DEPARTMENT OF THE ARMY
US ARMY INSTALLATION MANAGEMENT COMMAND
HEADQUARTERS, UNITED STATES ARMY GARRISON, REDSTONE
4488 MARTIN ROAD
REDSTONE ARSENAL, ALABAMA 35898-5000

REPLY TO
ATTENTION OF

IMSE-RED-ZA

2 4 SEP 2009

MEMORANDUM FOR

US Environmental Protection Agency, ATTN: s. Debbie Vaughn-Wright, Federal Facilities Branch, Waste Management Branch, 61 Forsyth Street, SW, Mail code 4WD-FFB-10th Floor, Atlanta, Georgia 30303-34013

Alabama Department of Environmental Management, ATTN: Mr. Philip Stroud, Government Facilities Section Hazardous Waste Branch, Land Division 1400 Coliseum Boulevard, Montgomery, AL 36130-1463

SUBJECT: Final Record of Decision for RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Pond; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6, Redstone Arsenal, Madison County, Alabama

1. Reference Installation Restoration Program at Redstone Arsenal, Alabama (EPA ID AL7 210 020 742).

2. This letter transmits one hard copy of subject document (enclosed) for your review and concurrence. This document is a FY 09 goal and must be completed in September. Please assist in meeting this commitment by reviewing in a timely manner.

3. My point of contact for this document is Ms. Terry de la Paz, Environmental Management Division (IMSE-RED-PWE), 256-955-6968, or e-mail terry.delapaz@us.army.mil.

Encl

ROBERT M. PASTORELLI
Colonel, LG
Garrison Commander

Copy Furnished (w/enclosures):
Tech Law, Incorporated, ATTN: Mr. Jim Ashworth, 310 Maxwell Road, Suite 500, Alpharetta, GA 30009

IMSE-RED-ZA
SUBJECT: Final Record of Decision for RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Pond; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6, Redstone Arsenal, Madison County, Alabama

Copy Furnished (w/enclosures) continued:

US Army Environmental Center, Installation Restoration Division (IMAE-CDS), ATTN: Mr. Bill Davis, 5179 Hoadley Road, Building #E4480, Aberdeen Proving Ground, MD 21010-5401

Wheeler National Wildlife Refuge, ATTN: Mr. Dwight Cooley, US Fish and Wildlife Service, 2700 Refuge HQ Road, Decatur, AL 35603

Alabama Department of Public Health, ATTN: Mr. Kenneth Calhoun, 201 Monroe Street, Suite 1450 Montgomery, AL 36104

Tennessee Valley Authority, Pickwick/Wheeler Watershed Team, ATTN: Mr. Randy McCann Post Office Box 1010, SB-1H-M, Muscle Shoals, AL 35662-1010

Marshall Space Flight Center, ATTN: Mr. Farley Davis, Building 4200, Mail Code AS-10, Marshall Space Flight Center, AL 35812

US Army Center for Health Promotion and Preventive Medicine (MCHB-TS-REH), ATTN: Mr. Larry Tannenbaum, Building #E-1675, Aberdeen Proving Ground, MD 21010-5403

Z-GeoInfo Incorporated, ATTN: Mr. Zhenhua Jiang, PhD, 200 E Joppa Rd, Suite 400, Towson, MD 21286

Shaw Environmental, Inc.
312 Directors Drive
Knoxville, TN 37923
865.690.3211
Fax 865.690.3626

Shaw Environmental, Inc.

September 18, 2009

SEI-COE-RSA/PBC05-0001-2000AB-16
Project No. 118166

Ms. Juana Torres-Perez
U.S. Army Corps of Engineers, Savannah District
CESAS-PM-H
100 W. Oglethorpe Avenue
Savannah, Georgia 31412

Contract: ACSIM MARC W91ZLK-05-D-0017, Delivery Order 0001
Redstone Arsenal, Alabama

Subject: Final Record of Decision for RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area Operable Unit 6

Dear Ms. Torres-Perez:

The subject document is provided on compact disc in Portable Document Format (PDF) for your records.

If you have questions regarding this submittal, or need further information, please contact me at (865) 694-7361.

Sincerely,

Stephen G. Moran

Stephen G. Moran, PG
Project Manager

Enclosure

FINAL

ACSIM MARC
Contract No. W91ZLK-05-D-0017
Delivery Order 0001

Submitted to:

US Army Corps of Engineers
Savannah District

and

U.S. Army Garrison
Redstone Arsenal

Record of Decision

RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6

Redstone Arsenal
Madison County, Alabama

September 2009

Shaw™ Shaw Environmental, Inc.

Record of Decision
RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

FINAL
Sept. 2009
Shaw™

Final

Record of Decision
RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area
Operable Unit 6

Redstone Arsenal
Madison County, Alabama

ACSIM MARC
Contract Number W91ZLK-05-D-0017
Delivery Order 0001

September 2009

Submitted to:

U.S. Army Corps of Engineers, Savannah District
Post Office Box 889
Savannah, Georgia 31402-0889

and

U.S. Army Garrison, Redstone Arsenal
Building 4488, Room A338
Redstone Arsenal, Alabama 35898

Prepared by:

Shaw Environmental, Inc.
312 Directors Drive
Knoxville, Tennessee 37923

Table of Contents

Page

Table of Contents (Continued)

Page

Page

List of Tables

List of Figures

List of Exhibits

List of Acronyms

ADEM	Alabama Department of Environmental Management
AO	arsenic trioxide
ARAR	applicable or relevant and appropriate requirement
Army	U.S. Army Garrison – Redstone
AT	arsenic trichloride
bgs	below ground surface
BHHRA	baseline human health risk assessment
BSV	background screening value
CD	compact disk
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chemical of concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CSM	conceptual site model
DAF	dilution attenuation factor
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HI	hazard index
HQ	hazard quotient
IRA	interim remedial action
IROD	interim record of decision
IT	IT Corporation
LUC	land use control
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	no further action
O&M	operation and maintenance
OU	Operable Unit
PAH	polynuclear aromatic hydrocarbon
PP	Proposed Plan
PRG	preliminary remediation goal
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act

List of Acronyms *(Continued)*

RD	remedial design
RfD	reference dose
RG	remedial goal
RGO	remediation goal option
RI	remedial investigation
ROD	Record of Decision
RSA-056	Closed Arsenic Waste Ponds
RSA-122	Dismantled Lewisite Manufacturing Plant Sites
RSA-139	Former Arsenic Trichloride Manufacturing and Disposal Area
Rust	Rust Environment and Infrastructure, Inc.
SAC	site access control
SB	Statement of Basis
Shaw	Shaw Environmental, Inc.
SLERA	screening-level ecological risk assessment
SM	sulfur monochloride
SSL	soil screening level
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TCRA	time-critical removal action
UCLM	upper confidence limit of the mean
VOC	volatile organic compound

