FINAL

PHASE II REMEDIAL INVESTIGATION REPORT

FOR

LOAD LINE 4 AT THE RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO

VOLUME 1 – MAIN TEXT

PREPARED FOR

US Army Corps of Engineers®

LOUISVILLE DISTRICT
CONTRACT No. DACA45-03-D-0026
DELIVERY ORDER 0001

September 2004

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Prepared by

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SHAW ENVIRONMENTAL, INC.
and
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contributed to the preparation of this document and should not
be considered eligible contractors for its review.

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Shaw Environmental, Inc. and Science Applications International Corporation (SAIC) have completed the Final Report for the Phase II Remedial Investigation for Load Line 4 at the Ravenna Army Ammunition Plant, Ravenna, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of data quality objectives; technical assumptions; methods, procedures, and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

Butch Will, SAIC — 09/03/04 Date
Study/Design Team Leader

Sally Absher, SAIC — 09/03/04 Date
Independent Technical Review Team Leader

Sharon K Robers

Sharon Robers, SAIC — 09/03/04 Date
Human Health Risk Assessment Reviewer

Thomas P. Burns for Barney Cornaby

Barney Cornaby, SAIC — 09/03/04 Date
Ecological Risk Assessment Reviewer

David Cobb, Shaw Environmental, Inc. — 09/03/04 Date
Project Manager

Significant concerns and the explanation of the resolution are as follows:

Independent technical review comments are recorded on an SAIC Document Review Record, per SAIC quality assurance procedure QAAP 3.1. This Document Review Record is maintained in the project file. Changes to the report addressing the comments have been verified by the Study/Design Team Leader.

As noted above, all concerns resulting from independent technical review of the project have been considered.

Mike Fitzgerald

Principal w/ A-E firm — 09/03/04 Date

CONTENTS

FIGURES

TABLES

ACRONYMS

ADD	average daily dose
AEC	U. S. Army Environmental Center
amsl	above mean sea level
AOC	Area of Concern
AT123D	Analytical Transient 1,2,3-Dimensional (model)
AUF	area use factor
BAF	bioaccumulation factor
BCF	bioconcentration factor
BERA	baseline ecological risk assessment
bgs	below ground surface
BHHRA	baseline human health risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMCOC	contaminant migration contaminant of concern
CMCOPC	contaminant migration contaminant of potential concern
COC	chemical of concern
COEC	chemical of ecological concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSF	cancer slope factor
CSM	conceptual site model
CX	Center of Excellence
DAF	dilution attenuation factor
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DLF	dust-loading factor
DNT	dinitrotoluene
DoD	U. S. Department of Defense
DQA	data quality assessment
DQO	data quality objective
EDQL	Ecological Data Quality Level
EPA	U. S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ESV	ecological screening value
EU	exposure unit
FCM	food chain multiplier
FS	Feasibility Study
FWHHRAM	Facility-Wide Human Health Risk Assessor's Manual
GAF	gastrointestinal absorption factor
GPS	global positioning system
GSSL	generic soil screening level
HELP	Hydrologic Evaluation of Landfill Performance (model)
HI	Hazard Index
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	hazard quotient
HVAC	heating, ventilation, and air conditioning
IDW	investigation-derived waste

IEUBK	Integrated Exposure Uptake Biokinetic (model)
ILCR	incremental lifetime cancer risk
IRP	Installation Restoration Program
LCS	laboratory control sample
LOAEL	lowest observed adverse effect level
MCL	maximum contaminant level
MDC	maximum detected concentration
MDL	method detection limit
MOA	Memorandum of Agreement
MS	matrix spike
MSD	matrix spike duplicate
NAWQC	National Ambient Water Quality Criteria
NFA	No Further Action
NGB	National Guard Bureau
NOAEL	no observed adverse effect level
NTU	nephelometric turbidity unit
NWI	National Wetlands Inventory
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ODOW	Ohio Department of Wildlife
OE	ordnance and explosives
OHARNG	Ohio Army National Guard
Ohio EPA	Ohio Environmental Protection Agency
OSC	Operations Support Command
OVA	organic vapor analyzer
PA	Preliminary Assessment
PAH	polycyclic aromatic hydrocarbon
PBT	persistent, bioaccumulative, and toxic
PCB	polychlorinated biphenyl
PEF	particulate emissions factor
PF	Parshall flume
ppm	parts per million
PRG	preliminary remediation goal
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RDA	recommended daily allowance
RDI	recommended daily intake
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RfC	reference concentration
RfD	reference dose
RGO	remedial goal option
RI	Remedial Investigation
RME	reasonable maximum exposure
RRSE	relative risk site evaluation
RTLS	Ravenna Training and Logistics Site
RVAAP	Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation

SAP	Sampling and Analysis Plan
SERA	screening ecological risk assessment
SESOIL	Seasonal Soil Compartment (model)
SHHRA	screening human health risk assessment
SRC	site-related contaminant
STL	Severn Trent Laboratories, Inc.
SVOC	semivolatile organic compound
T&E	threatened and endangered
TAL	target analyte list
TCLP	toxicity characteristic leaching procedure
TEF	toxicity equivalency factor
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	total organic carbon
TRV	toxicity reference value
UCL_{95}	95% upper confidence limit
USACE	U. S. Army Corps of Engineers
USCS	Unified Soil Classification System
UXO	unexploded ordnance
VOC	volatile organic compound
WBG	Winklepeck Burning Grounds
WOE	weight of evidence
WQS	Water Quality Standard
XRF	X-ray fluorescence

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EXECUTIVE SUMMARY

This Phase II Remedial Investigation (RI) Report characterizes the nature and extent of contamination, evaluates the fate and transport of contaminants, and assesses potential risk to human health and the environment resulting from former operations at Load Line 4 at the Ravenna Army Ammunition Plant (RVAAP) in Ravenna, Ohio. RVAAP, which consists of approximately 8,668.3 ha (21,419 acres), was constructed in 1940 and 1941 with the primary missions of depot storage and ammunition loading during World War II. Industrial operations at RVAAP consisted of 12 munitions-assembly facilities referred to as "load lines." In 1992, the status of RVAAP changed from inactive-maintained to modified-caretaker and plans are currently underway to demolish dilapidated buildings and structures at some Areas of Concern (AOCs).

The overall purpose of this Phase II RI Report is to describe the investigation conducted at Load Line 4 to define the vertical and horizontal extent of contamination. The specific objectives of the Phase II RI are as follows.

- Characterize the physical environment of Load Line 4 and surroundings to the extent necessary to define potential contaminant transport pathways and receptor populations.

- Characterize the nature and extent of contamination such that risk evaluations could be conducted and results compared to those from baseline risk assessments at a risk extrapolation reference site [Load Line 1 and Winklepeck Burning Grounds (WBG)]. The risk extrapolation process was developed among the U. S. Army, U. S. Army Corps of Engineers (USACE), and the Ohio Environmental Protection Agency (Ohio EPA), and is contained in a draft facility-wide risk assessment work plan, which is currently in review. In addition, a baseline ecological risk assessment (BERA) has been applied, following current U. S. Army and Ohio EPA guidance.

- Identify whether releases of contamination beyond the AOC boundary are occurring by collecting environmental samples (surface water and sediment) downstream of the AOC boundary within exit conveyances and using applicable historical information, including results of the Phase I RI. Data collected prior to the Phase I RI are of limited use due to the lack of corresponding quality assurance/quality control data and information on detection limits and any verification/validation processes.

- Characterize the sources of contamination at Load Line 4 sufficient to screen and evaluate remedial alternatives in a subsequent Feasibility Study (FS). Data on source locations, types and concentrations of contaminants, potential release mechanisms, physical and chemical properties of contaminants present, and geotechnical characteristics of environmental media were identified as key data needs.

- Provide recommendations for any additional investigations and/or actions.

In addition to the specific objectives listed above, a key project quality objective for the Phase II RI at Load Line 4 was to develop and document lessons learned so that future projects may benefit from lessons learned and constantly improve data quality and performance. Lessons learned pertaining to project mobilization, analytical interferences, use of field analytical methods, involvement of USACE and regulator staff, investigation-derived waste (IDW) coordination, field facilities, and actions to take in the event of a suspension of operations were developed and documented (see Section 8.4).

