analysis presented in Section G.4. For Load Line 12, surface water and sediment are currently being evaluated under another contract; therefore, this pathway is not being evaluated.

One of the principal migration pathways at these AOCs is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). However, because of the very heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within the unconsolidated soil are difficult to predict. Precipitation that does not leave the AOCs as surface runoff percolates into the subsurface. Some of the percolating water leaves this environment via evapotranspiration after little or no vertical migration. The remainder of the water percolates into the water table. As discussed in Section G.2.4, the rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Figure G-5 illustrates a general contaminant migration conceptual model.

Once the contaminant leachate percolates through the soil and reaches the water table, it migrates with the local groundwater and discharges at the downgradient receptors. Groundwater flow likely occurs along preferential pathways (e.g., sand seams, channel deposits, or other stratigraphic discontinuities) having higher permeabilities. For inorganic chemicals, lateral migration through groundwater will be very limited due to their high retardation by the bedrock material (USACE 2003, 2004b, 2004c, 2004d, 2005).

Additional factors that affect the leaching rate include a chemical’s solubility, sorption capacity (expressed by the K_d), and the amount of percolation. Insoluble chemicals will precipitate out of the solution in the subsurface or remain in insoluble forms with little leaching.

Another factor that affects whether a chemical will reach the water table through percolation of precipitation is the chemical’s rate of decay. Most organic compounds decay at characteristic rates proportional to the chemical’s half-life. For a given percolation rate, those chemicals with long half-lives have a greater potential for contaminating groundwater than those with shorter half-lives. For this analysis, the rate of decay/half-life was not considered in order to perform a conservative analysis.

Contaminant releases through gaseous emissions and airborne particulates are not significant at these AOcs. The AOCs are vegetated, located in a humid temperate climate, and soil moisture is typically high, which prevents dust borne contaminant migration. Therefore, there is likely little to no gaseous emission, and contaminant levels in the air pathway are minor to non-existent.

G.2.4 Water Budget

The potential for contaminant transport begins with precipitation. Percolation is the driving mechanism for soil contaminants leaching to groundwater. The actual amount of rainwater available for flow and percolation to groundwater is highly variable and depends upon soil type and climatic conditions. A water balance calculation can be used as a tool to quantitatively account for all components of the hydrologic cycle. The quantified elements of the water balance are used for inputs to the soil leaching and groundwater transport models discussed later. The components of a simple steady-state water balance model include precipitation, evapotranspiration, surface runoff, and groundwater recharge or percolation.

These terms are defined as follows:

$$P = ET + Sr + q \qquad \text{(Equation G-3)}$$

or

$$\text{Rainwater available for flow} = Sr + q = P - ET \qquad \text{(Equation G-4)}$$

Where:

P = precipitation
Sr = surface runoff
ET = evapotranspiration
q = groundwater recharge or percolation.

It is expected that loss of runoff also occurs in the form of evaporation. The remaining water, after runoff and evaporation, is available for percolation, which includes loss to the atmosphere by evapotranspiration. The water balance estimations were developed using the Hydrologic Evaluation of Landfill Performance (HELP) model (USEPA 1994). See Table G-3 for parameters used in the HELP model to develop the water budget estimates used in the evaluation. Calculations using precipitation and temperature data for a 100-year period were generated synthetically using coefficients for Cleveland, Ohio (e.g., the nearest weather station to Camp Ravenna with HELP model coefficients).

The annual average water balance estimates indicate an evapotranspiration of 28% (10.3 inches) of total precipitation (37 inches). The remaining 72% (26.7 inches) of rainwater is available for surface water runoff and percolation to groundwater. Of the 72% (27 inches) of water available for runoff or percolation, groundwater recharge (percolation) accounts for 13% (3.6 inches), and surface runoff (along downgradient topography to nearest surface water bodies) accounts for the remaining 87% (23.1 inches).

G.3 SOIL SCREENING ANALYSIS

Soil screening analyses are screening evaluations performed to identify COIs with the potential to leach to groundwater as CMCOPCs. This section describes the soil screening analysis approach and presents the limitations and assumptions.

G.3.1 Analysis Approach

The five steps for the soil leachability analysis are illustrated in Figure G-6 and described below.

The first step of the soil screening analysis is developing SRCs, as presented in Section 4.0. A summary of SRCs identified for soil and sediment is presented in Section G.1.

The second step of the soil screening process (Figure G-6) involves comparing the maximum concentrations of the SRCs with maximum contaminant level (MCL)-based generic soil screening levels (GSSLs). GSSLs were developed for Superfund sites for contaminant migration to groundwater (USEPA 1996, 2015). The GSSL is defined as the concentration of a chemical in soil that represents a level of contamination below which there is no concern for impacts to groundwater under CERCLA, provided conditions associated with the U.S. Environmental Protection Agency (USEPA) risk-based soil screening levels (SSLs) are met. Generally, if chemical concentrations in soil fall below the GSSL, and there are no groundwater receptors of concern or anticipated exposures, then no further study or action is warranted for that chemical. If the GSSL for a chemical is not available, the USEPA risk-based SSL for groundwater migration, dated May 2016 (USEPA 2016), will be obtained from the USEPA regional screening level (RSL) website and used. If neither the GSSL nor the USEPA risk-based SSL for a chemical is available, then no further evaluation of the chemical is performed and it is eliminated from the list of the initial CMCOPCs. However, some chemicals have been assigned surrogates by risk assessors if the chemical without an SSL is similar to another chemical with an SSL.

The third step of the soil screening process (Figure G-6) involves comparing the maximum chemical concentrations with the site-specific soil screening levels (SSSLs). The SSSL is defined as the GSSL (or the USEPA risk-based SSL for groundwater protection if a GSSL is not available) multiplied by the AOC-specific dilution attenuation factor (DAF). Direct partitioning is used to derive the GSSLs, assuming groundwater is in contact with the chemicals in soil and the groundwater concentration is equal to the leachate concentration. However, as leachate moves through soil, chemical concentrations are attenuated by adsorption and degradation. When the leachate reaches the water table, dilution by groundwater further reduces leachate concentrations. This concentration reduction can be expressed by a DAF. DAFs can vary based on AOC-specific characteristics (e.g., hydrogeologic properties, contaminated source area, and depth to contamination). As described in the *Soil Screening Guidance: Technical Background Document* (USEPA 1996), chemical dilution in groundwater is estimated at each AOC from an AOC-specific DAF. The DAF, which is defined as the ratio of soil leachate concentration to receptor point concentration, is minimally equal to 1. Dilution in groundwater is derived from a simple mixing zone equation (Equation G-5) and relies upon estimating the mixing zone depth (Equation G-6).

$$\mathrm{DAF} = 1 + \frac{(\mathrm{K} \times i \times \mathrm{d})}{(\mathrm{q} \times \mathrm{L})} \qquad \text{(Equation G-5)}$$

Where:

DAF = dilution attenuation factor
K = aquifer hydraulic conductivity (m/yr)
i = horizontal hydraulic gradient (m/m)
q = percolation rate (m/yr)
L = source length parallel to groundwater flow (m)
d = mixing zone depth (m) (which is defined below).

and

$$\mathrm{d} = \sqrt{0.0112 \times \mathrm{L}^2} + \mathrm{d_a} \times \left[1 - \exp\left(\frac{-\mathrm{L} \times \mathrm{I}}{\mathrm{K} \times i \times \mathrm{d_a}}\right)\right] \qquad \text{(Equation G-6)}$$

Where:

d_a = aquifer thickness (m)
$d \leq d_a$.

As stated above, if the aquifer thickness is less than the calculated mixing zone depth, then the aquifer thickness is used for “d” in the DAF calculation. The DAF calculation for the AOC is presented in Table G-4. It should be noted that the purpose of this screen is not to identify the chemicals that may pose risk at downgradient locations, but to target those chemicals that pose the greatest problem if they migrate from the AOC.

The fourth step of the soil screening process (Figure G-6) involves eliminating initial CMCOPCs identified in the SSSL evaluation that require more than 1,000 years to leach through the unsaturated zone before reaching the water table from further consideration. A period of 1,000 years was conservatively selected to evaluate eventual migration of the contaminant front to the water table despite uncertainties in vadose zone hydraulic parameters and groundwater recharge over time. Additionally, USACE suggests a screening value of 1,000 years be used due to the high uncertainty associated with predicting conditions beyond that time frame (USACE 2003b). Therefore, the initial CMCOPCs at the selected sources were screened against a travel time of greater than 1,000 years. The travel time in this screen is the time required for a CMCOPC to migrate vertically from the base of the soil interval detected above the background concentration to the water table. This distance is the leaching zone (see Table G-5), which may vary across the AOC based on the varying depths of soil sample concentrations above the facility-wide background concentrations and the elevation of the water table. The estimated travel time for each initial CMCOPC to reach the water table is determined using the following equations:

$$T = \frac{Lz \times R}{V_p} \qquad \text{(Equation G-7)}$$

Where:

T = leachate travel time (year)
Lz = thickness of attenuation zone (ft)
R = retardation factor (dimensionless) (Equation G-2)
V_p = porewater velocity (ft/year).

and

$$V_p = \frac{q}{\theta_w} \quad \text{(Equation G-8)}$$

Where:

q = percolation rate (ft/year)
θ_w = fraction of total porosity that is filled by water.

If the travel time for a chemical from a source area exceeded 1,000 years, then the chemical was eliminated from the list of initial CMCOPCs.

It should be noted here that in this evaluation of the COIs, only the fourth step of the screening analysis was performed to identify the COIs that have the potential to migrate to the water table within 1,000 years as the first three steps of the screenings had already been used to identify the COIs. Only the COIs with travel times less than 1,000 years were retained for further evaluation. Based on this screening, the COIs retained for further evaluations are:

- **Load Line 1:** Nitrobenzene and RDX.
- **Load Line 2:** 2,4-DNT and RDX.
- **Load Line 3:** 2,6-DNT and RDX.
- **Load Line 4:** RDX.
- **Load Line 12:** 1,3-DNB; 2,4-DNT; 2,6-DNT; 3-nitrotoluene; 4-nitrotoluene; nitrobenzene; and RDX.

The constituents were further evaluated using fate and transport models provided in Section G.5.

G.3.2 Limitations and Assumptions of Soil Screening Analysis

It is important to recognize that acceptable soil concentrations for individual chemicals are highly AOC-specific. The GSSLs used in the screening are based on a number of default assumptions chosen to be protective of human health for most AOC conditions (USEPA 1996). These GSSLs are expected to be more conservative than SSSLs based on AOC conditions. The conservative assumptions included in this analysis are: (1) no adsorption in the unsaturated zone or in the aquifer, (2) no biological or chemical degradation in the soil or aquifer, and (3) contamination is uniformly distributed throughout the source. However, the GSSL does not incorporate the existence of contamination already present within the aquifer.

G.4 SEDIMENT SCREENING ANALYSIS

Sediment SRCs are presented in Section G.1. The purpose of this screening analysis is to identify CMCOPCs based on contaminant migration from the sediment to groundwater. Any identified CMCOPCs are modeled with Analytical Transient 1-, 2-, 3-Dimensional (AT123D) to a downgradient receptor if present. The four steps for the sediment screening analysis are illustrated in Figure G-7.

Sediment SRCs were screened by developing leachate concentrations assuming equilibrium between sediment and groundwater. The predicted leachate concentrations were diluted based on a sample-specific DAF calculated by dividing the calculated leachate concentrations by the co-located surface water concentrations. The DAF was calculated for each chemical that was detected in the sediment and surface water at the same sample location. The calculated DAF was then used to calculate the maximum groundwater concentration, considering dilution for sediment SRCs and assuming that the sediment is in direct contact with groundwater. The lowest DAF calculated for the sample area was used for sediment SRCs that did not have a sample-specific DAF. The DAFs calculated for each chemical are shown in Tables G-6 through G-9 for Load Lines 1 through 4, respectively.

This sediment screening analysis assumed that the sediment concentration and the recharging groundwater concentration were in equilibrium and a sample-specific DAF for each chemical was used for dilution in the aquifer. Based on this screening analysis, following chemicals were identified as the initial sediment CMCOPCs:

- **Load Line 1:** Eight inorganic chemicals (antimony, cadmium, chromium, cobalt, copper, lead, selenium, and thallium).
- **Load Line 2:** Four inorganic chemicals (antimony, cadmium, cobalt, and silver), and eight organic chemicals (2,4-DNT; benz[a]anthracene; benzo[a]pyrene; benzo[b]fluoranthene; dibenz[a,h]anthracene; indeno[1,2,3-cd]pyrene; naphthalene; and beta-BHC).
- **Load Line 3:** Two inorganic chemicals (antimony and cobalt).
- **Load Line 4:** Four inorganic chemicals (antimony, hexavalent chromium, cobalt, and thallium), and eight organic chemicals (2,4-DNT; benz[a]anthracene; benzo[a]pyrene; benzo[b]fluoranthene; dibenz[a,h]anthracene; indeno[1,2,3-cd]pyrene; naphthalene; and beta-BHC).

These initial sediment CMCOPCs were further evaluated by comparing their maximum detected surface water concentrations against their respective MCL/RSLs. This analysis assumes that groundwater beneath the sediment and surface water is in contact and in equilibrium. An initial sediment CMCOPC was eliminated if the detected concentration in surface water was below its MCL/RSL (Table G-10) because there is no evidence that the initial sediment CMCOPC is contributing to groundwater/surface water that is in equilibrium. Based on this evaluation, all of the initial sediment CMCOPCs from Load Line 1 were eliminated from further evaluation, and only antimony from Load Line 2, cobalt from Load Line 3, and hexavalent chromium from Load Line 4 were identified as the final sediment CMCOPCs (Table G-10) and were further evaluated with AT123D modeling. However, if the groundwater receptor location (i.e., entering the surface water body) for a sediment CMCOPC was just beneath the sediment sample location, then the sediment CMCOPC was evaluated in the weight-of-evidence (WOE) discussion to identify the sediment CMCOC.

G.5 FATE AND TRANSPORT MODELING

Contaminant fate and transport modeling represents the fifth step in the fate and transport screening and evaluation process (Figure G-6). SESOIL modeling was performed for the remaining soil leaching COIs from the soil screening analysis presented in Section G.3. SESOIL modeling was performed to predict chemical concentrations in the leachate immediately beneath the selected source areas and just above the water table. If the predicted maximum leachate concentration of an initial CMCOPC was higher than the facility-wide background concentration and the lowest risk-based screening value (Resident Receptor Adult facility-wide cleanup goal [FWCUG], MCL, or RSL), the CMCOPC was further evaluated using the AT123D model to predict future maximum concentrations in groundwater beneath the source, as well as at downgradient receptor locations, if applicable. The downgradient receptor location (if required) is the closest surface water body feature downgradient from the source areas that is connected to the groundwater. The predicted concentrations from CMCOPCs in groundwater beneath the source were compared to available groundwater monitoring results for the AOC to validate modeling results and provide WOE for identifying or eliminating CMCOCs.

G.5.1 Modeling Approach

Contaminant transport includes the movement of water and dissolved material from the source areas to groundwater. This occurs as rainwater infiltrates the surface and percolates through the area of contamination, its surrounding soil, and into the saturated zone. The downward movement of water, driven by gravitational potential, capillary pressure, and other components of total fluid potential, mobilizes the contaminants and carries them through the soil into the mixing zone with the water table. Lateral transport within the shallow bedrock is controlled by the groundwater gradient. Vertical transport (evaluated with the SESOIL model) through the overburden to the water table and horizontal transport (evaluated with the AT123D model) through the shallow bedrock to downgradient receptor locations are illustrated in Figure G-5.

The output of the contaminant fate and transport modeling is presented as the expected maximum concentration of modeled contaminants at the selected receptor locations. For SESOIL, the receptor location is the groundwater table beneath the source area. A separate SESOIL analysis was performed for the remaining COIs presented in Section G.3.

The predicted maximum leachate concentration just above the water table, observed in the SESOIL results, was compared against its applicable RVAAP facility-wide background concentration, as well as RVAAP FWCUGs for the Resident Receptor Adult, MCLs, and RSLs. If the predicted maximum leachate concentration of an initial CMCOPC was higher than the facility-wide background concentration and the lowest risk-based screening value (Resident Receptor Adult FWCUG, MCL, or RSL), the CMCOPC was further evaluated using the AT123D model to predict future maximum concentrations in groundwater beneath the source, as well as at downgradient receptor locations, if applicable. If the predicted maximum leachate concentration of a COI was lower than the screening criteria, the chemical was eliminated from further evaluation using AT123D modeling.

For the remaining COIs, maximum concentrations predicted by AT123D in groundwater directly below the source areas and at the downgradient receptor locations were compared to the applicable RVAAP facility-wide background concentrations, as well as RVAAP FWCUGs for the Resident Receptor Adult, MCLs, and RSLs. If the predicted maximum concentration of a CMCOPC is higher than its facility-wide background concentration, and the lowest risk-based screening value (i.e., Resident Receptor Adult FWCUG, MCL, or RSL), the chemical was retained as a CMCOC. If the predicted maximum concentration of a COI in groundwater directly below the source areas and at the downgradient receptor location was lower than the screening criteria, the chemical was not considered a CMCOC.

CMCOCs identified by modeling results were evaluated with respect to WOE for retaining or eliminating CMCOCs from further consideration as a basis for potential soil or sediment remedial actions. Lines of evidence include validating modeling results using available AOC-specific groundwater monitoring data. Modeled timelines for potential leaching and lateral transport were evaluated with respect to estimated times for contaminant releases during RVAAP operations to determine if peak leaching concentrations would likely have occurred in the past. Some CMCOCs present at or below RVAAP soil or sediment background concentrations may have predicted leachate or groundwater concentrations exceeding risk-based criteria due to conservative model assumptions; therefore, these were also identified and considered in the evaluation. Additionally, identified CMCOCs were compared to COCs identified in the HHRA to determine if they had an associated risk related to direct exposure to soil or sediment or if CMCOCs and COCs were co-located and may be addressed simultaneously under a potential remedial action.

G.5.2 Model Applications

The SESOIL model (GSC 1998) used for leachate modeling, when applicable, estimates pollutant concentrations in the soil profile following introduction via direct application and/or interaction with transport media. The AT123D model (DOE 1992) is an analytical groundwater pollutant fate and transport model. It computes the spatial-temporal concentration distribution of waste in the aquifer system and predicts the transient spread of a contaminant plume through a groundwater aquifer. The application of both of these models is discussed in the following subsections.

G.5.2.1 SESOIL Modeling

The SESOIL model defines the soil column as compartments extending from the ground surface through the unsaturated zone and to the upper level of the saturated soil zone or top of bedrock. Processes simulated in SESOIL are categorized in three cycles: hydrologic, sedimentation, and pollutant. Each cycle is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, percolation, soil-water content, evapotranspiration, and groundwater recharge. The sediment washload cycle includes erosion and sediment transport.

The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A chemical in SESOIL can partition in up to four phases (liquid, adsorbed, air, and pure). Data requirements for SESOIL are not extensive and utilize a minimum of AOC-specific soil and chemical parameters and monthly or seasonal meteorological values as input.

The SESOIL model output includes pollutant concentrations at various soil depths and pollutant loss from the unsaturated soil zone in terms of surface runoff, percolation to groundwater, volatilization, and degradation. The mathematical representations in SESOIL generally consider the rate at which the modeled processes occur, the interaction of different processes with each other, and the initial conditions of the waste area and surrounding subsurface matrix material.

The input data for SESOIL can be grouped into four types: climatic, chemical, soil, and application data. Sixty-one separate parameters are contained in these four data groups. Wherever possible, AOC-specific parameter values were used for modeling. However, certain parameters were not available for the source areas and were estimated based on pertinent scientific literature, geochemical investigations, and checks for consistency between model results and historical data. Conservative estimates were used when a range of values existed or parameter values were not available.

G.5.2.2 Climate Data

The climatic data file of SESOIL consists of an array of mean monthly temperature, mean monthly cloud cover fraction, average monthly relative humidity, average monthly reflectivity of the earth’s surface (i.e., shortwave albedo), average daily evapotranspiration, monthly precipitation, mean number of storm events per month, mean duration of rainfall, and mean length of rainy season. The climatic data are presented in Table G-11. The data set was taken from the Youngstown National Weather Service Office weather station at the Youngstown-Warren Regional Airport in Vienna, Ohio, as it was determined to be most appropriate in corresponding to the latitude and longitude at Camp Ravenna.

Climate data from the Youngstown weather station did not have all of the necessary climatic parameters for the HELP model simulation. Accordingly, the water balance evaluation presented in Section G.2.4 was based on the nearest available weather station data with all necessary coefficients stored within the HELP model (Cleveland, Ohio). Inputs for the SESOIL model (Youngstown station) and HELP model (Cleveland station) produced virtually the same recharge rate (9.40 cm/yr for Cleveland and 9.42 cm/yr for Youngstown) for each location. Therefore, the use of the two different weather station data sets did not impact modeling results.

G.5.2.3 Chemical Data

The pollutant fate cycle of SESOIL focuses on various chemical transport and transformation processes that may occur in the soil zone. These processes include volatilization/diffusion, adsorption/desorption, cation exchange, biodegradation and hydrolysis, and metal complexation. The chemical-specific parameters used for SESOIL are presented in Tables G-1 and G-2. The K_d values for inorganic chemicals and the K_{oc} values or organic chemicals were obtained from the chemical-specific parameter table associated with the USEPA Risk Based Generic Screening Tables (USEPA 2015). The K_d values for organic chemicals were estimated from organic, carbon-based K_{oc} using the relationship $K_d = (f_{oc})(K_{oc})$, where f_{oc} = mass fraction of the organic carbon soil content obtained from AOC-specific measurements. In general, biodegradation rates are not applicable for inorganic CMCOPCs and biodegradation was not considered for the organic chemicals in this evaluation.

G.5.2.4 Soil Data

The soil data file of SESOIL contains input parameters describing the physical characteristics of the subsurface soil and is presented in Table G-12. These parameters include soil bulk density, intrinsic permeability, soil disconnectedness index, soil porosity, organic carbon content, and cation exchange capacity (CEC). AOC-specific data, if available, were used for the AOC-specific SESOIL input parameters. There is, however, no measurement method for the soil disconnectedness index or a measured value of the Freundlich exponent. The soil disconnectedness index is a parameter that relates the soil permeability to the moisture content, and the Freundlich exponent relates to the concentration of a solute on the surface of an adsorbent to the concentration of the solute in the liquid with which it is in contact. Thus, SESOIL default values were used for these two parameters.

An average intrinsic permeability for the vadose zone, representing the unconsolidated zone above the water table, was calibrated using the percolation rate of 9.42 cm/yr (3.6 inches/yr) as the calibration target. The model was calibrated against the percolation rate by varying the intrinsic permeability and keeping all other AOC-specific geotechnical parameters fixed. The final hydrogeologic parameter values used in this modeling are shown in Table G-12. The soil porosity was set to the AOC-specific value. The intrinsic permeability, calibrated in SESOIL to the percolation rate (determined from a water balance estimated in HELP), was found to match the AOC-specific measurements from geotechnical samples.

The soil disconnectedness index replaces the moisture retention curves (or characteristic curves) used by other unsaturated zone leaching models. SESOIL's User Guide defines this parameter to be the exponent relating the "wetting" and "drying" time-dependent permeability of soil to its saturated permeability (Hetrick and Scott 1993). This "one variable" approach of using the soil disconnectedness index in SESOIL simplifies the data estimation process and reduces computational time. In addition, this parameter was calibrated for four different soil types ranging from sandy loam to clay (Hetrick et al. 1986), and calibrated values fell within the default range specified in the SESOIL's User Guide.

G.5.2.5 Source Terms

Analytical data from surface and subsurface soil collected at the AOCs were used as source terms for SESOIL modeling. All the samples collected at different depth intervals were compiled to provide a detailed loading option for the SESOIL model. The maximum soil concentrations for each COI, listed in Table G-14, were used as source term concentrations for the SESOIL model.

G.5.2.6 Application Data

Different layering schemes were developed for sample locations within the AOCs due to varying thicknesses of the loading and leaching zones that are based on varying soil sample and groundwater depths throughout the AOCs. Details of the model layers utilized in this modeling are presented in Table G-13 and discussed below:

- **Load Line 1**: Each model was arranged in four layers. For the nitrobenzene model, Layer 1 with a thickness of 1 ft served as a loading zone in the 21-ft-thick vadose zone. Layers 2 and 3 served as the leaching zone of 20 ft-thickness. For the RDX model, Layers 1 (1-ft-thick) and 2 (6-ft-thick) served as the loading zone in the 21-ft-thick vadose zone. Layer 3 served as the leaching zone of 14 ft. In each of these models, Layer 4 was a thin layer, included just at the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater).
- **Load Line 2**: Each model was arranged in four layers. For the 2,4-DNT model, Layers 1 and 2 served as a loading zone in the 10-ft-thick vadose zone. Layer 3 served as the leaching zone of 3-ft thickness. For the RDX model, Layers 1 and 2 served as a loading zone in the 11-ft-thick vadose zone. Layer 3, a 4-ft-thick layer, served as the leaching zone. In each of these models, Layer 4 was a thin layer, included just at the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater).
- **Load Line 3**: Each model was arranged in four layers. For the 2,6-DNT model, Layer 1 served as a loading zone in the 17-ft-thick vadose zone. Layers 2 and 3 served as the leaching zone of 10-ft thickness. For the RDX model, Layers 1 and 2 served as a loading zone in the 28-ft-thick vadose zone. Layer 3 served as the leaching zone of 23 ft. In each of these models, Layer 4 was a thin layer, included just at the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater).
- **Load Line 4**: The RDX model was arranged in four layers. Layer 1 of the RDX model served as a loading zone in the 14-ft-thick vadose zone. Layers 2 and 3 served as the leaching zone of 13 ft. Layer 4 was a thin layer, included just at the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater).
- **Load Line 12**: Each model was arranged in four layers. For the 1,3-DNB; 2,4-DNT; and 2,6-DNT models, Layers 1 and 2 served as a loading zone in the 7.4-ft-thick vadose zone. Layer 3 served as the leaching zone of 4.4 ft. For the 3-nitrotoluene model, Layers 1 and 2 served as a loading zone in the 5-ft-thick vadose zone. Layer 3 served as the leaching zone of 2 ft-thickness. For the 4-nitrotoluene model, Layer 1 served as a loading zone in the 9.7-ft-thick vadose zone. Layers 2 and 3 served as the leaching zone of 8.7 ft. For the nitrobenzene model, Layers 1 and 2 served as a loading zone in the 8.5-ft-thick vadose zone. Layer 3 served as the leaching zone of 5 ft. For the RDX model, Layers 1 and 2 served as a loading zone in the 6.4-ft-thick vadose zone. Layer 3 served as the leaching zone of 1.4 ft. In each of these models, Layer 4 was a thin layer, included just at the water table to read output results at the water table/vadose zone interface (i.e., leachate concentration entering groundwater).

G.5.3 SESOIL Modeling Results

SESOIL modeling was performed for the COIs (nitrobenzene and RDX from Load Line 1; 2,4-DNT and RDX from Load Line 2; 2,6-DNT and RDX from Load Line 3; RDX from Load Line 4; and 1,3-DNB, 2,4-DNT, 2,6-DNT, 3-nitrotoluene, 4-nitrotoluene, nitrobenzene, and RDX from Load Line 12) that have the potential to reach the water table within 1,000 years based on the soil screening analysis results (Section G.3). Table G-14 presents the predicted peak leachate concentrations beneath the source areas relative to the discrete sample locations and Incremental Sample Method (ISM) areas corresponding to the time of peak leachate concentrations. The Resident Receptor Adult FWCUGs, RVAAP facility-wide background concentrations, and MCL/RSL values for the COIs, if available, are also shown in this table for comparison purposes. All of the COIs except 4-nitrotoluene (from Load Line 12) modeled in SESOIL were retained for further evaluations based on the results of the SESOIL modeling, as the predicted leachate concentrations below the source and just above the water table exceeded their respective screening criteria. These leachate concentrations do not reflect the groundwater concentrations beneath the source. When the leachate reaches the water table, dilution by groundwater further reduces leachate concentrations. Figures G-8 through G-20 show the leachate mass flux versus time plots generated by SESOIL that were used as input to the AT123D models.

G.5.4 AT123D Modeling in the Saturated Zone

The fate and transport processes accounted for in the AT123D model include advection, dispersion, adsorption/retardation, and decay. This model can be used as a tool for estimating the dissolved concentration of a chemical in three dimensions in the groundwater resulting from a mass release over a source area (point, line, area, or volume source). The model can handle instantaneous, as well as continuous, source loadings of COI concentrations. AT123D is frequently used by the scientific and technical community to perform quick and conservative estimates of groundwater plume movements in space and time. SESOIL and AT123D are linked in a software package (RISKPRO) so that mass loading to the groundwater predicted by SESOIL can be transferred directly to AT123D. Therefore, AT123D was chosen to predict the maximum concentration of contaminants in groundwater after mixing with the leachate and the future concentrations for the contaminants in groundwater at the receptor locations.

The hydrogeologic parameter values used in this modeling are shown in Table G-15. Most of the parameters presented in this table are AOC-specific values, unless otherwise indicated. The chemical-specific parameters used for AT123D are presented in Tables G-1 and G-2. A discussion of model assumptions and limitations is presented in Section G.5.6.

Figures G-21 through G-34 show the predicted concentration versus time curves based on AT123D modeling at the source as well as at the receptor location. The screening criteria (MCL/RSL and Resident Receptor FWCUG) are also plotted in these figures as a constant line.

G.5.5 AT123D Modeling Results

Results of AT123D modeling for final soil and sediment COIs are shown in Table G-15. The results show predicted groundwater concentrations for COIs beneath the source area and at the selected downgradient receptor locations. Using the closest available downgradient monitoring wells for comparison with modeled source areas, observed groundwater concentrations from AOC monitoring wells are included in Table G-15. The observed groundwater concentrations were added for comparison, not for screening criteria. The distances to the downgradient receptors were based on the distance along the groundwater flow direction to the closest surface water body.

From the remaining COIs, the maximum predicted concentration of only nitrobenzene in groundwater from Load Line 1 was predicted to not exceed the screening criteria beneath the source area and was eliminated as a CMCOC. The maximum predicted concentrations of RDX at Load Line 1; 2,4-DNT and RDX at Load Line 2; 2,6-DNT and RDX at Load Line 3; and 1,3-DNB, 2,4-DNT, 2,6-DNT, 3-nitrotoluene, nitrotoluene, and RDX at Load Line 12 were predicted to exceed the screening criteria in groundwater beneath the source area and were, therefore, modeled to the downgradient receptor locations. The identified sediment CMCOPCs (antimony from Load Line 2, cobalt from Load Line 3, and hexavalent chromium from Load Line 4) were also predicted by analytical solutions to exceed screening criteria in groundwater beneath their source and were retained for lateral transport modeling using the AT123D model.

Lateral transport modeling showed that of all the remaining soil leaching COIs, only RDX at Load Lines 1 and 2, and 3-nitrotoluene at Load Line 12 were predicted to exceed the screening criteria at the downgradient receptor locations. None of the sediment CMCOPCs were predicted to exceed screening criteria at their downgradient receptor locations. Figures G-35 through G-39 present CMCOCs identified based on AT123D modeling for Load Lines 1 through 4 and Load Line 12, respectively.

G.5.6 Limitations/Assumptions

In general, a conservative modeling approach was used, which may overestimate the contaminant concentration in the leachate for migration from observed soil concentrations. Listed below are important assumptions used in this analysis:

- The contaminant fate and transport evaluation included not only chemicals identified as being previously used during historical operations, but also included all chemicals identified as soil SRCs during the data screening and reduction process.
- Some soil SRCs were identified due to the absence of a background concentration or as having limited or slight exceedances of the established background concentrations.
- Chemical and biological degradation rates for organic CMCOPCs were not considered in the SESOIL and AT123D models.
- Using K_d and R to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid- and solution-phase concentrations and that the relationship is linear and reversible.