1.0 The Declaration

1.1 Site Name and Location

Dismantled Lewisite Manufacturing Plant Sites (RSA-122)
Closed Arsenic Waste Ponds (RSA-056)
Former Arsenic Trichloride Manufacturing and Disposal Area (RSA-139)
Operable Unit (OU) 6
Redstone Arsenal
Madison County, Alabama

Comprehensive Environmental Response, Compensation, and Liability Information System Number: AL7 210 020 742

U.S. Army Garrison – Redstone (Army)

1.2 Statement of Basis and Purpose

This Record of Decision (ROD) presents the Selected Remedy of Soil Excavation, Treatment, Off-Site Disposal, Backfill, Short-Term Sediment and Groundwater Monitoring, and Institutional Controls for the surface media (defined as surface soil, subsurface soil perched groundwater, soil vapor, sediments and surface water) at RSA-122, RSA-056 and RSA-139 at Redstone Arsenal in Madison County, Alabama. The remedy was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986, and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations, Part 300. The remedy is designed to meet CERCLA requirements and address the substantive requirements under the Resource Conservation and Recovery Act (RCRA), where applicable. The goal was to select a remedy that is acceptable under both programs and one which limits duplication of closure efforts.

The remedy selection was based on information contained in the Administrative Record file for RSA-122, RSA-056 and RSA-139, which has been developed in accordance with Section 113 (k) of CERCLA and which is available for review at the information repository locations presented in Exhibit 1 on page 2-8.

The Army and the U.S. Environmental Protection Agency (EPA) have selected the final remedy of Soil Excavation, Treatment, Off-Site Disposal, Backfill, Short-Term Sediment and Groundwater Monitoring, and Institutional Controls for RSA-122, RSA-056, and RSA-139. The Alabama Department of Environmental Management (ADEM) concurs with the Selected Remedy.

A glossary of terms used in this ROD is presented in Appendix A.

1.3 Assessment of the Site

The response action selected in this ROD is necessary for the protection of public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

1.4 Description of the Selected Remedy

The Army and EPA, with concurrence from ADEM, have determined that Alternative 2, Soil Excavation, Treatment, Off-Site Disposal, Backfill, Short-Term Sediment and Groundwater Monitoring, and Institutional Controls addresses the low-level threat source materials presenting an unacceptable risk to human health and the environment. This remedy is intended as a final remedial action for the surface media at RSA-122. The contaminants of concern identified in site soils are arsenic and mercury. Groundwater under RSA-122, RSA-056 and RSA-139, other than perched groundwater, is not part of the scope of this surface media ROD; any further groundwater investigation/cleanup will be conducted with the RSA-147 groundwater site. Perched groundwater will be addressed with this action.

The following are the major components of the Selected Remedy:

- Soil Excavation
  - Approximately 1,775 cubic yards of soil are expected to be excavated at the site.
- Treatment
  - Excavated soil may require chemical stabilization to treat elevated concentrations of arsenic and mercury.
- Off-Site Disposal
  - The soil will be loaded into trucks and taken to the off-site disposal facility.
- Backfill
  - After the excavation and confirmation of sampling, the site will be backfilled with clean soil, compacted to grade, and revegetated.
- Short-Term Sediment and Groundwater Monitoring
  - Biennial sediment and groundwater sampling will be conducted for four years at RSA-122, RSA-056 and RSA-139.

- Institutional Controls
  - The institutional control at RSA-122 is to prohibit future use of the property for anything other than industrial use including prohibiting specific commercial uses such as day cares, schools, or hospitals.

1.5 Statutory Determinations

The Selected Remedy (1) is protective of human health and the environment, (2) complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial actions, (3) is cost effective, and (4) utilizes permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable. The remedy includes engineering and administrative controls to ensure its long-term effectiveness and permanence. The Selected Remedy does not meet the statutory preference for treatment as a principal element of the remedy since no cost-effective or technically viable commercial technologies are available for the site conditions and contaminants at the site.

Because this remedy will result in hazardous substances remaining on-site above levels that allow for unlimited use and unrestricted exposure, LUCs will be instituted. A statutory review will be conducted within five years after initiation of the remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

1.6 Record of Decision Data Certification Checklist

The following information is included in the Decision Summary (Chapter 2.0) of this ROD. Additional information can be found in the Administrative Record file for this site.

- Chemicals of concern (COC) and their respective concentrations (see Sections 2.5.2, 2.5.3, and 2.7)

- Baseline risk represented by the COCs (see Section 2.7)

- Cleanup levels established for COCs and the basis for these levels (see Section 2.8)

- How source materials constituting principal threat source material are addressed (see Sections 2.5.2.1, 2.5.3, 2.7.3, and 2.9.2)

- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater used in the baseline human health risk assessment (BHHRA) and ROD (see Section 2.6)

- Potential land and groundwater use that will be available at the site as a result of the Selected Remedy (see Section 2.6)

- Estimated capital, annual operation and maintenance (O&M), and total present worth costs; discount rate; and the number of years over which the remedy cost estimates are projected (see Sections 2.9.2.2 and 2.11.2)

- Key decision factor(s) that led to selecting the remedy (see Sections 2.9 and 2.10)

1.7 Authorizing Signatures

Robert M. Pastorelli Colonel, US Army Garrison Commander	Date	Franklin E. Hill, Director Superfund Division U.S. Environmental Protection Agency, Region 4	Date

Concurrence:

Wm. Gerald Hardy, Chief Land Division Alabama Department of Environmental Management	Date

2.0 Decision Summary

2.1 Site Name, Location, and Description

Dismantled Lewisite Manufacturing Plant Sites (RSA-122)
Closed Arsenic Waste Ponds (RSA-056)
Former Arsenic Trichloride Manufacturing and Disposal Area (RSA-139)
Operable Unit (OU) 6
Redstone Arsenal
Madison County, Alabama

CERCLIS Identification Number: AL7 210 020 742

Lead Agency: Army

Redstone Arsenal is located in Madison County in the northern portion of Alabama. Redstone Arsenal is in the southwestern portion of Madison County, Alabama, and is bounded by the city of Huntsville on the north and east and the Tennessee River to the south. The city of Madison and the town of Triana are northwest and southwest, respectively, of Redstone Arsenal (Figure 1).

Redstone Arsenal is a U.S. Army facility that encompasses approximately 38,300 acres of land, all of which are either owned or controlled by the Army (Figure 2). Development within Redstone Arsenal has largely revolved around the historical production of (and later disposal of) conventional and chemical munitions and, more recently, development and testing of missiles and rockets. These processes have produced chemical wastes since operations began in the early 1940s. Redstone Arsenal includes Wheeler National Wildlife Refuge to the south; industrial areas in the southeastern portion; administrative facilities at the National Aeronautics and Space Administration's George C. Marshall Space Flight Center in the central portion; and family housing and commercial, training, recreational, and medical centers in the north portion. Missile/rocket test ranges, along with the associated range fans, test area safety fans, and explosive safety-quantity distance arcs, are present in the western and southern portions of Redstone Arsenal. Other mission-related land use in the southern portion of Redstone Arsenal primarily includes munitions storage.