This Phase II RI was conducted as part of the U. S. Army's Installation Restoration Program (IRP) approach to implement the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) process at RVAAP, which prioritizes environmental restoration at AOCs based on their relative potential threat to human health and the environment. The purpose of the Phase II RI is to determine the nature and extent of contamination in the environmental media so that screening level human health and ecological risk assessments (ERAs) can be performed. Results of the risk assessments will be used to determine whether an AOC requires no further action (NFA) or will be the subject of an FS.

PHYSICAL ENVIRONMENT

Load Line 4 is situated in the southeastern quadrant of the RVAAP facility. The topography within the AOC is characterized as subdued on a glacial till surface. The overall topography slopes very gently from north to south within the AOC, with localized steeper slopes cut along main streams and the edge of the steeling pond. Cultural features include asphalt and gravel access roads, man made ditches, sanitary and storm sewer lines, manholes, railroad beds, and buildings.

The regional geology at RVAAP consists of horizontal to gently dipping bedrock strata of Mississippian- and Pennsylvanian-age overlain by varying thicknesses of unconsolidated glacial deposits. Subsurface characterization during the Phase II RIs did not identify bedrock in any boring drilled at Load Line 4; the deepest boring was drilled to approximately 6.7 m (22 ft) below ground surface (bgs). Soils of the Mahoning series, characterized as poorly drained, silty clay loam or clay loam which formed over glacial till, are present at Load Line 4. The unconsolidated zone varies widely in character from one area to another due to lateral discontinuity within the glacial till.

Sand and gravel aquifers are present in buried-valley and outwash deposits in Portage County. Recharge of these units comes from surface water infiltration of precipitation and surface streams. Due to the heterogeneous nature of the unconsolidated glacial materials, groundwater flow patterns are difficult to determine. Laterally, most groundwater flow occurs along preferential pathways (sand seams, channel deposits, etc.). A facility-wide water table map prepared in August 2001 as part of the Phase II RI shows the water table is a subdued representation of the surface topography. The predominant groundwater flow direction is to the east, with flow to the south in the vicinity of Load Line 4.

The primary surface water conveyance at Load Line 4 enters the AOC from the west and is sourced from comparatively undisturbed areas, flowing from northwest to southeast and into the large settling pond. Drainage from the pond flows southeast of the AOC, exiting RVAAP at Parshall flume (PF)-8.

PREVIOUS INVESTIGATIONS

The Phase II RI at Load Line 4 was designed to collect data to supplement information obtained from two previous investigations at the site

- *Preliminary Assessment for the Ravenna Army Ammunition Plant* (USACE 1996), and

- *Phase I Remedial Investigation of High Priority Areas of Concern at the Ravenna Army Ammunition Plant* (USACE 1998).

The preliminary assessment of Load Line 4 performed in 1996 included the site within the list of medium priority sites based on a relative risk ranking methodology. Evaluation of operational history and the potential for contamination of environmental media resulted in the load line being assigned to a group of 11 high-priority AOCs under the RVAAP IRP.

The Phase I RI performed at Load Line 4 in 1996 included sampling and analysis of surface soils, sediment, and groundwater at three temporary well points. Phase I RI sampling data indicated concentrations of explosives, inorganics, and organic compounds occurring in soil and sediment, primarily within the former operations areas.

PHASE II REMEDIAL INVESTIGATION INVESTIGATIVE APPROACH

The findings and data gaps identified during previous investigations guided the specific objectives and sampling design of the Phase II RI at Load Line 4. As detailed in the *Sampling and Analysis Plan Addendum No. 1 for the Phase II RI of Load Lines 2, 3, and 4 at the Ravenna Army Ammunition Plant, Ravenna Ohio* (USACE 2001b), the Phase II RI sampling objectives, by medium, included the following.

Surface Soil and Sediment

- Determining the nature and horizontal extent of contamination using biased sampling at each area within Load Line 4 having either explosives at concentrations ≥ 1 mg/kg, lead ≥ 100 mg/kg and/or chromium ≥ 35 mg/kg, or polychlorinated biphenyls (PCBs) ≥ 1 mg/kg in surface soil during the Phase I RI. Primary areas of interest include Buildings G-8 and G-12/-12A and the settling basin. Other areas of interest not characterized during the Phase I RI include the storm and sanitary sewer system.

- Comparing the surface soil and sediment data to the RVAAP facility-wide background data set, which characterizes natural facility-wide variability for 23 target analyte list (TAL) metals.

- Characterizing large non-production areas by random-grid sampling using a statistical approach to ensure adequate area coverage and density.

- Assessing the suitability of field-based colorimetric analyses of trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in soil and sediment samples. Results of these tests will determine the suitability of explosive field data for future environmental investigations and remedial activities.

Subsurface Soil

- Defining the vertical extent of contamination and studying transport pathways of any such materials.

Surface Water

- Determining whether runoff from contaminated areas around the former production area may contribute contaminants in dissolved and suspended form to the surface water system at Load Line 4.

- Determining whether drainages at Load Line 4 allow contaminants to migrate south off of RVAAP.

Groundwater

- Characterizing the Load Line 4 hydrogeologic flow system and chemical groundwater quality to identify possible contamination in groundwater and potential off-AOC transport of contamination to the south.

- Comparing groundwater results to the facility-wide background data set.

These objectives were met through the field activities conducted from July to September 2001 at Load Line 4.

AVAILABLE DATA

Load Line 4 has remained relatively undisturbed between the Phase I and Phase II RIs. No demolition of structures or extensive disturbance of soil has occurred. Soil data obtained during the Phase I RI in 1996 were deemed to still represent current conditions at the AOC; thus, the data are evaluated in conjunction with Phase II data in the contaminant nature and extent evaluation. The Phase I soil data are also included in quantitative analyses (e.g., summary statistics and risk evaluations).

Phase I sediment data are also assumed to be representative of site conditions as they exist today and are included in the Phase II evaluations. Where a Phase I station was re-sampled during the Phase II RI, the latter data were used as the most representative of current conditions in assessment of contaminant nature and extent and risk evaluations. In locations where only Phase I RI data existed, they were used by necessity to provide an overall evaluation of contamination and risk. Phase I RI dry sediment samples from intermittent ditch lines (non-viable habitat) were addressed as soil.

Phase I groundwater data are not included for any further evaluation purposes because of their age and the fact that samples were not obtained from specification monitoring wells.

Phase I data are appropriately qualified in the nature and extent and risk evaluations with respect to uncertainties resulting from their age, changes in analytical methods and detection limits, and limited TAL metals for many samples. However, the Phase I RI data for soil and sediment provide valuable information regarding extent of contamination related to source areas and within exit conveyances from the source areas.

The data collected under this Phase II RI include

- 82 surface soil samples,
- 11 subsurface soil samples,
- 9 main stream and settling pond sediment samples,
- 10 main stream and settling pond surface water samples,
- 8 groundwater samples,
- 11 storm and sanitary/sewer and sump/basin sediment samples,
- 7 storm and sanitary/sewer and sump/basin water samples, and
- 3 floor sweep samples.

Geological characterization was achieved through the collection of undisturbed and disturbed geotechnical samples from soil sampling stations, monitoring well borings, and test pits.

NATURE AND EXTENT

The RI evaluated the nature and extent of contaminated surface soil [0 to 0.3 m (0 to 1 ft) bgs]; subsurface soil to depths of 1 m (3 ft), sediment, surface water, and groundwater. The surface and subsurface soil, sediment, and surface water were divided into spatial aggregates based on former process operations and drainage areas. Surface soil and subsurface soil were divided into two groups; those believed to be impacted by process-related activities and those believed to be relatively non-contaminated. Sediment and surface water were grouped by drainage area into three aggregates to facilitate examination of contamination spread by these media and to focus on the receptor exposure points for the screening level human health and ERAs. Groundwater was considered on an AOC-wide basis. Samples from storm and sanitary sewers and buildings and structures are addressed as separate aggregates because these samples do not fill the risk exposure scenarios evaluated in this RI.

Surface Soil

Explosive and propellant compounds in surface soil at Load Line 4 are relatively few in number and concentrations are comparatively low relative to Load Lines 1 through 3, and are limited in extent to the immediate proximity of source areas. Pervasive inorganic site-related contaminants (SRCs) in surface soil include inorganic constituents such as barium, cadmium, chromium, copper, lead, thallium, and zinc. Semivolatile organic compounds (SVOCs) detected in surface soil were primarily polycyclic aromatic hydrocarbons (PAHs), which were observed frequently although at generally low concentrations. Few volatile organic compounds (VOCs) were detected in surface soil samples from Load Line 4 and concentrations were generally low. PCBs are not nearly as widespread as compared to the other melt-pour load lines at RVAAP. Some pesticides were detected sporadically. The key results for contaminant nature and extent in soil are summarized by aggregate below.