- Since AOC-specific data are not available, the K_d and K_{oc} values used in this analysis for all CMCOPCs represent literature or calculated values and may not represent conditions at the AOCs.
- The K_d for inorganic chemicals used in the modeling evaluation assumed a pH of 6.8 (i.e., the middle value in the USEPA's evaluation presented in the soil screening guidance document [USEPA 1996]). The K_d for inorganic chemicals varies with pH (generally decreasing with decreasing pH, although there are few exceptions); therefore, if AOC-specific pH measurements are greater or less than 6.8, the K_d and calculated screening parameters (such as R) will deviate from those presented here.
- Flow and transport in the vadose zone is one-dimensional (i.e., only in the vertical direction).
- This modeling used current soil concentrations that were collected approximately 65 years after historical operations were terminated at the AOCs. Therefore, it does not account for constituents that have already leached to groundwater.
- Flow and transport are not affected by density variations. Variability in the distribution of soil contamination and overall impacts to predicted groundwater concentrations were not considered in the models. A realistic distribution of soil contamination was not considered. The maximum concentration value was used as the source term concentration for SESOIL model layers; this is a highly conservative assumption that is expected to produce higher leachate concentrations for CMCOPCs than the average condition. The horizontal distribution of soil contamination was assumed based on concentration levels from nearby sample locations as opposed to taking into account the entire area.
- The water balance represents an overall average rainwater recharge and assumes an even distribution of infiltration in the modeled area. An average water balance assumes some areas will have higher or lower recharge based on the heterogeneity of the soil and varying topography.

The inherent uncertainties associated with using these assumptions must be recognized. K_d values are highly sensitive to changes in the major chemistry of the solution phase. Therefore, it is important that the values be measured or estimated under conditions that will closely represent those of the contaminant plume. Deviations of actual AOC-specific parameter values from assumed literature values may significantly affect contaminant fate predictions. It is also important to note that the contaminant plume will change over time and will be affected by multiple solutes present at the AOCs. The effects of heterogeneity and anisotropy are not addressed in these simulations. The discrepancy between the contaminant concentrations measured in the field and the values predicted by the model could be investigated by performing sensitivity analyses on the model input parameters that have the most influence on the model predictions.

These parameters are: (1) biodegradation rate constants for organic chemicals; (2) saturated hydraulic conductivity; (3) soil porosity; (4) fraction organic carbon (f_{oc}) for organic chemicals; (5) K_d for inorganic chemicals; and (6) longitudinal, transverse, and vertical dispersivity values. Generally, higher biodegradation rates will produce lower concentrations, and lower rates will produce higher concentrations for organic chemicals without impacting the results of the inorganic chemicals. In this analysis, biodegradation rates for organic chemicals have been assumed to be zero, thereby predicting higher concentrations for the organic chemicals in groundwater than would be expected to be observed in the future. Higher hydraulic conductivity and dispersivity causes higher advection and dispersion, thereby producing lower peaks near the source area, but increasing the migration distance. The reverse will be true with lower hydraulic conductivity and dispersivity values. Higher f_{oc} values have a similar effect on organic chemicals as higher K_d has on inorganic chemicals; they decrease the mobility of the chemicals as well as produce lower concentrations in groundwater.

G.6 EVALUATION TO IDENTIFY CMCOCs

This evaluation of contaminant fate and transport uses a soil screening analysis to identify COIs that have potential to leach to groundwater, performs SESOIL modeling to conservatively estimate remaining COI leachate concentrations before the chemicals enter the groundwater system beneath the sources with highest level of contamination, and uses AT123D modeling to present a conservative maximum concentration in groundwater of the final list of COIs beneath the sources and at downgradient receptor locations.

This analysis also includes a sediment screening analysis that was performed for sediment samples at the four AOCs (Load Lines 1 through 4). Chemical-specific DAFs were calculated using co-located surface water and sediment concentrations for identified sediment SRCs. The estimated groundwater concentrations using these DAFs along with observed maximum surface water concentrations were used in the sediment screening analysis to identify the final sediment CMCOPCs for further evaluation.

The limitations and assumptions of the overall process are presented in Section G.5.6. The text below provides a list of the remaining final CMCOPCs in soil and sediment, and a qualitative assessment of the results and considerations of the limitations and assumptions.

G.6.1 Evaluation of Remaining Soil Leaching COIs

G.6.1.1 Load Line 1

RDX – The maximum subsurface soil concentration for RDX (1,500 mg/kg at LL1sb-638M-0013-SO) at a depth interval of 1 to 5 ft bgs was above the Resident Receptor Adult FWCUG at a TR of 1E-06, hazard quotient (HQ) of 0.1, as well as the Resident Receptor Adult FWCUG at a TR of 1E-05, HQ of 1 (80.3 mg/kg). The modeling estimates that RDX concentrations in groundwater beneath the source areas could potentially exceed its RSL by orders of magnitude at about 150 years or less with peak concentrations occurring at approximately 600 years or less. RDX also was detected in the AOC groundwater samples exceeding its RSL collected from 2011 to 2015 (Table G-15). However, the maximum predicted RDX groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). Therefore, it may be concluded that although RDX is not expected to migrate off-site from this AOC, it will continue to impact groundwater beneath the source for a long period of time without any remedial action.

G.6.1.2 Load Line 2

2,4-DNT – The maximum surface soil concentration for 2,4-DNT (3.3 mg/kg at LL2ss-087) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1. 2,4-DNT modeling results using this maximum concentration indicate groundwater concentrations beneath the source area could potentially exceed its RSL in less than 150 years with peak concentration occurring at approximately 250 years; 2-4-DNT was not detected above its RSL in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). In addition, the maximum predicted 2,4-DNT groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 2,4-DNT would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

RDX – The maximum surface soil concentration for RDX (25 mg/kg at LL2ss-162-0944) was above the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, but below the Resident Receptor Adult FWCUG at a TR of 1E-05, HQ of 1 (80.3 mg/kg). The modeling estimates that RDX concentrations in groundwater beneath the source areas could potentially exceed its RSL at about 20 years or less with peak concentrations occurring at approximately 40 years or less; the maximum predicted RDX groundwater concentration at the downgradient receptor location is also expected to be above its RSL (Table G-15). However, RDX was not detected in the AOC groundwater samples exceeding its RSL collected from 2011 to 2015 (Table G-15). Based on the AOC period of operations, RDX should have already been detected in groundwater exceeding its RSL. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and RDX would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

G.6.1.3 Load Line 3

2,6-DNT – The maximum surface soil concentration for 2,4-DNT (0.23 mg/kg at LL3ss-067) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, and 2,6-DNT was not considered a soil COC in the HHRA. 2,6-DNT modeling results using this maximum concentration indicate groundwater concentrations beneath the source area could potentially exceed its FWCUG in less than 450 years with peak concentration occurring at approximately 750 years; 2,6-DNT was not detected above its RSL/FWCUG in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). In addition, the maximum predicted 2,6-DNT groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 2,6-DNT would be expected to be below its RSL/FWCUG based on its estimated site-specific biodegradation rate.

RDX – The maximum surface soil concentration for RDX (34 mg/kg at LL3ss-117-0851) was above the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, but below the Resident Receptor Adult FWCUG at a TR of 1E-05, HQ of 1 (80.3 mg/kg). The modeling estimates that RDX concentrations in groundwater beneath the source areas could potentially exceed its RSL at about 150 years or less with peak concentrations occurring at approximately 250 years or less; however, the maximum predicted RDX groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). RDX was not detected in the AOC groundwater samples exceeding its RSL collected from 2011 to 2015 (Table G-15). Based on the AOC period of operations, RDX should have already been detected in groundwater exceeding its RSL. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and RDX would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

G.6.1.4 Load Line 4

RDX – The maximum surface soil concentration for RDX (19 mg/kg at LL4ss-142-0878) was above the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, but below the Resident Receptor Adult FWCUG at a TR of 1E-05, HQ of 1 (80.3 mg/kg). The modeling estimates that RDX concentrations in groundwater beneath the source areas could potentially exceed its RSL at about 50 years or less with peak concentrations occurring at approximately 100 years or less; the maximum predicted RDX groundwater concentration at the downgradient receptor location is also expected to be above its RSL (Table G-15). However, RDX was not detected in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). Based on the AOC period of operations, RDX should have already been detected in groundwater. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and RDX would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

G.6.1.5 Load Line 12

1,3-DNB – The maximum soil concentration for 1,3-DNB (0.032 mg/kg at LL12so-120-0510) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, and 1,3-DNB was not considered a soil COC in the HHRA. 1,3-DNB modeling results using this maximum concentration indicate groundwater concentrations beneath the source area could potentially exceed its RSL in less than 40 years with peak concentration occurring at approximately 100 years; 1,3-DNB was not detected in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). In addition, the maximum predicted 1,3-DNB groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 1,3-DNB would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

2,4-DNT – The maximum soil concentration for 2,4-DNT (0.17 mg/kg at LL12so-120-0510) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1. 2,4-DNT modeling results using this maximum concentration indicate groundwater concentrations beneath the source area could potentially exceed its RSL in less than 100 years with peak concentration occurring at approximately 100 years; 2-4-DNT was not detected above its RSL in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). In addition, the maximum predicted 2,4-DNT groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 2,4-DNT would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

2,6-DNT – The maximum surface soil concentration for 2,4-DNT (1.7 mg/kg at LL12ss-143-0553) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1. 2,6-DNT modeling results using this maximum concentration indicate groundwater concentrations beneath the source area could potentially exceed its RSL in less than 100 years with peak concentration occurring at approximately 100 years; 2,6-DNT was not detected above its RSL in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). In addition, the maximum predicted 2,6-DNT groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 2,6-DNT would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

3-Nitrotoluene – The maximum surface soil concentration for 3-nitrotoluene (0.2 mg/kg at LL12ss-236-0695) was below the resident soil RSL at a TR of 1E-06 and HQ of 0.1. The modeling estimates that 3-nitrotoluene concentrations in groundwater beneath the source areas could potentially exceed its RSL at about 25 years or less with peak concentrations occurring at approximately 50 years or less; the maximum predicted 3-nitrotoluene groundwater concentration at the downgradient receptor location is also expected to be above its RSL (Table G-15). However, 3-nitrotoluene was not detected in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). Based on the AOC period of operations, 3-nitrotoluene should have already been detected in groundwater. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and 3-nitrotoluene would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

Nitrobenzene – The maximum soil concentration for nitrobenzene (0.12 mg/kg at LL12so-059-0374) was below the resident soil RSL at a TR of 1E-06 and HQ of 0.1. The modeling estimates that nitrobenzene concentrations in groundwater beneath the source areas could potentially exceed its RSL at about 25 years or less with peak concentrations occurring at approximately 50 years or less; however, the maximum predicted nitrobenzene groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). In addition, nitrobenzene was not detected in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). Based on the AOC period of operations, nitrobenzene should have already been detected in groundwater. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and nitrobenzene would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

RDX – The maximum soil concentration for RDX (21 mg/kg at LL12so-143-0554) a depth interval of 1 to 3 ft bgs was above the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, but below the Resident Receptor Adult FWCUG at a TR of 1E-05, HQ of 1 (80.3 mg/kg). The modeling estimates that RDX concentrations in groundwater beneath the source areas could potentially exceed its RSL at about 5 years or less with peak concentrations occurring at approximately 25 years or less; however, the maximum predicted RDX groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15). In addition, RDX was not detected above its RSL in the AOC groundwater samples collected from 2011 to 2015 (Table G-15). Based on the AOC period of operations, RDX should have already been detected in groundwater exceeding its RSL.

Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and RDX would be expected to be below its RSL based on its estimated site-specific biodegradation rate.

G.6.2 Evaluation of Remaining Sediment COIs

G.6.2.1 Load Line 2

Antimony – The maximum sediment concentration for antimony (9.5 mg/kg at FSW-SD-034-0000) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, and antimony was not identified as a sediment COC in the HHRA for this area. The modeling assumes that the sediment is in direct contact with groundwater and no attenuation due to sorption is occurring; therefore, antimony is predicted to be already in groundwater beneath the source area exceeding its MCL, although antimony was not detected above its MCL in the AOC groundwater samples collected from 2012 to 2015 (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and antimony would be expected to be below its MCL based on attenuation while accounting for the vertical leaching distance.

G.6.2.2 Load Line 3

Cobalt – The maximum sediment concentration for cobalt (15.3 mg/kg at LL3sd-051-1079-SD) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, and cobalt was not identified as a sediment COC in the HHRA for this area. The modeling assumes that the sediment is in direct contact with groundwater and no attenuation due to sorption is occurring; therefore, cobalt is predicted to be already in groundwater beneath the source area exceeding its RSL, although cobalt was not detected above its RSL in the AOC groundwater samples collected from 2012 to 2015 (Table G-15). Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and cobalt would be expected to be below its RSL based on attenuation while accounting for the vertical leaching distance.

G.6.2.3 Load Line 4

Hexavalent Chromium – The maximum sediment concentration for hexavalent chromium (1.4 mg/kg at LL4sd-057-0973-SD) was below the Resident Receptor Adult FWCUG at a TR of 1E-06 and HQ of 0.1, and hexavalent chromium was not identified as a sediment COC in the HHRA. The modeling assumes that the sediment is in direct contact with groundwater; therefore, hexavalent chromium is predicted to be already in groundwater beneath the source area exceeding the RSL, although hexavalent chromium was never detected in groundwater. The modeling also predicted that it would take approximately 200 years for hexavalent chromium to be below its RSL; however, the maximum predicted hexavalent chromium groundwater concentration at the downgradient receptor location is expected to be below its RSL (Table G-15).

It should be noted that hexavalent chromium in groundwater is considered to be of concern because the evaluation assumes the minimum DAF calculated for chromium using co-located surface water and sediment data for the AOC can be applicable to hexavalent chromium. This assumption was made because hexavalent chromium was not analyzed in surface water, and a DAF for hexavalent chromium could not be calculated. However, if the DAF calculated for chromium is applied to hexavalent chromium, then the estimated concentration of hexavalent chromium would be below its RSL. Therefore, this evaluation concludes that the model-predicted concentrations are conservative, and hexavalent chromium in groundwater beneath the source would be expected to be below its RSL based on its attenuation in the vadose zone before reaching the water table and its estimated site-specific DAF.

G.7 SUMMARY AND CONCLUSIONS

Mainly organic COIs were identified in surface soil and subsurface soil at the AOCs under evaluation in this FS Addendum. The soil leaching COIs were further evaluated to determine if residual concentrations in surface and subsurface soils may potentially impact groundwater quality and warrant evaluation in an FS. In addition, all sediment SRCs were evaluated to determine if residual concentrations in sediment may potentially impact groundwater quality and warrant evaluation in an FS. All of the soil leaching COIs at Load Lines 1 through 4 and Load Line 12, and the SRCs identified in the sediment at Load Lines 1 through 4, were evaluated through the stepwise fate and transport evaluation. The evaluation of modeling results with respect to current groundwater data for the AOCs and model limitations identified the following CMCOCs:

- Among the soil leaching COIs, RDX at Load Lines1 and 4; 2,4-DNT and RDX at Load Line 2; 2,6-DNT and RDX at Load Line 3; and 1,3-DNB, 2,4-DNT, 2,6-DNT, 3-nitrotoluene, nitrotoluene, and RDX at Load Line 12 were predicted to exceed the screening criteria in groundwater beneath the source area. However, only RDX at Load Line 1 and Load Line 2, and 3-nitrotoluene at Load Line 12 were predicted to exceed the screening criteria at the downgradient receptor locations.
- Among the sediment CMCOPCs, antimony from Load Line 2, cobalt from Load Line 3, and hexavalent chromium from Load Line 4 were predicted by analytical solutions to exceed screening criteria in groundwater beneath their respective sources; however, none of these CMCOPCs were predicted to be above criteria in the downgradient receptor locations.

A qualitative assessment of the sample results and considerations of the limitations and assumptions of the models were performed to identify if any CMCOCs are present in soil and sediment at these AOCs that may impact the groundwater beneath their respective source or at the downstream receptor locations. This qualitative assessment concluded that other than RDX from Load Line 1, there were no other CMCOCs present in soil and sediment that may impact the groundwater beneath their respective sources or at the downstream receptor locations. Therefore although no further action is required of soil and sediment at Load Lines 2, 3, 4 and 12 for the protection of groundwater; remedial action is required for the surface and subsurface soils at Load Line 1 for the protection of groundwater.

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Table G-1. Physical and Chemical Properties of Inorganic Soil Leaching COIs and Sediment SRCs

Analyte[a]	Molecular Weight	Solubility (mg/L)	K_{oc} (L/kg)	K_d (L/kg)	HLC (atm-m^3/mol)	Diffusion Coefficient in Air (cm^2/sec)	Diffusion Coefficient in Water (cm^2/sec)	Groundwater Criteria (mg/L)	Groundwater Criteria Type	GSSL (mg/kg)	GSSL Type
Aluminum	27.0	NA	NA	1.50E+03	NA	NA	NA	2.00E+01	RSL	3.00E+04	Risk
Antimony	124.8	NA	NA	4.50E+01	NA	NA	NA	6.00E-03	MCL	2.70E-01	MCL
Arsenic	77.9	NA	NA	2.90E+01	NA	NA	NA	1.00E-02	MCL	2.90E-01	MCL
Barium	139.4	NA	NA	4.10E+01	NA	NA	NA	2.00E+00	MCL	8.20E+01	MCL
Beryllium	11.0	NA	NA	7.90E+02	NA	NA	NA	4.00E-03	MCL	3.20E+00	MCL
Cadmium	112.4	NA	NA	7.50E+01	NA	NA	NA	5.00E-03	MCL	3.80E-01	MCL
Chromium	52.0	NA	NA	1.80E+06	NA	NA	NA	1.00E-01	MCL	1.80E+05	MCL
Chromium, hexavalent	52.0	1.69E+06	NA	1.90E+01	NA	NA	NA	3.50E-04	RSL	6.70E-03	Risk
Cobalt	58.9	NA	NA	4.50E+01	NA	NA	NA	6.00E-03	RSL	2.70E-01	Risk
Copper	63.5	NA	NA	3.50E+01	NA	NA	NA	1.30E+00	MCL	4.60E+01	MCL
Lead	207.2	NA	NA	9.00E+02	NA	NA	NA	1.50E-02	MCL	1.40E+01	MCL
Mercury	200.6	6.00E-02	NA	5.20E+01	8.62E-03	3.07E-02	6.30E-06	2.00E-03	MCL	1.00E-01	MCL
Nickel	58.7	NA	NA	6.50E+01	NA	NA	NA	3.90E-01	RSL	2.60E+01	Risk
Selenium	79.0	NA	NA	5.00E+00	NA	NA	NA	5.00E-02	MCL	2.60E-01	MCL
Silver	107.9	NA	NA	8.30E+00	NA	NA	NA	9.40E-02	RSL	8.00E-01	Risk
Thallium	205.4	NA	NA	7.10E+01	NA	NA	NA	2.00E-03	MCL	1.40E-01	MCL
Vanadium	50.9	NA	NA	1.00E+03	NA	NA	NA	8.60E-02	RSL	8.60E+01	Risk
Zinc	65.4	NA	NA	6.20E+01	NA	NA	NA	6.00E+00	RSL	3.70E+02	Risk
Nitrate/Nitrite (NO3/NO2-N)	62.0	NA	NA	NA	NA	NA	NA	1.00E+01	MCL	NA	NA
Ammonia	17.0	482000	NA	NA	1.61E-05	2.31E-01	2.23E-05	NA	NA	NA	NA

[a] All physical and chemical properties are from U.S. Environmental Protection Agency (USEPA) regional screening levels (RSL) Generic Tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.

COI = Constituent of Interest.
GSSL = Generic Soil Screening Level.
HLC = Henry's Law Constant.
K_d = Distribution Coefficient.
K_{oc} = Organic Carbon Partition Coefficient.
MCL = Clean Water Act Drinking Water Maximum Contaminant Level.
NA = Not Applicable.
RSL = USEPA Regional Screening Level (USEPA 2016).
SRC = Site-related Chemical.

Table G-2. Physical and Chemical Properties of Organic Soil Leaching COIs and Sediment SRCs

Analyte[a]	Molecular Weight	Solubility (mg/L)	K_{oc} (L/kg)	HLC (atm-m^3/mol)	Diffusion Coefficient in Air (cm^2/sec)	Diffusion Coefficient in Water (cm^2/sec)	Groundwater Criteria (mg/L)	Groundwater Criteria Type	GSSL (mg/kg)	GSSL Type
Explosives										
1,3-Dinitrobenzene	168.1	5.33E+02	3.52E+02	4.90E-08	4.85E-02	9.21E-06	2.00E-03	RSL	1.80E-03	Risk
1,3,5-Trinitrobenzene	213.1	2.78E+02	1.68E+03	6.50E-09	2.90E-02	7.69E-06	5.90E-01	RSL	2.10E+00	Risk
2,4,6-Trinitrotoluene	227.1	1.15E+02	2.81E+03	2.08E-08	2.95E-02	7.92E-06	9.80E-03	RSL	5.70E-02	Risk
2,4-Dinitrotoluene	182.1	2.00E+02	5.76E+02	5.40E-08	3.75E-02	7.90E-06	2.40E-03	RSL	3.20E-03	Risk
2,6-Dinitrotoluene	182.1	1.82E+02	5.87E+02	7.47E-07	3.70E-02	7.76E-06	4.90E-04	RSL	6.70E-04	Risk
3-Nitrotoluene	137.1	5.00E+02	3.63E+02	9.30E-06	5.87E-02	8.65E-06	1.70E-03	RSL	1.60E-03	Risk
4-Nitrotoluene	137.1	4.42E+02	3.63E+02	5.63E-06	5.74E-02	8.41E-06	4.30E-02	RSL	4.00E-02	Risk
4-Amino-2,6-Dinitrotoluene	197.2	1.22E+03	2.83E+02	3.27E-11	5.61E-02	6.55E-06	3.90E-02	RSL	3.00E-02	Risk
Nitrobenzene	123.1	2.09E+03	2.26E+02	2.40E-05	6.81E-02	9.45E-06	1.40E-03	RSL	9.20E-04	Risk
Nitrocellulose	387.3	1.00E+06	1.00E+01	3.29E-23	3.58E-02	4.18E-06	6.00E+04	RSL	1.30E+04	Risk
RDX	222.1	5.97E+01	8.91E+01	2.01E-11	3.12E-02	8.50E-06	7.00E-03	RSL	2.70E-03	Risk
Semi-volatile Organic Chemicals										
Acenaphthene	154.2	3.90E+00	5.03E+03	1.84E-04	5.06E-02	8.33E-06	5.30E-01	RSL	5.50E+00	Risk
Acenapthylene[b]	152.2	1.35E-01	7.40E+03	1.19E-05	2.78E-02	7.25E-06	1.20E-01	RSL	1.30E+01	Risk
Anthracene	178.2	4.34E-02	1.64E+04	5.56E-05	3.90E-02	7.85E-06	1.80E+00	RSL	5.80E+01	Risk
Benzo(a)anthracene	228.3	9.40E-03	1.77E+05	1.20E-05	2.61E-02	6.75E-06	1.20E-04	RSL	4.20E-02	Risk
Benzo(a)pyrene	252.3	1.62E-03	5.87E+05	4.57E-07	4.76E-02	5.56E-06	2.00E-04	MCL	2.40E-01	MCL
Benzo(b)fluoranthene	252.3	1.50E-03	5.99E+05	6.57E-07	4.76E-02	5.56E-06	3.40E-04	RSL	4.10E-01	Risk
Benzo(g,h,i)perylene[b]	276.3	1.35E-01	1.07E+07	1.19E-05	2.78E-02	7.25E-06	1.20E-01	RSL	1.30E+01	Risk
Benzo(k)fluoranthene	252.3	8.00E-04	5.87E+05	5.84E-07	4.76E-02	5.56E-06	3.40E-03	RSL	4.00E+00	Risk
Bis(2-ethylhexyl)phthalate	390.6	2.70E-01	1.20E+05	2.70E-07	1.73E-02	4.18E-06	6.00E-03	MCL	1.40E+00	MCL
Carbazole	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	228.3	2.00E-03	1.81E+05	5.23E-06	2.61E-02	6.75E-06	3.40E-02	RSL	1.20E+01	Risk
Di-n-butyl phthalate	278.4	1.12E+01	1.16E+03	1.81E-06	2.14E-02	5.33E-06	9.00E-01	RSL	2.30E+00	Risk
Dibenz(a,h)anthracene	278.4	2.49E-03	1.91E+06	1.41E-07	4.46E-02	5.21E-06	3.40E-05	RSL	1.30E-01	Risk
Fluoranthene	202.3	2.60E-01	5.55E+04	8.86E-06	2.76E-02	7.18E-06	8.00E-01	RSL	8.90E+01	Risk
Fluorene	166.2	1.69E+00	9.16E+03	9.62E-05	4.40E-02	7.89E-06	2.90E-01	RSL	5.40E+00	Risk
Indeno(1,2,3,-cd)pyrene	276.3	1.90E-04	1.95E+06	3.48E-07	4.48E-02	5.23E-06	3.40E-04	RSL	1.30E+00	Risk

Table G-2. Physical and Chemical Properties of Organic Soil Leaching COIs and Sediment SRCs (continued)

Analyte[a]	Molecular Weight	Solubility (mg/L)	K_{oc} (L/kg)	HLC (atm-m^3/mol)	Diffusion Coefficient in Air (cm^2/sec)	Diffusion Coefficient in Water (cm^2/sec)	Groundwater Criteria (mg/L)	Groundwater Criteria Type	GSSL (mg/kg)	GSSL Type
Naphthalene	128.2	3.10E+01	1.54E+03	4.40E-04	6.05E-02	8.38E-06	1.70E-03	RSL	5.40E-03	Risk
Phenanthrene[b]	178.2	1.35E-01	1.82E+04	1.19E-05	2.78E-02	7.25E-06	1.20E-01	RSL	1.30E+01	Risk
Pyrene	202.3	1.35E-01	5.43E+04	1.19E-05	2.78E-02	7.25E-06	1.20E-01	RSL	1.30E+01	Risk
Pesticides/PCBs										
4,4'-DDD	320.1	9.00E-02	1.18E+05	6.60E-06	4.06E-02	4.74E-06	3.20E-04	RSL	7.50E-02	Risk
4,4'-DDE	318.0	4.00E-02	1.18E+05	4.16E-05	2.30E-02	5.86E-06	4.60E-04	RSL	1.10E-01	Risk
4,4'-DDT	354.5	5.50E-03	1.69E+05	8.32E-06	3.79E-02	4.43E-06	2.30E-03	RSL	7.70E-01	Risk
Endrin ketone[c]	380.9	NA	5.50E+03	NA	NA	NA	2.00E-03	MCL	8.10E-02	MCL
beta-BHC	290.8	2.40E-01	2.81E+03	4.40E-07	2.77E-02	7.40E-06	2.50E-04	RSL	1.50E-03	Risk
PCB-1248	618.4	1.00E-01	7.65E+04	4.40E-04	1.63E-02	3.94E-06	7.80E-05	RSL	1.20E-02	Risk
PCB-1254	326.4	4.30E-02	1.31E+05	2.83E-04	2.37E-02	6.10E-06	7.80E-05	RSL	2.00E-02	Risk
Volatile Organic Chemicals										
2-Butanone	72.1	2.23E+05	4.51E+00	5.69E-05	9.14E-02	1.02E-05	5.60E+00	RSL	1.20E+00	Risk
Acetone	58.1	1.00E+06	2.36E+00	3.50E-05	1.06E-01	1.15E-05	1.40E+01	RSL	2.90E+00	Risk
Toluene	92.1	5.26E+02	2.34E+02	6.64E-03	7.78E-02	9.20E-06	1.00E+00	MCL	6.90E-01	MCL

[a] All physical and chemical properties are from U.S. Environmental Protection Agency (USEPA) regional screening levels (RSL) Generic Tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.

[b] Pyrene was used as a surrogate for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene, except K_{oc}. K_{oc} for these analytes from USEPA 1994. Risk Reduction Engineering Laboratory (RREL) Treatability Database, Version 5.0, Office of Research and Development, Cincinnati, Ohio.

[c] K_{oc} for endrin ketone from Lyman et al 1990. Handbook of Chemical Property Estimation Methods. W. J. Lyman, W. F. Reehl and D. H. Rosenblatt. American Chemical Society, Washington DC, 1990. 960 pp. ISBN 0-8412-1761-0.

COI = Constituent of Interest.
GSSL = Generic Soil Screening Level.
HLC = Henry’s Law Constant.
K_d = Distribution Coefficient.
K_{oc} = Organic Carbon Partition Coefficient.
MCL = Clean Water Act Drinking Water Maximum Contaminant Level.
NA = Not Applicable.
PCB = Polychlorinated Biphenyl.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
RSL = USEPA Regional Screening Level (USEPA 2016).
SRC = Site-related Contaminant.

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

Layer	Layer Type	Thickness (in)	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 (in) =	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, OH Coefficients

Temperature Data
Synthetically Generated Using Cleveland, OH Coefficients

Solar Radiation Data
Synthetically Generated Using Cleveland, OH Coefficients

HELP= Hydrologic Evaluation of Landfill Performance.
K= Hydraulic Conductivity.

Table G-4. DAF Calculation for Load Lines 1 Through 4 and Load Line 12

Parameter	Symbol	Unit	Load Line 1	Load Line 2	Load Line 3	Load Line 4	Load Line 12	Notes
DAF	DAF	unitless	1.37	5.84	1.58	1.84	1.04	Calculated from Equation G-5.
Aquifer hydraulic conductivity	K	m/year	8.62E+01	3.49E+02	1.71E+01	1.40E+02	7.85E+00	Average of the site-specific slug test data from bedrock wells at Load Lines 1, 2, 3, and 4 and unconsolidated wells at Load Line 12.
Horizontal hydraulic gradient	i	unitless	1.80E-02	1.00E-02	1.00E-02	2.00E-03	4.60E-03	Groundwater potentiometric map presented in the Final Phase II RIs for Load Lines 1, 2, 3, and 4 and the Draft Final Phase III RI for Load Line 12.
Percolation rate	q	m/year	9.42E-02	9.42E-02	9.42E-02	9.42E-02	9.42E-02	0.1 SESOIL Precipitation for Youngstown, Ohio.
Source length parallel to groundwater flow	L	m	271	94	94	106	60	Approximate length based on extent of contamination.
Mixing zone depth	d	m	6	12.26	30	30	6	Determined from the lower value between for “d” (Equation G-6) and d_a.
Aquifer thickness	d_a	m	6	15	30	30	6	Based on the Final Phase II RIs for Load Lines 1, 2, 3, and 4 and the Draft Final Phase III RI for Load Line 12.

DAF = Dilution Attenuation Factor.
RI = Remedial Investigation.
SESOIL = Seasonal Soil Compartment.