RSA-122 consists of 42 acres of land located in the east-central portion of RSA that was the former site of lewisite manufacturing operations. The area is located to the west of Patton Road, north of Viper Road, south of Metrology Drive, and east of Jungerman Road and includes an unnamed north-south trending perennial creek (approximately 8 acres) which ultimately discharges to Huntsville Spring Branch (Figures 2 and 3).

Although these 42 acres of land are defined as the RSA-122 "site," included within the site boundary are several former chemical manufacturing areas, waste disposal ponds (RSA-056 and RSA-139) associated with these manufacturing operations, and four identified Resource Conservation and Recovery Act (RCRA) sites.

RSA-122, RSA-056, and RSA-139 are included in OU-6, which contains production, storage, and waste disposal sites used by the Army in the early 1940s to manufacture the chemical agent lewisite. These sites are located in the central portion of Redstone Arsenal (Figure 3). RSA-122 consists of an area formerly occupied by plants that manufactured lewisite and its raw materials. The arsenic trichloride (AT) Manufacturing Area was located in RSA-122NW, Lewisite Plants 3 and 4 were located in RSA-122S, and Plants 5 and 6 were located in RSA-122E. RSA-056 and RSA-139 are located within the RSA-122 site boundary and consist of the waste disposal ponds built to contain waste material generated from the production of lewisite.

RSA-056 and RSA-139 are located in close proximity to each other (Figure 3) and were associated with the lewisite manufacturing process; therefore, conditions at these two sites are very similar. The two areas collectively occupy approximately 3 acres. The waste ponds have been filled and are now vegetated with pine trees and grass. A small creek flows around the perimeter of RSA-056 and along the eastern boundary of RSA-139. This section provides a brief site description and history for RSA-056 and RSA-139.

RSA-056. RSA-056 consists of two lagoons that cover an area of approximately 2 acres. The site is in the east-central portion of RSA, north of Viper Road, west of Metrology Drive, and east of Calibration Drive (Figure 3). When in use in the early 1940s, the lagoons were open, unlined surface impoundments that received arsenic-contaminated industrial waste sludge and liquids from lewisite manufacturing facilities (RSA-122 South). The lewisite manufacturing plants were dismantled and demolished sometime around 1960. Available historical reference documents list a range of dates centered around 1960. Select plant debris was flashed and salvaged, and the remaining plant debris was bulldozed into the lagoons. The lagoons remained partially open after the plant site was razed but were filled with soil and asphalt rubble in 1972. A 2.5-foot-thick protective soil cover (clay and topsoil) is currently installed over RSA-056 pursuant to a 1995 interim remedial action (IRA) and a 2000/2001 time-critical removal action (TCRA) conducted at the site under CERCLA regulatory authority. The 1995 IRA included a soil cover, and ditch relocation. The 2001 TCRA also included extension of the soil cover from 1995. The site was fenced under an installation-wide TCRA also performed in 2001.

RSA-139. RSA-139 is located northwest of RSA-056, north of Viper Road, west of Metrology Drive, and east of Calibration Drive (Figure 3). The site consists of a former disposal pond and several buildings, some of which were involved in the manufacture of AT. The pond was an open, unlined surface impoundment that received arsenic-contaminated industrial waste sludge and wastewater from AT manufacturing facilities in the early 1940s. The waste pond at RSA-139 occupies approximately 1 acre. Around 1960, most of the buildings associated with AT manufacturing were dismantled and demolished. Select plant debris was flashed and salvaged, and the remaining debris was bulldozed into the ponds. The pond remained partially open after the plant site was razed but was filled with soil and asphalt rubble in 1972. A 2.5-foot-thick protective soil cover (clay and topsoil) is currently installed over RSA-139 pursuant to a 1995 IRA and a 2000/2001 TCRA conducted at the site under CERCLA regulatory authority. The 1995 IRA included a soil cover and ditch relocation. The 2001 TCRA also included extension of the soil cover from 1995. The site was fenced under an installation-wide TCRA also performed in 2001.

Four other sites listed on RSA's RCRA Part B permit are located within the boundaries of RSA-122. All four sites are in the No Further Action (NFA) phase of RSA's RCRA Corrective Action program. A brief description of each site is as follows:

- RSA-033 is an active electroplating facility. Confirmation sampling of concrete floor drains located inside Building 5432 was completed in 2000. No releases were detected from RSA-033. ADEM concurred with an NFA recommendation for RSA-033 in 2002.

- RSA-043 is an underground used oil storage tank located outside of building 5435A. This site is listed as NFA.

- RSA-044 was a 500-gallon waste oil underground storage tank located behind Building 5435. The tank was removed in 1994 but had received hydraulic waste from calibration equipment that was used in Building 5435B. Confirmation sampling was performed between 2000 and 2005 and no releases were detected from this site. ADEM concurred with an NFA recommendation for RSA-044 in 2007.

- RSA-127 was a concrete sump located outside of a photographic chemical storage area for Building 5451. Building 5451 served as a photographic processing laboratory from the late 1940s until it was demolished in the fall of 1999. A removal action for elevated concentrations of silver in soil was performed in 2002. Following confirmation sampling, ADEM concurred with the NFA recommendation for surface media in 2006.

2.2 Site History and Enforcement Activities

This section presents a history of site activities and describes investigative and CERCLA enforcement activities at RSA-122, RSA-056, and RSA-139.

2.2.1 History of Site Activities

A total of six lewisite plants were constructed at RSA during the early 1940s. Four of the six plants (Plants 3 through 6) were located within RSA-122. Lewisite Plants 3 and 4 began production in May 1943 and operated until October 30, 1943; however, Plant 4 was not operated continuously due to a shortage of AT. Plants 5 and 6 were reportedly never brought on line for lewisite production, although Plant 5 was reportedly used for the decontamination of 1-ton containers after World War II. Based on the January 1948 demilitarization analysis report, the 1-ton containers contained lewisite. An area of stockpiling was located in the northern part of RSA-122. The type of materials that were stockpiled is unknown. The stockpiling activities were possibly related to open burning activities conducted at a trench northeast of the RSA-122 boundary, which is currently identified as RSA-126. AT produced in the northwestern portion of RSA-122 was supplied to all operational lewisite plants at RSA.

Historical operations of each manufacturing process are discussed separately below:

Sulfur Monochloride Manufacturing Process. Sulfur monochloride (SM) was a raw material used in the production of AT. Bulk sulfur was brought in by railroad cars and stored in the sulfur warehouse (Building 5436), while bulk chlorine was supplied by tank car. Exhaust gases were piped to a scrubber pit, where water was introduced for decomposition and then released to the industrial sewer.