Explosive Handling Areas Aggregate

- This exposure unit (EU) contained the highest concentrations and most extensive SRCs within Load Line 4.
- Explosives within this aggregate are limited in extent to the proximity of the major production and processing buildings. Concentrations were generally low, with a maximum detected value of 19 mg/kg for RDX near Building G-8.
- Numerous inorganic SRCs were identified in this aggregate; aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, and zinc were most pervasive. SVOCs were detected frequently, with the highest concentrations clustered near Buildings G-8 and G-12.
- VOCs are generally absent in this aggregate.
- Low concentrations of PCBs were detected in a number of samples with the highest concentrations (up to 28 mg/kg) clustered in the vicinity of the former production buildings.
- Low concentrations of pesticides were detected.

Preparation and Receiving Areas Aggregate

- Explosives were not detected in samples submitted for laboratory analysis.
- Nitrocellulose was present at low concentrations at one location north of Building G-1A.
- Pervasive inorganic SRCs include arsenic, barium, chromium, cobalt, copper, cyanide, lead, manganese, nickel, vanadium, and zinc. Although their distribution is widely variable, the highest overall concentrations of inorganics appear to be clustered on the south side of Building G-4.
- Low concentrations of PAHs were detected; most observed detections were clustered near Building G-4.

- PCBs appear to be clustered near Building G-4 at concentrations up to 48 mg/kg.
- VOCs are generally absent.
- No pesticides were detected.

Packaging and Shipping Areas Aggregate

- Explosives were not detected in this aggregate.
- Nitrocellulose was detected in one sample south of Building G-19.
- Pervasive inorganic SRCs include barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, thallium, and zinc.
- SVOCs (primarily PAHs) were detected in only two samples with the highest concentration occurring near Building G-19.
- Low levels of PCBs (up to 1.3 mg/kg) and trace levels of pesticides were observed in the vicinity of Building G-19.
- VOCs, with the exception of trace levels of toluene, were not detected.

Change Houses Aggregate

- No explosives compounds greater than 1 mg/kg were detected during field analyses.
- Few inorganic results exceeded RVAAP background values; lead occurred at the highest concentrations.
- Low estimated concentrations of 16 PAHs and 3 VOCs were detected on the east side of Building G-6.
- PCB-1260 was detected once at an estimated concentration of 0.059 mg/kg in a sample collected on the east side of Building G-6.
- Pesticides were not detected in this aggregate.

Perimeter Area Aggregate

- Field analyses of samples collected near the WW-23 Water Tower detected TNT at concentrations up to 2.8 mg/kg.
- Inorganic SRCs exceeding background concentrations were clustered in the vicinity of the WW-23 Water Tower with lead occurring most frequently at concentrations up to 1,340 mg/kg.
- Low, estimated concentrations of several PAHs and bis(2-ethylhexyl)phthalate were detected near the WW-23 Water Tower.
- VOCs, with the exception of trace levels of toluene, were not detected.

Melt-Pour Area Drainage Ditches Aggregate

- No explosives compounds were detected at a concentration of 1.0 mg/kg or greater during field analyses.
- Extent and distribution of inorganic SRCs was limited and maximum concentrations rarely exceeded background values by factors of more than 2 times.
- Low, estimated concentrations of several PAHs were detected in one sample.
- VOCs, with the exception of trace levels of acetone, were not detected.

Subsurface Soil

Contamination in subsurface soil within Load Line 4 is limited, with inorganics representing the primary SRCs. Explosives and propellants were not detected. Metals detected at concentrations exceeding background criteria include barium, beryllium, cadmium, lead, and zinc. The highest concentrations of metals above background occur in the vicinity of Building G-1A in the Preparation and Receiving Areas Aggregate and Building G-9 in the Explosives Handling Areas Aggregate.

Sediment

- Explosive compounds were detected in sediment samples, although at concentrations less than 1 mg/kg.
- Inorganic SRCs were identified in sediment; however, the maximum concentrations for all detected constituents were only between 2 and 3 times the established background criteria. Cadmium was detected in sediment collected from all three EUs established within the main stream and settling pond, although all values were estimated concentrations of 1 mg/kg or less. The number and concentrations of inorganics are greatest in sediment within the settling pond.
- One PCB compound was detected at a concentration of less than 0.5 mg/kg.
- VOCs were only sporadically detected at low concentrations.
- Pesticides and SVOCs were not detected in sediment.

Surface Water

- Explosives were not detected in water samples.
- Vanadium is the only inorganic SRC detected across all of the surface water aggregates with concentrations ranging from 0.00099 mg/L at the upstream surface water station to 0.0014 mg/L in the Exit Drainage Aggregate. All other inorganic SRCs were detected sporadically and at low concentrations, except manganese. Manganese was detected in surface water at concentrations nearly 10 times background at the two locations upstream of Perimeter Road.
- The pesticide 4,4’-dichlorodiphenyltrichloroethane (DDT) was detected in one water sample from the settling pond; no SVOCs or PCBs were detected.
- VOCs were only sporadically detected at low concentrations in surface water.

Groundwater

- Explosives, propellants, pesticides, and PCBs were not detected in groundwater at Load Line 4.

- Low concentrations of metals identified as SRCs were observed; however, their occurrence and distribution above background criteria were sporadic.

- One SVOC and two VOCs were detected at low, estimated concentrations in three groundwater samples collected from monitoring wells in Load Line 4.

Sewer System Water and Sediment

Storm and Sanitary Sewer System Water

- Trace levels of RDX; 2-amino-4,6-dinitrotoluene (DNT); and 4-amino-2,6-DNT were detected in water collected from three manholes.

- Water samples contained elevated levels of inorganic SRCs.

- PAHs, PCBs, and pesticides were not detected in the storm/sanitary sewer system waters.

Storm and Sanitary Sewer System Sediment

- Accumulation of explosives in sediment within the storm and sanitary sewer system of Load Line 4 is not evident based on limited sediment samples collected from sewer system manholes during the Phase II RI (Section 4.3.3).

- Sediment collected from several manholes contained inorganic SRCs at concentrations between 5 and 9 times RVAAP background values for sediment.

- Low levels of PAHs, PCBs, and pesticides were detected in the sewer system sediment samples.

- VOCs are generally absent in sediment within the storm and sanitary sewer systems at Load Line 4.

Buildings and Structures

- Soil collected from beneath building sub-floors is generally uncontaminated based upon a limited number of samples collected from beneath building floor slabs (Section 4.8.1).

- Sediment collected from the Building G-8 washout basin contained elevated levels of metals, explosives, propellants, PCBs, and pesticides. The associated water sample contained elevated levels of many constituents observed at high concentrations in sediment.

- Sediment collected from the Building G-16 sedimentation basin contained elevated concentrations of several metals related to historical processes (chromium, copper, and lead). No water was present within this basin.

- Floor sweep samples were comprised of a high percentage of iron. Copper, cadmium, chromium, and lead were present at high concentrations. Low concentrations of explosives were detected only in samples collected from Buildings G-8 and G-19. Low concentrations of PCBs, pesticides, and various PAHs were also detected. Cadmium and lead were detected in toxicity characteristic leaching procedure (TCLP) extracts; however, no constituent exceeded their respective criteria for characteristically hazardous wastes.

FATE AND TRANSPORT ANALYSIS

Contaminant fate and transport modeling performed as part of the Phase II RI included leachate modeling [Seasonal Soil Compartment (SESOIL)] at the source area within Load Line 4 demonstrating the highest levels of process-related contaminants (Buildings G-8 vicinity). Groundwater modeling [Analytical Transient 1-, 2-, 3-Dimensional (AT123D)] was conducted from this source to selected receptors or exit points from the AOC. The receptor and exit points selected for groundwater transport modeling included the main stream at its closest point to Building G-8; the main stream is the nearest presumed groundwater baseflow discharge point. In addition, groundwater transport modeling from the source area to the RVAAP facility boundary was conducted to evaluate the potential for off-site migration of any identified contaminant migration contaminants of potential concern (CMCOPCs).