Table G-5. Remaining Soil Leaching COIs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years

Analyte	Maximum Concentration (mg/kg)	Sample ID of Maximum Concentration	Sample Depth of Maximum Concentration (ft)	Lz[a] (ft)	K_{oc}[b] (L/kg)	K_d[b] (L/kg)	Retardation Factor (R)[c]	Arrival Time (T) from Sample Max Depth to Groundwater[d] (years)	T <1,000? from Sample Depth to Groundwater Table (Yes/No)
Load Line 1									
Explosives									
1,3,5-Trinitrobenzene	8.70E+00	LL1SB-638M-0102-SO	3.0 - 5.0	16.5	1.68E+03	5.20E+01	3.72E+02	4.65E+03	No
1,3-Ditrobenzene	8.10E-02	LL1ss-355-1302-SO	0.0 - 1.0	23.0	3.52E+02	1.09E+01	7.85E+01	1.37E+03	No
2,4,6-Trinitrotoluene	2.70E+03	LL1SB-638M-0102-SO	3.0 - 5.0	16.5	2.81E+03	8.69E+01	6.21E+02	7.76E+03	No
2,4-Dinitrotoluene	4.80E-01	LL1ss-110-0756-SO	0.0 - 1.0	30.5	5.76E+02	1.78E+01	1.28E+02	2.95E+03	No
2,6-Dinitrotoluene	8.60E-01	LL1ss-137-0792-SO	0.0 - 1.0	31.9	5.87E+02	1.82E+01	1.31E+02	3.15E+03	No
Nitrobenzene	**5.90E-01**	**LL1ss-156-0845-SO**	**0.0 - 1.0**	**20.0**	**2.26E+02**	**7.00E+00**	**5.09E+01**	**7.71E+02**	**Yes**
RDX	**1.50E+03**	**LL1SB-638M-0013-SO**	**1.0 - 5.0**	**16.3**	**8.91E+01**	**2.75E+00**	**2.06E+01**	**2.55E+02**	**Yes**
Load Line 2									
Explosives									
2,4-Dinitrotoluene	**3.30E+00**	**LL2ss-087-0743-SO**	**0.0 - 1.0**	**8.6**	**5.76E+02**	**7.02E+00**	**4.44E+01**	**3.26E+02**	**Yes**
RDX	**2.50E+01**	**LL2ss-162-0944-SO**	**0.0 - 1.0**	**10.8**	**8.91E+01**	**1.09E+00**	**7.71E+00**	**7.10E+01**	**Yes**
Load Line 3									
Explosives									
2,4,6-Trinitrotoluene	7.00E+02	LL3ss-265M-1204-SO	0.0 - 1.0	27.1	2.81E+03	4.84E+01	2.96E+02	6.94E+03	No
2,6-Dinitrotoluene	**2.30E-01**	**LL3ss-067-0719-SO**	**0.0 - 1.0**	**16.5**	**5.87E+02**	**1.01E+01**	**6.27E+01**	**8.93E+02**	**Yes**
RDX	**3.40E+01**	**LL3ss-117-0851-SO**	**0.0 - 1.0**	**26.7**	**8.91E+01**	**1.53E+00**	**1.04E+01**	**2.39E+02**	**Yes**
Load Line 4									
Explosives									
RDX	**1.90E+01**	**LL4ss-142-0878-SO**	**0.0 - 1.0**	**13.0**	**8.91E+01**	**1.18E+00**	**7.26E+00**	**1.02E+02**	**Yes**
Load Line 12									
Explosives									
1,3-Dinitrobenzene	**3.20E-02**	**L12so-120-0510-SO**	**1.0 - 3.0**	**4.4**	**3.52E+02**	**2.20E+00**	**1.20E+01**	**5.60E+01**	**Yes**
2,4-Dinitrotoluene	**1.70E-01**	**L12so-120-0510-SO**	**1.0 - 3.0**	**4.4**	**5.76E+02**	**3.61E+00**	**1.89E+01**	**8.80E+01**	**Yes**
2,6-Dinitrotoluene	**1.70E+00**	**L12ss-143-0553-SO**	**0.0 - 1.0**	**6.4**	**5.87E+02**	**3.68E+00**	**1.93E+01**	**1.31E+02**	**Yes**
3-Nitrotoluene	**2.20E-01**	**L12ss-236-0395-SO**	**0.0 - 1.0**	**4.0**	**3.63E+02**	**2.28E+00**	**1.23E+01**	**5.20E+01**	**Yes**
4-Nitrotoluene	**2.00E-01**	**L12ss-239-0561-SO**	**0.0 - 1.0**	**8.7**	**3.63E+02**	**2.28E+00**	**1.23E+01**	**1.14E+02**	**Yes**
Nitrobenzene	**1.20E-01**	**L12so-059-0374-SO**	**3.0 - 3.5**	**5.0**	**2.26E+02**	**1.42E+00**	**8.05E+00**	**4.30E+01**	**Yes**
RDX	**2.10E+01**	**L12so-143-0554-SO**	**1.0 - 3.0**	**3.4**	**8.91E+01**	**5.58E-01**	**3.78E+00**	**1.40E+01**	**Yes**

Table G-5. Remaining Soil Leaching COIs Based on Arrival Time to Groundwater Table in Less Than or Equal to 1,000 Years (continued)

Bold = Initial CMCOPCs that indicate < 1,000-year travel time to the groundwater table and will be evaluated with SESOIL modeling.
[a] Based on the topography at each specific sample ID location and associated potentiometric surface from the Phase II RIs for Load Line 1, 2, 3, and 4 and the Phase II RI from Load Line 12.
[b] All physical and chemical properties are from U.S. Environmental Protection Agency (USEPA) regional screening levels (RSL) Generic Tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables. The K_d was calculated by multiplying the K_{oc} by the fraction organic carbon content for each Load Line.
[c] Retardation factor calculated by Equation 1.
[d] Leachate travel time calculated by Equations G-7 and G-8.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
K_d = Distribution Coefficient.
K_{oc} = Organic Carbon Partition Coefficient.
Lz = Leaching Zone.
R = Retardation Factor.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
SESOIL = Seasonal Soil Compartment.
ID = Identifier.
COI = Chemical of Interest.
RI = Remedial Investigation.
T = Travel Time.

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Table G-6. Initial Sediment Screening Results for Load Line 1

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														
Antimony	**7440-36-0**	**0.00E+00**	**1.20E+00**	**LL1sd-047-1270-SD**	**NA**	**NA**	**4.50E+01**	**d**	**2.67E-02**	**4**	**6.40E-03**	**6.00E-03**	**MCL**	**Yes**
Arsenic	7440-38-2	1.95E+01	3.79E+01	LL1sd-320-1100-SD	NA	NA	2.90E+01	d	1.31E+00	178	7.36E-03	1.00E-02	MCL	No
Barium	7440-39-3	1.23E+02	1.33E+02	LL1sd-046-1048-SD	NA	NA	4.10E+01	d	3.24E+00	17	1.92E-01	2.00E+00	MCL	No
Beryllium	7440-41-7	3.80E-01	1.00E+00	LL1sd-396-1049-SD	NA	NA	7.90E+02	d	1.27E-03	4	3.04E-04	4.00E-03	MCL	No
Cadmium	**7440-43-9**	**0.00E+00**	**1.70E+00**	**LL1sd-070-1054-SD**	**NA**	**NA**	**7.50E+01**	**d**	**2.27E-02**	**4**	**5.44E-03**	**5.00E-03**	**MCL**	**Yes**
Chromium	**7440-47-3**	**1.81E+01**	**3.34E+01**	**LL1sd-320-1059-SD**	**NA**	**NA**	**1.90E+01**	**d**	**1.76E+00**	**4**	**4.22E-01**	**1.00E-01**	**MCL**	**Yes**
Cobalt	**7440-48-4**	**9.10E+00**	**1.75E+01**	**LL1sd-396-1049-SD**	**NA**	**NA**	**4.50E+01**	**d**	**3.89E-01**	**35**	**1.12E-02**	**6.00E-03**	**RSL**	**Yes**
Copper	**7440-50-8**	**2.76E+01**	**2.27E+02**	**LL1sd-320-1059-SD**	**NA**	**NA**	**3.50E+01**	**d**	**6.49E+00**	**4**	**1.56E+00**	**1.30E+00**	**MCL**	**Yes**
Lead	**7439-92-1**	**2.74E+01**	**1.41E+02**	**LL1SD-733-2534-SD**	**NA**	**NA**	**9.00E+02**	**d**	**1.57E-01**	**4**	**3.76E-02**	**1.50E-02**	**MCL**	**Yes**
Mercury	7439-97-6	5.90E-02	1.10E-01	LL1sd-047-1270-SD	NA	NA	5.20E+01	d	2.12E-03	4	5.08E-04	2.00E-03	MCL	No
Nickel	7440-02-0	1.77E+01	5.30E+01	LL1sd-320-1059-SD	NA	NA	6.50E+01	d	8.15E-01	85	9.60E-03	3.90E-01	RSL	No
Selenium	**7782-49-2**	**1.70E+00**	**2.20E+00**	**LL1sd-320-1100-SD**	**NA**	**NA**	**5.00E+00**	**d**	**4.40E-01**	**4**	**1.06E-01**	**5.00E-02**	**MCL**	**Yes**
Thallium	**7440-28-0**	**8.90E-01**	**1.10E+00**	**LL1sd-070-1054-SD**	**NA**	**NA**	**7.10E+01**	**d**	**1.55E-02**	**4**	**3.72E-03**	**2.00E-03**	**MCL**	**Yes**
Vanadium	7440-62-2	2.61E+01	2.88E+01	LL1sd-396-1049-SD	NA	NA	1.00E+03	d	2.88E-02	4	6.91E-03	8.60E-02	RSL	No
Semi-volatile Organic Chemicals														
Benz(a)anthracene	56-55-3	NA	5.60E-02	LL1sd-077-1015-SD	1.77E+05	d	5.47E+03	e	1.02E-05	4	2.46E-06	1.20E-04	RSL	No
Benzo(a)pyrene	50-32-8	NA	5.60E-02	LL1sd-077-1015-SD	5.87E+05	d	1.82E+04	e	3.09E-06	4	7.40E-07	2.00E-04	MCL	No
Benzo(b)fluoranthene	205-99-2	NA	7.10E-02	LL1sd-077-1015-SD	5.99E+05	d	1.85E+04	e	3.83E-06	4	9.20E-07	3.40E-04	RSL	No
Fluoranthene	206-44-0	NA	7.30E-02	LL1sd-077-1015-SD	5.55E+04	d	1.71E+03	e	4.26E-05	4	1.02E-05	8.00E-01	RSL	No
Volatile Organic Chemicals														
Acetone	67-64-1	NA	9.60E-03	LL1sd-077-1015-SD	2.36E+00	d	7.30E-02	e	1.31E-01	4	3.15E-02	1.40E+01	RSL	No

Bold = CMCOPCs carried forward into next screen.

[a] Background criteria for sediment from final facility-wide background values for RVAAP, 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] A chemical-specific DAF was calculated based on the sediment and co-located surface water concentrations used in the screening. The lowest calculated DAF [4 for vanadium] was used for analytes that did not have a sample-specific DAF.

[d] U.S. Environmental Protection Agency (USEPA) regional screening levels generic tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.

[e] Kd value for organic chemicals calculated by multiplying K_{oc} by f_{oc} of 0.0309.

CAS = Chemical Abstract Service.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
DAF = Dilution Attenuation Factor (DAF = 20).
ID = Identifier.
K_{oc} = Organic Carbon Partition Coefficient.
K_d = Distribution Coefficient.
MCL = Maximum Contaminant Level.
NA = Not Applicable.
RSL = Regional Screening Level.

Table G-7. Initial Sediment Screening Results for Load Line 2

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	1.64E+04	FSW-SD-034-0000	NA	NA	1.50E+03	d	1.09E+01	9	1.21E+00	2.00E+01	RSL	No
Antimony	**7440-36-0**	**0.00E+00**	**9.50E+00**	**FSW-SD-034-0000**	**NA**	**NA**	**4.50E+01**	**d**	**2.11E-01**	**1**	**1.68E-01**	**6.00E-03**	**MCL**	**Yes**
Beryllium	7440-41-7	3.80E-01	9.60E-01	FSW-SD-034-0000	NA	NA	7.90E+02	d	1.22E-03	1	9.65E-04	4.00E-03	MCL	No
Cadmium	**7440-43-9**	**0.00E+00**	**7.90E-01**	**FSW-SD-034-0000**	**NA**	**NA**	**7.50E+01**	**d**	**1.05E-02**	**1**	**8.36E-03**	**5.00E-03**	**MCL**	**Yes**
Chromium	7440-47-3	1.81E+01	3.62E+01	FSW-SD-034-0000	NA	NA	1.90E+01	d	1.91E+00	1191	1.60E-03	1.00E-01	MCL	No
Cobalt	**7440-48-4**	**9.10E+00**	**1.22E+01**	**FSW-SD-034-0000**	**NA**	**NA**	**4.50E+01**	**d**	**2.71E-01**	**1**	**2.15E-01**	**6.00E-03**	**RSL**	**Yes**
Copper	7440-50-8	2.76E+01	2.88E+01	LL2sd-053-1129-SD	NA	NA	3.50E+01	d	8.23E-01	117	7.03E-03	1.30E+00	MCL	No
Lead	7439-92-1	2.74E+01	1.01E+02	LL2SD-633-2529-SD	NA	NA	9.00E+02	d	1.12E-01	26	4.27E-03	1.50E-02	MCL	No
Mercury	7439-97-6	5.90E-02	8.30E-02	FSW-SD-034-0000	NA	NA	5.20E+01	d	1.60E-03	1	1.27E-03	2.00E-03	MCL	No
Nickel	7440-02-0	1.77E+01	3.03E+01	FSW-SD-034-0000	NA	NA	6.50E+01	d	4.66E-01	222	2.10E-03	3.90E-01	RSL	No
Selenium	7782-49-2	1.70E+00	2.10E+00	FSW-SD-034-0000	NA	NA	5.00E+00	d	4.20E-01	168	2.50E-03	5.00E-02	MCL	No
Silver	**7440-22-4**	**0.00E+00**	**4.10E+00**	**LL2sd-055-1133-SD**	**NA**	**NA**	**8.30E+00**	**d**	**4.94E-01**	**1**	**3.92E-01**	**9.40E-02**	**RSL**	**Yes**
Vanadium	7440-62-2	2.61E+01	2.88E+01	FSW-SD-034-0000	NA	NA	1.00E+03	d	2.88E-02	8	3.54E-03	8.60E-02	RSL	No
Anions														
Nitrate/Nitrite (NO3/NO2-N)	14797-55-8	NA	5.60E+00	FSW-SD-034-0000	NA	NA	NA	NA	NA	NA	NA	10	MCL	No
Miscellaneous														
Ammonia	7664-41-7	NA	5.40E+01	FSW-SD-034-0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	No
Explosives														
2,4,6-Trinitrotoluene	118-96-7	NA	2.70E-01	LLsd-182-0998-SD	2.81E+03	d	3.43E+01	e	7.87E-03	1	6.25E-03	9.80E-03	RSL	No
2,4-Dinitrotoluene	**121-14-2**	**NA**	**1.90E-01**	**LLsd-182-0998-SD**	**5.76E+02**	**d**	**7.02E+00**	**e**	**2.71E-02**	**1**	**2.15E-02**	**2.40E-03**	**RSL**	**Yes**
4-Amino-2,6-Dinitrotoluene	19406-51-0	NA	1.30E-01	LLsd-182-0998-SD	2.83E+02	d	3.45E+00	e	3.77E-02	1	2.99E-02	3.90E-02	RSL	No
Nitrocellulose	9004-70-0	NA	4.30E-01	LL2sd-271-1076-SD	1.00E+01	d	1.22E-01	e	3.52E+00	1	2.80E+00	6.00E+04	RSL	No
Semi-volatile Organic Chemicals														
Acenaphthene	83-32-9	NA	9.30E-01	LL2SD-631-2528-SD	5.03E+03	d	6.13E+01	e	1.52E-02	1	1.20E-02	5.30E-01	RSL	No
Acenaphthylene[g]	208-96-8	NA	3.73E-01	LL2SD-631-2528-SD	7.40E+03	f	9.03E+01	e	4.13E-03	1	3.28E-03	5.30E-01	RSL	No
Anthracene	120-12-7	NA	2.33E+00	LL2SD-631-2528-SD	1.64E+04	d	2.00E+02	e	1.17E-02	1	9.27E-03	1.80E+00	RSL	No
Benz(a)anthracene	**56-55-3**	**NA**	**1.64E+01**	**LL2SD-631-2528-SD**	**1.77E+05**	**d**	**2.16E+03**	**e**	**7.60E-03**	**1**	**6.03E-03**	**1.20E-04**	**RSL**	**Yes**
Benzo(a)pyrene	**50-32-8**	**NA**	**2.36E+01**	**LL2SD-631-2528-SD**	**5.87E+05**	**d**	**7.17E+03**	**e**	**3.29E-03**	**1**	**2.62E-03**	**2.00E-04**	**MCL**	**Yes**
Benzo(b)fluoranthene	**205-99-2**	**NA**	**4.12E+01**	**LL2SD-631-2528-SD**	**5.99E+05**	**d**	**7.31E+03**	**e**	**5.63E-03**	**1**	**4.47E-03**	**3.40E-04**	**RSL**	**Yes**
Benzo(g,h,i)perylene[h]	191-24-2	NA	2.02E+01	LL2SD-631-2528-SD	1.07E+07	f	1.31E+05	e	1.55E-04	1	1.23E-04	1.20E-01	RSL	No
Benzo(k)fluoranthene	207-08-9	NA	1.31E+01	LL2SD-631-2528-SD	5.87E+05	d	7.17E+03	e	1.83E-03	1	1.45E-03	3.40E-03	RSL	No
Bis(2-ethylhexyl)phthalate	117-81-7	NA	1.45E-01	FSW-SD-034-0000	1.20E+05	d	1.46E+03	e	9.94E-05	1	7.89E-05	6.00E-03	MCL	No
Carbazole	86-74-8	NA	3.65E-01	FSW-SD-034-0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	No
Chrysene	218-01-9	NA	2.08E+01	LL2SD-631-2528-SD	1.81E+05	d	2.20E+03	e	9.45E-03	1	7.50E-03	3.40E-02	RSL	No
Di-n-butyl phthalate	84-74-2	NA	2.25E+00	FSW-SD-034-0000	1.16E+03	d	1.41E+01	e	1.59E-01	39	4.10E-03	9.00E-01	RSL	No
Dibenz(a,h)anthracene	**53-70-3**	**NA**	**4.55E+00**	**LL2SD-631-2528-SD**	**1.91E+06**	**d**	**2.33E+04**	**e**	**1.95E-04**	**1**	**1.55E-04**	**3.40E-05**	**RSL**	**Yes**
Fluoranthene	206-44-0	NA	3.32E+01	LL2SD-631-2528-SD	5.55E+04	d	6.76E+02	e	4.91E-02	1	3.90E-02	8.00E-01	RSL	No
Fluorene	86-73-7	NA	6.88E-01	LL2SD-631-2528-SD	9.16E+03	d	1.12E+02	e	6.16E-03	1	4.89E-03	2.90E-01	RSL	No
Indeno(1,2,3-cd)pyrene	**193-39-5**	**NA**	**1.91E+01**	**LL2SD-631-2528-SD**	**1.95E+06**	**d**	**2.38E+04**	**e**	**8.02E-04**	**1**	**6.37E-04**	**3.40E-04**	**RSL**	**Yes**
Naphthalene	**91-20-3**	**NA**	**3.15E-01**	**LL2SD-631-2528-SD**	**1.54E+03**	**d**	**1.88E+01**	**e**	**1.67E-02**	**1**	**1.33E-02**	**1.70E-03**	**RSL**	**Yes**
Phenanthrene[h]	85-01-8	NA	8.59E+00	LL2SD-631-2528-SD	1.82E+04	f	2.22E+02	e	3.87E-02	1	3.07E-02	1.20E-01	RSL	No
Pyrene	129-00-0	NA	2.86E+01	LL2SD-631-2528-SD	5.43E+04	d	6.63E+02	e	4.31E-02	1	3.43E-02	1.20E-01	RSL	No

Table G-7. Initial Sediment Screening Results for Load Line 2 (continued)

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)
Pesticides/PCBs														
4,4'-DDD	72-54-8	NA	1.50E-02	FSW-SD-034-0000	1.18E+05	d	1.43E+03	e	1.05E-05	1	8.31E-06	3.20E-04	RSL	No
4,4'-DDE	72-55-9	NA	2.10E-02	LLsd-182-0998-SD	1.18E+05	d	1.43E+03	e	1.46E-05	1	1.16E-05	4.60E-04	RSL	No
4,4'-DDT	50-29-3	NA	3.70E-03	LLsd-182-0998-SD	1.69E+05	d	2.06E+03	e	1.80E-06	1	1.43E-06	2.30E-03	RSL	No
Endrin ketone	53494-70-5	NA	1.00E-02	LLsd-182-0998-SD	5.50E+03	i	6.71E+01	e	1.49E-04	1	1.18E-04	2.00E-03	MCL	No
beta-BHC	**319-85-7**	**NA**	**7.90E-02**	**LLsd-182-0998-SD**	**2.81E+03**	**d**	**3.42E+01**	**e**	**2.31E-03**	**1**	**1.83E-03**	**2.50E-04**	**RSL**	**Yes**

Bold = CMCOPCs carried forward into next screen.

[a] Background criteria for sediment from final facility-wide background values for RVAAP, 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] A chemical-specific DAF was calculated based on the sediment and co-located surface water concentrations used in the screening. The lowest calculated DAF [1.3 for antimony] was used for analytes that did not have a sample-specific DAF.

[d] U.S. Environmental Protection Agency (USEPA) regional screening levels generic tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.

[e] K_d value for organic chemicals calculated by multiplying K_{oc} by f_{oc} of 0.0122.

[f] USEPA 1994. Risk Reduction Engineering Laboratory (RREL) Treatability Database, Version 5.0, Office of Research and Development, Cincinnati, Ohio.

[g] Acenaphthene RSL was used as a surrogate for acenaphthylene.

[h] Pyrene RSL was used as a surrogate for benzo(g,h,i)perylene and phenanthrene.

[i] Lyman et al 1990. Handbook of Chemical Property Estimation Methods. W. J. Lyman, W. F. Reehl and D. H. Rosenblatt. American Chemical Society, Washington DC, 1990. 960 pp. ISBN 0-8412-1761-0.

AT123D = Analytical Transient 1-,2-,3-Dimensional.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
DAF = Dilution Attenuation Factor (DAF = 20).
K_{oc} = Organic Carbon Distribution Coefficient.
K_d = Distribution Coefficient.
MCL = Maximum Contaminant Level.
NA = Not Applicable.
RSL = Regional Screening Level.
SRC = Site-related Contaminant.

Table G-8. Initial Sediment Screening Results for Load Line 3

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														
Antimony	**7440-36-0**	**0.00E+00**	**1.82E+01**	**LL3sd-051-1079-SD**	**NA**	**NA**	**4.50E+01**	**d**	**4.04E-01**	**24**	**1.66E-02**	**6.00E-03**	**MCL**	**Yes**
Beryllium	7440-41-7	3.80E-01	6.60E-01	LL3sd-156-0960-SD	NA	NA	7.90E+02	d	8.35E-04	24	3.42E-05	4.00E-03	MCL	No
Cadmium	7440-43-9	0.00E+00	3.50E+00	LL3sd-051-1079-SD	NA	NA	7.50E+01	d	4.67E-02	24	1.91E-03	5.00E-03	MCL	No
Chromium	7440-47-3	1.81E+01	2.01E+01	LL3sd-051-1079-SD	NA	NA	1.90E+01	d	1.06E+00	24	4.34E-02	1.00E-01	MCL	No
Cobalt	**7440-48-4**	**9.10E+00**	**1.53E+01**	**LL3sd-051-1079-SD**	**NA**	**NA**	**4.50E+01**	**d**	**3.40E-01**	**36**	**9.56E-03**	**6.00E-03**	**RSL**	**Yes**
Copper	7440-50-8	2.76E+01	2.22E+02	LL3sd-051-1079-SD	NA	NA	3.50E+01	d	6.34E+00	24	2.60E-01	1.30E+00	MCL	No
Lead	7439-92-1	2.74E+01	9.16E+01	LL3sd-051-1079-SD	NA	NA	9.00E+02	d	1.02E-01	24	4.17E-03	1.50E-02	MCL	No
Nickel	7440-02-0	1.77E+01	4.20E+01	LL3sd-051-1079-SD	NA	NA	6.50E+01	d	6.46E-01	24	2.65E-02	3.90E-01	RSL	No
Silver	7440-22-4	0.00E+00	1.05E+01	LL3sd-051-1079-SD	NA	NA	8.30E+00	d	1.27E+00	24	5.18E-02	9.40E-02	RSL	No
Zinc	7440-66-6	5.32E+02	2.19E+03	LL3sd-051-1079-SD	NA	NA	6.20E+01	d	3.53E+01	42	8.40E-01	6.00E+00	RSL	No
Explosives														
2,4,6-Trinitrotoluene	118-96-7	NA	6.50E-01	LL3sd-053-1073-SD	2.81E+03	d	4.84E+01	e	1.34E-02	24	5.51E-04	9.80E-03	RSL	No
4-Amino-2,6-Dinitrotoluene	19406-51-0	NA	3.70E-01	LL3sd-053-1073-SD	2.83E+02	d	4.87E+00	e	7.60E-02	24	3.11E-03	3.90E-02	RSL	No
Pesticides/PCBs														
PCB-1254	11097-69-1	NA	1.80E-01	LL3sd-052-1071-SD	1.31E+05	d	2.24E+03	e	8.02E-05	24	3.29E-06	7.80E-05	RSL	No

Bold = CMCOPCs carried forward into next screen.

[a] Background criteria for sediment from final facility-wide background values for RVAAP, 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] A chemical-specific DAF was calculated based on the sediment and co-located surface water concentrations used in the screening. The lowest calculated DAF [24 for nickel] was used for analytes that did not have a sample-specific DAF.

[d] U.S. Environmental Protection Agency (USEPA) regional screening levels generic tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables.

[e] Kd value for organic chemicals calculated by multiplying K_{oc} by f_{oc} of 0.0172.

CAS = Chemical Abstract Service.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
DAF = Dilution Attenuation Factor (DAF = 20).
K_{oc} = Organic Carbon Distribution Coefficient.
K_d = Distribution Coefficient.
MCL = Maximum Contaminant Level.
NA = Not Applicable.
RSL = Regional Screening Level.
SRC = Site-related Contaminant.

Table G-9. Initial Sediment Screening Results for Load Line 4

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	1.65E+04	LL4sd-055-0969-SD	NA	NA	1.50E+03	d	1.10E+01	5	2.32E+00	2.00E+01	RSL	No
Antimony	**7440-36-0**	**0.00E+00**	**1.80E+00**	**FSW-SD-025-0000**	**NA**	**NA**	**4.50E+01**	**d**	**4.00E-02**	**4**	**9.75E-03**	**6.00E-03**	**MCL**	**Yes**
Barium	7440-39-3	1.23E+02	1.63E+02	LL4sd-055-0969-SD	NA	NA	4.10E+01	d	3.98E+00	14	2.78E-01	2.00E+00	MCL	No
Beryllium	7440-41-7	3.80E-01	6.20E-01	FSW-SD-032-0000	NA	NA	7.90E+02	d	7.85E-04	4	1.91E-04	4.00E-03	MCL	No
Cadmium	7440-43-9	0.00E+00	1.00E+00	LL4sd-055-0969-SD	NA	NA	7.50E+01	d	1.33E-02	11	1.20E-03	5.00E-03	MCL	No
Chromium	7440-47-3	1.81E+01	2.15E+01	LL4sd-055-0969-SD	NA	NA	1.90E+01	d	1.13E+00	364	3.11E-03	1.00E-01	MCL	No
Chromium, hexavalent	**18540-29-9**	**NA**	**1.40E+00**	**LL4sd-057-0973-SD**	**NA**	**NA**	**1.90E+01**	**d**	**7.37E-02**	**4**	**1.80E-02**	**3.50E-04**	**RSL**	**Yes**
Cobalt	**7440-48-4**	**9.10E+00**	**1.68E+01**	**LL4sd-054-0967-SD**	**NA**	**NA**	**4.50E+01**	**d**	**3.73E-01**	**4**	**9.10E-02**	**6.00E-03**	**RSL**	**Yes**
Copper	7440-50-8	2.76E+01	3.12E+01	LL4sd-055-0969-SD	NA	NA	3.50E+01	d	8.91E-01	4	2.17E-01	1.30E+00	MCL	No
Lead	7439-92-1	2.74E+01	2.77E+01	LL4sd-055-0969-SD	NA	NA	9.00E+02	d	3.08E-02	4	7.50E-03	1.50E-02	MCL	No
Mercury	7439-97-6	5.90E-02	1.30E-01	LL4sd-054-0967-SD	NA	NA	5.20E+01	d	2.50E-03	7	3.66E-04	2.00E-03	MCL	No
Nickel	7440-02-0	1.77E+01	3.34E+01	LL4sd-055-0969-SD	NA	NA	6.50E+01	d	5.14E-01	85	6.04E-03	3.90E-01	RSL	No
Thallium	**7440-28-0**	**8.90E-01**	**2.70E+00**	**LL4sd-055-0969-SD**	**NA**	**NA**	**7.10E+01**	**d**	**3.80E-02**	**4**	**9.27E-03**	**2.00E-03**	**MCL**	**Yes**
Vanadium	7440-62-2	2.61E+01	2.70E+01	LL4sd-055-0969-SD	NA	NA	1.00E+03	d	2.70E-02	6	4.67E-03	8.60E-02	RSL	No
Anions														
Nitrate/Nitrite (NO3/NO2-N)	14797-55-8	NA	7.50E+00	FSW-SD-032-0000	NA	NA	NA	NA	NA	NA	NA	10	MCL	No
Miscellaneous														
Ammonia	7664-41-7	NA	8.10E+01	FSW-SD-032-0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	No
Semi-volatile Organic Chemicals														
Di-n-butyl phthalate	84-74-2	NA	1.80E+00	FSW-SD-032-0000	1.16E+03	d	1.54E+01	e	1.17E-01	37	3.20E-03	9.00E-01	RSL	No
Pesticides/PCBs														
PCB-1248	12672-29-6	NA	9.00E-02	LL4sd-058-0975-SD	7.65E+04	d	1.02E+03	e	8.84E-05	4	2.16E-05	7.80E-05	RSL	No
Volatile Organic Chemicals														
2-Butanone	78-93-3	NA	1.10E-01	LL4sd-054-0967-SD	4.51E+00	d	6.00E-02	e	1.83E+00	4	4.47E-01	5.60E+00	RSL	No
Acetone	67-64-1	NA	4.10E-01	LL4sd-054-0967-SD	2.36E+00	d	3.14E-02	e	1.30E+01	4207	3.10E-03	1.40E+01	RSL	No
Toluene	108-88-3	NA	3.80E-03	LL4sd-048-0957-SD	2.34E+02	d	3.11E+00	e	1.22E-03	4	2.98E-04	1.00E+00	MCL	No

Bold = CMCOPCs carried forward into next screen.

[a] Background criteria for sediment from final facility-wide background values for RVAAP, 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] A chemical-specific DAF was calculated based on the sediment and co-located surface water concentrations used in the screening. The lowest calculated DAF [4 for lead] was used for analytes that did not have a sample-specific DAF.

[d] U.S. Environmental Protection Agency (USEPA) regional screening levels generic tables May 2016; found at: http://www2.epa.gov/risk/risk-based-screening-table-generic-tables

[e] Kd value for organic chemicals calculated by multiplying K_{oc} by f_{oc} of 0.0133.

AT123D = Analytical Transient 1-,2-,3-Dimensional.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
DAF = Dilution Attenuation Factor (DAF = 20).
K_{oc} = Organic Carbon Distribution Coefficient.
K_d = Distribution Coefficient.
MCL = Maximum Contaminant Level.
NA = Not Applicable.
RSL = Regional Screening Level.
SRC = Site-related Contaminant.