Arsenic Trichloride Manufacturing Process. AT was used in the production of lewisite and was manufactured by reacting SM with arsenic trioxide (AO). AT generation occurred in a reactor vessel with the addition of SM and AO. Distilled AT was then transported via tank cars to lewisite manufacturing plants in former Plant Areas 1 and 2, where it was used in the production of lewisite. Bulk AO was delivered by rail, transferred to storage silos or directly to a weigh hopper for distribution to AT reactor vessels using a pneumatic conveyor system, and then stored in silos.

AO was transported to the AT manufacturing building via an aboveground contained screen conveyor system to be deposited at each AT reactor vessel. A pumping pit, located in the southeast corner of the AT plant, contained two sets of dual pumps (one each for AT and SM). AT was pumped from the AT reactor building to the bulk storage facility via an aboveground line running through the pump pit. An underground line also ran from the AT bulk storage facility to the pumping pit and eventually to the disposal collection pit, presumably to remove waste or impure AT from the bulk storage facility. An underground drainage line ran from the AT manufacturing building to the disposal collection pit, and another underground line also discharged material from the AT manufacturing building directly to the drainage ditch south of the plant. Material was moved via underground lines from the storage silos and AT bulk storage to the pumping pit. The material was then piped underground to a below-ground concrete disposal collection pit. Two sump pumps were located within the pit to transfer waste material to the disposal pond.

Lewisite Manufacturing Process. Lewisite is manufactured by reacting AT with acetylene in the presence of mercuric chloride as a catalyst. This reaction occurred in the reactor vessel, producing crude lewisite. Further distillation of the crude lewisite resulted in distilled lewisite, which was then filled into large containers for transport to munitions filling buildings elsewhere at Redstone Arsenal.

The lewisite plants were identical in construction. Plants 3 and 4 were used for lewisite production, but Plants 5 and 6 were reportedly never brought on line for lewisite production. However, Plant 5 was used to decontaminate 1-ton containers used to store lewisite. Each plant consisted of an acetylene generation building, where acetylene was generated, then scrubbed in an acetylene scrubber building. Sulfuric acid was supplied from a storage tank to both the acetylene scrubber buildings at Plants 3 and 4 via underground pipes. Acetylene from the scrubber building was supplied via overhead lines to the lewisite reactor building, and AT was supplied to the reactor building from AT storage tanks. The ground floor of the reactor building contained a trench, which appeared to be for the collection of spills from the tanks and reactor vessels as well as housing of process pipes.

Crude lewisite produced in the reactor building was transferred under gravity to the crude M-1 storage building via an underground pipe. The crude lewisite was transferred to the distillation building via an overhead pipeline for distillation. Distilled and purified lewisite was then transferred into munitions shells of various types.

There was also a collecting pit that served as a collection point for liquid waste from all large buildings and was connected to each building by underground pipes. The waste was pumped from the collecting pit to the disposal ponds after treatment with lime. An overflow pipe connected the pit with the industrial sewer as a contingency in case the pumps in the pit failed. Underground pipes were extensively used for transferring liquid chemicals or waste among buildings and to the collecting pit.

As a result of the waste streams generated during lewisite production, two sets of arsenic and acetylene generator sludge ponds (RSA-056) with associated disposal reactors and acetylene gas scrubbers were constructed to treat arsenic waste from Plants 3 and 4. The other set of ponds (RSA-057) with associated disposal reactors were constructed for Plants 5 and 6 and appear to have received waste from Plants 3 and 4. Liquid waste from Plants 3 and 4 was pumped to lagoons at RSA-056 (and most likely at RSA-057) while the plants were in operation.

Debris from the manufacturing plants was reportedly disposed of in the RSA-056 disposal ponds. The disposal ponds at RSA-056 were closed, backfilled with soil, and revegetated in 1977. In 1995, a clayey soil cover was placed over the former disposal ponds as an interim remedial action (IRA). In 2000/2001 a time-critical removal action (TCRA) was implemented at RSA-056 and RSA-139 to restrict access to areas of elevated risk posed by high arsenic concentrations in soils (IT, 2002). Excavation-restricted areas were established and administrative and institutional controls were initiated. Soil cover extensions were also implemented at RSA-056 and RSA-139 to eliminate direct exposure of site workers to arsenic in surface and subsurface soil at concentrations that exceed PRGs and to minimize the migration of soil contaminants to other areas or media. The sites were fenced under an installation-wide TCRA also performed in 2001.

As of February 2007, the site of the former lewisite plants contains a few buildings and is largely open; partly tree covered; and vegetated with grass, briars and trees. Although none of the production buildings from Plants 3, 4, and 5 exist today, some of the drainage ditches and the industrial sewer system are still evident.

2.2.2 History of Investigative Activities

A number of assessments/investigations have been conducted at RSA-122, RSA-056, and RSA-139. Table 1 summarizes the site activities conducted at these sites, which include the following:

- Four monitoring wells were installed around the capped waste disposal ponds by Testing, Inc. in 1979 as part of an off-post contamination survey study (Army, 1983).

- P.E. LaMoreaux and Associates collected four subsurface soil samples and groundwater samples from existing monitoring wells and performed in situ permeability tests in 1988 (G&M, 1991).

- Geraghty and Miller, Inc. (1991) collected two soil samples as a part of the site investigation in 1990 (G&M, 1991).

- Environmental Science and Engineering, Inc. conducted a site characterization in relation to the capped waste disposal ponds (currently RSA-056 and RSA-139), the former Lewisite Plants 3 and 4 area (currently a portion of RSA-122S), and the stockpiling area (currently RSA-122N). Seven monitoring wells were installed and subsequent groundwater sample and soil sample collection was conducted. In addition, surface water and sediment samples were collected from the unnamed creek (ESE, 1996).

- A supplemental investigation (SI) was completed by IT Corporation (IT) in 1997 at the former Lewisite Plants 3 and 4 area and at the stockpiling area (RSA-122N). Activities included the installation of 12 hydropunch borings, with 2 soil samples and 1 groundwater sample collected per boring; and the collection of 16 surface soil samples, 4 collocated surface water/sediment samples, and 22 groundwater monitoring well samples. Surface water and sediment samples were collected from the unnamed creek at RSA-122 (IT, 1997).

- A supplemental remedial investigation (RI) was conducted at the Plants 3 and 4, Plants 5 and 6, and AT areas in the spring of 2000. A perched groundwater zone was identified at the Plants 3 and 4 areas during this investigation. Soil sampling at the Plants 5 and 6 areas (RSA-122E) was conducted for the first time during this supplemental RI. Groundwater samples were collected from all existing and newly installed wells in the AT area. Additionally, surface water, sediment, and subsurface soil samples were collected from the unnamed creek and secondary ditches (IT, 2000).

- In 2001, IT conducted a soil sampling effort to support a future time-critical removal action (TCRA) that was being considered by Redstone Arsenal. Samples were collected from 33 borings installed in a grid in the grassy area south of Building 5436 (IT, 2002).