SESOIL Modeling

Chromium, selenium, and RDX were the only chemicals identified as initial CMCOPCs based on source loading predicted by the leachability analysis near the selected primary source (Building G-8). The SESOIL modeling results indicate that all of these three constituents may leach from surface soil to groundwater with concentrations beneath the source area above groundwater maximum contaminant levels (MCLs) or risk-based concentrations (RBCs). The timeframe for RDX to exceed its criteria is 6 years, suggesting that such leaching has already occurred. The timeframes for chromium and selenium are 411 and 119 years, respectively, suggesting that concentrations may increase in the future. None of these constituents were detected in groundwater at Load Line 4. The leaching modeling is conservative and migration of these constituents may be attenuated because of moderate to high retardation factors for these constituents.

AT123D Modeling

Modeling of contaminant transport in shallow groundwater was conducted for five identified CMCOPCs from the Building G-8 source area to two endpoints. Three of these five CMCOPCs (chromium, selenium, and RDX) were identified from SESOIL modeling results and the remaining two (iron and manganese) were based on observed groundwater concentrations. The first endpoint evaluated was the main stream at the closest point to the source area; the main stream is presumed to be a discharge area for shallow groundwater based on potentiometric data. The second endpoint modeled was the RVAAP facility boundary at its closest point to the source area.

AT123D modeling results indicate that migration of RDX to the main stream endpoint may occur with concentrations at the endpoint above RBCs. The predicted timeframe for migration is 1,000 years, suggesting that concentrations at the endpoint may increase over time. None of the metals (chromium, iron, manganese, and selenium) were predicted to exceed RBCs or MCLs at the main stream within the 1,000-year modeling period. Modeling results indicated that migration of the five CMCOPCs to the RVAAP boundary endpoint at concentrations exceeding MCLs or RBCs will not occur within the 1,000-year modeling period.

SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT

A screening human health risk assessment was conducted to identify chemicals of concern (COCs) and remedial goal options (RGOs) for contaminated media at Load Line 4 for three potential future use scenarios: National Guard use, recreational use, and residential use. Results have been presented for all scenarios and exposure pathways. The following steps were used to generate conclusions regarding human health risks and hazards associated with contaminated media at Load Line 4:

- identification of chemicals of potential concern (COPCs);
- calculation of exposure point concentrations (EPCs) for COPCs;
- calculation of screening RGOs at a chemical hazard index (HI) of 0.1 or risk level of 10^{-6} for all identified COPCs;
- identification of COCs by comparing COPC concentrations against screening RGOs; and
- calculation of risk-based RGOs (HI of 1 or risk level of 10^{-5}) to move forward to the FS.

COCs were identified for National Guard receptors (Trainee, Security Guard/Maintenance Worker, and Fire/Dust Suppression Worker), recreational receptors (Hunter/Trapper/Fisher), and residential receptors (Resident Subsistence Farmer Adult and Child). A COC summary is presented in Table ES-1, with results discussed below for each medium. Risk-based RGOs were calculated for all chemicals identified as COCs (see Chapter 6.0) for any medium or receptor [e.g., arsenic is identified as a COC in surface water for the National Guard Trainee and for the Resident Farmer (adult and child), but not for the Fire/Dust Suppression Worker or the Hunter/Trapper/Fisher; however, risk-based RGOs are calculated for this metal for all five receptors exposed to surface water].

Groundwater

Two COCs (arsenic and manganese) were identified for the National Guard Trainee exposed via potable use of groundwater; these COCs were also identified for the On-Site Residential Farmer scenarios. For these groundwater COCs, ratios of EPCs to RGOs indicate that estimated cancer risks would be slightly greater than 10^{-5} for the National Guard Trainee and slightly greater than 10^{-4} for the residential farmer scenarios. These are hypothetical future scenarios; no receptors are currently using groundwater from the AOC for any purpose.

Surface Water and Sediment

Exposure to surface water and sediment was evaluated for five receptor scenarios: National Guard Fire/Dust Suppression Worker, National Guard Trainee, Hunter/Trapper/Fisher, and Resident Farmer (adult and child). The following summarizes the resulting COCs in surface water and sediment at Load Line 4.

- Three Load Line 4 COCs were identified for the National Guard Trainee exposed to surface water, including two metals (arsenic and manganese) and one pesticide (4,4'-DDT). All three COCs were also identified for the On-Site Residential Farmer scenarios. Two COCs (arsenic and manganese) were identified for the Main Stream Segment Upstream of Perimeter Road Bridge Aggregate and one COC (4,4'-DDT) was identified for the Main Stream Segment Downstream of Perimeter Road Bridge and the Settling Pond Aggregate; no surface water COCs were identified for the Exit Drainage Aggregate. For the surface water COCs, ratios of EPCs to RGOs indicate that estimated cancer risks would be less than 10^{-6} for the Fire/Dust Suppression Worker and the Hunter/Trapper/Fisher and between 10^{-6} and 10^{-5} for the National Guard Trainee and the residential farmer scenarios.

Table ES-1. Chemicals Exceeding RGOs (COCs) by Receptor/Medium/Exposure Unit Combination at Load Line 4

COC	Groundwater			Surface Water					Sediment				
	National Guard Trainee	Resident Farmer Adult	Resident Farmer Child	Dust/Fire Control Worker	National Guard Trainee	Hunter/ Trapper/ Fisher	Resident Farmer Adult	Resident Farmer Child	Dust/Fire Control Worker	National Guard Trainee	Hunter/ Trapper/ Fisher	Resident Farmer Adult	Resident Farmer Child
Inorganics													
Aluminum										MS			MS
Arsenic	LL4	LL4	LL4		MU		MU	MU					
Manganese	LL4	LL4	LL4		MU		MU	MU					
Thallium													MS
Organic PCBs													
PCB-1254													
PCB-1260													
Organic Pesticides													
4,4'-DDT					MS		MS	MS					
Organic Semivolatiles													
Benz(*a*)anthracene													
Benzo(*a*)pyrene													
Benzo(*b*)fluoranthene													
Dibenz(*a,h*)anthracene													
Indeno(1,2,3-*cd*)pyrene													

Table ES-1. Chemicals Exceeding RGOs (COCs) by Receptor/Medium/Exposure Unit Combination at Load Line 4 (continued)

	Shallow Surface Soil					**Deep Surface Soil**	**Subsurface Soil**	
COC	**Security Guard/ Maintenance Worker**	**Dust/Fire Control Worker**	**Hunter/ Trapper/ Fisher**	**Resident Farmer Adult**	**Resident Farmer Child**	**National Guard Trainee**	**Resident Farmer Adult**	**Resident Farmer Child**
Inorganics								
Aluminum					EH	EH,PR		PR
Arsenic	EH,MP,PR			EH,MP,PR	EH,MP,PR	EH,MP,PR		
Manganese					EH,PA,PR,PS	EH,PA,PR,PS	PR	PR
Thallium					CH,EH,MP,PR			
Organic PCBs								
PCB-1254	EH,PR			EH,PR,PS	EH,PR,PS	PR		
PCB-1260	EH,PR			EH,PR,PS	EH,PR,PS			
Organic Pesticides								
4,4'-DDT								
Organic Semivolatiles								
Benz(*a*)anthracene				EH				
Benzo(*a*)pyrene	CH,EH,PA			CH,EH,PA,PS	CH,EH,PA,PS			
Benzo(*b*)fluoranthene	EH			CH,EH	EH			
Dibenz(*a,h*)anthracene	EH			CH,EH	EH			
Indeno(1,2,3-*cd*)pyrene				EH				

COCs are shown for each medium/receptor/area of concern combination. Chemicals whose exposure point concentration exceeds its screening risk-based RGO are COCs.
Area of concern codes are as follows:

- LL4 = Load Line 4.
- CH = Change Houses Aggregate.
- ED = Exit Drainage Aggregate.
- EH = Explosives Handling Areas Aggregate.
- MP = Melt-Pour Area Drainage Ditches Aggregate.
- MS = Main Stream Segment and Settling Pond Aggregate.
- MU = Main Stream Segment Upstream of Perimeter Road Aggregate.
- PA = Perimeter Area Aggregate.
- PR = Preparation and Receiving Areas Aggregate.
- PS = Packaging and Shipping Areas Aggregate.

COC = Chemical of concern.
DDT = Dichlorodiphenyltrichloroethane.
PCB = Polychlorinated biphenyl.
RGO = Remedial goal option. Screening risk-based RGOs are based on a cancer risk level of 10^{-6} or a hazard level of 0.1 (whichever is smaller) and are shown in Tables Q-10 through Q-15. Screening of Load Line 3 data to determine COCs is shown in Tables Q-16 through Q-21.