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Table G-10. Final Sediment Screening to Identify the Sediment COIs for AT123D Modeling

Initial Sediment CMCOPCs	CAS Number	Maximum Detected Surface Water Concentration (mg/L)	Surface Water Sample ID at Maximum Detect	MCL or RSL (mg/L)	MCL or RSL?	Maximum Detected Surface Water Concentration > MCL or RSL?	Final Sediment CMCOPC?[a]
Load Line 1							
Antimony	7440-36-0	ND	NA	6.00E-03	MCL	No	No
Cadmium	7440-43-9	ND	NA	5.00E-03	MCL	No	No
Chromium	7440-47-3	2.40E-03	LL1sw-059-1070-SW	1.00E-01	MCL	No	No
Cobalt	7440-48-4	4.60E-03	LL1sw-320-1094-SW	6.00E-03	RSL	No	No
Copper	7440-50-8	ND	NA	1.30E+00	MCL	No	No
Lead	7439-92-1	3.10E-03	LL1sw-059-1070-SW	1.50E-02	MCL	No	No
Selenium	7782-49-2	ND	NA	5.00E-02	MCL	No	No
Thallium	7440-28-0	ND	NA	2.00E-03	MCL	No	No
Load Line 2							
Antimony	**7440-36-0**	**1.50E-02**	**LL2sw-053-1130-SW**	**6.00E-03**	**MCL**	**Yes**	**Yes**
Cadmium	7440-43-9	2.80E-04	LL2sw-052-1128-SW	5.00E-03	MCL	No	No
Cobalt	7440-48-4	7.70E-04	FSW-SW-074-0000	6.00E-03	RSL	No	No
Silver	7440-22-4	1.20E-03	FSW-SW-034-0000	9.40E-02	RSL	No	No
2,4-Dinitrotoluene	121-14-2	ND	NA	2.40E-03	RSL	No	No
Benz(a)anthracene	56-55-3	ND	NA	1.20E-04	RSL	No	No
Benzo(a)pyrene	50-32-8	ND	NA	2.00E-04	MCL	No	No
Benzo(b)fluoranthene	205-99-2	ND	NA	3.40E-04	RSL	No	No
Dibenz(a,h)anthracene	53-70-3	ND	NA	3.40E-05	RSL	No	No
Indeno(1,2,3-cd)pyrene	193-39-5	ND	NA	3.40E-04	RSL	No	No
Naphthalene	91-20-3	ND	NA	1.70E-03	RSL	No	No
beta-BHC	319-85-7	ND	NA	2.50E-04	RSL	No	No
Load Line 3							
Antimony	7440-36-0	2.50E-03	LL3sw-052-1072-SW	6.00E-03	MCL	No	No
Cobalt	**7440-48-4**	**6.50E-03**	**LL3sw-052-1072-SW**	**6.00E-03**	**RSL**	**Yes**	**Yes**
Load Line 4							
Antimony	7440-36-0	2.50E-03	LL4sw-057-0974-SW	6.00E-03	MCL	No	No
Chromium, hexavalent	**18540-29-9**	**Not analyzed**	**NA**	**3.50E-04**	**RSL**	**NA**	**Yes**
Cobalt	7440-48-4	ND	NA	6.00E-03	RSL	No	No
Thallium	7440-28-0	ND	NA	2.00E-03	MCL	No	No

Table G-10. Final Sediment Screening to Identify the Sediment COIs for AT123D Modeling (continued)

Bold = Identified final sediment CMCOPC for AT123D Modeling.

[a] Analyte is a sediment CMCOPC if the maximum detected surface water concentration exceeds the MCL or RSL, or if there is no surface water data available. This analysis assumes that groundwater and surface water are in contact and in equilibrium.

AT123D = Analytical Transient 1-, 2-, and 3-Dimensional Model.
CAS = Chemical Abstract Service.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
ID = Identifier.
MCL = Maximum Contaminant Level.
mg/L = Milligrams per Liter.
NA = Not Applicable.
ND = Not Detected.
RSL = Regional Screening Level (USEPA 2016).

Table G-11. Climatic Data from SESOIL

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	7.40	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	0.30	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	7.40	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	9.80	0.30	6.06	30.4
August	21.11	0.55	0.70	0.16	0.00	8.14	0.30	6.06	30.4
September	17.67	0.55	0.70	0.16	0.00	7.85	0.40	5.44	30.4

[a] Data calculated in SESOIL model from Gerber Dam, Oregon; 0.00 indicates evapotranspiration is calculated from other climatic data.
1996 data from Youngstown, Ohio, Weather Service Office – Airport Station.
SESOIL = Seasonal Soil Compartment.

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Table G-12. Unit-Specific Parameters Used in SESOIL and AT123D Modeling for Load Lines 1 through 4 and 12

Parameters	Symbol	Units	Load Line 1	Load Line 2	Load Line 3	Load Line 4	Load Line 12	Source for Value
SESOIL								
Percolation Rate (Recharge Rate)	q	m/yr	9.42E-02	9.42E-02	9.42E-02	9.42E-02	9.42E-02	0.1 SESOIL Precipitation for Youngstown, Ohio
Horizontal Area	A_p	cm^2	2.97E+08	4.18E+07	4.18E+07	5.62E+07	1.80E+07	Load Line Specific
Intrinsic Permeability – clayey sand	p	cm^2	1.05E-10	1.05E-10	1.05E-10	1.05E-10	1.05E-10	Calibrated from SESOIL model
Disconnectedness Index	c	unitless	11	11	11	11	11	Calibrated from SESOIL model
Freundlich Equation Exponent	n	unitless	1	1	1	1	1	SESOIL default
Fraction Organic Carbon[a]	f_{oc}	unitless	3.09E-02	1.22E-02	1.72E-02	1.33E-02	6.27E-03	Based on the site-specific geotechnical data from the Final Phase II RIs for Load Lines 1, 2, 3, and 4 and the Draft Final Phase III RI for Load Line 12.
Bulk Density	$\square_b$	kg/L	1.67	1.63	1.63	1.77	1.63	Based on the site-specific geotechnical data from the Final Phase II RIs for Load Lines 1 and 4 and the Draft Final Phase III RI for Load Line 12. The bulk density for Load Line 12 was used for Load Lines 2 and 3.
Moisture Content	w	wt %	14.0	16.2	16.4	18.9	20.1	Based on the site-specific geotechnical data from the Final Phase II RIs for Load Lines 1, 2, 3, and 4 and the Draft Final Phase III RI for Load Line 12.
Water-filled Soil Porosity	Tw	unitless	0.234	0.264	0.267	0.335	0.328	Calculated based on moisture content and bulk density.
Air-filled Soil Porosity	Ta	unitless	0.136	0.095	0.092	0.031	0.031	Water-filled soil porosity subtracted from total porosity.
Porosity – Total	n_T	unitless	0.370	0.359	0.359	0.366	0.359	Based on the site-specific geotechnical data from the Final Phase II RIs for Load Lines 1 and 4 and the Draft Final Phase III RI for Load Line 12. The bulk density for Load Line 12 was used for Load Lines 2 and 3.
Vadose Zone Thickness	Vz	m	6.4	3.05 - 3.35	5.33 - 8.56	4.27	1.52 - 2.94	Based on topography and water level data.
Leaching Zone Thickness	Th	m	4.3 - 6.1	0.91 - 1.2	3.05 - 7.01	3.96	1.04 - 2.64	Based on soil contamination and vadose zone thickness.
AT123D								
Aquifer Thickness	h	m	6	15	30	30	6	Conservative assumptions used in the Final Phase II RIs for Load Lines 1, 2, 3, and 4 and the Draft Final Phase III RI for Load Line 12.
Hydraulic Conductivity in Saturated Zone	K_S	cm/s	2.73E-04	1.11E-03	5.42E-05	4.43E-04	2.49E-05	Average of the site-specific slug test data from bedrock wells at Load Lines 1, 2, 3, and 4 and unconsolidated wells at Load Line 12.
Hydraulic Gradient in Saturated Zone	i	m/m	1.80E-02	1.00E-02	1.00E-02	2.00E-03	4.60E-03	Groundwater potentiometric map presented in the Final Phase II RIs for Load Lines 1, 2, 3, and 4 and the Draft Final Phase III RI for Load Line 12.
Effective Porosity	n_e	unitless	0.2	0.2	0.2	0.2	0.2	Assumed for sandstone (USEPA 1985)
Dispersivity, Longitudinal	α_L	m	30	30	30	30	30	Assumed
Dispersivity, Transverse	α_T	m	3	3	3	3	3	0.1 α_L
Dispersivity, Vertical	α_V	m	0.3	0.3	0.3	0.3	0.3	0.01 α_L
Downgradient Receptor Location	-	-	Criggy's Pond	Kelly's Pond	Unnamed Tributary to Cobbs Pond	Load Line 4 Pond (Soil) or RVAAP Boundary (Sediment)	North of Active Area Channel or the RVAAP Boundary	Based on groundwater flow direction and the nearest surface water body.

[a] Fraction organic carbon (F_{oc}) = Total organic carbon ´ 10-6. Total organic carbon is derived from geotechnical analyses.

AT123D = Analytical Transient 1-, 2-, and 3-Dimensional Model.
RI = Remedial Investigation.
SESOIL = Seasonal Soil Compartment.

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Table G-13. Load Application Data for SESOIL Model

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Load Line 1 – 21-ft-Thick Vadose Zone for Nitrobenzene							
Nitrobenzene	4	1	1	2	1	0.59	Contaminant Loading
					2	0.59	
		2	6	3	1	0	Leaching
					2	0	
					3	0	
		3	14	2	1	0	
					2	0	
		4	0.5	1	1	0	
Load Line 1 – 21-ft-Thick Vadose Zone for RDX							
RDX	4	1	1	2	1	67	Contaminant Loading
					2	67	
		2	6	3	1	1500	
					2	1500	
					3	8.6	
		3	14	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 2 – 10-ft-Thick Vadose Zone for 2,4-Dinitrotoluene							
2,4-Dinitrotoluene	4	1	1	2	1	3.3	Contaminant Loading
					2	3.3	
		2	6	3	1	0.39	
					2	0.2	
					3	0.24	
		3	3	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 2 – 11-ft-Thick Vadose Zone for RDX							
RDX	4	1	1	2	1	25	Contaminant Loading
					2	25	
		2	6	3	1	9.65	
					2	0.24	
					3	0.092	
		3	4	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 3 – 17-ft-Thick Vadose Zone for 2,6-Dinitrotoluene							
2,6-Dinitrotoluene	4	1	1	2	1	0.23	Contaminant Loading
					2	0.23	
		2	6	3	1	0	Leaching
					2	0	
					3	0	
		3	10	2	1	0	
					2	0	
		4	0.5	1	1	0	

Table G-13. Load Application Data for SESOIL Model (continued)

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Load Line 3 – 28-ft-Thick Vadose Zone for RDX							
RDX	4	1	1	2	1	34	Contaminant Loading
					2	34	
		2	4	4	1	0.17	
					2	1.28	
					3	1.28	
					4	0.082	
		3	23	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 4 – 14-ft-Thick Vadose Zone for RDX							
RDX	4	1	1	2	1	19	Contaminant Loading
					2	19	
		2	6	3	1	0	Leaching
					2	0	
					3	0	
		3	7	2	1	0	
					2	0	
		4	0.5	1	1	0	
Load Line 12 – 7.4-ft-Thick Vadose Zone for 1,3-Dinitrobenzene							
1,3-Dinitrobenzene	4	1	1	2	1	0	Contaminant Loading
					2	0	
		2	2	1	1	0.032	
		3	4.4	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 12 – 7.4-ft-Thick Vadose Zone for 2,4-Dinitrotoluene							
2,4-Dinitrotoluene	4	1	1	2	1	0	Contaminant Loading
					2	0	
		2	2	1	1	0.17	
		3	4.4	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 12 – 7.4-ft-Thick Vadose Zone for 2,6-Dinitrotoluene							
2,6-Dinitrotoluene	4	1	1	2	1	1.7	Contaminant Loading
					2	1.7	
		2	2	1	1	1.5	
		3	4.4	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 12 – 5.0-ft-Thick Vadose Zone for 3-Nitrotoluene							
3-Nitrotoluene	4	1	1	2	1	0.22	Contaminant Loading
					2	0.22	
		2	2	1	1	0.14	
		3	2	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	

Table G-13. Load Application Data for SESOIL Model (continued)

Analyte	Number of Layers	Layer Number	Thickness of Layer (ft)	Number of Sublayers	Sublayer Number	Maximum Concentration (mg/kg)	Layer Purpose
Load Line 12 – 9.7-ft-Thick Vadose Zone for 4-Nitrotoluene							
4-Nitrotoluene	4	1	1	2	1	0.2	Contaminant Loading
					2	0.2	
		2	2	2	1	0	Leaching
					2	0	
		3	6.7	2	1	0	
					2	0	
		4	0.5	1	1	0	
Load Line 12 – 8.5-ft-Thick Vadose Zone for Nitrotoluene							
Nitrobenzene	4	1	3	3	1	0.093	Contaminant Loading
					2	0.1	
					3	0.1	
		2	0.5	1	1	0.12	
		3	5	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	
Load Line 12 – 6.4-ft-Thick Vadose Zone for RDX							
RDX	4	1	1	2	1	12	Contaminant Loading
					2	12	
		2	4	2	1	21	
					2	0.25	
		3	1.4	2	1	0	Leaching
					2	0	
		4	0.5	1	1	0	

RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.

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Table G-14. Summary of SESOIL Modeling Results

Initial CMCOPC	Maximum Soil Concentration (mg/kg)	Location of Maximum Soil Concentration	Maximum Depth of Contamination (ft bgs)	Depth to Groundwater (ft bgs)	Predicted $C_{L, max}$ Beneath Source (mg/L)	Time Required to Reach $C_{L, max}$ (years)	RSL[a] (mg/L)	Resident Receptor Adult FWCUG[a] (mg/L)	Final CMCOPC?[b] (yes/no)
Load Line 1									
Explosives									
Nitrobenzene	**5.90E-01**	**LL1ss-156-0845-SO**	**1**	**21**	**5.97E+01**	**131**	**1.40E-03**	**1.83E-02**	**Yes**
RDX	**1.50E+03**	**LL1SB-638M-0013-SO**	**7**	**21**	**7.51E-03**	**405**	**7.00E-03**	**7.74E-03**	**Yes**
Load Line 2									
Explosives									
2,4-Dinitrotoluene	**3.30E+00**	**LL2ss-087-0743-SO**	**7**	**10**	**1.44E-01**	**151**	**2.40E-03**	**1.20E-03**	**Yes**
RDX	**2.50E+01**	**LL2ss-162-0944-SO**	**7**	**11**	**7.05E+00**	**30**	**7.00E-03**	**7.74E-03**	**Yes**
Load Line 3									
Explosives									
2,6-Dinitrotoluene	**2.30E-01**	**LL3ss-067-0719-SO**	**1**	**17**	**2.76E-03**	**466**	**4.90E-04**	**1.22E-03**	**Yes**
RDX	**3.40E+01**	**LL3ss-117-0851-SO**	**1**	**28**	**1.24E+00**	**117**	**7.00E-03**	**7.74E-03**	**Yes**
Load Line 4									
Explosives									
RDX	**1.90E+01**	**LL4ss-142-0878-SO**	**1**	**14**	**2.48E+00**	**55**	**7.00E-03**	**7.74E-03**	**Yes**
Load Line 12									
Explosives									
1,3-Dinitrobenzene	**3.20E-02**	**L12so-120-0510-SO**	**3**	**7.4**	**7.53E-03**	**43**	**2.00E-03**	**3.65E-03**	**Yes**
2,4-Dinitrotoluene	**1.70E-01**	**L12so-120-0510-SO**	**3**	**7.4**	**2.53E-02**	**68**	**2.40E-03**	**1.20E-03**	**Yes**
2,6-Dinitrotoluene	**1.70E+00**	**L12ss-143-0553-SO**	**3**	**7.4**	**3.39E-01**	**69**	**4.90E-04**	**1.22E-03**	**Yes**
3-Nitrotoluene	**2.20E-01**	**L12ss-236-0395-SO**	**1**	**5.0**	**8.88E-02**	**29**	**1.70E-03**	**NA**	**Yes**
4-Nitrotoluene	2.00E-01	L12ss-239-0561-SO	1	9.7	1.65E-02	64	4.30E-02	5.01E-02	No
Nitrobenzene	**1.20E-01**	**L12so-059-0374-SO**	**3.5**	**8.5**	**2.70E-02**	**27**	**1.40E-03**	**1.83E-02**	**Yes**
RDX	**2.10E+01**	**L12so-143-0554-SO**	**5**	**6.4**	**2.40E+01**	**10**	**7.00E-03**	**7.74E-03**	**Yes**

Bold = CMCOPCs exceeding RSL within 1,000 years

[a] The RSL and the Resident Receptor Adult FWCUG is based on a target risk of 10-5 and a Hazard Index of 1.

[b] The Final CMCOPC was identified comparing predicted maximum leachate concentration to RSLs and Resident Receptor Adult FWCUGs. A constituent is an initial CMCOPC if its predicted leachate concentration exceeds its RSL within 1,000 years.

bgs = Below Ground Surface.
C_L = Leachate Concentration
CMCOPC = Contaminant Migration Chemical of Potential Concern.
FWCUG = Facility-Wide Cleanup Goal.
mg/kg = Milligram per Kilogram.
mg/L = Milligram per Liter.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
RSL = Regional Screening Level.
SESOIL = Seasonal Soil Compartment Model.

Table G-15. Summary of AT123D Modeling Results

Final CMCOPC	Maximum Leachate Concentration, ($C_{L,\ max}$)[a] (mg/L)	Predicted Max Groundwater Concentration ($C_{gw,MAX}$) Beneath Source[b] (mg/L)	Predicted Max Groundwater Concentration ($C_{R,MAX}$) Downgradient Receptor[b] (mg/L)	Distance to Downgradient Receptor[c] (ft)	MCL/RSL[c] (mg/L)	Resident Receptor Adult FWCUG[d] (mg/L)	Facility-wide Background Groundwater[e] (mg/L)	Observed Maximum Groundwater Concentration[f] (mg/L)	Location of Maximum Groundwater Concentration	Date of Maximum Groundwater Concentration	CMCOC for Further WOE Evaluation?[g] (yes/no)
Final CMCOPCs in Soil											
Load Line 1											
Explosives											
Nitrobenzene	5.97E+01	1.08E-03	0.00E+00	3,200	1.40E-03	1.83E-02	NA	1.20E-04	LL1mw-063	10/10/2008	No
RDX	**7.51E-03**	**2.73E+01**	**7.73E-04**	**3,200**	**7.00E-03**	**7.74E-03**	**NA**	**8.80E-02**	**LL1mw-080**	**7/14/2010**	**Yes**
Load Line 2											
Explosives											
2,4-Dinitrotoluene	**1.44E-01**	**3.25E-02**	**9.51E-09**	**2,850**	**2.40E-03**	**1.20E-03**	**NA**	**4.20E-04**	**LL2mw-059**	**3/24/2015**	**Yes**
RDX	**7.05E+00**	**1.48E+00**	**3.57E-02**	**2,400**	**7.00E-03**	**7.74E-03**	**NA**	**1.30E-03**	**LL2mw-267**	**7/23/2015**	**Yes**
Load Line 3											
Explosives											
2,6-Dinitrotoluene	**2.76E-03**	**3.24E-03**	**0.00E+00**	**1,750**	**4.90E-04**	**1.22E-03**	**NA**	**3.80E-04**	**LL3mw-238**	**7/20/2015**	**Yes**
RDX	**1.24E+00**	**2.11E+00**	**7.77E-06**	**1,100**	**7.00E-03**	**7.74E-03**	**NA**	**6.80E-03**	**LL3mw-238**	**7/20/2015**	**Yes**
Load Line 4											
Explosives											
RDX	**2.48E+00**	**2.03E+00**	**8.11E-02**	**640**	**7.00E-03**	**7.74E-03**	**NA**	**ND**	**NA**	**NA**	**Yes**
Load Line 12											
Explosives											
1,3-Dinitrobenzene	**7.53E-03**	**7.67E-03**	**0.00E+00**	**3,250**	**2.00E-03**	**3.65E-03**	**NA**	**ND**	**NA**	**NA**	**Yes**
2,4-Dinitrotoluene	**2.53E-02**	**2.96E-02**	**0.00E+00**	**3,250**	**2.40E-03**	**1.20E-03**	**NA**	**ND**	**NA**	**NA**	**Yes**
2,6-Dinitrotoluene	**3.39E-01**	**3.96E-01**	**0.00E+00**	**3,500**	**4.90E-04**	**1.22E-03**	**NA**	**ND**	**NA**	**NA**	**Yes**
3-Nitrotoluene	**8.88E-02**	**8.62E-02**	**3.30E-03**	**175**	**1.70E-03**	**NA**	**NA**	**ND**	**NA**	**NA**	**Yes**
Nitrobenzene	**2.70E-02**	**3.00E-02**	**0.00E+00**	**2,375**	**1.40E-03**	**1.83E-02**	**NA**	**ND**	**NA**	**NA**	**Yes**
RDX	**2.40E+01**	**2.63E+01**	**0.00E+00**	**3,500**	**7.00E-03**	**7.74E-03**	**NA**	**6.70E-05**	**L12mw-188**	**7/12/2010**	**Yes**
Final CMCOPCs in Sediment											
Load Line 2											
Metals											
Antimony	**1.68E-01**	**1.68E-01**	**NA**	**0**	**6.00E-03**	**1.30E+01**	**0.00E+00**	**4.30E-04**	**LL2mw-060**	**7/20/2015**	**Yes**
Load Line 3											
Metals											
Cobalt	**1.68E-01**	**1.68E-01**	**NA**	**0**	**6.00E-03**	**7.29E+02**	**0.00E+00**	**7.50E-03**	**LL3mw-236**	**4.08E+04**	**Yes**
Load Line 4											
Metals											
Hexavalent Chromium	**1.80E-02**	**1.80E-02**	**0.00E+00**	**1,200**	**3.50E-04**	**NA**	**NA**	**ND**	**NA**	**NA**	**Yes**

Bold = CMCOCs exceeding RSL and site-specific background within 1,000 years

[a] Represents SESOIL predicted maximum leachate concentration at the water table for soil CMCOPCs and the maximum groundwater concentration divided by the DAF for sediment CMCOPCs.

[b] The predicted concentrations beneath the source and at the downgradient receptor location was estimated using the results from SESOIL for soil and the screening for sediment and applying the AT123D model.

[c] The distance to the downgradient receptor is 0 because the sample was collected from within the receptor location.

[d] The RSL and the Resident Receptor Adult FWCUG is based on a target risk of 10-5 and a Hazard Index of 1.

[e] The facility-wide background groundwater concentrations are for bedrock for Load Lines 1 through 4 and unconsolidated materials for Load Line 12.

[f] Observed maximum groundwater concentrations were based on the maximum detection for the last two sampling events in each well.

[g] The CMCOC was identified comparing predicted concentration in groundwater beneath the source to the RSL and Resident Receptor Adult FWCUGs. A constituent is a CMCOC if its predicted concentration in groundwater exceeds all its screening criteria within 1,000 years.

AT123D = Analytical Transient 1-, 2-, and 3-Dimensional Model.
CMCOC = Contaminant Migration Chemical of Concern.
CMCOPC = Contaminant Migration Chemical of Potential Concern.
FWCUG = Facility-wide Cleanup Goal.
MCL = Maximum Contaminant Level.
mg/L = Milligram per Liter.
NA = Not Available.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
RSL = Regional Screening Level.
WOE = Weight-of-Evidence.