- General Phase II RI sampling activities were conducted in 2004 and 2005 by Shaw Environmental, Inc. During the Phase II RI, soil borings with combined surface and subsurface soil sampling were strategically located within former manufacturing and stockpiling areas, in areas surrounding and between those areas, and at locations along the unnamed creek. A total of 199 surface soil samples, 790 subsurface soil samples, 22 surface water/sediment samples, and numerous groundwater samples were collected during the Phase II RI (Shaw, 2007a).

2.2.3 History of Interim Remedial Activities

Interim remedial activities conducted at RSA-122, RSA-056, and RSA-139 were regulated by CERCLA and are as follows:

- In 1995, an IRA was conducted that included diversion of the drainage ditch, relocation of utilities, removal of vegetation, and installation of a 2.5-foot-thick protective soil cover (clay and topsoil) over the ponds at RSA-056 and RSA-139 (Army, 1996).

- In 2000/2001, a TCRA was implemented at RSA-056 and RSA-139 to eliminate the direct exposure of site workers to arsenic in surface and subsurface soils and to minimize the migration of soil contaminants to other areas or other media (e.g., surface water or groundwater) (IT, 2002). From January 2001 to March 2001, the protective covers at RSA-056 and RSA-139 were extended to cover the surface and subsurface soil with elevated arsenic concentrations (IT, 2002).

- In 2000/2001, as part of an installation-wide TCRA, fencing and signs were installed around RSA-056 and RSA-139 (Shaw, 2003).

2.2.4 History of CERCLA Enforcement Activities

No CERCLA or RCRA enforcement activities have been conducted to date at RSA-122, RSA-056, or RSA-139.

2.3 Community Participation

Throughout Redstone Arsenal’s history, community concern and involvement have been low. The Army has kept the community and other interested parties apprised of site activities through the following means:

- Informational materials and presentations
- Press releases
- Administrative Record file and information repositories
- Public meetings and comment periods.

Informational materials, such as fact sheets, are sent to community members on an ongoing basis. A mailing list of community members and individuals that have requested information is maintained. Presentations and tours for community groups are designed specifically for members of the public and are also announced through mailings or by the media. A Community Relations Plan (Shaw Environmental, Inc. [Shaw], 2006) has been published to keep the community informed of cleanup progress at Redstone Arsenal and to provide opportunities for the public to interact with the Army on remedial activities.

The Army periodically holds a public meeting to inform the interested public about ongoing environmental activities and to solicit interest in forming a restoration advisory board for Redstone Arsenal. A meeting was held on November 1, 2007 to present an update of the Army's baseline realignment and closure expansion plans for Redstone Arsenal and progress on environmental investigation and cleanup activities, including an interim record of decision (IROD) for groundwater land use controls (LUC) (Shaw, 2007b). The last public meeting was held on October 6, 2008 to provide an update on the progress of the RSA-146 groundwater site investigation. A public meeting is planned for fall 2009.

A complete set of documents (hard copy and compact disk [CD]) used to make decisions about the cleanup efforts at RSA-122, RSA-056, and RSA-139 is available in the Administrative Record file managed on post by the Army's Environmental Office. Electronic copies on CD are also located at local libraries. Exhibit 1 presents a listing of locations and phone numbers for more information.

Exhibit 1: Administrative Record File and Information Repository Locations

Administrative Record File:

U.S. Army Garrison, Redstone Arsenal

Contact:	Ms. Salee Sloan (256) 842-0314
Location:	Environmental Management Division, Building 4488, Room A327, Redstone Arsenal, Alabama
Hours:	Monday – Friday, 7:00 a.m. – 4:30 p.m. (Central time zone)

Information Repositories:

Triana Public Library (Triana Youth Center)

Contact:	Ms. Blanche Orr Qualls (256) 772-3677
Location:	280 Zierdt Road, Triana, Alabama
Hours:	Monday – Thursday 4:00 p.m. – 7:00 p.m. and Friday 2:00 p.m. – 5:00 p.m.(Central time zone)

Huntsville-Madison County Public Library

Contact:	Ms. Annewhite Fuller (256) 532-5969
Location:	Heritage Room, 915 Monroe Street, Huntsville, Alabama
Hours:	Monday – Thursday, 9 a.m. – 9 p.m.; Friday – Saturday, 9 a.m. – 5 p.m.; and Sunday, 1 p.m. – 5 p.m. (Central time zone)

Documents covering RSA-122, RSA-056, and RSA-139 can also be obtained online from the Redstone Arsenal Web site: www.environmental.redstone.army.mil. This ROD will become part of the Administrative Record File (NCP 300.825(a)(2)).

The Final Statement of Basis (SB)/Proposed Plan (PP) was released in August 2009 for a public 30-day review and comment period which began on August 1, 2009 and ended on August 30, 2009 (Shaw, 2009a). A notice of availability of the SB/PP and other related documents in the Administrative Record file was published in *The Huntsville Times* on August 4, 2009; in the *Speakin' Out News* on August 5, 2009; and in the *Redstone Rocket* on August 5, 2009. The SB/PP stated that a public meeting would be held if there was sufficient interest from the public. A meeting was not requested, and no comments were received during the public comment period (see Chapter 3.0).

2.4 Scope and Role of Operable Unit or Response Action

This section includes the scope and role of the response action for RSA-122, RSA-056, and RSA-139 within the cleanup strategy for Redstone Arsenal, the scope of the problems addressed by the response action for these sites, and a discussion of the relationship of the proposed action to removal actions or other OUs.

2.4.1 Overall Remedial Strategy for Redstone Arsenal and RSA-122, RSA-056, and RSA-139

The environmental concerns at Redstone Arsenal are extremely complex. As a result, work at over 200 sites in the Installation Restoration Program at Redstone Arsenal has been underway, and the sites have been organized into 20 OUs. These OUs have recently been defined based on similarities in historical processes or functions which have resulted in site releases of a similar nature (Shaw, 2007a). Surface media sites are included in OUs 1 through 18. All 13 groundwater sites are included in OU-19. OU-20 is reserved for the wetland Integrator Operable Unit. Investigations and remedial decisions for groundwater are being managed on the basis of the groundwater site. Surface soil, subsurface soil, and soil vapor (and perched groundwater and surface water/sediment, if applicable) are being investigated and evaluated for discrete, location-bounded surface media sites.

A portion of the surface media sites on Redstone are located above commingled groundwater plumes and have historically contributed to the development of these plumes. Where commingled plumes occur, Redstone Tier 1 Risk Managers have determined that remedial decisions for the groundwater under these sites will be made on the basis of the groundwater site. For locations where isolated plumes are located beneath a surface media site, decisions for groundwater will generally be made concurrently in order to address the technical issue of potential sourcing from soil to the underlying groundwater. For administrative purposes only, surface media and groundwater sites will continue to be treated as separate units in order to maintain consistency in the RSA program.