- Aluminum was the only COC identified for the National Guard Trainee exposed to sediment; this COC and thallium were also identified for the On-Site Residential Farmer Child. Both COCs were identified for the Main Stream Segment Downstream of Perimeter Road Bridge and the Settling Pond Aggregate; no sediment COCs were identified for the Main Stream Segment Upstream of Perimeter Road Bridge or Exit Drainage Aggregates. Aluminum and thallium are both non-carcinogenic chemicals.

Soil

Soil was evaluated at six EUs defined on the basis of Load Line 4 operational history and site characteristics. Three vertical aggregations of the soil column were evaluated depending on the receptor scenario:

- shallow surface soil from 0 to 0.3 m (0 to 1 ft) bgs, as applied to all receptors, except the National Guard Trainee;
- deep surface soil from 0 to 1.3 m (0 to 4 ft) bgs, as applied only the National Guard Trainee; and
- subsurface soil defined as all soil deeper than 0.3 m (> 1 ft) bgs for the Resident Farmer adult and child only.

Direct contact (ingestion, dermal contact, and inhalation) with surface and subsurface soils was evaluated for six receptors: National Guard Security Guard/Maintenance Worker (shallow surface soil), National Guard Fire/Dust Suppression Worker (shallow surface soil), National Guard Trainee (deep surface soil), Hunter/Trapper/Fisher (shallow surface soil), and Resident Farmer (adult and child) (shallow surface soil and subsurface soil). The following summarizes the resulting COCs in soil at Load Line 4.

Shallow Surface Soil

Eleven Load Line 4 COCs were identified for shallow surface soil (Table ES-1). Multiple shallow surface soil COCs were identified for the Security Guard/Maintenance Worker, the Resident Farmer Adult, and the Resident Farmer Child. No COCs were identified for the Dust/Fire Control Worker or the Hunter/Trapper/Fisher. The number of shallow surface soil COCs identified for each EU ranged from 2 (Melt-Pour Drainage Ditches Aggregate and Perimeter Area Aggregate) to 11 (Explosives Handling Areas Aggregate).

Ratios of EPCs to RGOs provide an indication of estimated cancer risks. All estimated risks for shallow surface soil COCs would be less than 10^{-6} for the Fire/Dust Suppression Worker and Hunter/Trapper/Fisher. For the Security Guard/Maintenance Worker, most COCs would produce a cancer risk at or slightly above 10^{-6}, with one exception: the estimated cancer risk would be slightly larger than 10^{-5} for PCB-1254 in the Preparation and Receiving Areas Aggregate.

For the resident farmer scenarios, estimated cancer risks would exceed 10^{-5} for several shallow surface soil COCs, including:

- arsenic in the Explosives Handling Areas, the Preparation and Receiving Areas, and the Melt-Pour Drainage Ditches Aggregates;
- PCB-1254 in the Preparation and Receiving Areas Aggregate;
- PCB-1260 in the Explosives Handling Areas Aggregate; and
- benzo(*a*)pyrene in the Explosives Handling Areas Aggregate.

Deep Surface Soil

Four Load Line 4 COCs were identified for the National Guard Trainee exposed to deep surface soil, including three metals (aluminum, arsenic, and manganese), and one PCB (PCB-1254). The number of deep surface soil COCs identified for each EU varied: none for the Change Houses Aggregate; one for the Melt-Pour Drainage Ditches, the Packaging and Shipping Areas, and the Perimeter Area Aggregates; three for the Explosives Handling Areas Aggregate; and four for the Preparation and Receiving Areas Aggregate.

Ratios of EPCs to RGOs indicate that estimated cancer risks would be below 10^{-6} for most deep surface soil COCs; two COCs would result in estimated cancer risk to the National Guard Trainee of slightly larger than 10^{-6} at the Explosives Handling Areas Aggregate (arsenic), at the Preparation and Receiving Areas Aggregate (arsenic and PCB-1254), and at the Melt-Pour Drainage Ditches Aggregate (arsenic).

Subsurface Soil

Two metals were identified as Load Line 4 subsurface soil COCs for the resident farmer scenarios: aluminum and manganese. The COCs were identified for the Preparation and Receiving Areas Aggregate only; no subsurface soil COCs were identified for the Explosives Handling Areas, Packaging and Shipping Areas, and the Perimeter Area Aggregates. Aluminum and manganese are both non-carcinogenic chemicals.

SCREENING AND BASELINE ECOLOGICAL RISK ASSESSMENT

The Load Line 4 site contains sufficient terrestrial and aquatic (surface water and sediment) habitat to support various classes of ecological receptors, such as vegetation, small and large mammals, and birds. Due to the presence of suitable habitat and observed receptors at the site, a screening ecological risk assessment (SERA) was performed. The SERA was performed in accordance with written guidance from the U. S. Environmental Protection Agency (EPA), as well as the Army's protocol for the site-wide ERA at Ravenna. The objective of the SERA was to identify whether any of the detected analytes in surface soil, sediment, and surface water at Load Line 4 posed sufficient potential risk to ecological receptors to warrant the analytes being classified as chemicals of potential ecological concern (COPECs). This was done for the most important pathways involving soil, sediment, and surface water and receptors that would be exposed to the media. Following the SERA, a BERA (Ohio EPA Level III) was performed on the preliminary COPECs. The methods followed the Army and Ohio EPA protocols and resulted in constituents of ecological concern (COECs). Deep groundwater is not considered an exposure medium because ecological receptors are unlikely to contact groundwater at its depth of greater than 5 ft bgs. Shallow groundwater, once it surfaces, is assumed to be the same as surface water where a complete pathway was possible. Air is not considered an exposure medium because potential volatile organics are believed to have dissipated. Thus, surface soil, sediment, surface water (for direct exposure), and biota (e.g., indirect exposure via the food chain) were retained as the exposure media for the Load Line 4 SERA.

Soil

Risks were evaluated for five EUs for surface soil based on historical use and geographic proximity. At all EUs, except the Melt-Pour Area Drainage Ditches Aggregate, most preliminary COPECs were identified by comparison of maximum detects to ecological screening values (ESVs). One constituent (PCB-1254) was identified as a COPEC in absence of ESVs. There were no new analytes detected at Load Line 4 compared to Load Line 1. All of these preliminary COPECs were further evaluated by having screening hazard quotients (HQs) calculated. BERA activities depended on the following ecological receptors: vegetation, soil invertebrates, cottontail rabbits, shrews, foxes, and hawks.

The Explosives Handling Areas Aggregate contained the most preliminary COPECs for soil (16 metals, 2 pesticides, and 1 PCB), whereas the Perimeter Area Aggregate had the fewest preliminary COPECs for soil (5 metals). The Preparation and Receiving Areas and Packaging and Shipping Areas Aggregates had the second highest number of preliminary COPECs (seven metals and one PCB). The Melt-Pour Area Drainage Ditches Aggregate had eight metals that were identified as preliminary COPECs. BERA activities reduced the number of COPECs in every location. The Explosives Handling Areas Aggregate had 8 COECs (down from 15 COPECs), the Preparation and Receiving Areas Aggregate showed 7 (down from 10), and the Packaging and Shipping Areas Aggregate had 9 (down from 12). The North Ditch Aggregate remained the lowest one with only one COEC (down from three) and the Perimeter Area Aggregate was intermediate with four (down from five).

Sediment and Surface Water

Sediment

The Main Stream Segment and Settling Pond Aggregate contained the most preliminary COPECs for sediment (11 metals and 1 explosive), whereas the Exit Drainages Aggregate had the fewest preliminary COPECs for sediment (1 metal and 1 PCB). The Main Stream Segment Upstream of Perimeter Road Aggregate had the second highest number of preliminary COPECs (four metals and one explosive). At all EUs, except the Exit Drainage Aggregate, the rationale that was responsible for identifying the most preliminary COPECs was No ESV. The rationale that was responsible for identifying the fewest preliminary COPECs was Maximum detection > ESV, which only identified cadmium and nickel at the Main Stream Segment and Settling Pond Aggregate. All of these preliminary COPECs were further evaluated by having screening HQs calculated. BERA activities utilized the following ecological receptors: benthic invertebrates, riparian herbivores (muskrats and mallards), and riparian carnivores (mink and herons). BERA activities reduced the number of COPECs in every location. For example, at the Kelly's Pond and Exit Drainage Aggregate there are 18 COECs (down from 28 COPECs) and at the North Pond Aggregte there are 2 (down from 3).