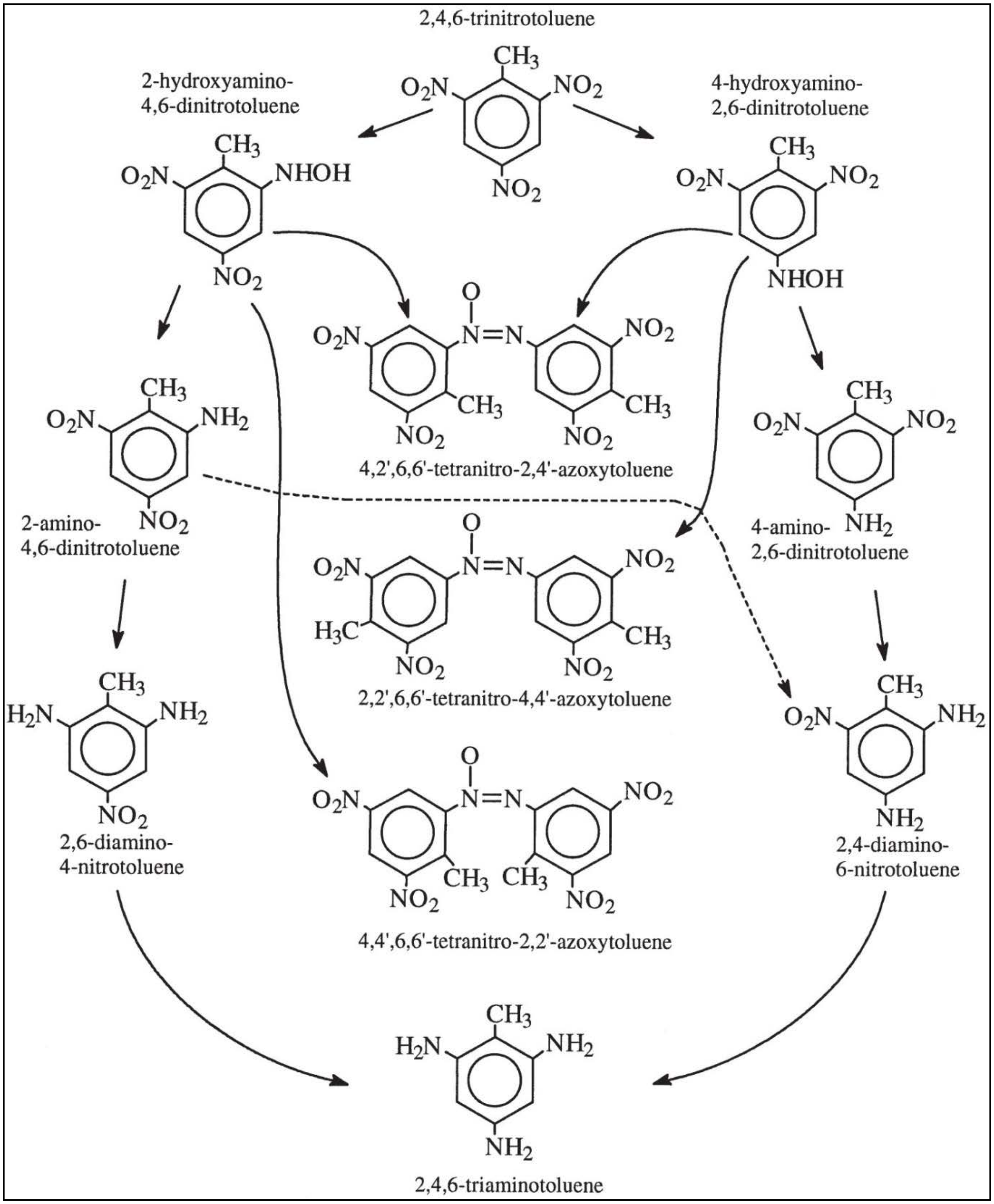


Figure G-1. TNT Biotransformation Pathway

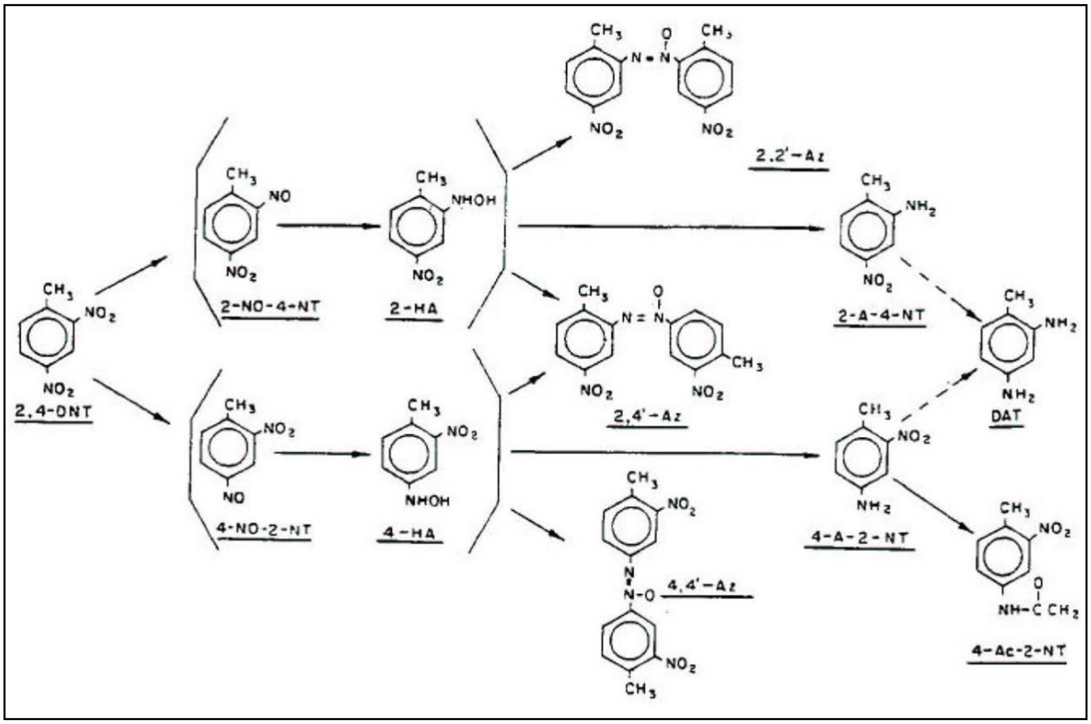


Figure G-2. 2,4-DNT Biotransformation Pathway

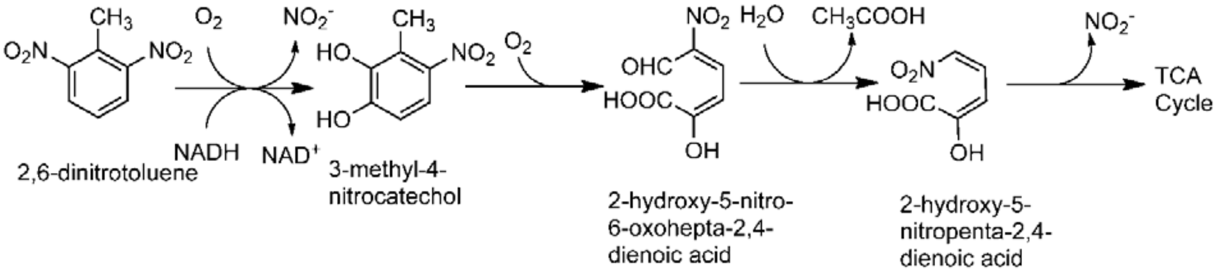


Figure G-3. 2,6-DNT Biotransformation Pathway

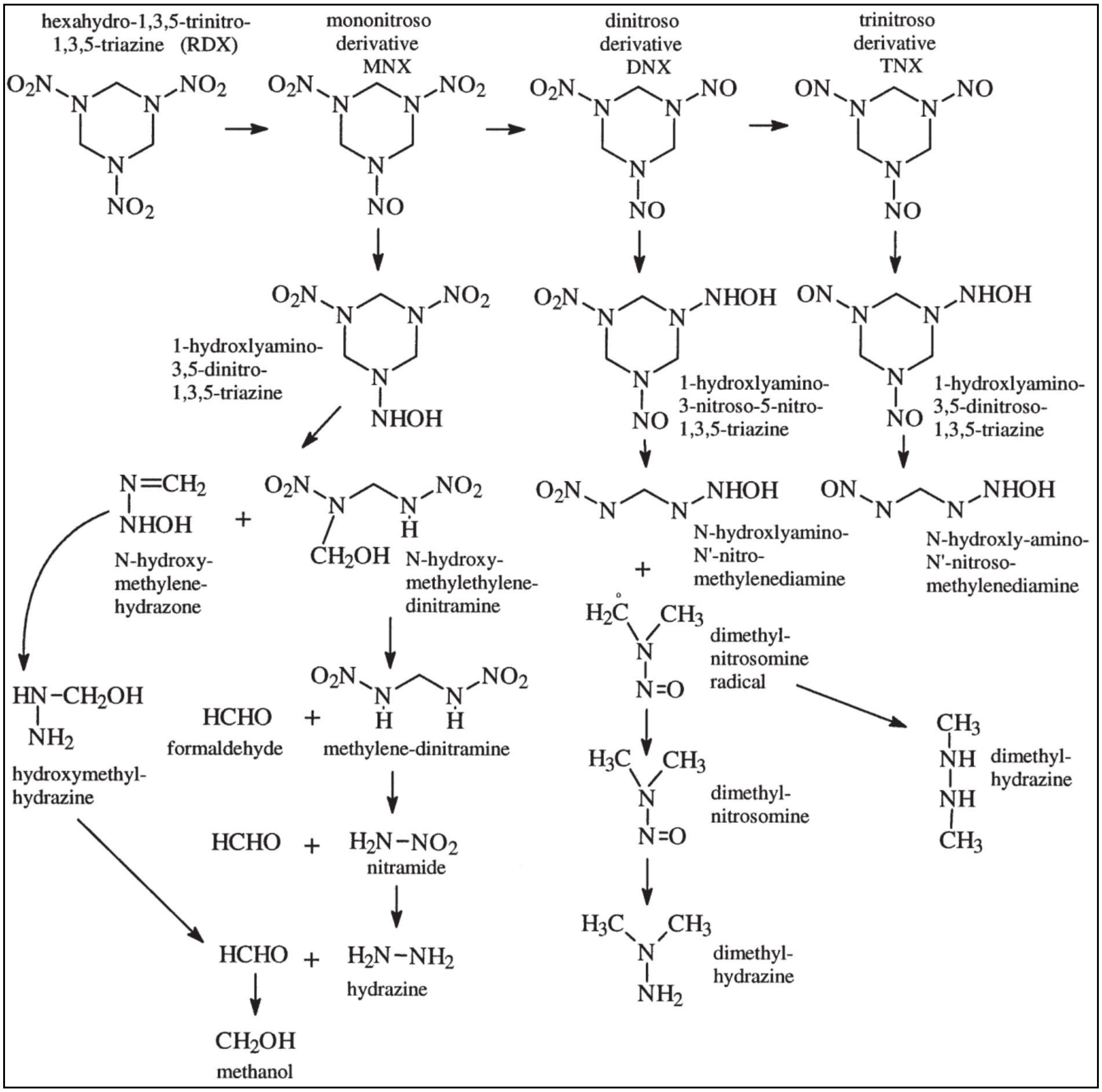
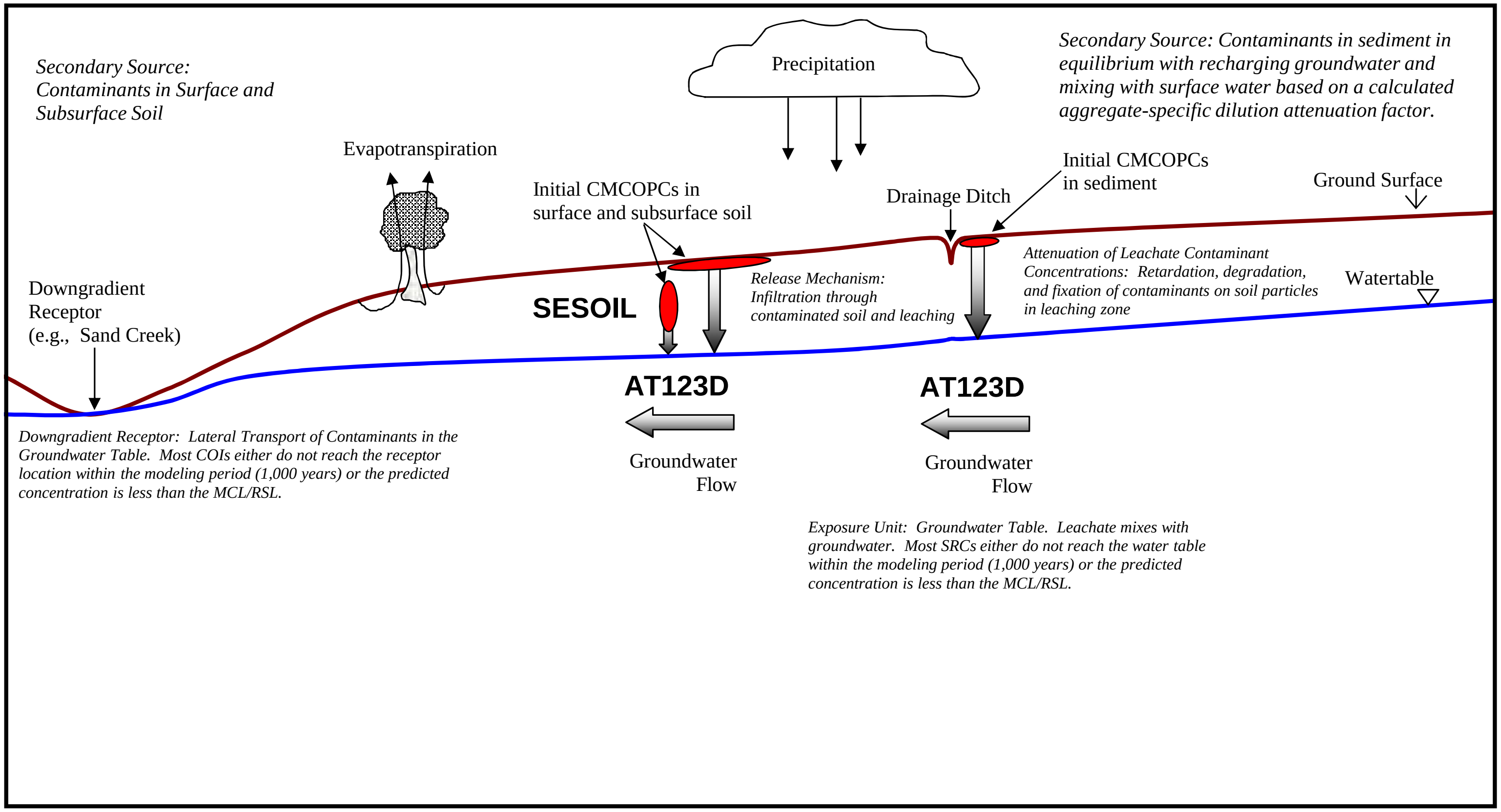


Figure G-4. RDX Biotransformation Pathway



Secondary Source: Contaminants in Surface and Subsurface Soil

Secondary Source: Contaminants in sediment in equilibrium with recharging groundwater and mixing with surface water based on a calculated aggregate-specific dilution attenuation factor.

Release Mechanism: Infiltration through contaminated soil and leaching

Attenuation of Leachate Contaminant Concentrations: Retardation, degradation, and fixation of contaminants on soil particles in leaching zone

Downgradient Receptor: Lateral Transport of Contaminants in the Groundwater Table. Most COIs either do not reach the receptor location within the modeling period (1,000 years) or the predicted concentration is less than the MCL/RSL.

Exposure Unit: Groundwater Table. Leachate mixes with groundwater. Most SRCs either do not reach the water table within the modeling period (1,000 years) or the predicted concentration is less than the MCL/RSL.

Figure G-5. Contaminant Migration Conceptual Model

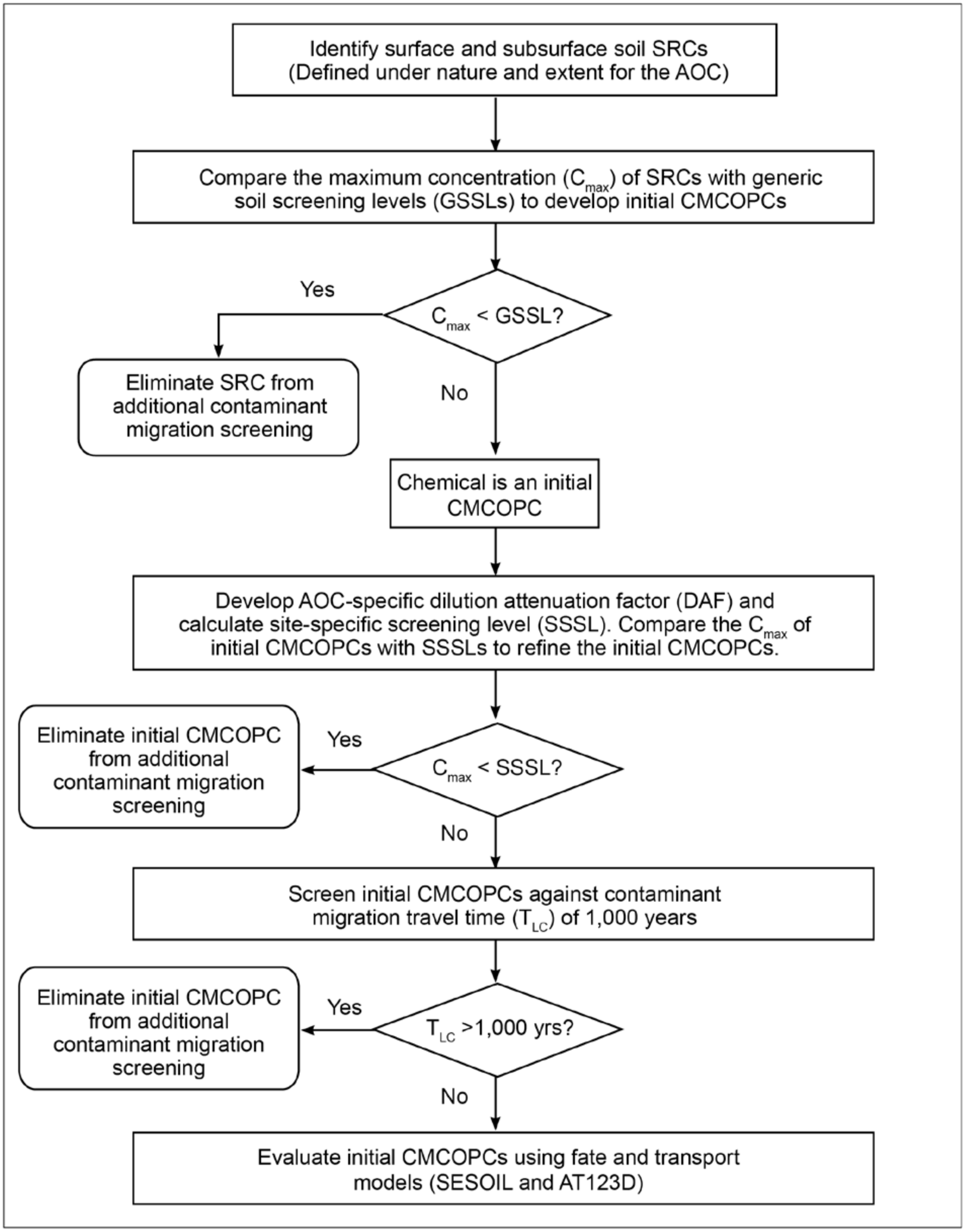


Figure G-6. AOC-Specific Fate and Transport Modeling Approach – Soil

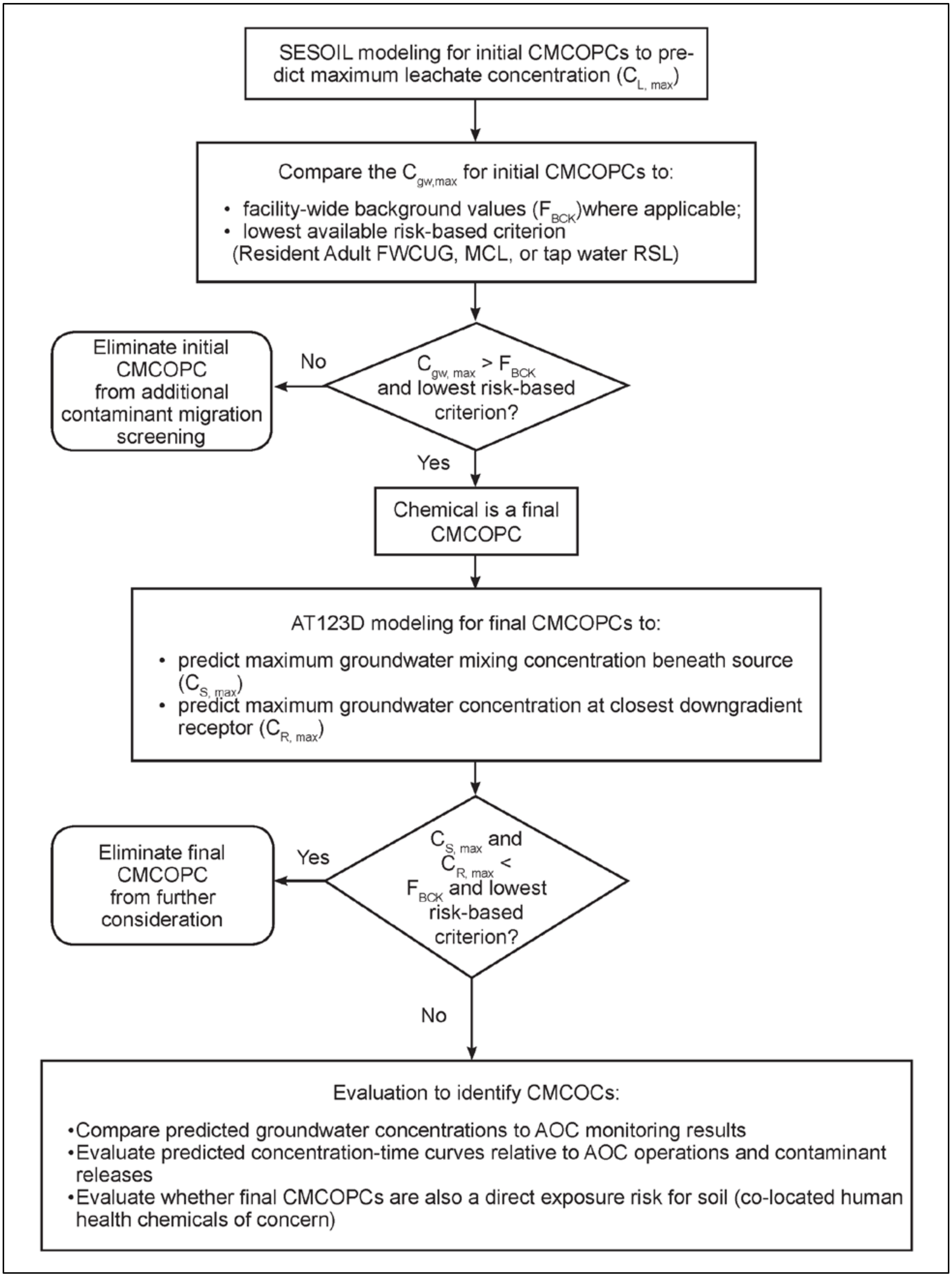


Figure G-6. AOC-Specific Fate and Transport Modeling Approach – Soil (continued)

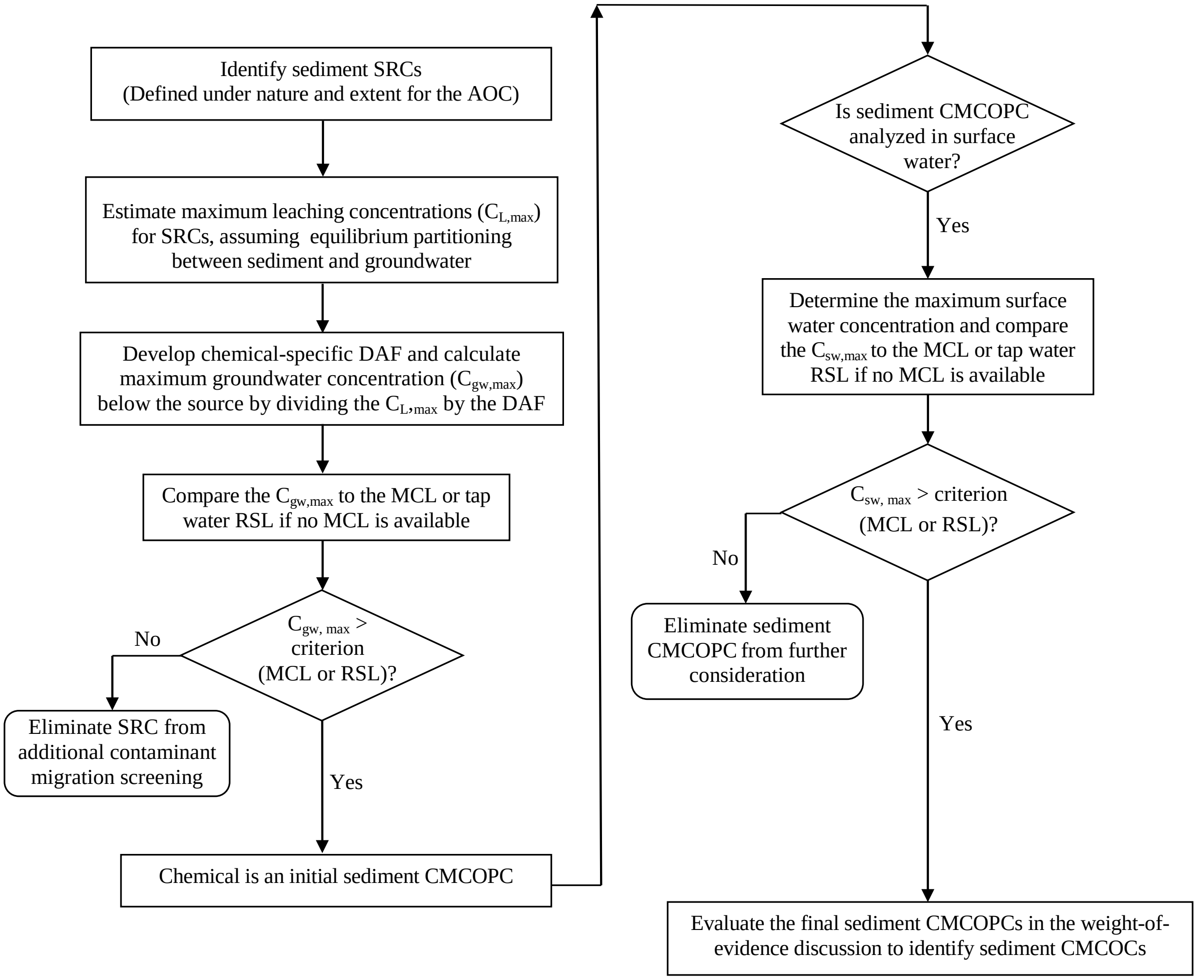


Figure G-7. AOC-specific Fate and Transport Modeling Approach – Sediment

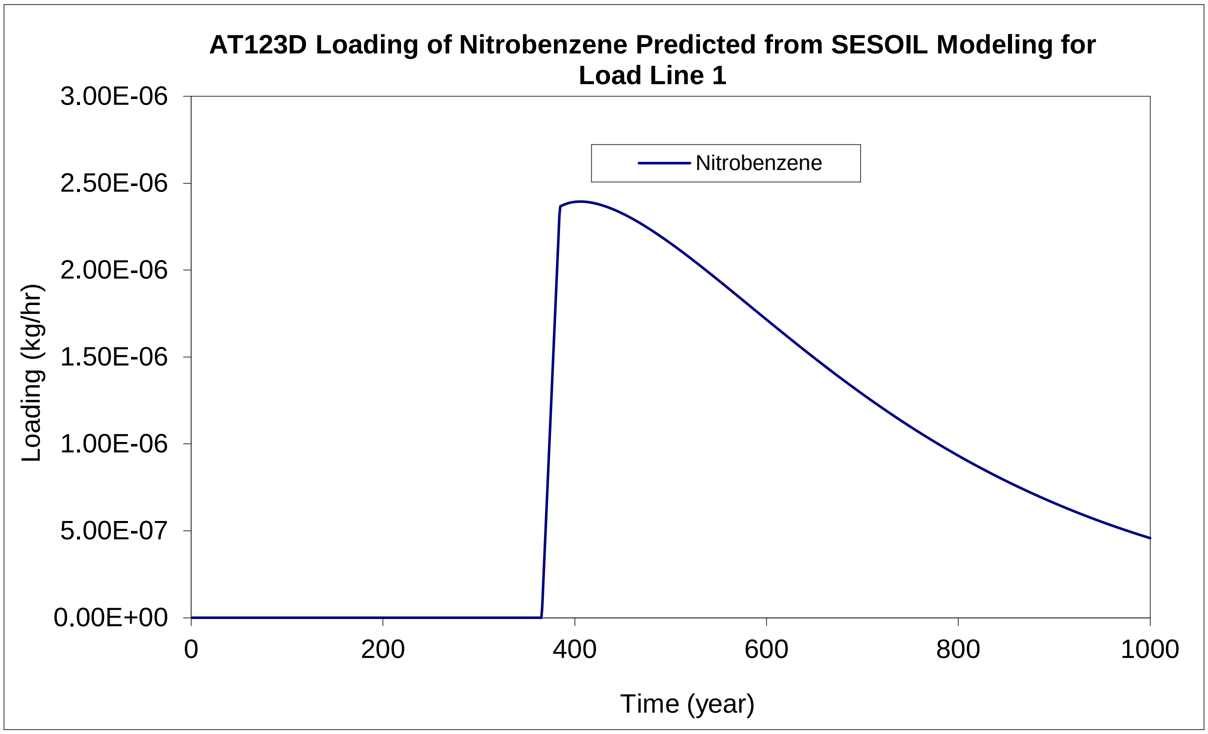


Figure G-8. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 1 – Nitrobenzene