Final RODs for surface media have been approved at OU-5, RSA-049; OU-6, RSA-057; OU-10, RSA-011; OU-2, RSA-047; OU-10, RSA-099; and OU-18, MSFC-002/087. An IROD has been approved for installation-wide groundwater LUCs in OU-19 (Shaw, 2007b; 2009b). Numerous investigations are underway at the remaining sites.

The Selected Remedy (Alternative 2) for RSA-122, RSA-056, and RSA-139 addresses risks from surface media, which include the surface soil, subsurface soil, perched groundwater, soil vapor, sediment and surface water located within the site boundary. Surface media do not include overburden or bedrock groundwater under the site, which is being investigated as part of the larger RSA-147 groundwater site. The groundwater contamination under RSA-122, RSA-056, and RSA-139, like many of the CERCLA sites at Redstone Arsenal, encompasses contributions from more than one surface media site. The final remedy for groundwater site RSA-147 will be selected following completion of an RI/feasibility study (FS), and any actions to address groundwater located under RSA-122 will be included as part of the RSA-147 groundwater site remedy.

RSA-122 was included in the RCRA Part B permit as a solid waste management unit. Redstone Arsenal was named to the National Priorities List on June 30, 1994. As a result, restoration activities must meet CERCLA requirements. As per EPA policy, the Army coordinates with EPA and ADEM to integrate CERCLA and RCRA requirements, respectively, for site cleanup activities at this federal facility (EPA, 1995). It is Redstone Arsenal's goal to select a remedy that is compliant with CERCLA and RCRA regulations and one which limits duplication of closure efforts. The Army and EPA select the remedial action with concurrence from ADEM and after consideration of public acceptance of the remedial action in accordance with CERCLA and the NCP.

An Army regulated site access control program is currently in place to control access to the CERCLA sites at Redstone Arsenal to prevent inadvertent exposure to contamination in the interim until remediation, as required, is accomplished (Army, 2008). Controls through the site access control program for groundwater prevent the installation of wells for drinking water, industrial processes, or agricultural purposes on Redstone Arsenal. This restriction prevents the use of groundwater as a source of drinking water and allows nonpotable uses of groundwater to be managed. To continue to ensure protection from exposure to potentially contaminated groundwater under these sites and elsewhere on Redstone Arsenal, a groundwater IROD has been approved (Shaw, 2007b), which selected LUCs for groundwater as the interim remedy. LUCs have been implemented to prevent potable use of groundwater and to manage nonpotable uses such that exposure to contaminated groundwater is minimized (Shaw, 2009b). This interim remedy will remain in place for the groundwater under RSA-122, RSA-056, and RSA-139 until a final remedy has been selected in a ROD for the RSA-147 groundwater site.

2.4.2 Scope of Problems Addressed by RSA-122, RSA-056, and RSA-139 Response Action

The problem warranting action at RSA-122, RSA-056, and RSA-139 is contaminants in surface soil, subsurface soil, perched groundwater, soil vapor, sediment and surface water resulting in risks to human health and the environment, including the potential for migration of contamination from soil to groundwater. Thus, the action or scope covered by this ROD is the surface media at RSA-122, RSA-056, and RSA-139. Remedial actions planned for surface media are intended as the final remedial actions. By removing soils contaminated with arsenic and mercury at RSA-122 or implementing long-term cap maintenance at RSA-056, and RSA-139 the Preferred Alternative will also eliminate or greatly reduce the threat to groundwater from the soil-to-groundwater migration pathway.

2.4.3 Relationship of Selected Remedy to Removal or Other Operable Units

In 1995, as an IRA, arsenic contamination at the disposal pits at RSA-056 and RSA-139 was addressed by installing clayey soil covers over the pits, where elevated arsenic concentrations are present. Under a TCRA in early 2001, the covers were extended and the stream bank of the unnamed creek adjacent to these sites was stabilized using shotcrete and riprap. An additional TCRA was conducted to address the human health threat from arsenic-contaminated soil in the former AT manufacturing area at RSA-139 in 2002. Excavation-restricted areas were established and administrative and institutional controls were initiated throughout the actions taken at RSA-056 and RSA-139.

Several CERCLA and RCRA sites are located adjacent to RSA-122 in OU-6, and separate RIs are underway to address contamination present in surface media at these sites. Site RSA-057, located to the east of RSA-122, was a disposal area for wastes from Plants 5 and 6. Although Plants 5 and 6 were never brought on line for lewisite production, historical documentation indicates the ponds were likely used sporadically between 1943 and 1959 to support lewisite Plants 3 and 4 and for lewisite container decontamination activities at Plant 5. Actions to address arsenic at RSA-057 through excavation have been completed, and the closure report is in preparation.

Groundwater under RSA-122, RSA-056, and RSA-139 will be further investigated during the RSA-147 groundwater site RI.

2.5 Site Characteristics

RSA-122, RSA-056, and RSA-139 are located within an industrialized portion of Redstone Arsenal that is currently used for administrative purposes. The site of the former lewisite plants contains a few buildings and is largely open and vegetated with lawn, with small areas of landscaped trees and shrubs. Although none of the production buildings from Plants 3, 4, and 5 exist today, some of the drainage ditches and the industrial sewer system are still evident. Several buildings originally used as office buildings or for storage are still present and in use. Other site features have been paved or covered and are no longer evident. An unnamed creek that runs north to south through the site was rerouted around RSA-056 in 1992. This surface water feature is still present on site and discharges into Huntsville Spring Branch.

2.5.1 Conceptual Site Model

A conceptual site model (CSM) is a three-dimensional "picture" of site conditions that illustrates contaminant sources, release mechanisms, exposure pathways, migration routes, and potential human and ecological receptors. The CSM presented on Figure 4 shows the geologic and hydrogeologic setting of RSA-122. The CSM shows these areas relative to major surface and subsurface features at or near the site.

The main components of the CSM presented on Figure 4 include the following:

- The site originated from the manufacturing of lewisite and its related processes, which took place in several buildings throughout RSA-122S and RSA-122E. Arsenic and mercury were used in AT, SM, and lewisite manufacturing processes.

- Potential sources or release points include the following:

    - Areas where feedstocks (AT, etc.) were off-loaded or transferred; these were generally in the manufacturing areas and led to surface spills or releases.
    - Underground temporary waste collection points, sumps, pits, underground chemical transfer lines, industrial sewers, etc., within the historical AT and lewisite manufacturing areas.
    - The neutralized sludge/waste pumped into the RSA-056 and RSA-139 disposal ponds.

- RCRA sites within the boundaries of RSA-122.

- Site-related contaminants, including arsenic and mercury, were detected in surface and subsurface soil at RSA-122. The highest concentrations of arsenic are present in borings near the off-loading rail spur and arsenious oxide storage silos of the former AT plant, the sump by the former SM plant, and an area off the southeast corner of the AT waste disposal pond (RSA-139) associated with RSA-122NW; the sump by the AT storage tanks and collecting pits of Plants 3 and 4 and blowcase pit at the distillation building (Plant 4) associated with RSA-122S; the trench located within the former lewisite reactor building (Plant 5); and the blowcase pit associated with the distillation building (Plant 5) associated with RSA-122E. Outfall locations of the former industrial sewer system also exhibit elevated arsenic.