Surface Water

The Main Stream Segment Upstream of Perimeter Road Aggregate contained the most preliminary COPECs for surface water (seven metals), whereas the Main Stream Segment and Settling Pond Aggregate and the Exit Drainages Aggregate each had two preliminary COPECs. At all EUs, except the Main Stream Segment and Settling Pond Aggregate, the rationale that was responsible for identifying the most preliminary COPECs was No ESV. The rationale that was responsible for identifying the fewest preliminary COPECs was Maximum detection > ESV, which only identified two metals at one EU, one pesticide at another EU, and no preliminary COPECs at the Exit Drainages Aggregate. All of these preliminary COPECs were further evaluated by having screening HQs calculated. BERA activities used the following ecological receptors: aquatic life, riparian herbivores (muskrats and mallards), and riparian carnivores (mink and herons). BERA activities further screened the three COPECs to two COECs.

CONCEPTUAL SITE MODEL

A revised conceptual site model (CSM) was developed using data obtained during the Phase II RI and computer models that assess the potential fate and transport of contaminants that leach from surface soil into the groundwater system and migrate to a potential receptor or exit point. Elements of the CSM include

- primary contaminant source areas and release mechanisms,
- contaminant migration pathways and exit points, and
- data gaps and uncertainties.

Source-Term and Release Mechanisms

Results of the Phase II RI soil sampling indicate that the Explosives Handling Areas Aggregate, particularly areas surrounding Building G-8, contain the greatest numbers and concentrations of contaminants. Metals, explosives, PAHs, and PCBs/pesticides are present in soil in these areas at concentrations greater than background or risk screening criteria. Other source areas defined by Phase II RI data include the vicinity of Building G-4 (inorganics and PCBs), the WW-23 Water Tower (primarily elevated inorganics), and the vicinity of the Building G-19 (PAHs, low levels of nitrocellulose, inorganics). Inorganic contaminants and SVOCs were observed in other locations; however, their distribution is sporadic.

The majority of soil contamination at Load Line 4 is within the surface soil interval less than a depth of 0.3 m (1.0 ft). Explosives were not detected in subsurface soil; some inorganics in subsurface soil exceed background criteria to varying degrees, primarily in the vicinity of Building G-1A in the Preparation and Receiving Areas Aggregate and Building G-9 in the Explosives Handling Areas Aggregate.

Two primary mechanisms for release of contaminants from the source areas are identified: (1) erosional and/or dissolved phase transport of contaminants from soil sources with transport into the storm drain network or drainage ditches, and (2) leaching of constituents to groundwater via infiltration of rainwater through surface and subsurface soils. Evaluation of these release mechanisms was done through sampling of storm drainage network (ditches and storm sewers) and numerical modeling of soil leaching processes in addition to sampling of groundwater wells. Discussion of the results of evaluation of data for preferred contaminant migration pathways and exit points is presented below. Airborne dispersion of contaminants was not quantified or modeled. The chemical characteristics of the SRCs present high, annual precipitation levels, and heavy vegetation cover at Load Line 4 likely precludes any substantial dispersion of contaminants via this pathway.

Contaminant Migration Pathways and Exit Points

Surface Water Pathways

Migration of contaminants from soil sources via surface water occurs primarily by (1) movement of particle-bound (e.g., clays or colloids) contaminants in surface water runoff, and (2) transport of dissolved constituents in surface water. Surface runoff is directed to drainage ditches and the storm drainage network, most of which terminate at the main stream or settling pond within the AOC. The main stream flows from northwest to southeast across the AOC and eventually exits the facility at PF-8.

Upon reaching quiescent portions of surface water conveyances, flow velocities decrease and particle-bound contaminants are expected to settle out as sediment accumulation. Sediment-bound contaminants may be re-mobilized during storm events. Sediment-bound contaminants may also partition to surface water and be transported in dissolved phase. Sampling of the dry sediment from the Melt-Pour Area Drainage Ditches Aggregate indicates minimal contaminant accumulation from the Explosives

Handling Areas Aggregate and migration through these conveyances into the main stream that exits the AOC to the south. Results of sediment and water sampling from the storm sewer network indicate very little accumulation of explosives in sediment and only trace concentrations in water; however, inorganics and low levels of PCBs do appear to have accumulated. Some inorganics in storm sewer sediment appear to be partitioning to water. The sanitary sewer system is largely a closed system (except where pipes may be cracked) and is not open to receiving substantial surface water runoff.

Substantial contaminant accumulation within the main stream and settling pond is not evident based on Phase I and II RI data. Accumulated explosive compounds were less than 1 mg/kg in stream and pond sediment and partitioning to water with subsequent dissolved phase transport is not evident. SVOCs and PCBs were not detected in stream and pond sediment. Inorganic SRCs were detected in stream and pond sediment and the highest concentrations (above background) appear to have accumulated within the settling pond. However, the magnitude of background exceedances is generally low and partitioning of contaminants from sediment to water is not evident based on available data. The highest observed concentrations for inorganics relative to background occurred in the main stream aggregate upstream of the Load Line 4 Perimeter Road.

Leaching and Groundwater Pathways

Theoretical numerical modeling of leaching potential for soil source areas indicates that only chromium, selenium, and RDX may be expected to leach from the contaminated surface soil into the groundwater and reach concentrations exceeding groundwater MCLs or RBCs. The absence of these constituents and lack of overall substantial contamination in groundwater at Load Line 4 suggest that retardation processes (e.g., sorption, degradation, etc.) effectively attenuate contaminants within the vadose zone.

Shallow groundwater flow follows stream drainage and topographic patterns with flow to the south toward the AOC and RVAAP boundaries. Modeling results indicate that migration of RDX via shallow groundwater to the main stream closest to the major sources at concentrations above RBCs may occur. Chromium and selenium were not predicted to exceed RBCs or MCLs at the main stream within the 1,000-year modeling period. Modeling results indicated that migration of the three CMCOPCs to the RVAAP boundary endpoint at concentrations exceeding MCLs or RBCs will not occur within the 1,000-year modeling period. However, the lack of detectable RDX in groundwater suggests that the conservative modeling results may not fully represent retardation and attenuation effects in the subsurface.

Given that a portion of the storm and sanitary sewer system at Load Line 4 is flooded, these utility networks may serve as preferential conduits for shallow groundwater movement. These systems were evaluated to determine if they facilitate transport of contaminants dissolved in groundwater or function as sources of dissolved phase contaminants to groundwater. As noted above, the storm drain network contains some accumulated inorganics and PCBs that appear to be partitioning to water, although concentrations are not grossly elevated relative to background values. Accordingly, the storm drain network may act as a minor source of contaminant flux to groundwater and likely facilitates the movement of shallow groundwater in the vicinity of cracked or broken pipes where inflow or outflow may occur. The sanitary sewer system at Load Line 4 contains some accumulated inorganics and may contribute some level of contaminant flux to groundwater. However, the utility system is a closed system except where pipes may be cracked, and contaminant concentrations were not grossly elevated; thus, it is not considered a primary source to groundwater or migration pathway.

Uncertainties

The CSM is developed based on available site characterization and chemical data. Uncertainties are inherent in the CSM where selected data do not exist or are sparse. The uncertainties within the CSM for Load Line 4 include the following.

- Groundwater monitoring wells installed during the Phase II RI targeted the water table interval only. The observed extent and magnitude of contamination in AOC soil and shallow groundwater do not indicate substantial contamination of groundwater within the AOC and conservative modeling results suggest that off-AOC migration of contaminants will not occur. However, groundwater within deeper flow zones was not characterized and conclusions regarding groundwater contaminant transport are representative of only the source areas modeled and hydrostratiographic intervals that were characterized.

- The exact source(s) of PAHs at Load Line 4 is unknown, although they may, in part, be anthropogenic combustion products derived from coal and/or fuel oil-fired power and boiler plant emissions.

- Leachate and transport modeling are limited by uncertainties in the behavior and movement of contaminants in the presence of multiple solutes. In addition, heterogeneity, anisotropy, and spatial distributions of permeable zones (e.g., sand or gravel zones) could not be fully characterized during the field investigation nor addressed in the modeling. Therefore, effects of these features on contaminant transport at Load Line 4 are uncertain and modeling results are considered as conservative representations.