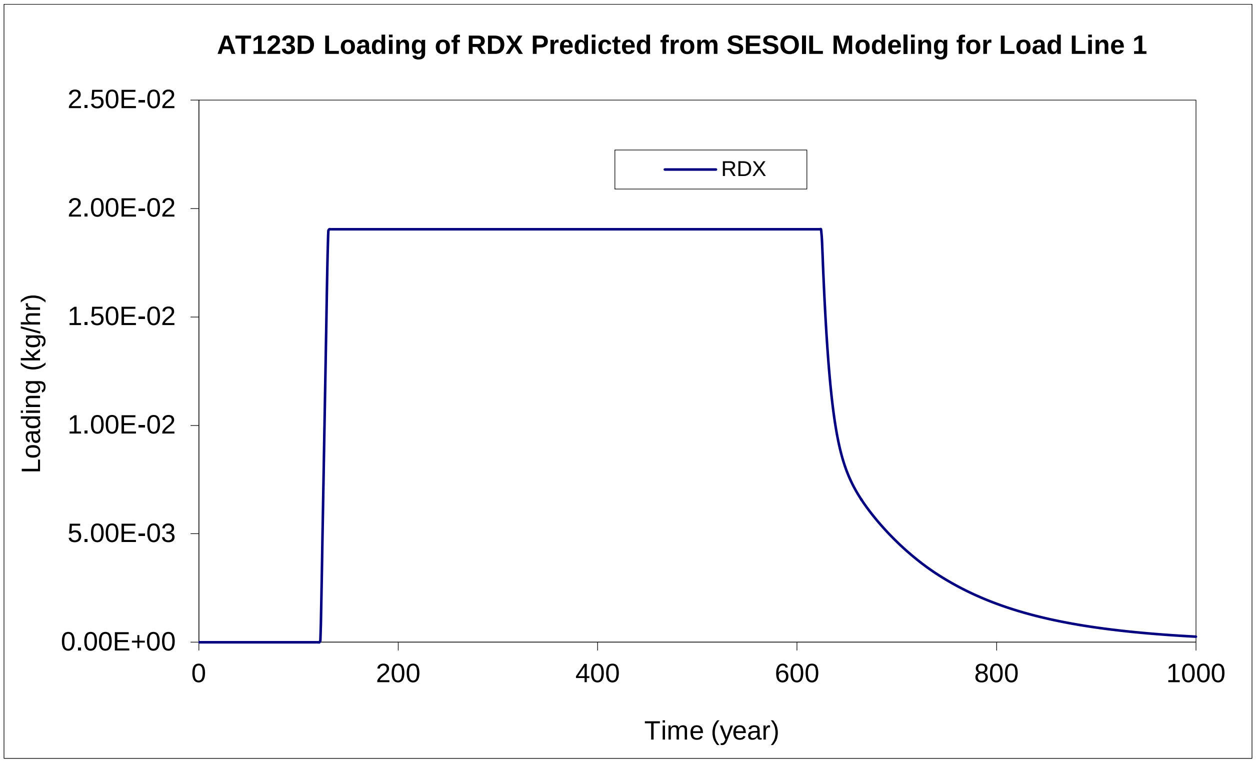


Figure G-9. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 1 – RDX

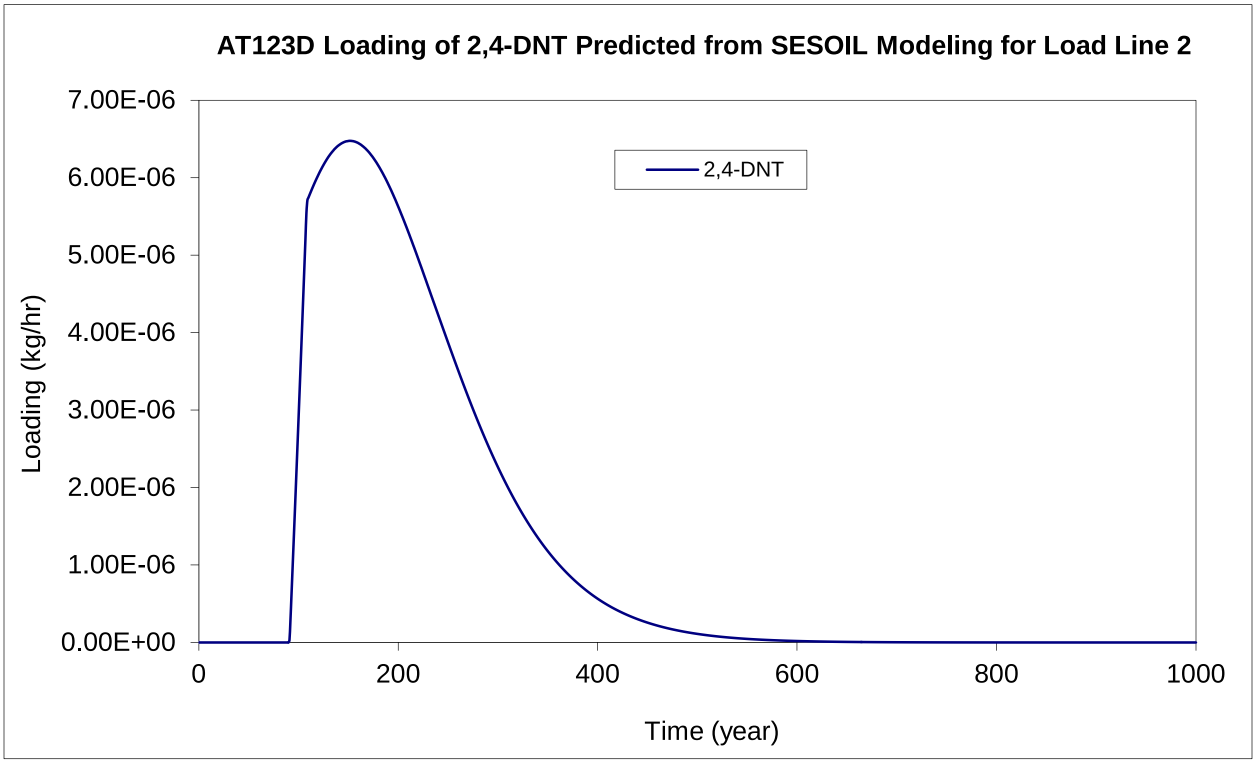


Figure G-10. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 2 – 2,4-DNT

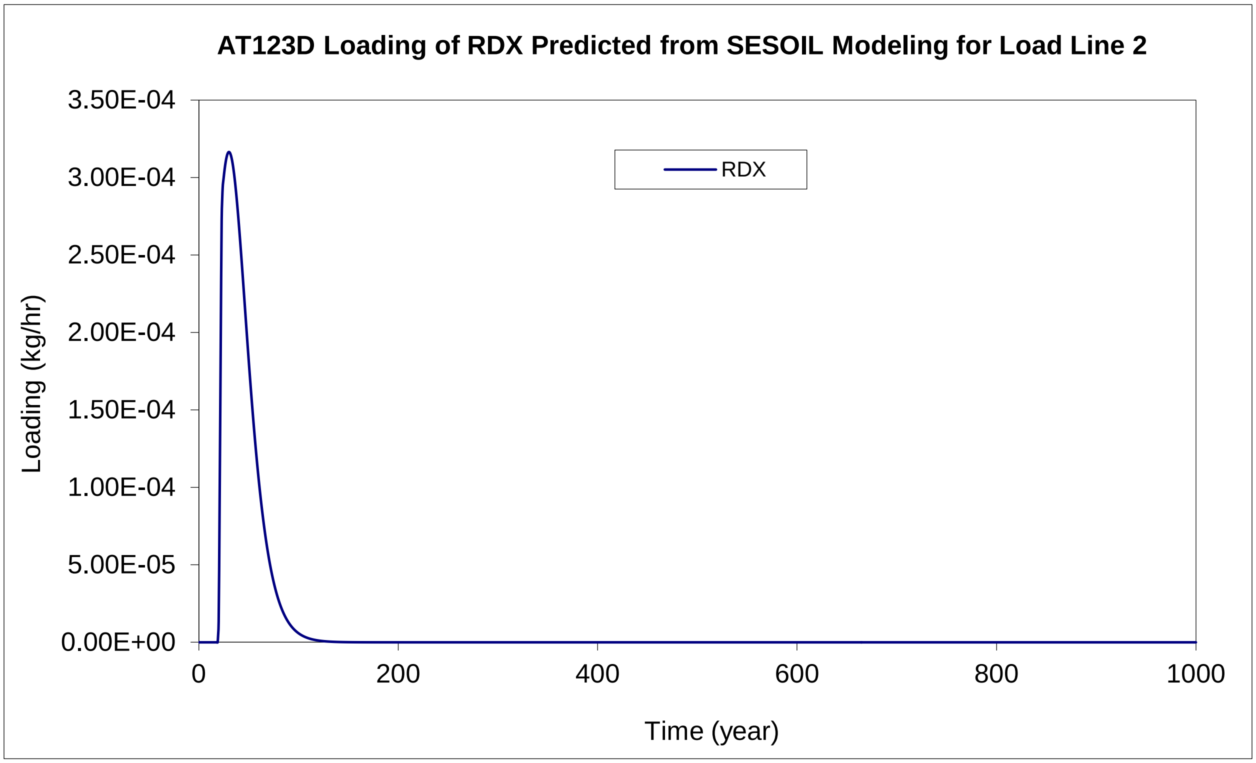


Figure G-11. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 2 – RDX

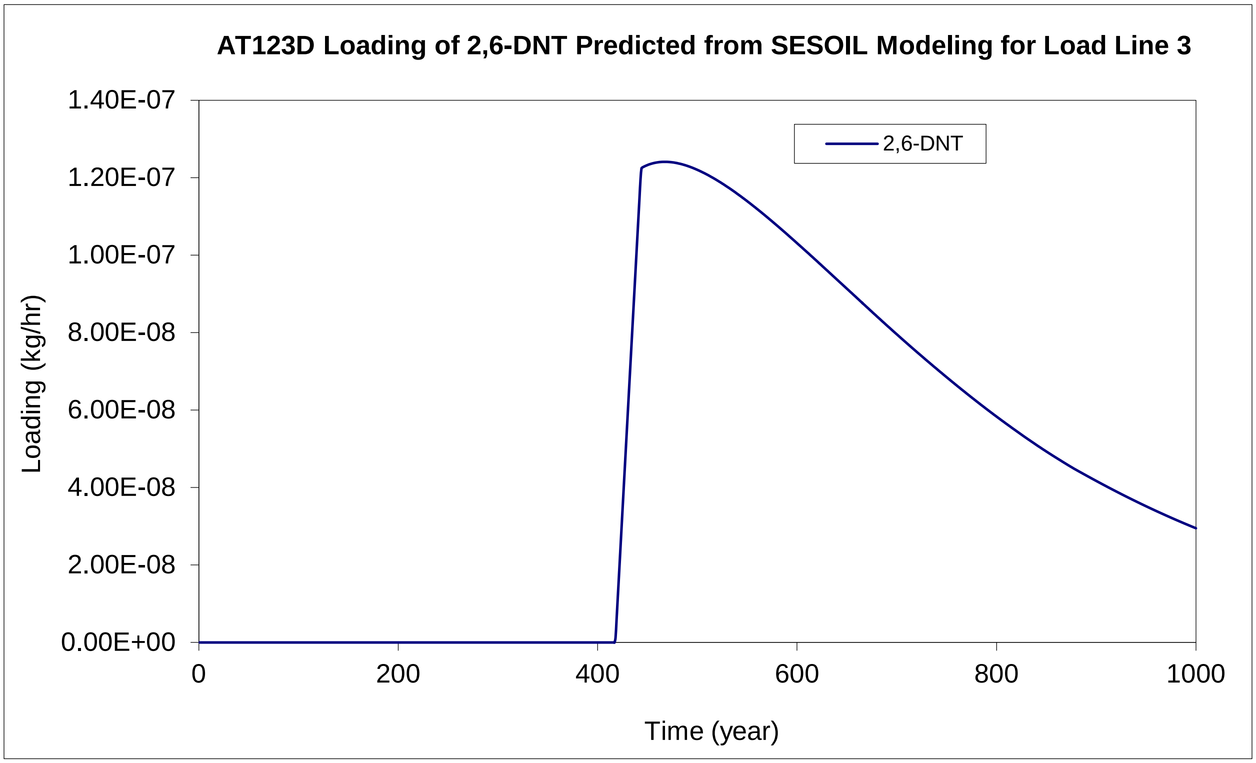


Figure G-12. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 3 – 2,6-DNT

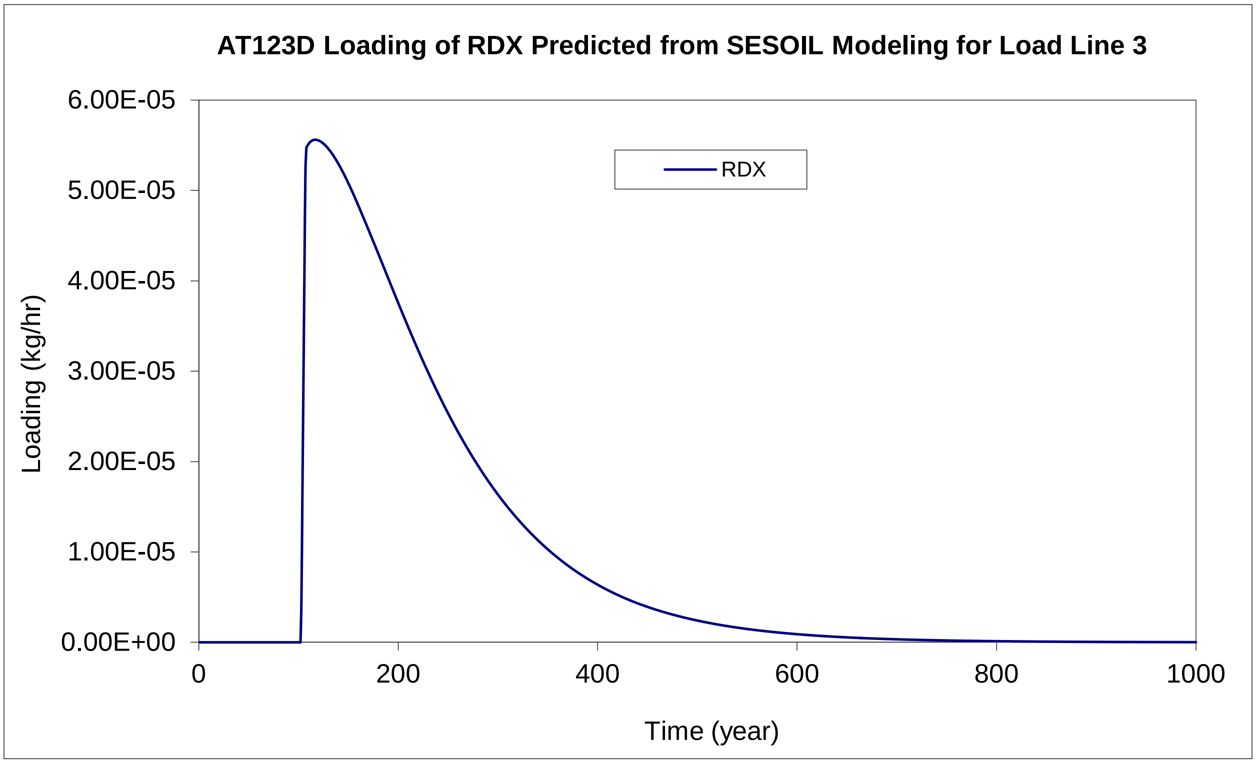


Figure G-13. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 3 – RDX

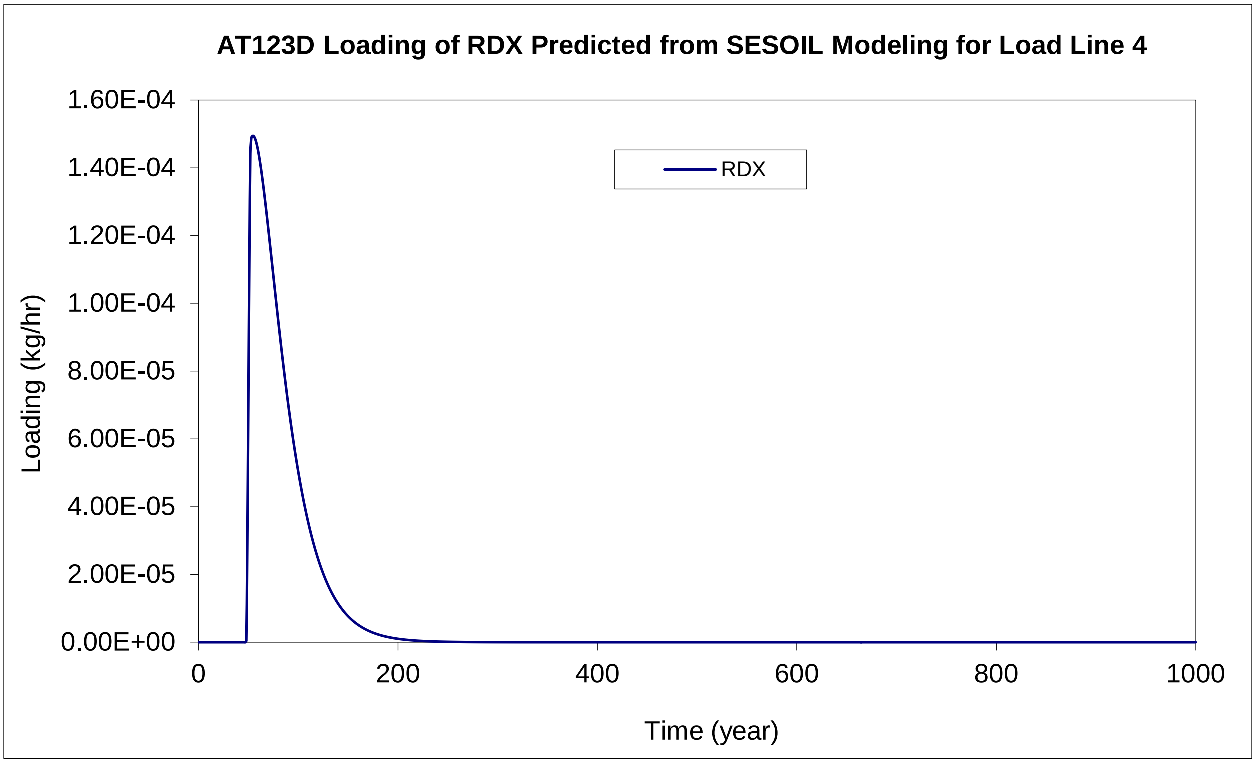


Figure G-14. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 4 – RDX

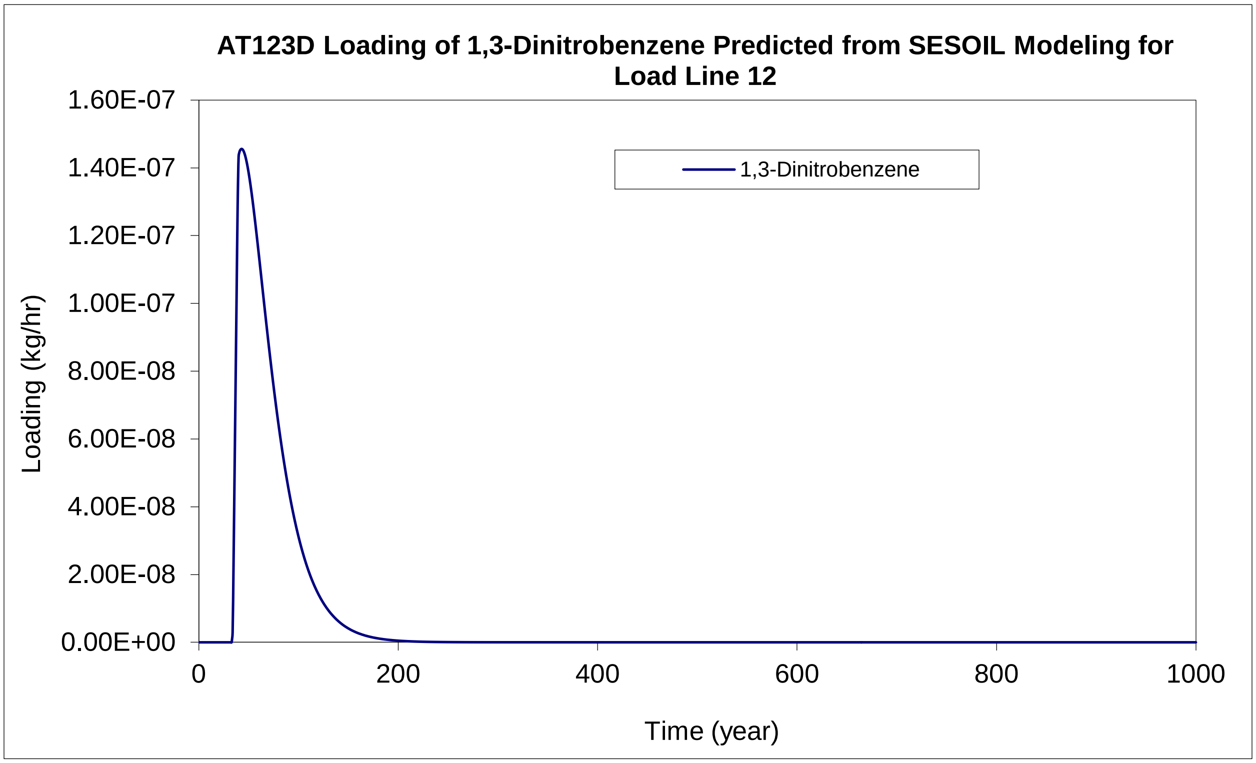


Figure G-15. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 12 – 1,3-Dinitrobenzene

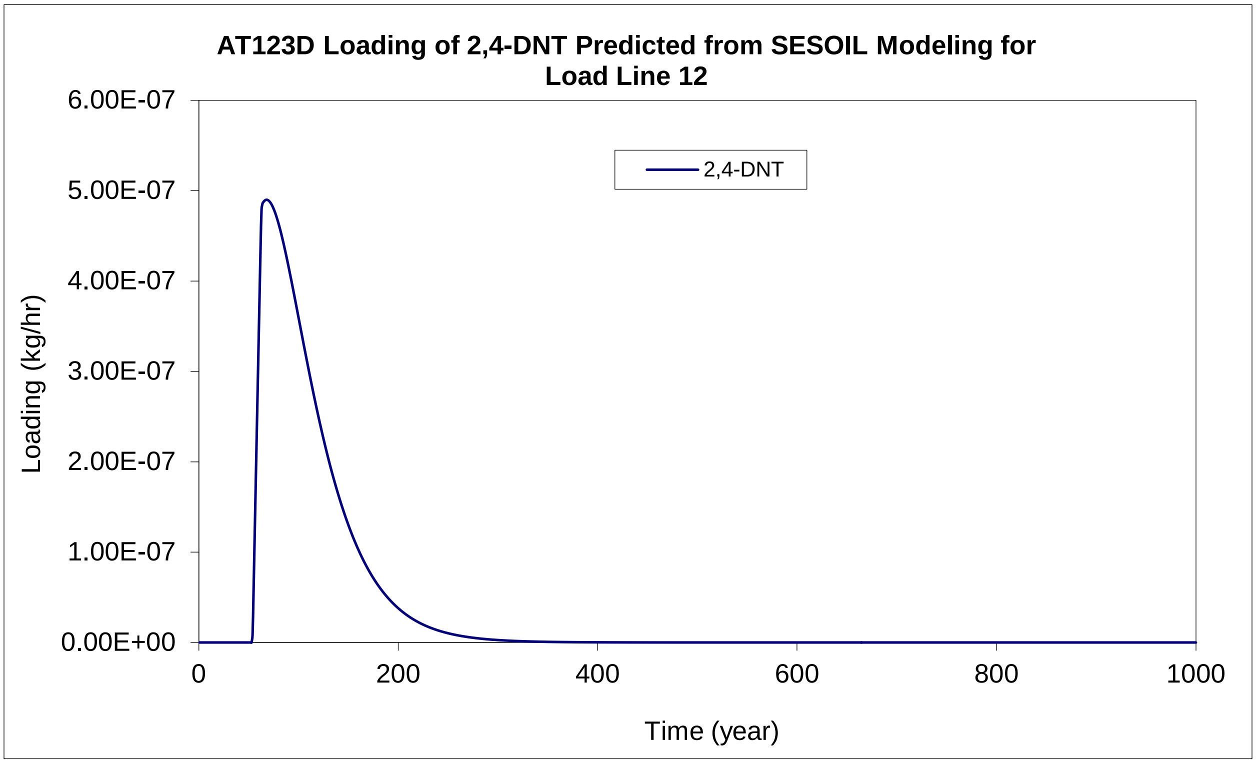


Figure G-16. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 12 – 2,4-DNT

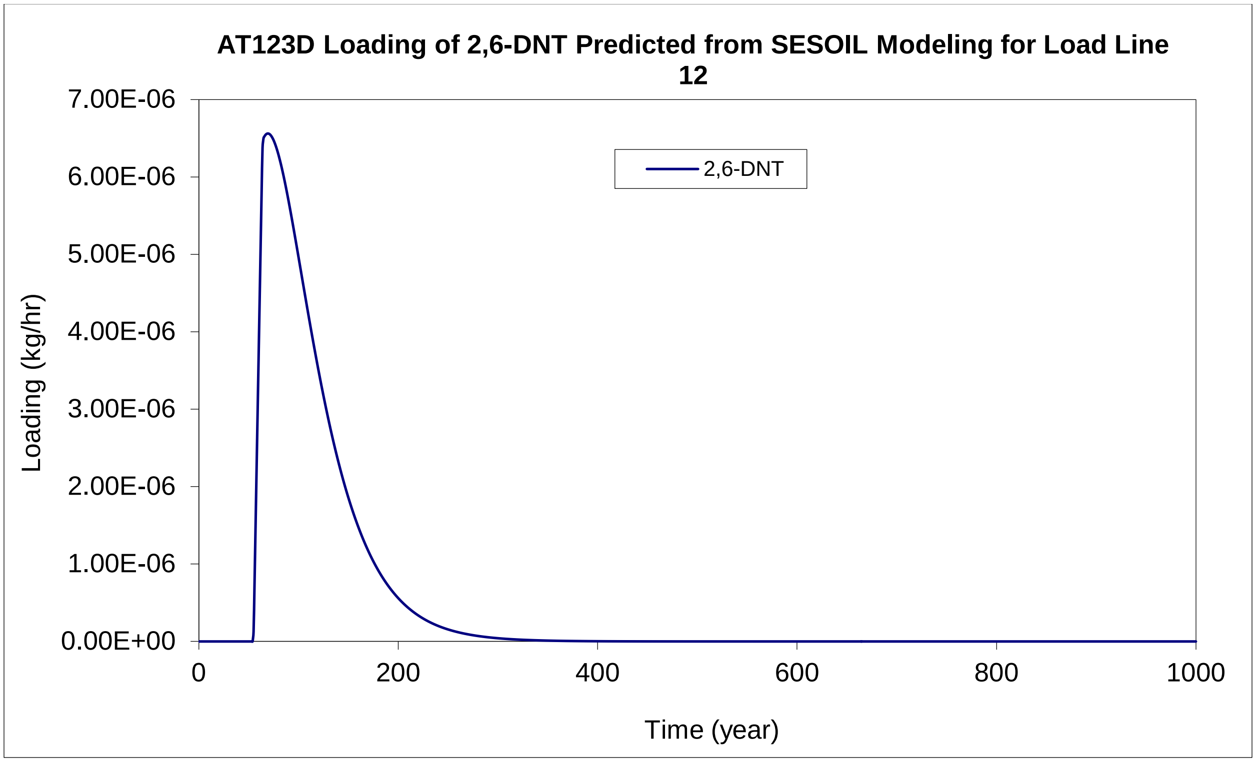


Figure G-17. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 12 – 2,6-DNT

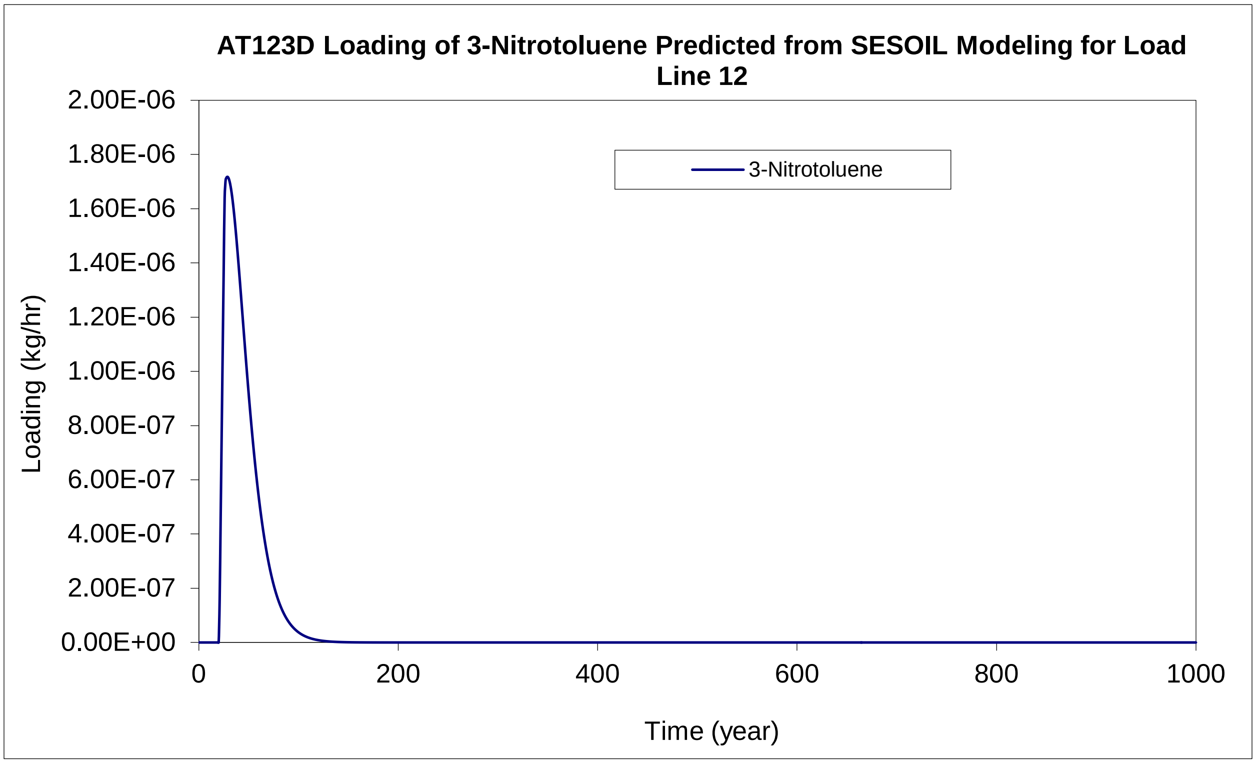


Figure G-18. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 12 – 3-Nitrotoluene

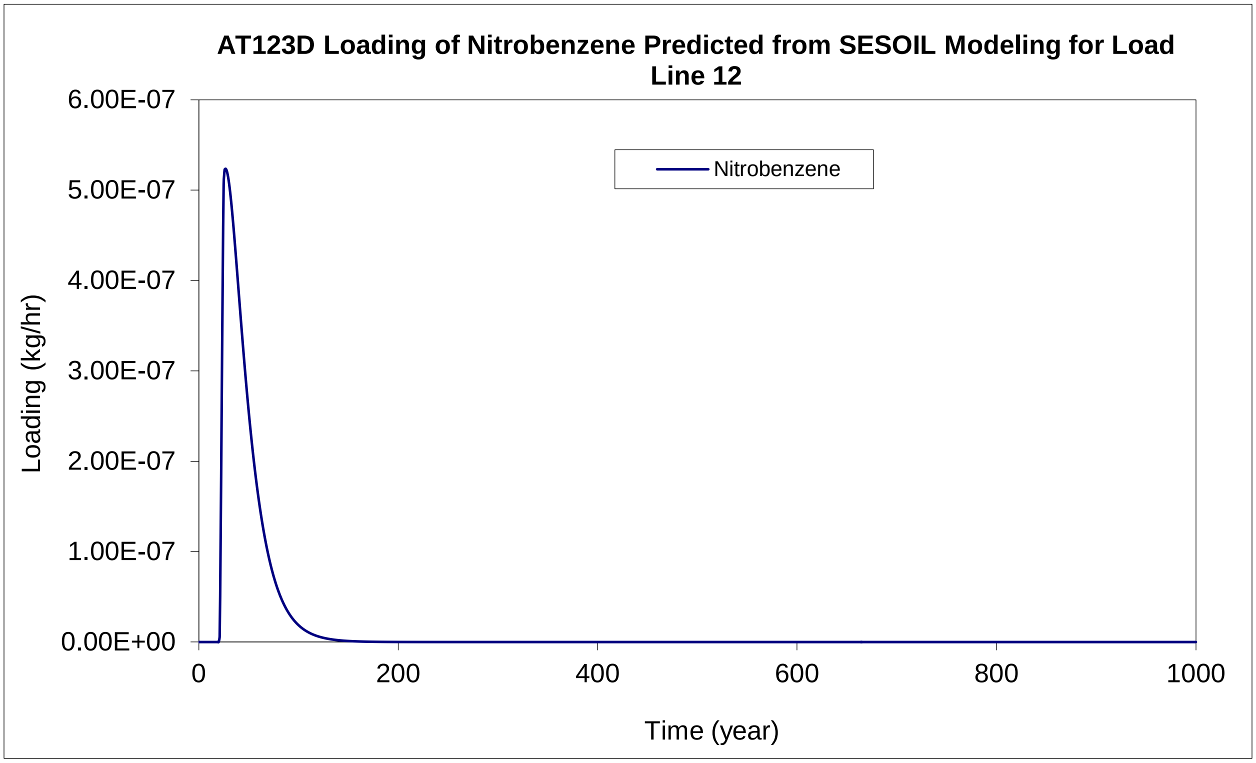


Figure G-19. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 12 – Nitrobenzene

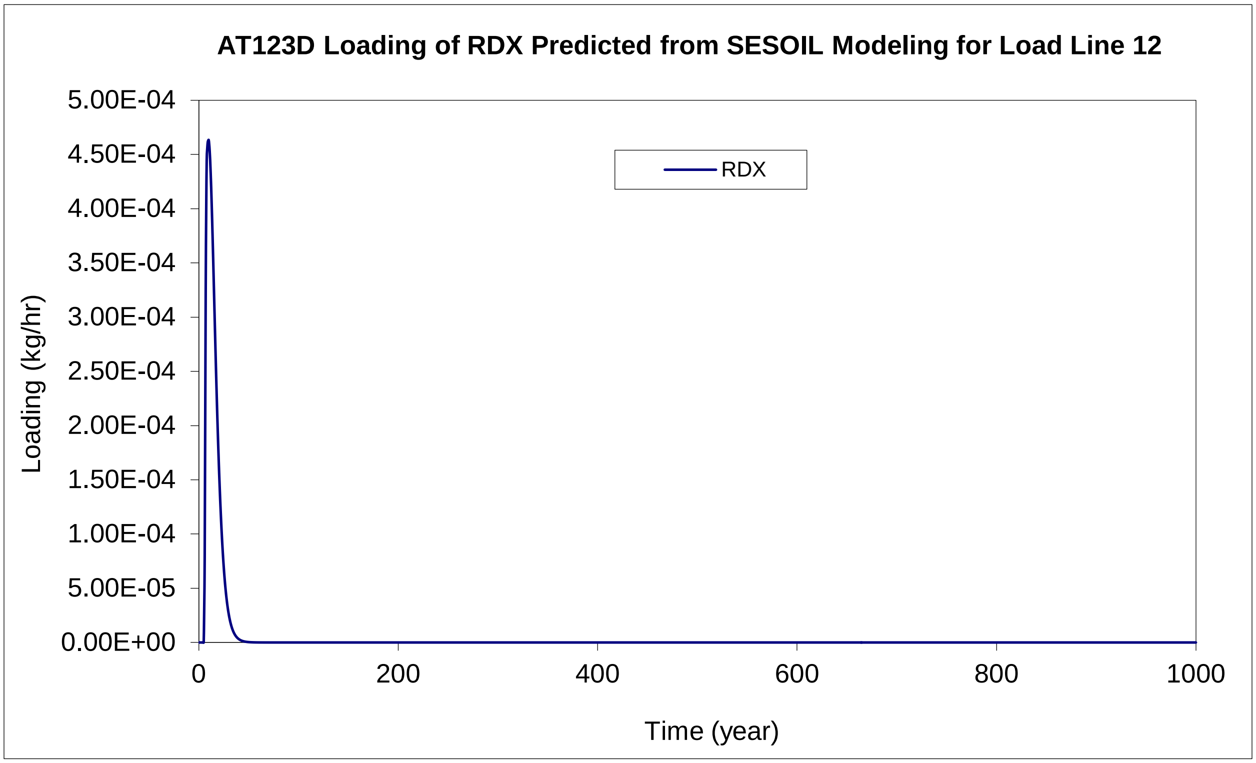


Figure G-20. Predicted Contaminant Mass Loading for AT123D Modeling at Load Line 12 – RDX

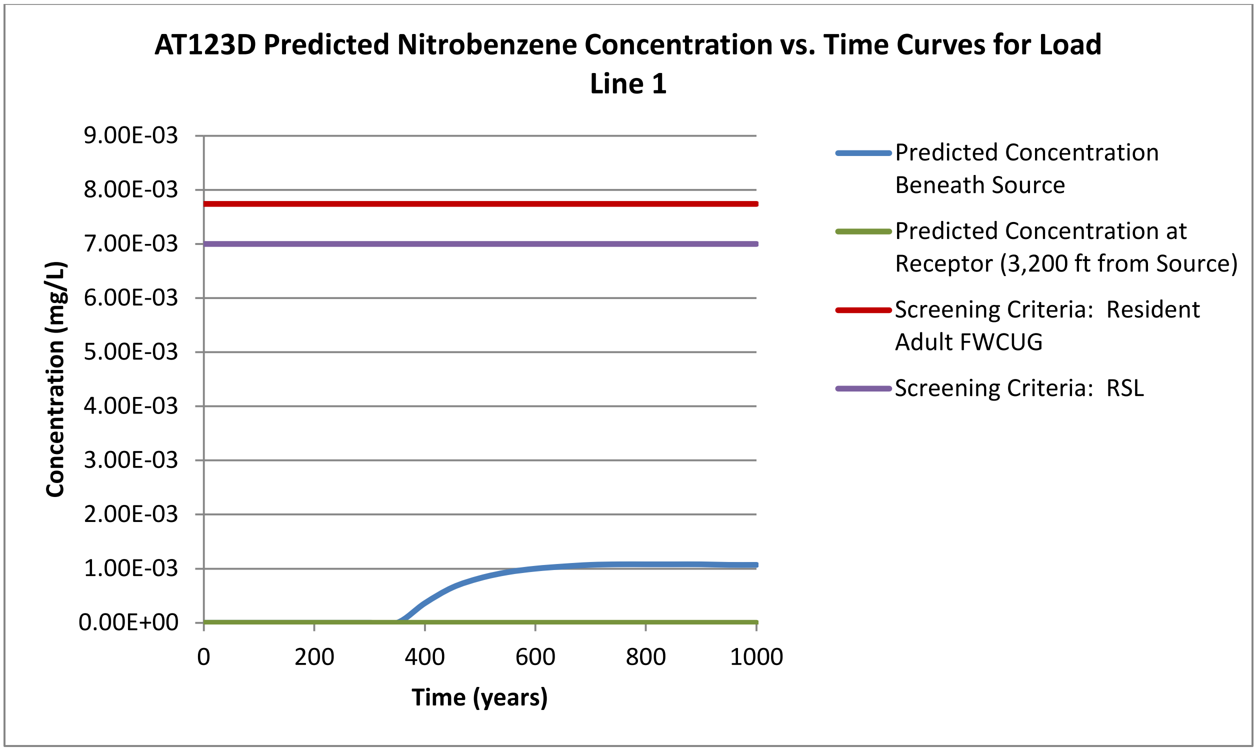


Figure G-21. Predicted Concentration of Nitrobenzene in Groundwater Based on AT123D Modeling at Load Line 1 in Soil