- Depth to groundwater at RSA-122, RSA-056, and RSA-139 typically ranges from 3 to 30 feet below ground surface (bgs). The groundwater flow is predominantly to the south-southeast in the vicinity of RSA-122. Disposal of wastes at the site has resulted in contaminants having leaked or leached through the soil column to shallow overburden groundwater.

Current and future potential human receptors evaluated for RSA-122 include groundskeepers, construction workers, and trespassers, any of which might, under specific circumstances, be exposed to site-related contamination. A hypothetical residential receptor was evaluated under a potential future site use where houses were built on RSA-122. An indoor commercial worker and hypothetical future residential receptor were used in the evaluation of potential risks posed by indoor air contaminated via the vapor intrusion transport pathway.

- The site is maintained on a regular basis; the groundskeeper serves as a conservative surrogate for all site workers who might be exposed to surface soil. The groundskeeper, who typically cuts the grass, could be exposed to soil through incidental dermal contact, inhalation of soil particulates, or incidental ingestion. The soil at the site is covered by grass such that there would be minimal direct exposure to soils.

- A construction worker was included as a plausible receptor for evaluating subsurface soil and total soil (the combination of surface and subsurface soil data sets with starting depths of 10 feet bgs or less).

- A trespasser was included as a plausible receptor to evaluate recurring exposure of a youthful, unauthorized entrant to the surface soil at the site.

- Groundwater exposure pathways are incomplete under current conditions because groundwater is not utilized as a potable water supply on Redstone Arsenal (Army, 2008; Shaw, 2009b, 2007b). Exposure to groundwater was evaluated in the risk assessment to meet requirements for assessing risks from multiple media cumulatively, as specified under the NCP. This assessment is needed because the current remedy in place for groundwater is only an interim remedy (EPA, 1991b).

Small wetlands and aquatic habitat areas occur within RSA-122. As listed in Redstone Arsenal's *Endangered Species Management Plan* (Army, 2005), no threatened or endangered species or special status species are present at RSA-122. No areas of archeological or historical importance are present at RSA-122. The site risks are discussed in Section 2.7.

2.5.2 Nature and Extent of Contamination

Surface soil, subsurface soil, surface water, sediment, and groundwater have been sampled at RSA-122 as part of the RI and earlier studies. RI sampling at RSA-122 began in 1994 and was completed by 2005. Potential release points were sampled to determine the nature and extent of contamination at RSA-122. The Phase II RI report (Shaw, 2007a) contains the detailed sample information, analytical data, the screening criteria for data evaluation, and maps for the investigations conducted at RSA-122.

EPA has published studies that estimate health and environmental risks associated with many of the organic and inorganic compounds found in the environment at Redstone Arsenal. Analytical data from RSA-122 were compared to EPA Region 9 preliminary remediation goals (PRG) (EPA, 2004) to help determine the extent and magnitude of contamination at this site. PRGs combine current human health toxicity values with standard exposure factors to estimate contaminant concentrations in environmental media (soil, air, and water) that are considered by EPA to be health protective of human exposures (including sensitive groups) over a lifetime. For the purpose of visualizing contaminant distribution only, surface soil data were compared to residential PRGs in case the site can be released for unlimited use and subsurface soil data were compared to industrial PRGs because the anticipated reuse for the site is industrial. Other screening criteria used to identify and determine the severity of the contamination at Redstone Arsenal environmental sites includes the EPA soil screening levels (SSL), EPA Region 9 tap water PRGs or maximum contaminant levels (MCL) in groundwater, and background screening values (BSV) specific to a sitewide data set for metals at Redstone Arsenal (EPA, 2004; 2002).

The following subsections summarize, by medium, the characterization of the nature and extent of contamination encountered at RSA-122. Details are available in the RI report (Shaw, 2007a).

2.5.2.1 Nature and Extent of Soil Contamination

Surface Soil. The majority of arsenic concentrations in surface soils (0 to 1 foot) are present around the off-loading rail spur and arsenious oxide storage silos of the former AT plant (maximum of 1,640 milligrams per kilogram [mg/kg]), the sump by the former SM plant, and an area off the southeast corner of the AT waste disposal pond (RSA-139) associated with RSA-122NW (Table 2-8 of the RI report [Shaw, 2007a]); the sump by the AT storage tanks and collecting pits of Plants 3 and 4 (maximum of 641 mg/kg) and blowcase pit at the distillation building (Plant 4) associated with RSA-122S; the trench located within the former lewisite reactor building (Plant 5); and the blowcase pit associated with the distillation building (Plant 5) associated with RSA-122E. Outfall locations of the former industrial sewer system also exhibit elevated arsenic (maximum of 303 mg/kg) (Table 2). In general, the elevated arsenic concentrations are bounded by sample locations with much lower arsenic concentrations, which suggests that the extent of the most highly contaminated soil has been delineated.

Elevated mercury concentrations in surface soil (maximum of 67.7 mg/kg) were associated with the manufacturing and storage buildings of the AT plant, the manufacturing and distillation buildings and collecting pits of Lewisite Plants 3 and 4, and industrial sewer outfalls (Table 2). Three of the six most elevated mercury detections were associated with the industrial sewer system outfalls. Elevated concentrations of mercury and arsenic are collocated.

Subsurface Soil. As with surface soils, arsenic and mercury were identified as site-related contaminants in subsurface soils at the site. Arsenic concentrations were highest in the area of the former AT plant (2,770 mg/kg at RSA-122NW) and near below-grade structures (sumps, pits, trenches) associated with Lewisite Plants 3 and 4 (RSA-122S) (Table 2-12 in the RI Report [Shaw, 2007a]). Elevated arsenic concentrations in the shallow subsurface are evident in the area of the industrial sewer outfalls. Concentrations of mercury (maximum of 117 mg/kg) are highest in the area of the collecting pits at Plants 3 and 4 (RSA-122S), with minor concentrations at Plant 5 (RSA-122E) near the collecting pit and manufacturing building (Table 2-9 of the RI Report [Shaw, 2007a]).

2.5.2.2 Nature and Extent of Surface Water Contamination

Surface Water. Limited concentrations of organic compounds have been detected in surface water in the springs associated with the unnamed creek at locations south of Mills Road RSA-122, with only a few concentrations exceeding tap water screening levels.

Concentrations of arsenic in surface water samples exceeded screening criteria at locations near the capped waste disposal ponds and downstream of the industrial sewer outfall from former Plants 5 and 6 (RSA-122E). Concentrations of copper, lead, mercury, and zinc exceeded surface water applicable or relevant and appropriate requirements (ARAR). However, the ARARs for copper, lead, and mercury are less than background values.