- The exact source(s) of some inorganics (specifically manganese) in surface water and sediment in the Main Stream Aggregate upstream of the Load Line 4 perimeter road is unknown. Data evaluated in the nature and extent and risk evaluations address all accumulated contamination within the main stream and settling pond, whether from natural or anthropogenic sources. Results of the evaluations may reflect, in part, contributions from sources other than Load Line 4 (e.g., slag or pre-RVAAP activities).

- Limited data collected from beneath building floor slabs indicate no substantial contamination of subfloor soils. However, additional data may be required to further characterize such soils if building floor slabs are removed as part of a future action.

CONCLUSIONS

The conclusions presented below, by medium, combine the findings of the contaminant nature and extent evaluation, fate and transport modeling, and the human health and ecological risk evaluations. To support remedial alternative selection and evaluation in future CERCLA documents (e.g., FS), RGOs were developed for identified COCs in surface soil, subsurface soil, surface water, sediment, and groundwater at Load Line 4. A summary of the results of the human health RGO comparisons is provided in Chapter 6.0.

A target excess individual lifetime cancer risk for carcinogens of 1×10^{-5} and an target HI of 1 for non-carcinogens was identified as appropriate for calculating RGOs for each exposure medium and the type of COCs (carcinogenic or non-carcinogenic).

Surface and Subsurface Soil

Explosives Handling Areas Aggregate

The primary identified source areas in the Explosives Handling Areas Aggregate include Buildings G-8 and G-12. Metals, explosives, PAHs, and PCBs represent the most pervasive SRCs in the former production areas. The spatial distribution and concentrations of contaminants were highly variable in the vicinity of these source areas. With respect to vertical distribution, the numbers and concentrations of SRCs in subsurface soil at these source areas decreased substantially relative to surface soil.

Theoretical numerical modeling of leaching potential for source areas indicates that metals and RDX may be expected to leach from contaminated surface soil into groundwater resulting in concentrations at the groundwater table in excess of risk-based criteria. The migration of metals constituents from the source areas to the closest groundwater baseflow discharge at concentrations in excess of risk-based criteria was not predicted to occur within a timeframe of 1,000 years from the Building G-8 source area. Migration of RDX from Building G-8 to the closest groundwater baseflow discharge point may occur with concentrations above RBCs. The predicted timeframe for migration is 1,000 years. Migration of most of the constituents is expected to be attenuated because of moderate to high retardation factors, as well as degradation of organic compounds; these processes are not reflected in the conservative modeling results.

Comparison of concentrations of Load Line 4 COPCs in shallow surface soil to screening RGOs shows a total of 11 chemicals exceeded the RGOs for at least one receptor scenario. Four metals: aluminum, manganese, and thallium, all for the Resident Farmer Child only; and arsenic, for the Security Guard/Maintenance Worker, Resident Farmer Adult, and Resident Farmer Child; two PCBs: PCB-1254 and PCB-1260, both for the Security Guard/Maintenance Worker, Resident Farmer Adult, and Resident Farmer Child; and five PAHs: benz(*a*)anthracene and indeno(*1,2,3-cd*)pyrene, both for the Resident Farmer Adult only; and benzo(*a*)pyrene, benzo(*b*)fluoranthene, and dibenz(*a,h*)anthracene, all for the Security Guard/Maintenance Worker, Resident Farmer Adult, and Resident Farmer Child. Three deep surface soil COCs (aluminum, arsenic, and manganese) were identified for the National Guard Trainee. No COPCs, and consequently no COCs, were identified from exposure to subsurface soil at the Explosives Handling Areas Aggregate. For the Security Guard/Maintenance Worker, most COCs would produce a cancer risk at or slightly above 10^{-6}. For the resident farmer scenarios, estimated cancer risks would exceed 10^{-5} for arsenic, PCB-1260, and benzo(*a*)pyrene in the Explosives Handling Areas Aggregate. In deep surface soil, arsenic would result in an estimated cancer risk to the National Guard Trainee of slightly larger than 10^{-6}. No subsurface soil COCs were identified for the Resident Farmer Scenario.

Preparation and Receiving Areas Aggregate

The primary identified source areas in the Preparation and Receiving Areas Aggregate include Buildings G-1A and G-4. Metals, PAHs, and PCBs represent the most pervasive SRCs in these areas. The spatial distribution and concentrations of contaminants were highly variable. With respect to vertical distribution, the numbers and concentrations of SRCs in subsurface soil at these source areas decreased substantially relative to surface soil.

Comparison of concentrations of Load Line 4 COPCs in shallow surface soil to screening RGOs shows a total of five chemicals exceeded the RGOs for at least one receptor scenario. Four COCs were identified for deep surface soil for the National Guard Trainee. Two metals were identified as COCs for the Resident Farmer (adult and child) in subsurface soil.

Packaging and Shipping Areas Aggregate

The primary identified source area in the Packaging and Shipping Areas Aggregate is Building G-19. Metals are the most pervasive SRCs in these areas; low concentrations of PAHs and PCBs were detected sporadically. The spatial distribution and concentrations of contaminants were highly variable. With respect to vertical distribution, the numbers and concentrations of SRCs in subsurface soil at these source areas decreased substantially relative to surface soil.

Comparison of concentrations of Load Line 4 COPCs in shallow surface soil to screening RGOs shows a total of four chemicals exceeded the RGOs for at least one receptor scenario. One metal was identified as a deep surface soil COC for the National Guard Trainee. No COPCs, and consequently no COCs, were identified for the Resident Farmer Scenario in subsurface soil.

Change Houses Aggregate

Surface soil in this EU is relatively uncontaminated. Few inorganic results exceeded RVAAP background values; the distribution of exceedances was very sporadic. No explosives compounds greater than 1 mg/kg were detected during field analyses. Accordingly, subsurface soil samples were not collected. Maximum levels of SRCs were detected in the vicinity of Building G-6.

Comparison of concentrations of Load Line 4 COPCs in shallow surface soil to screening RGOs shows that a total of four chemicals exceeded RGOs for at least one receptor scenario. No deep surface soil COCs were identified for the National Guard Trainee. Subsurface soil samples were not collected at the Change Houses Aggregate.

Perimeter Area Aggregate

The only identified contaminant source in this aggregate is the WW-23 Water Tower vicinity. Low concentrations of TNT (field analyses only), inorganics (primarily lead), and PAHs were clustered in the vicinity of the water tower. Lead concentrations in subsurface soil decreased substantially from those observed in surface soil.

Comparison of concentrations of Load Line 4 COPCs in shallow surface soil to screening RGOs shows a total of two chemicals exceeded the RGOs for at least one receptor. One metal was identified as a deep surface soil COC for the National Guard Trainee. No COCs were identified in subsurface soil in the Perimeter Area Aggregate.

Melt-Pour Area Drainage Ditches Aggregate

Surface soil in this EU exhibited little contamination. Explosives compounds were not detected at a concentration of 1.0 mg/kg or greater during field analyses. Inorganic SRCs rarely exceeded background values by factors of more than 2 times and only low concentrations of PAHs were observed. Subsurface soil samples were not collected from this aggregate due to the lack of detectable field explosives in surface soil.

Comparison of concentrations of Load Line 4 COPCs to screening RGOs shows a total of two chemicals exceeded the RGOs for at least one receptor scenario. One metal was identified as a deep surface soil COC for the National Guard Trainee. Subsurface soil samples were not collected from the Melt-Pour Drainage Ditches.

Sediment and Surface Water

Sediment

Explosives contamination in sediment in all three Load Line 4 main stream aggregates is not widespread. Concentrations of explosives are less than 1 mg/kg, inorganic SRCs exceeded background criteria by factors of only 2 to 3 times, and only trace concentrations of one PCB compound were detected. The number and concentrations of inorganics are greatest in the Main Stream and Settling Pond Aggregate.

Two metals were identified as sediment COCs at the aggregate designated as Main Stream Segment Downstream of Perimeter Road Bridge and the Settling Pond.

Aluminum was identified as a COC for the National Guard Trainee and Resident Farmer Child; thallium was identified as a COC for the Resident Farmer Child only.

No COCs were identified in the Main Stream Upstream of Perimeter Road Bridge or the Exit Drainages Aggregates.

Surface Water

Explosives were not detected in water samples collected from any of the three EUs established within the main stream at Load Line 4. Vanadium and manganese were the only two inorganic SRCs detected consistently in surface water above background criteria; maximum concentrations of manganese occurred within the aggregate upstream of the Load Line 4 Perimeter Road. The pesticide 4,4'-DDT was detected in one water sample from the settling pond; no SVOCs or PCBs were detected. VOCs were only sporadically detected at low concentrations.