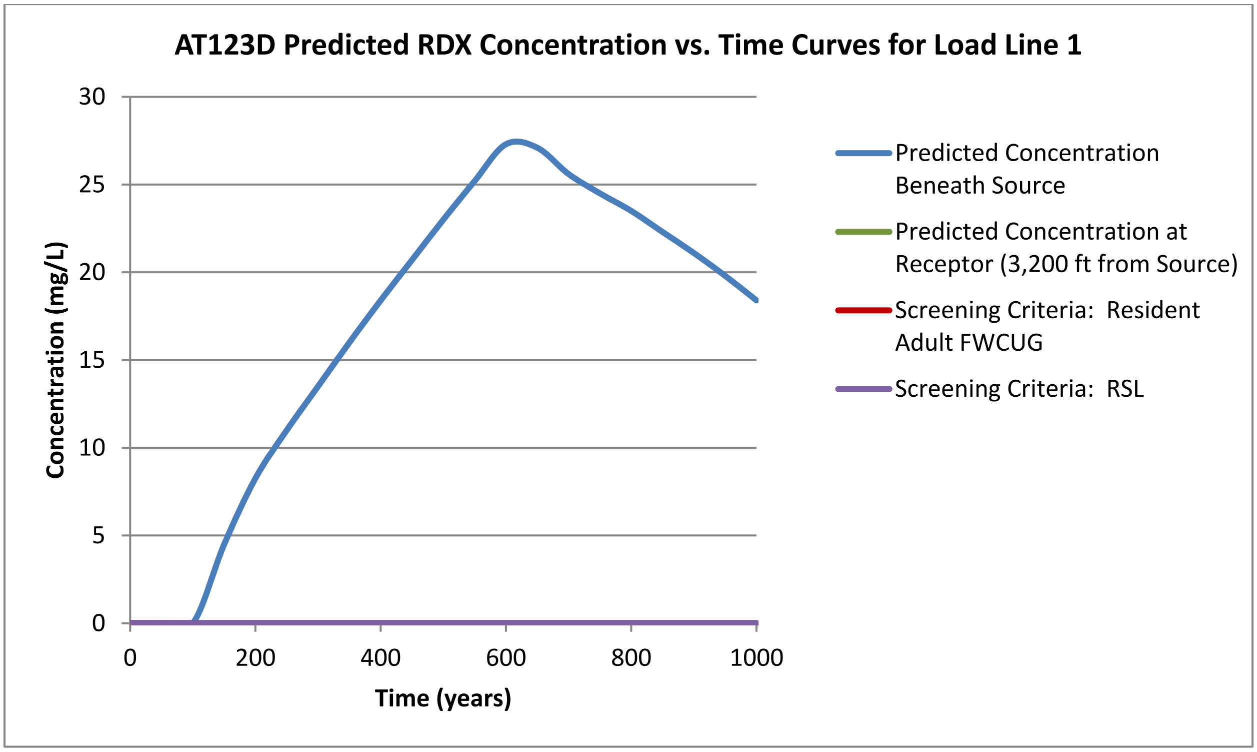


Figure G-22. Predicted Concentration of RDX in Groundwater Based on AT123D Modeling at Load Line 1 in Soil

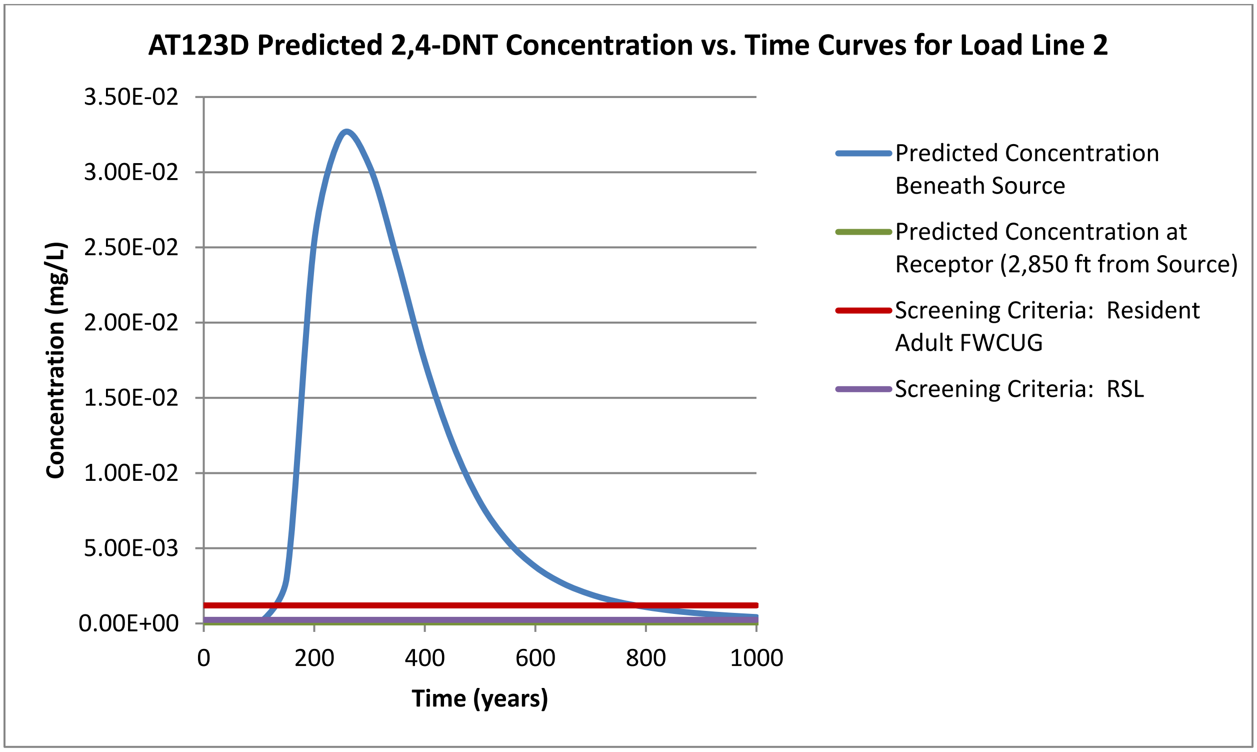


Figure G-23. Predicted Concentration of 2,4-DNT in Groundwater Based on AT123D Modeling at Load Line 2 in Soil

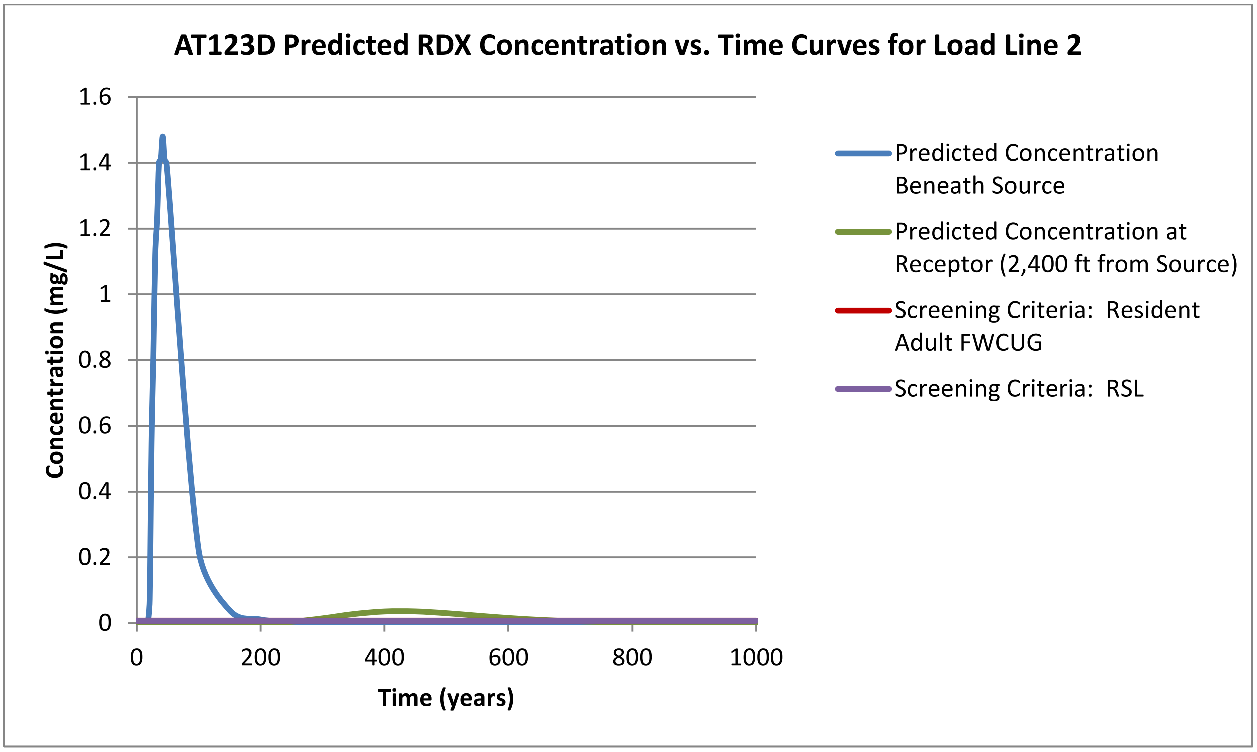


Figure G-24. Predicted Concentration of RDX in Groundwater Based on AT123D Modeling at Load Line 2 in Soil

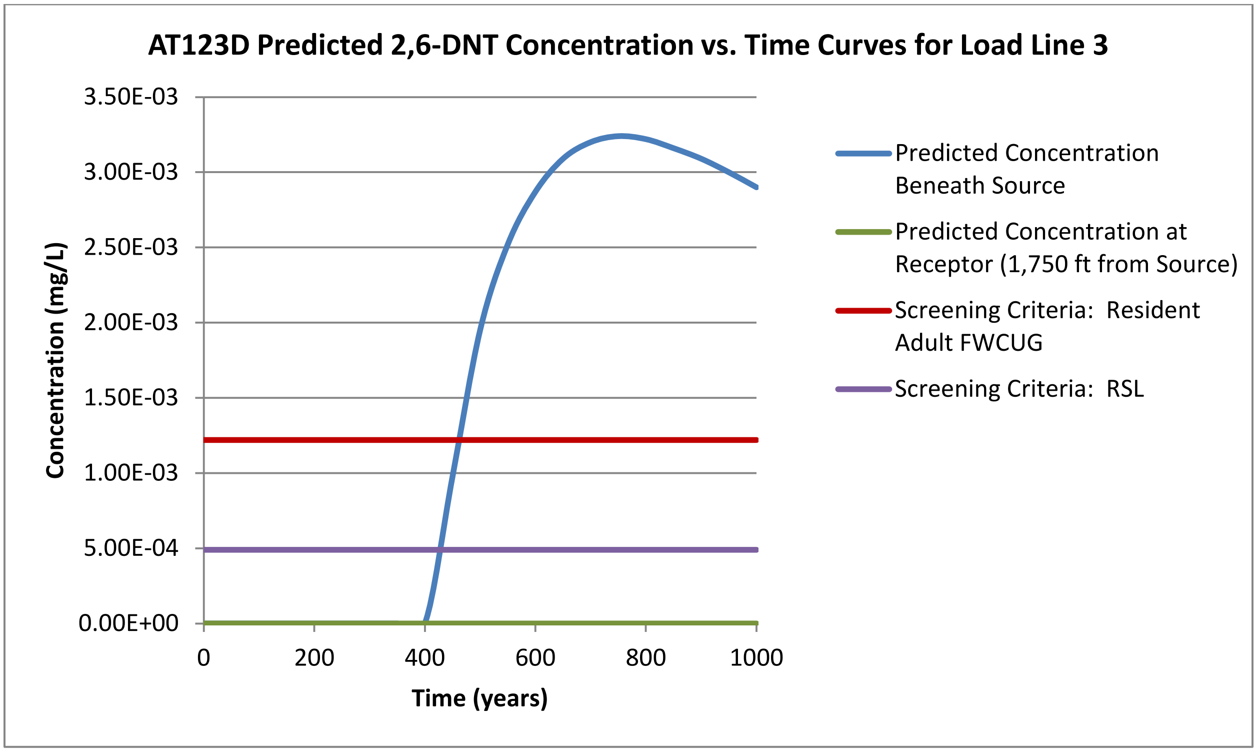


Figure G-25. Predicted Concentration of 2,6-DNT in Groundwater Based on AT123D Modeling at Load Line 3 in Soil

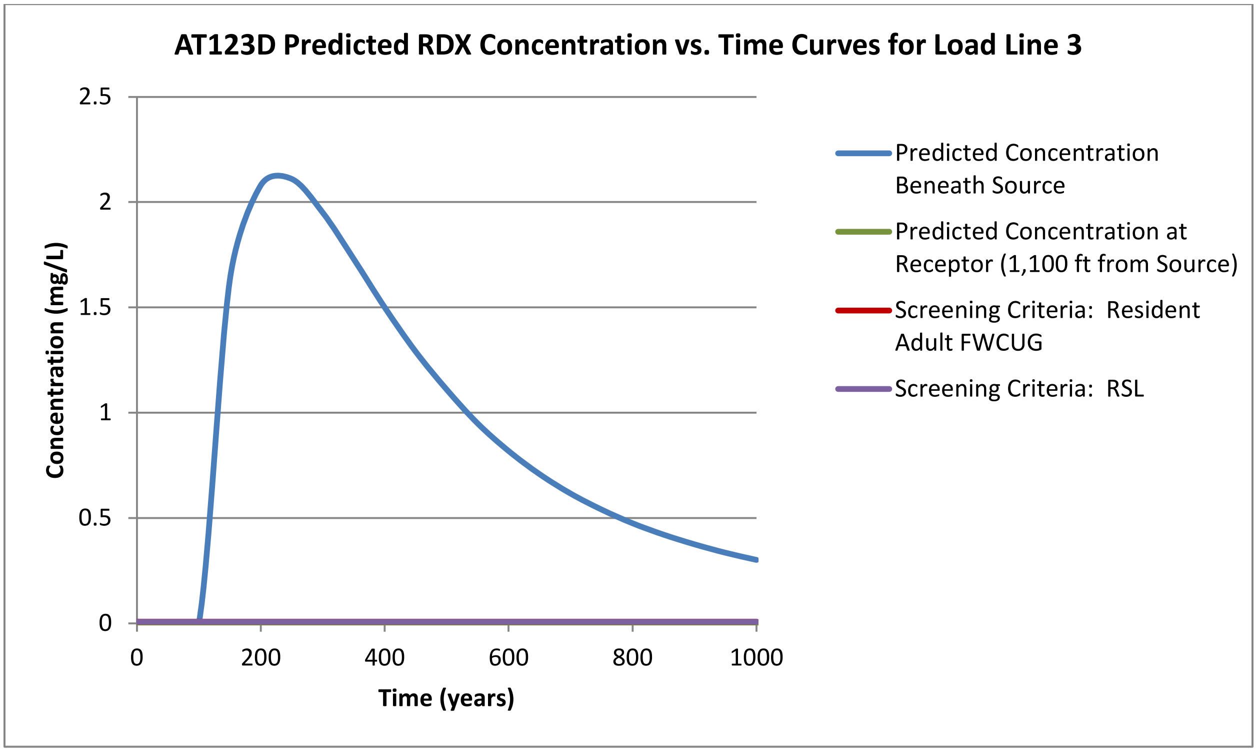


Figure G-26. Predicted Concentration of RDX in Groundwater Based on AT123D Modeling at Load Line 3 in Soil

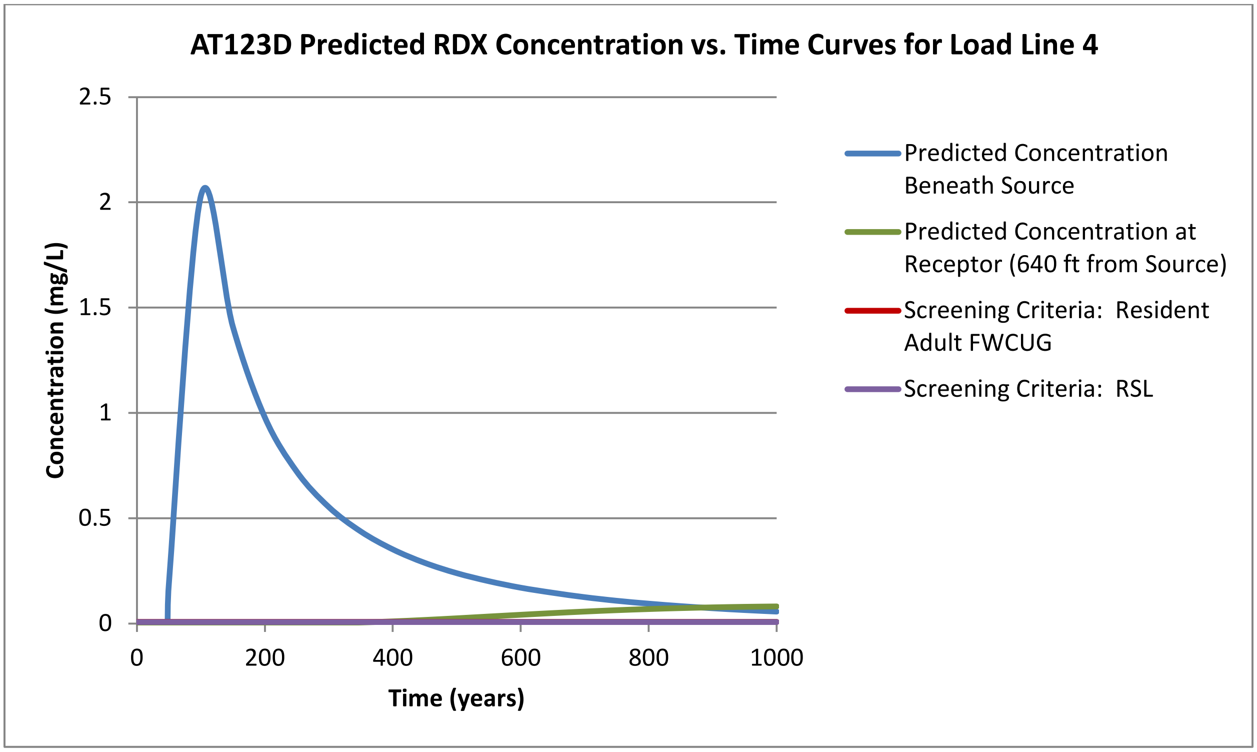


Figure G-27. Predicted Concentration of RDX in Groundwater Based on AT123D Modeling at Load Line 4 in Soil

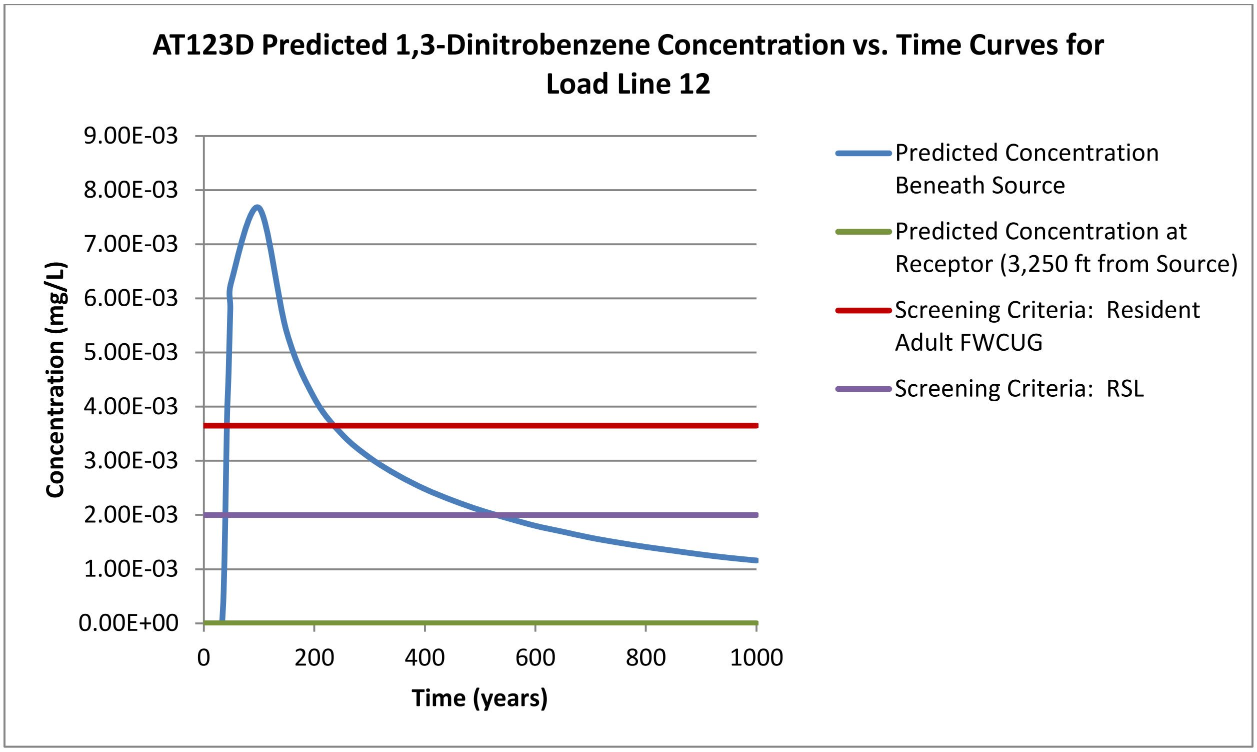


Figure G-28. Predicted Concentration of 1,3-Dinitrobenzene in Groundwater Based on AT123D Modeling at Load Line 12 in Soil

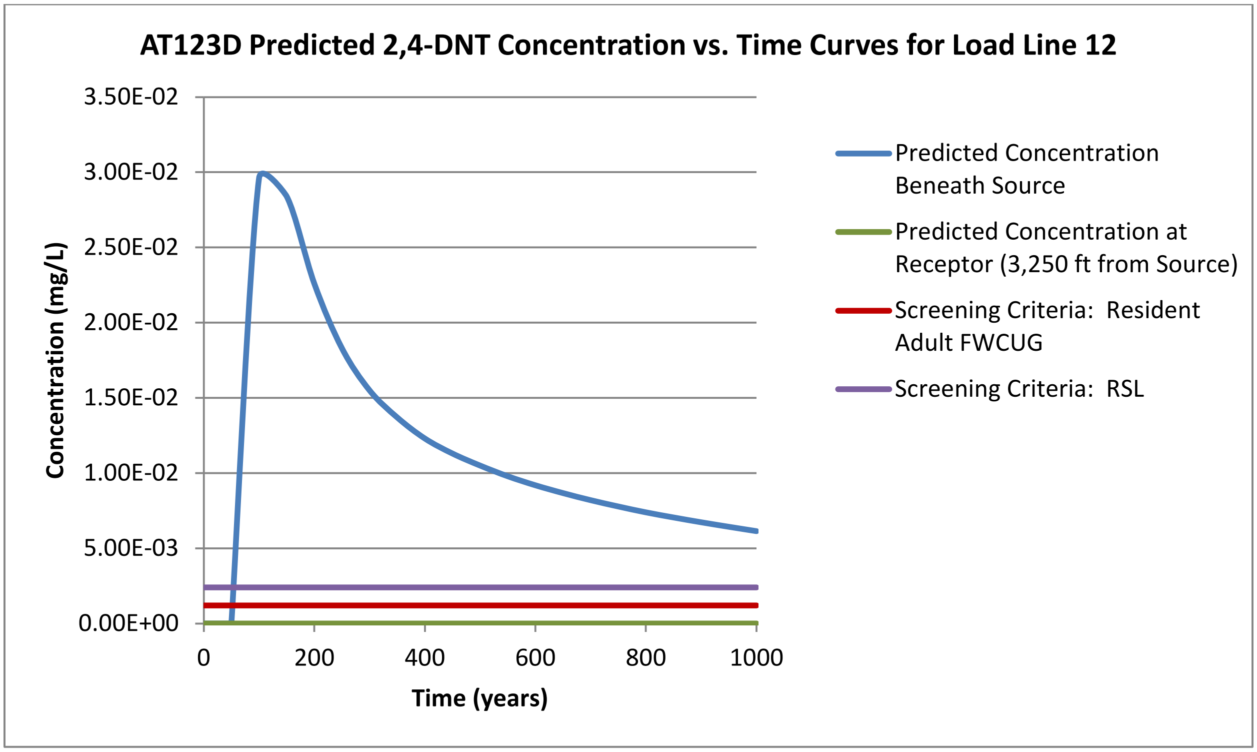


Figure G-29. Predicted Concentration of 2,4-DNT in Groundwater Based on AT123D Modeling at Load Line 12 in Soil

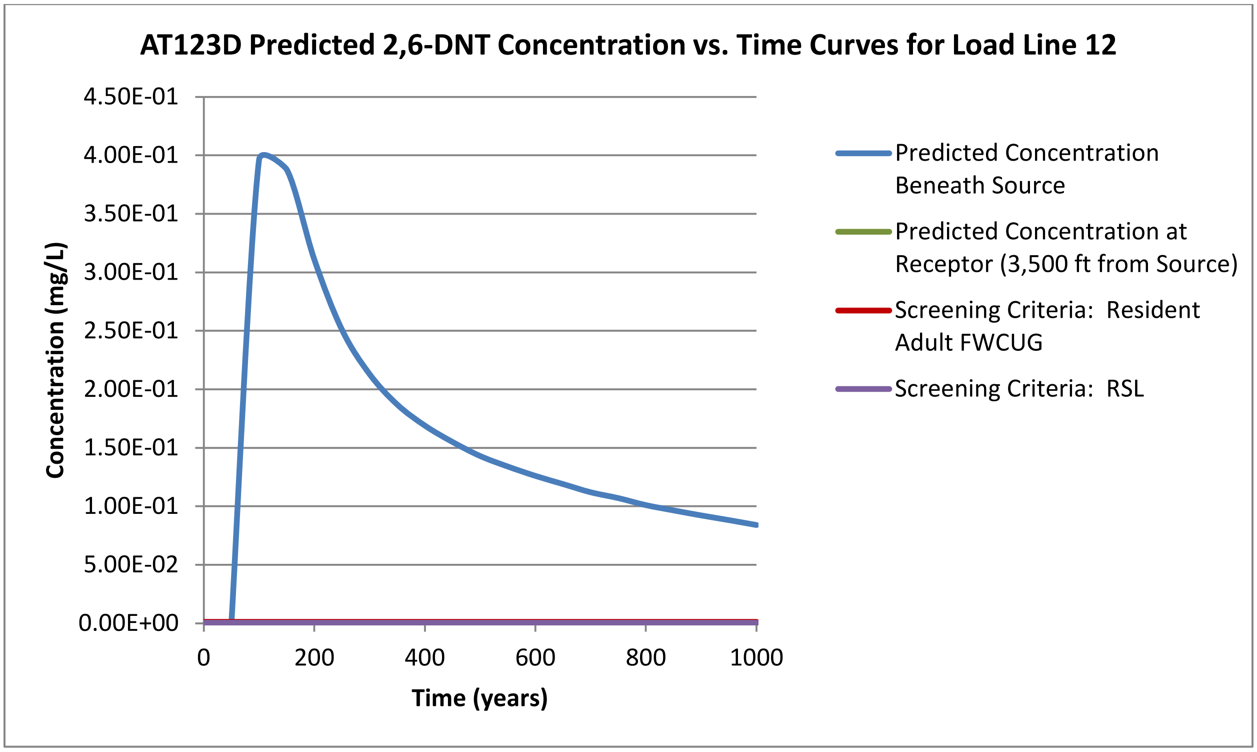


Figure G-30. Predicted Concentration of 2,6-DNT in Groundwater Based on AT123D Modeling at Load Line 12 in Soil

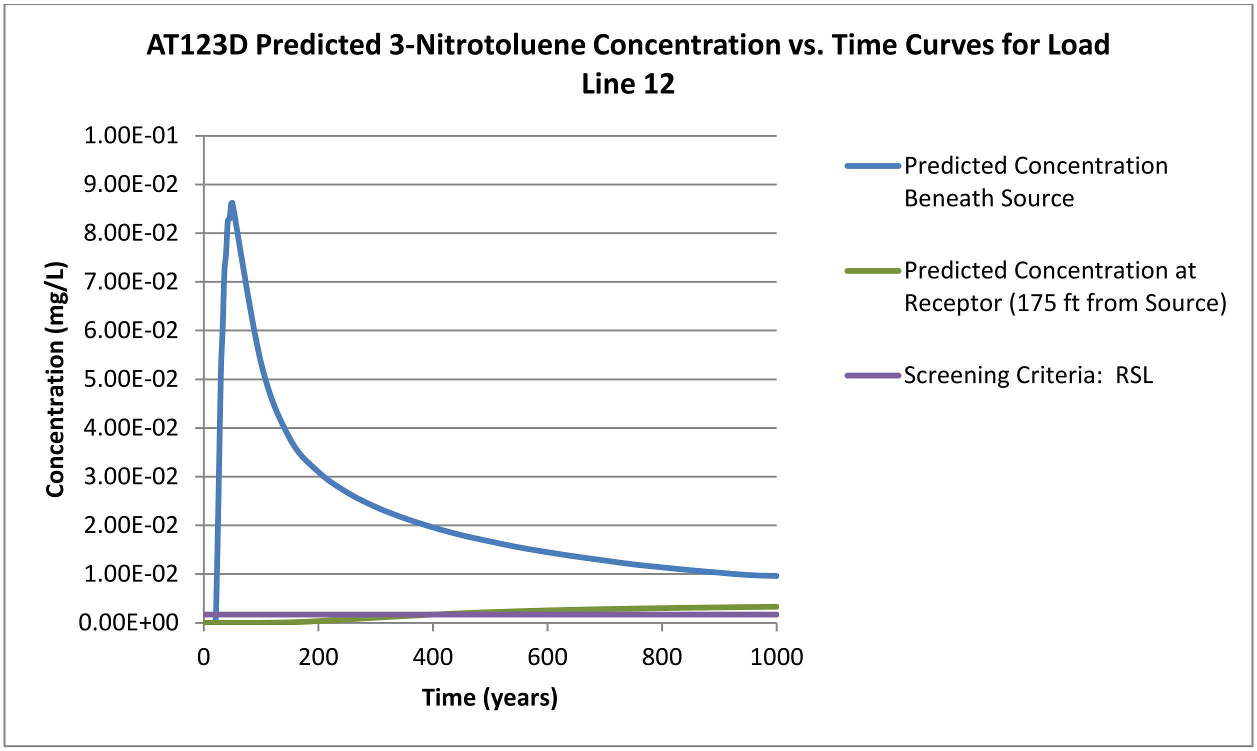


Figure G-31. Predicted Concentration of 3-Nitrotoluene in Groundwater Based on AT123D Modeling at Load Line 12 in Soil

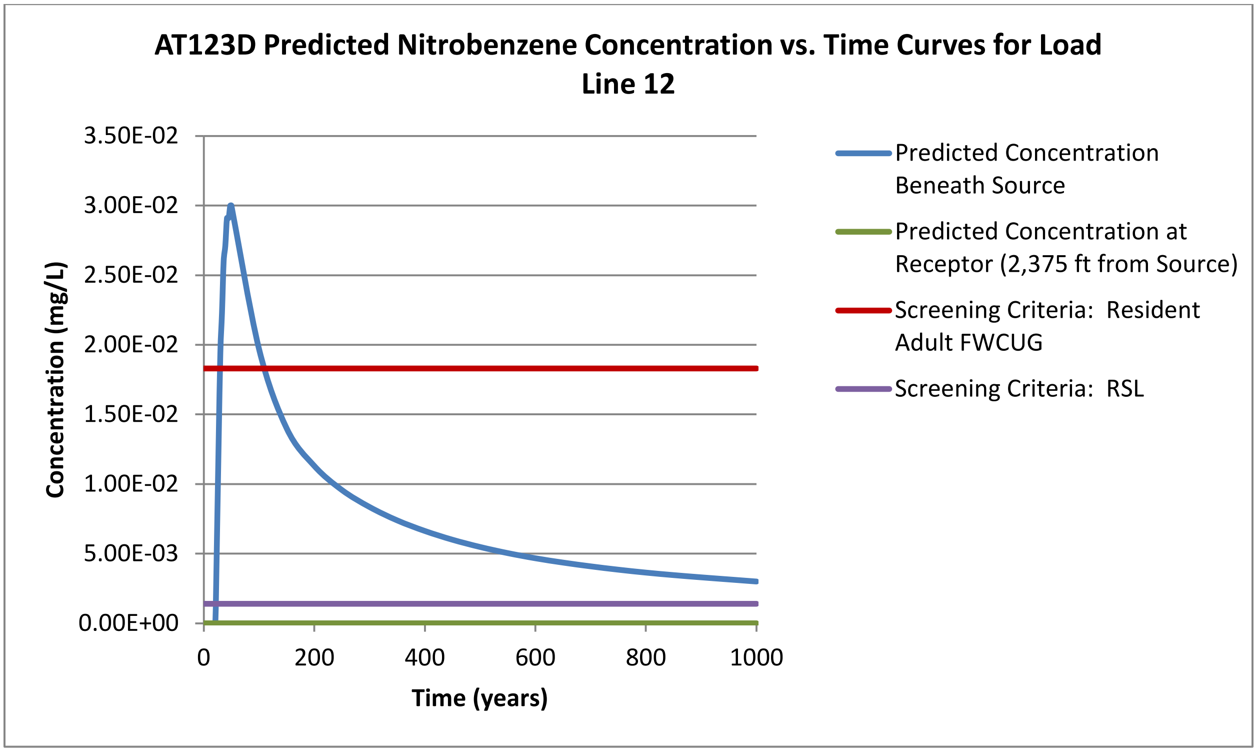


Figure G-32. Predicted Concentration of Nitrobenzene in Groundwater Based on AT123D Modeling at Load Line 12 in Soil

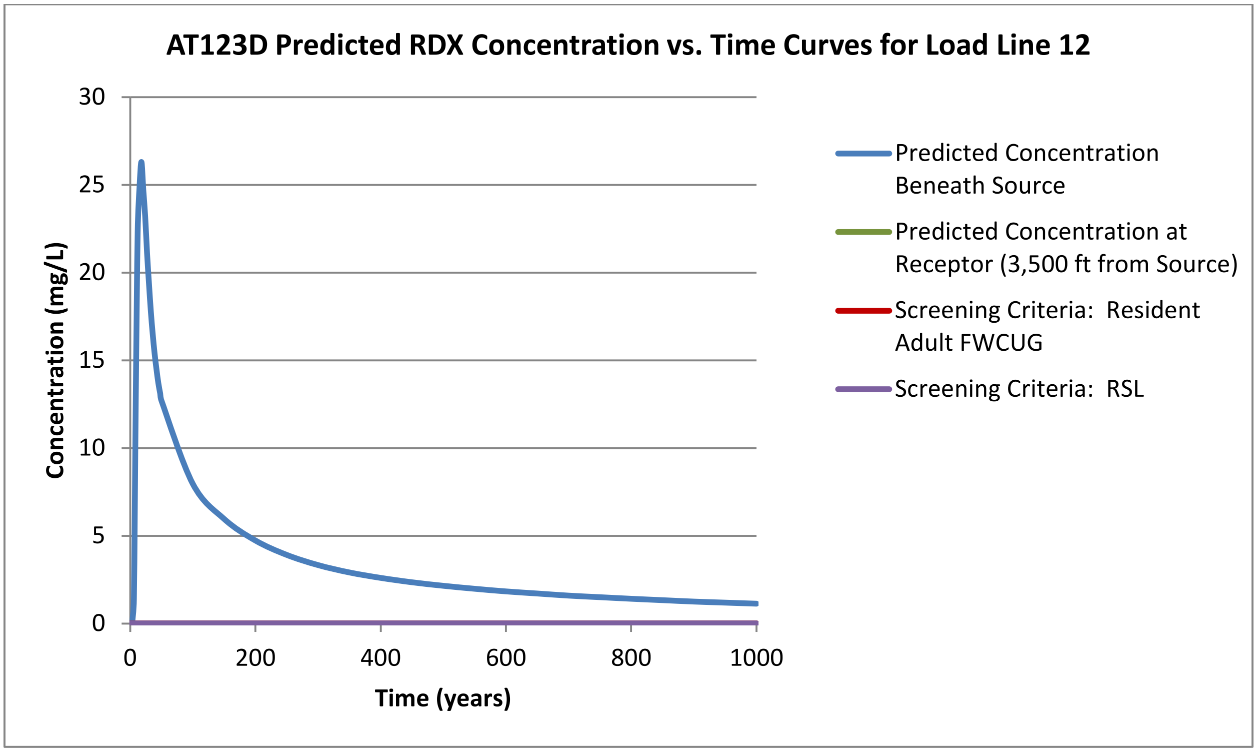


Figure G-33. Predicted Concentration of RDX in Groundwater Based on AT123D Modeling at Load Line 12 in Soil

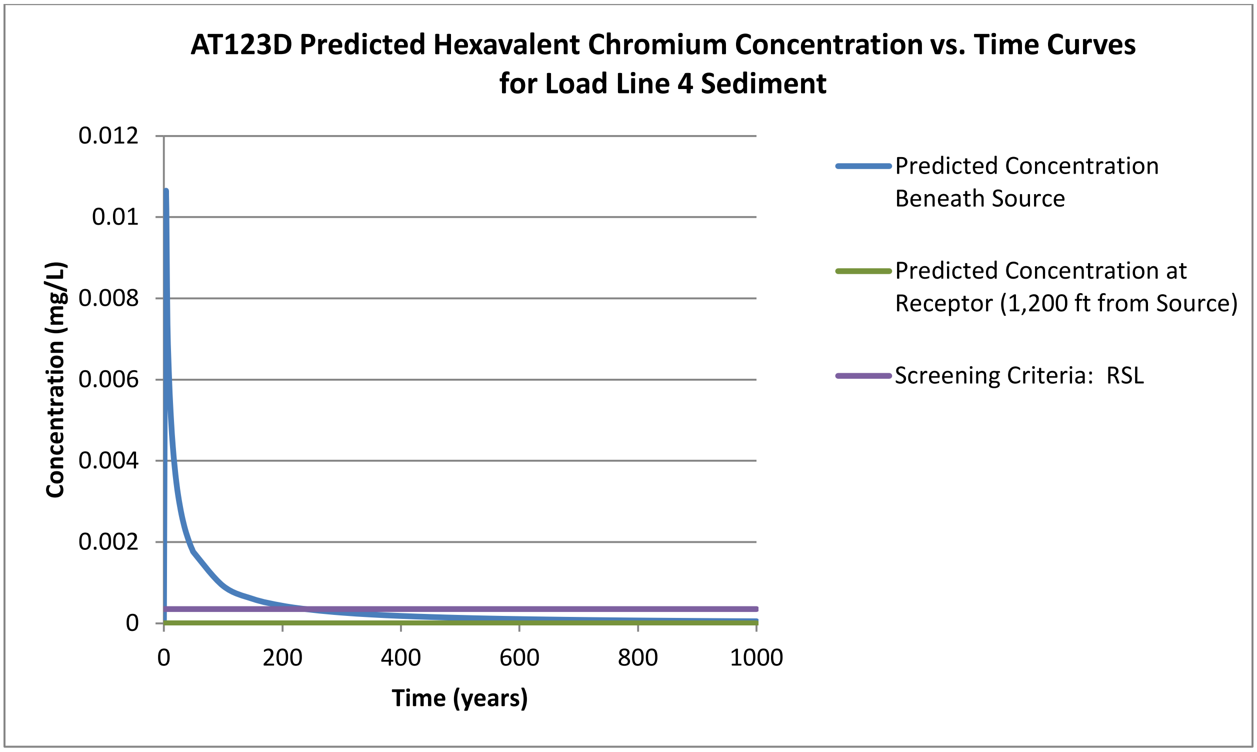


Figure G-34. Predicted Concentration of Hexavalent Chromium in Groundwater Based on AT123D Modeling at Load Line 12 in Sediment

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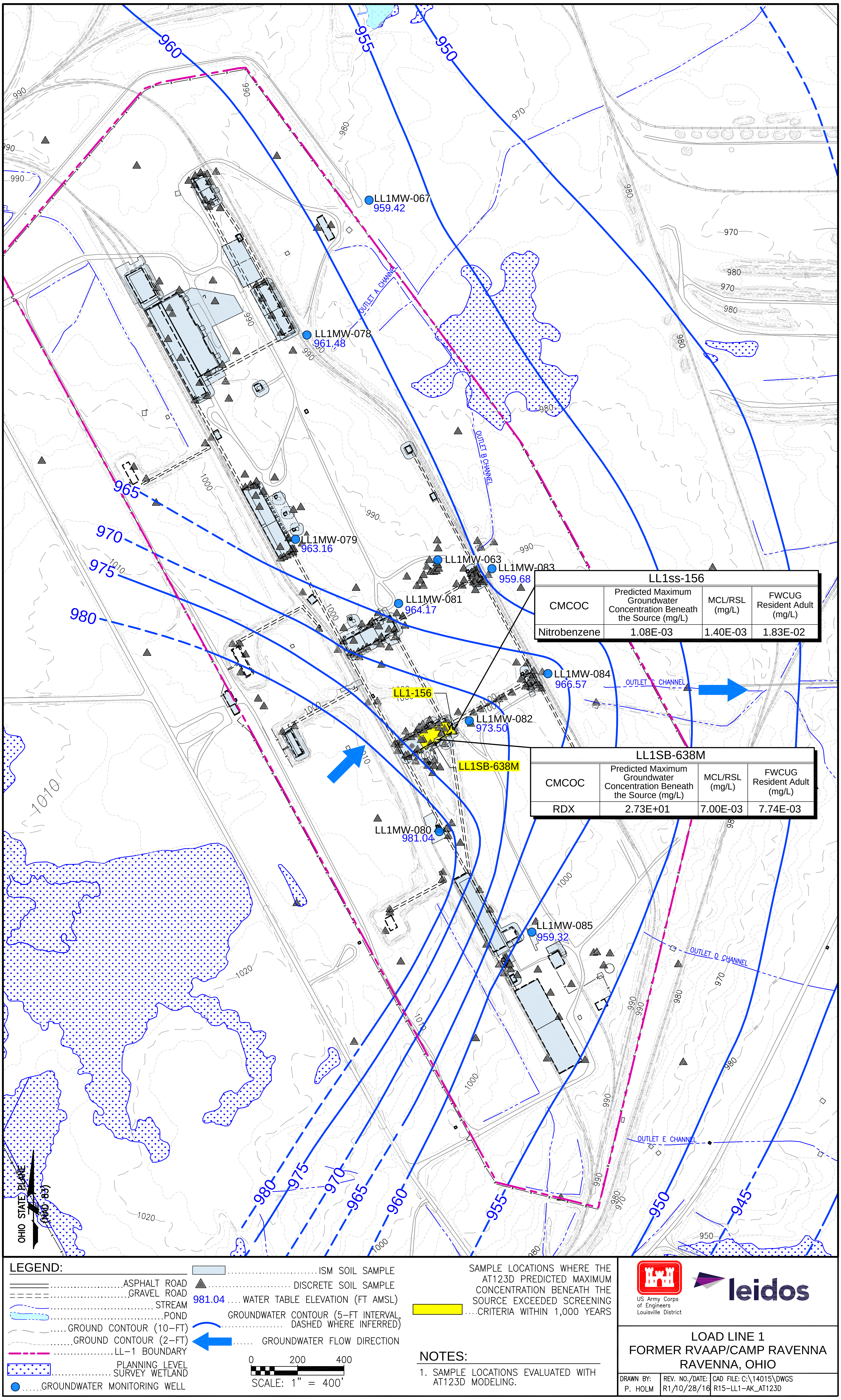


LL1ss-156

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
Nitrobenzene	1.08E-03	1.40E-03	1.83E-02

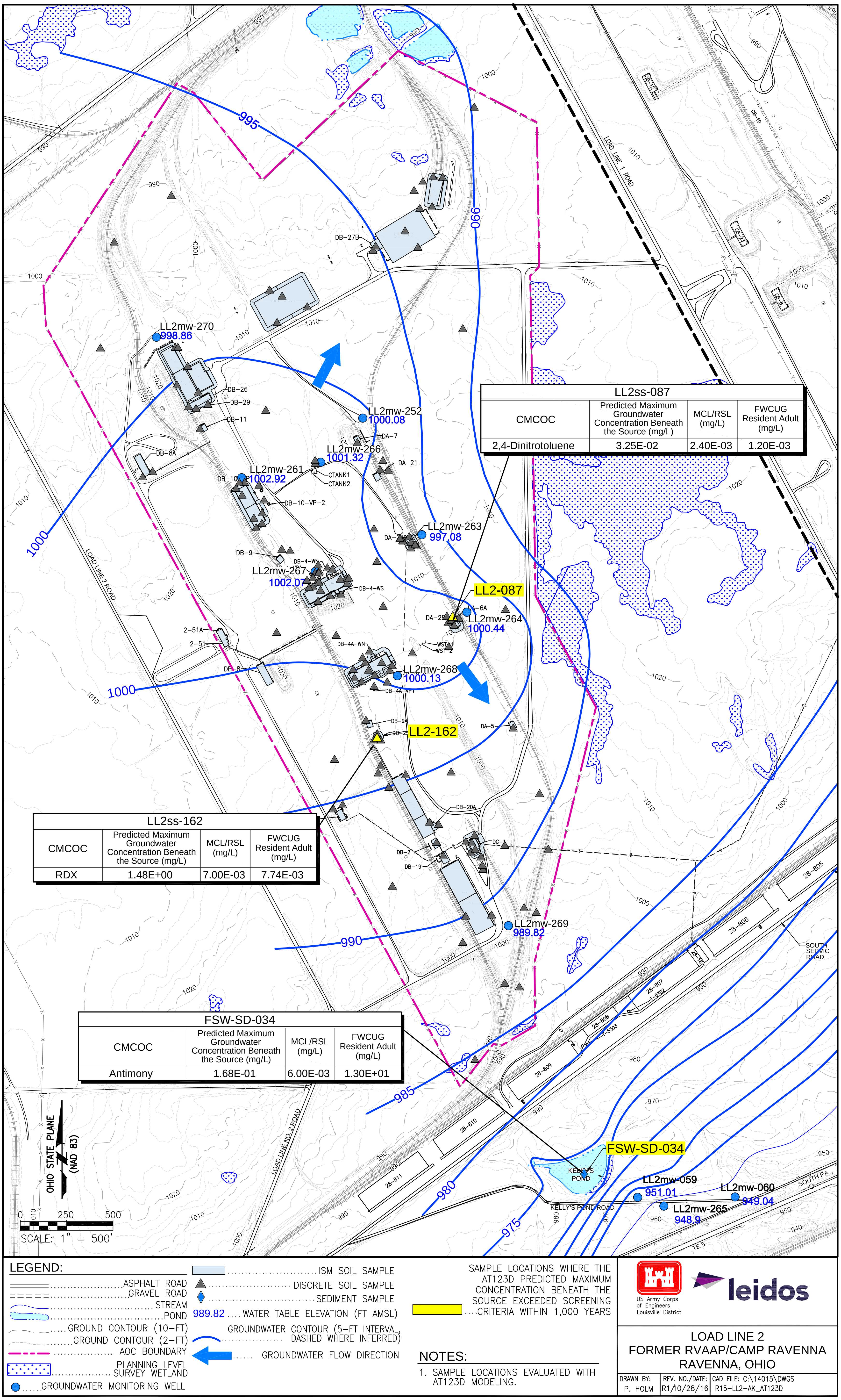
LL1SB-638M

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
RDX	2.73E+01	7.00E-03	7.74E-03

NOTES:

1. SAMPLE LOCATIONS EVALUATED WITH AT123D MODELING.

Figure G-35. CMCOCs Identified for Further Weight-of-Evidence Evaluation Based on AT123D Modeling at Load Line 1



LL2ss-087			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
2,4-Dinitrotoluene	3.25E-02	2.40E-03	1.20E-03

LL2ss-162			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
RDX	1.48E+00	7.00E-03	7.74E-03

FSW-SD-034			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
Antimony	1.68E-01	6.00E-03	1.30E+01

LEGEND:

═══	ASPHALT ROAD
═ ═ ═	GRAVEL ROAD
─ ─	STREAM
▭	POND
─ ─	GROUND CONTOUR (10–FT)
‐ ‐ ‐	GROUND CONTOUR (2–FT)
─ ─ ─	AOC BOUNDARY
▨	PLANNING LEVEL SURVEY WETLAND
●	GROUNDWATER MONITORING WELL
▭	ISM SOIL SAMPLE
▲	DISCRETE SOIL SAMPLE
◆	SEDIMENT SAMPLE
989.82	WATER TABLE ELEVATION (FT AMSL)
⌒	GROUNDWATER CONTOUR (5–FT INTERVAL, DASHED WHERE INFERRED)
←	GROUNDWATER FLOW DIRECTION
🟨	SAMPLE LOCATIONS WHERE THE AT123D PREDICTED MAXIMUM CONCENTRATION BENEATH THE SOURCE EXCEEDED SCREENING CRITERIA WITHIN 1,000 YEARS

NOTES:

1. SAMPLE LOCATIONS EVALUATED WITH AT123D MODELING.

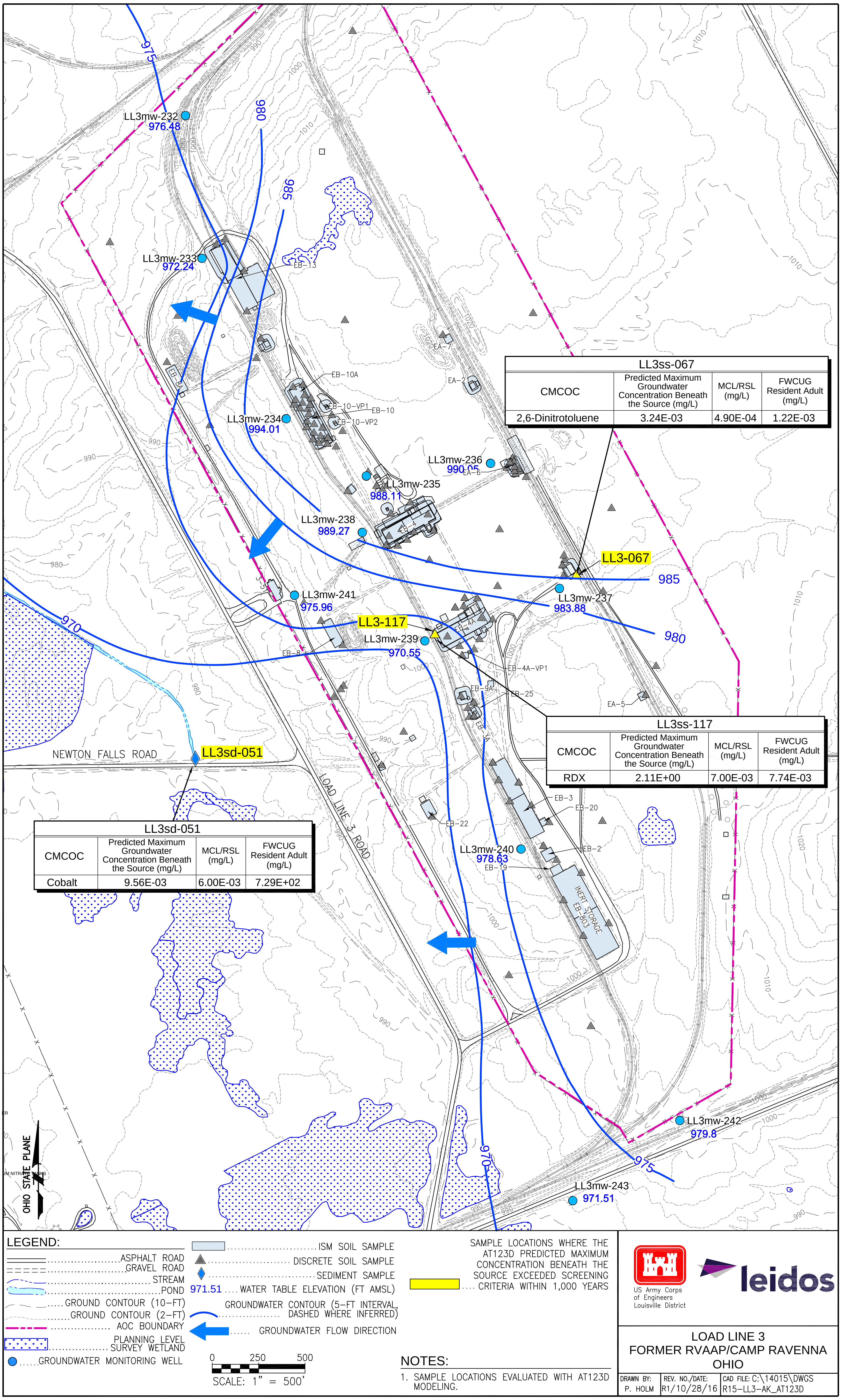
US Army Corps of Engineers Louisville District

leidos

LOAD LINE 2
FORMER RVAAP/CAMP RAVENNA
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\14015\DWGS
P. HOLM	R1/10/28/16	R15–LL2–AK_AT123D

Figure G-36. CMCOCs Identified for Further Weight-of-Evidence Evaluation Based on AT123D Modeling at Load Line 2



LL3ss-067

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
2,6-Dinitrotoluene	3.24E-03	4.90E-04	1.22E-03

LL3ss-117

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
RDX	2.11E+00	7.00E-03	7.74E-03

LL3sd-051

CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
Cobalt	9.56E-03	6.00E-03	7.29E+02

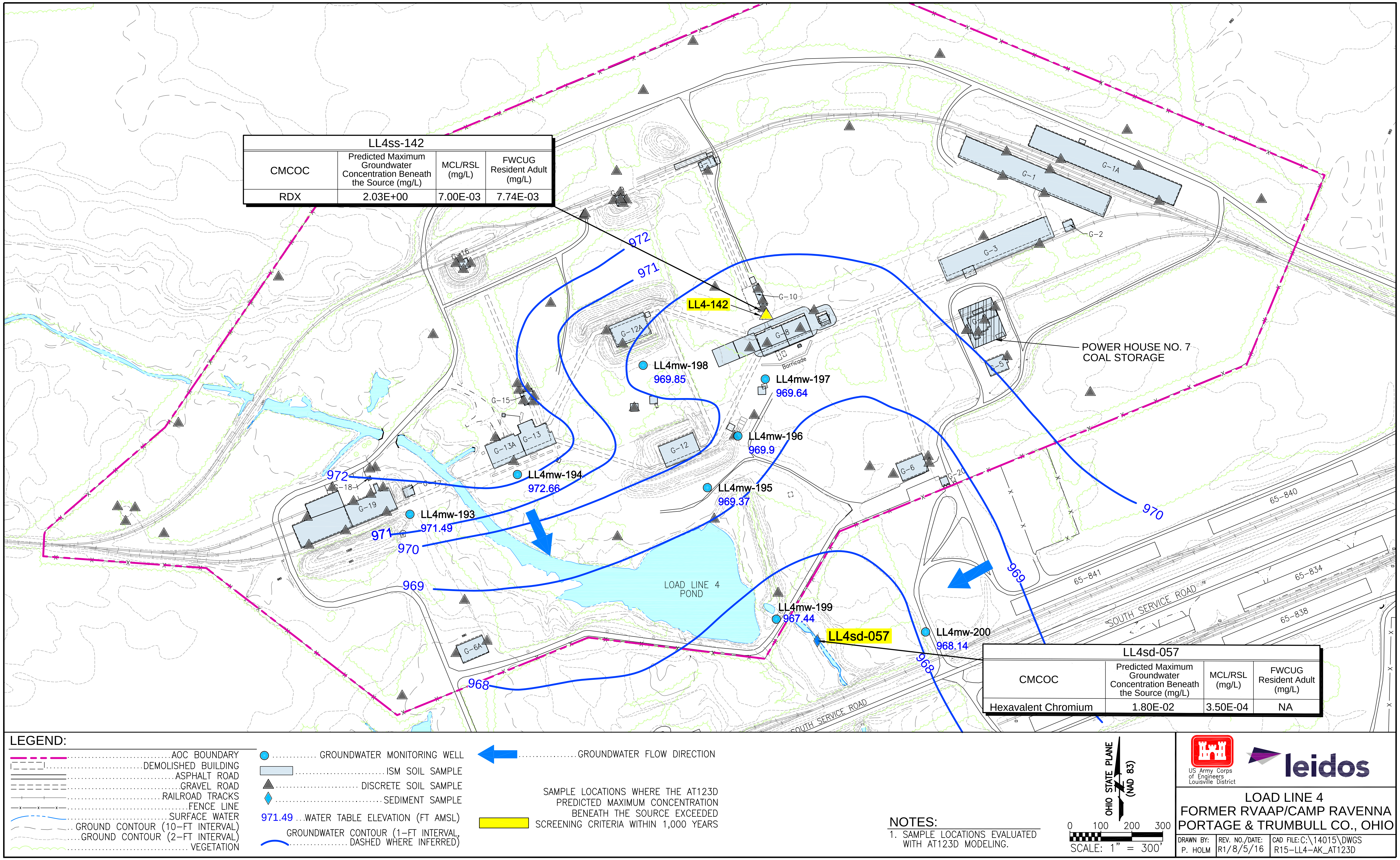
NOTES:

1. SAMPLE LOCATIONS EVALUATED WITH AT123D MODELING.

LOAD LINE 3
FORMER RVAAP/CAMP RAVENNA
OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\14015\DWGS
P. HOLM	R1/10/28/16	R15-LL3-AK_AT123D

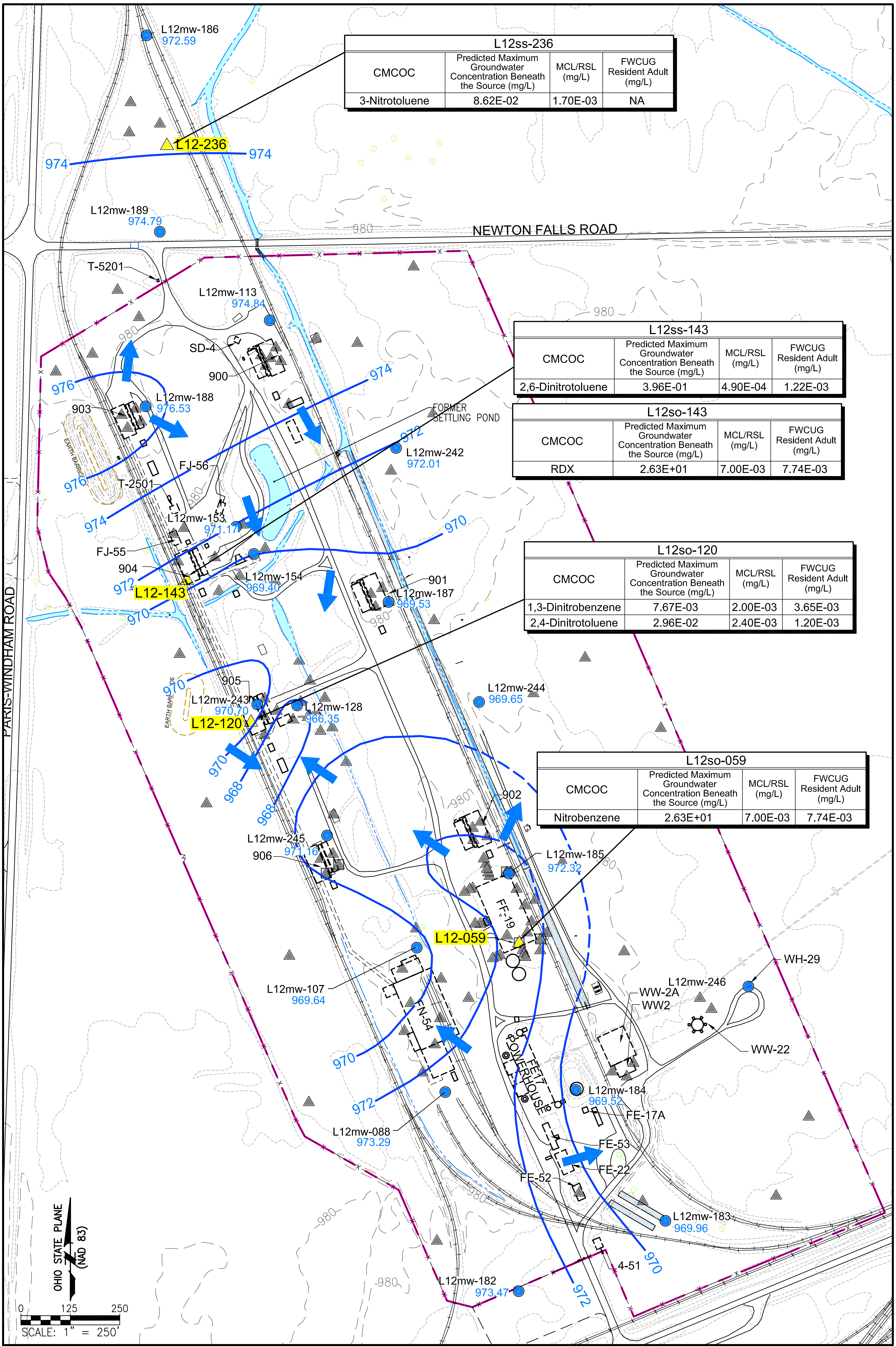
Figure G-37. CMCOCs Identified for Further Weight-of-Evidence Evaluation Based on AT123D Modeling at Load Line 3



LL4ss-142			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
RDX	2.03E+00	7.00E-03	7.74E-03

LL4sd-057			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
Hexavalent Chromium	1.80E-02	3.50E-04	NA

Figure G-38. CMCOCs Identified for Further Weight-of-Evidence Evaluation Based on AT123D Modeling at Load Line 4



L12ss-236			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
3-Nitrotoluene	8.62E-02	1.70E-03	NA

L12ss-143			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
2,6-Dinitrotoluene	3.96E-01	4.90E-04	1.22E-03

L12so-143			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
RDX	2.63E+01	7.00E-03	7.74E-03

L12so-120			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
1,3-Dinitrobenzene	7.67E-03	2.00E-03	3.65E-03
2,4-Dinitrotoluene	2.96E-02	2.40E-03	1.20E-03

L12so-059			
CMCOC	Predicted Maximum Groundwater Concentration Beneath the Source (mg/L)	MCL/RSL (mg/L)	FWCUG Resident Adult (mg/L)
Nitrobenzene	2.63E+01	7.00E-03	7.74E-03

LEGEND:

⊏⊐	DEMOLISHED BUILDING
═	ASPHALT ROAD
┼	RAILROAD TRACKS
—x—x—	FENCE LINE
▭	SURFACE WATER
— —	GROUND CONTOUR (10–FT INTERVAL)
- - -	GROUND CONTOUR (2–FT INTERVAL)
～	VEGETATION
— —	AOC BOUNDARY
●	GROUNDWATER MONITORING WELL
▭	ISM SOIL SAMPLE
▲	DISCRETE SOIL SAMPLE
972.01	WATER TABLE ELEVATION (FT AMSL)
⌒	GROUNDWATER CONTOUR (2–FT INTERVAL, DASHED WHERE INFERRED)
⬅	GROUNDWATER FLOW DIRECTION
🟨	SAMPLE LOCATIONS WHERE THE AT123D PREDICTED MAXIMUM CONCENTRATION BENEATH THE SOURCE EXCEEDED SCREENING CRITERIA WITHIN 1,000 YEARS

NOTES:

1. SAMPLE LOCATIONS EVALUATED WITH AT123D MODELING.

US Army Corps
of Engineers
Louisville District

leidos

LOAD LINE 12
FORMER RVAAP/CAMP RAVENNA
PORTAGE & TRUMBULL COUNTIES, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE: C:\14015\DWGS
P. HOLM	R1/11/9/16	R15–LL12–AK_AT123D

Figure G-39. CMCOCs Identified for Further Weight-of-Evidence Evaluation Based on AT123D Modeling at Load Line 12

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