Three Load Line 4 COCs were identified for the National Guard Trainee and On-Site Residential Farmer scenarios. These include two metals (arsenic and manganese) and one pesticide (4,4'-DDT).

Groundwater

Groundwater within the AOC contains few contaminants that can be related to historical operations. Low concentrations of metals identified as SRCs were observed; however, their occurrence and distribution above background criteria was sporadic. SVOCs and VOCs were detected in groundwater samples collected from monitoring wells in Load Line 4.

Comparisons of Load Line 4 COPCs in groundwater to screening RGOs show that arsenic and manganese exceeded RGOs for the National Guard Trainee and Resident Farmer (adult and child) scenarios.

Storm and Sanitary Sewers

The storm sewer system does not contain accumulated explosives in sediment based on Phase II RI sampling results (Section 4.4.3), although accumulated inorganics and low levels of PAHs, PCBs, and pesticides are present. Inorganics and PCBs appear to be partitioning to water at detectable concentrations. The storm drain network may act as a minor source of contaminant flux to groundwater and likely facilitates the movement of shallow groundwater in the vicinity of cracked or broken pipes where inflow or outflow may occur.

The sanitary sewer system does not contain accumulated explosives in sediment based on Phase II RI sampling results, although accumulated inorganics are present that may be partitioning to accumulated water within the system. The sanitary sewer system does not receive large influxes of storm runoff and is largely a closed system, except where pipes may be cracked. Considering the characteristics of the sanitary sewer system and the fact that contaminant concentrations were not grossly elevated; it is not considered a primary source to groundwater or migration pathway.

Buildings and Structures

Data collected during the Phase II RI indicate an overall absence of contamination in soil beneath building sub-floors based upon a limited number of samples collected from beneath building floor slabs (Section 4.8.1).

Any future demolition of the Building G-8 washout basin should consider that sediment in this structure contained elevated levels of metals, explosives, propellants, PCBs, and pesticides. The associated water sample contained elevated levels of many constituents that were detected at high concentrations in sediment.

Any future demolition of the Building G-16 sedimentation basin should consider that sediment in this structure contained elevated concentrations of several metals related to historical processes (chromium, copper, and lead).

Floor sweep samples collected from Buildings G-3, G-8, and G-19 were comprised of a high percentage of iron. Copper, cadmium, chromium, and lead were present at high concentrations, particularly in Buildings G-8 and G-19. Low concentrations of explosives were detected in samples from Buildings G-8 and G-19. Low concentrations of PCBs, pesticides, and various PAHs were also detected. Cadmium and lead were detected in TCLP extracts; however, no constituent exceeded their respective criteria for characteristically hazardous wastes.

LESSONS LEARNED

A key project quality objective for the Phase II RI at Load Line 4 was to document lessens learned so that future projects could constantly improve data quality and performance. The primary lessons learned through the recent activities associated with the Load Line 4 RI are as follows.

- The integration of RI activities for Load Lines 2, 3, and 4 was a valuable tool to minimize reporting costs (i.e., preparation of a single work document) and field mobilization costs for Science Applications International Corporation and its subcontractors. The integration also allowed field work for each load line to be accomplished consecutively, using the same personnel who were familiar with the sites and the project.

- The designation of a single, formal, IDW Compliance Officer, allowed all IDW issues to be handled through a single contact. This representative coordinated the on-site management and disposal of all IDW, which led to no compliance issues related to IDW during the course of the project.

- Analytical difficulties were encountered for some floor sweep and other sample types due to the suspected presence of paint chips, creosotes, or other materials. Prior notification to the laboratory is advised when such unusual samples may be collected so the laboratory can adjust extraction or analytical protocols, as needed, to avoid potential faulting of the instrumentation.

- The use of field-portable X-ray fluorescence (XRF) analysis was not employed during the Phase II RI field activities. However, this field procedure may have provided useful information regarding the distribution of inorganic constituents in soil. Upon completion of the evaluation and testing of new method(s), use of the field XRF to help guide characterization sampling activities or to conduct remediation verification should be considered.

- The incorporation of undesignated contingency samples into the project plan afforded the project greater flexibility to sample select locations based on field observations and site-specific conditions.

- The on-site presence of Ohio EPA and USACE staff during field operations was beneficial in that potential changes to the project work plan due to field conditions could quickly be discussed, resolved, and implemented.

- The availability of on-site facilities for field operations use was extremely beneficial. Having high quality shelter facilities for sample storage, equipment decontamination, and management operations improves the overall project quality and efficiency.

- Field operations were temporarily suspended for 5 days beginning September 12, 2001, due to RVAAP security measures in response to the terrorist attacks of September 11, 2001. As a result, field operations were placed in a safe and compliant standby condition. Future work plans for RVAAP may include a section containing instructions for unplanned events resulting in the immediate suspension of field operations.

RECOMMENDATIONS

To provide decision makers with the information necessary to evaluate remedial alternatives to reduce or eliminate potential risks to human and/or ecological receptors, it is recommended that the Load Line 4 proceed to the FS phase under the RVAAP CERCLA process. It is recommended that the FS phase employ a streamlined remedial alternatives evaluation process based on the most likely land use assumptions and evaluate a range of effective alternatives and technologies and associated costs. The intent of this strategy is to accelerate site-specific analysis of remedies by focusing the FS efforts to appropriate remedies that have been evaluated at other sites with operational histories similar to Load Line 4.

The future land uses and controls envisioned for Load Line 4 should be determined prior to selection of the path forward for the site. Establishment of the most likely land use scenario(s) will allow decision makers the initial information necessary to determine the correct remedial action, such as source removal, land use controls, and/or continued monitoring, to achieve requisite protection of human health and the environment. The envisioned future use of the AOC, or a portion of the AOC, is an important consideration in determining the extent of remediation necessary to achieve the required degree of protectiveness. For example, a residential versus a National Guard land use scenario influences how much cleanup is needed to lower the risk to protective levels. Establishment of land use will also allow for streamlined evaluation of remedies and will be necessary for documentation in a remedial decision.

Areas having the same projected land use within Load Line 4 (and at other melt-pour lines at RVAAP) will incorporate the same RGOs into remedial alternative development. Also, the FS should consider potential future separate actions related to surface water systems and recognize the connection of surface water exit pathways among the four major melt-pour lines (Load Lines 1 through 4), as well as Load Line 12. The FS should apply results of the ecological field truthing effort at the WBG (pending agreement by Ohio EPA) to remedial goal development for Load Line 4 to the extent practicable.

Key data uncertainties have been identified in the RI to help guide any future sampling efforts. Details of additional nature and extent assessment, as needed to fill any remaining data gaps in order to evaluate remedial alternatives, are deferred to the FS planning stage. The following components may be necessary for a thorough FS evaluation or may be considered under a separate remedial action process for integrator media, such as surface water or groundwater.

- Refinement of EU boundaries, if remedial decisions by EU are considered most feasible by decision makers. Such a delineation would allow

    1. Prioritization of EUs or areas from highest potential risk to lowest potential risk.

    2. Selection of cleanup actions and exit strategies per EU and/or per buildings are in each EU, (e.g., certain areas may remediated by soil removal, whereas remediation of other areas, such as a process building vicinity, may require an alternate approach).

    3. Potential elimination of all or portions of certain EUs from additional investigation or further action, such as portions of the Perimeter Area Aggregate, thus reducing the footprint of the AOC.

- Assessment of shallow groundwater at Load Line 4 indicated little, if any, contamination related to historical process operations. Subsurface soil data at Load Line 4 indicated very low levels of SRCs below the surface interval. Although little evidence of vertical migration of contaminants exists, assessment of deep groundwater at the site has not been performed and may be a potential data gap. Characterization or monitoring of deeper groundwater may be necessary to evaluate certain potential remedial actions or to support future resource use decisions.

- Sediment in stream and pond aggregates and the dry conveyances in the Melt-Pour Area Drainage Ditches Aggregate were characterized to typical depths of 0.15 m (0.5 ft). Characterization of deeper sediment in drainage conveyances and the settling pond is a potential data gap and additional sampling at deeper intervals may be necessary to evaluate potential remedial actions or to support future resource use decisions.

- The requirements of the Toxic Substances and Control Act (TSCA) should be evaluated to determine if they may be warranted. Likewise, TSCA may be an applicable or appropriate and relevant requirement for future remedial actions involving soil or sediment containing PCBs above certain threshold criteria.