2.5.2.3 Nature and Extent of Groundwater Contamination

Shallow Overburden (Perched) Groundwater. Perched groundwater was found at the Plants 3 and 4 areas and was formed from water supply lines, storm sewers, and steam line condensate discharge. Trichloroethene (TCE) was the volatile organic compound (VOC) most frequently detected above screening criteria. No sources of TCE were found in soils at RSA-122. Three metals (antimony, arsenic, and lead) were detected at concentrations that exceed background values and screening values.

Overburden Groundwater. TCE was the VOC most frequently detected above screening criteria and is the only organic compound detected in the shallow overburden (perched zone) and overburden at RSA-122 with regularity. The source(s) of TCE has not been identified; however, it was likely used as a solvent during the lewisite manufacturing process or was disposed in the waste disposal ponds. Carbon tetrachloride, which was detected in soils associated with below-grade collection units, is also evident in deeper overburden groundwater samples, but at concentrations less than the MCL. No sources of TCE or carbon tetrachloride were found in soils at RSA-122.

Arsenic is the only metal detected at concentrations that exceed background values and screening values in overburden groundwater. Only the highest concentrations of arsenic in soils have impacted very localized areas of perched groundwater in the shallow subsurface at the site and overburden groundwater beneath the site. The presence of arsenic in overburden groundwater at a maximum concentration of 1,740 micrograms per liter (µg/L) is contrary to the travel-time analysis. There is evidence that some contaminants have been released directly into the shallow overburden (perched) groundwater (arsenic at 5,490 µg/L) or overburden (arsenic at 1,740 µg/L) groundwater zone and therefore, in some cases, travel distances are essentially zero. The distribution of arsenic, for example, around the Plant 3 and Plant 4 collecting pits suggest that the base of the pit was a release point for arsenic-containing wastes. However, plumes appear to be limited in lateral extent within the unit boundaries.

2.5.3 Fate and Transport

Soils, surface water, sediment, and groundwater samples were collected from around the RSA-122 site to identify the locations and concentrations of potentially toxic contaminants at the site.

Multiple release points were identified within each of the four study areas, and a different set of migration or transport mechanisms was applicable to each of the four study areas (Figure 3). The following text summaries the potential contaminant migration pathways investigated in the RI. The results of the Fate and Transport evaluation are presented in Section 2.7.3 of this ROD.

RSA-122N. This area contains none of the manufacturing plants but does contain an open storage area; little contamination was identified in this portion of RSA-122. Although several viable migration mechanisms were noted, no major contaminant transport pathways were identified during the RI.

RSA-122NW. This area contains the SM and AT manufacturing areas. Viable and major migration pathways identified for this area include the following:

- Leaching of soil contaminants to deeper levels of the vadose zone and to the groundwater.
- Overland storm water runoff has probably moved contaminants with a low potential to migrate to groundwater (e.g., metals) from surface soil into the shallow engineered drainage ditches within RSA-122NW. These contaminants are now part of the sediment load in the main ditch.
- Groundwater containing solvents (e.g., carbon tetrachloride) and arsenic, most likely from the RSA-122 site, is being discharged through a series of springs into the main creek south of the site boundary.

RSA-122S. This area contains the former Lewisite Plants 3 and 4. Viable and major migration pathways identified for this area include the following:

- Leaching of soil contaminants to deeper levels of the vadose zone and to the groundwater.
- The presence of the temporary waste collection points (sumps and pits) within the lewisite plants area has led to the release of lewisite sludge/waste directly into the deeper vadose zone soils (as deep as 13 to 14 feet bgs), enhancing the ability of these wastes to migrate to even deeper portions of the vadose zone and to the overburden groundwater.

- Overland storm water runoff has probably moved recalcitrant contaminants (e.g., metals) present in surface soil into the shallow engineered drainage ditches within RSA-122S. These contaminants are now part of the sediment load in the main ditch.

- Overflows from the collecting pits were directed into the industrial sewer lines draining the site. The industrial sewer lines for RSA-122S discharge into the main ditch south of the manufacturing areas. Contaminant migration through the industrial sewer lines has led to surface soil and sediment contamination in the main creek at the outfall of the sewer line.

- Groundwater containing solvents (e.g., carbon tetrachloride) and arsenic, most likely from the RSA-122 site, is being discharged through a series of springs into the main creek south of the site boundary. The collecting pits within RSA-122S are identified sources of groundwater solvent and arsenic contamination. This contaminated groundwater is probably traveling along a preferred flowpath, parallel to the strike of a northwest-southeast-trending subsurface fault that connects the manufacturing areas to the main creek.

RSA-122E. This portion of the site contains former Lewisite Plants 5 and 6. According to historical documents, neither plant was operational; however, Plant 5 was later used for decontamination activities associated with lewisite. Migration pathways are identical to those identified for RSA-122S, although it does appear that in a relative measure, contaminant loading in RSA-122E is less than for RSA-122S.

In addition to the source areas associated with the RSA-122 site described above, the RSA-056 and RSA-139 arsenic ponds represent major sources of arsenic, mercury, and solvents within the RSA-122 site boundary. Although capped in the late 1990s, contaminants were released into the soils, surface water, sediment, and groundwater from these features for approximately 50 years.

2.6 Current and Potential Future Land and Resources Use

This section presents current and future land and groundwater uses for this site.

2.6.1 Current and Future Land Use

Current Land Use. Based on the information from the Department of Public Works Master Planning for Redstone Arsenal, the land use for this area is currently identified as industrial.

No recreational activities (e.g., hunting, fishing, camping) are currently permitted at RSA-122, RSA-056, or RSA-139. Recreational hunters are authorized for entry onto Redstone Arsenal through staffed security gates at the facility boundaries. Individuals accessing Redstone Arsenal for any recreational purposes are directed to the outdoor recreation office for maps. These maps identify all approved hunting areas as well as other recreational areas. Prohibited areas such as CERCLA sites (i.e., RSA-122, RSA-056, and RSA-139) are noted on the maps. Game wardens and other security personnel routinely enforce the recreational use regulations on Redstone Arsenal. Where practical, the Army has restricted entry into environmental sites by fencing them and/or by placing warning signs at key entry points per the Site Access Control program (Army, 2008).

Future Land Use. Land use at RSA-122 is listed as administrative in the base master plan. The site has the potential for future building projects, probably administrative in nature. Future construction at RSA-122 is expected to include two industrial buildings and a parking lot. The Department of Public Works Master Planning has requested flexibility with regard to the precise locations for siting industrial buildings and other support features. Currently there are no plans to use this site for recreational or residential purposes. If the site is ever proposed for recreational or residential use, then this land use change would require approval by EPA and ADEM.

2.6.2 Current and Future Groundwater Use

Current Groundwater Use. Groundwater under RSA-122, RSA-056, and RSA-139 is not currently used for human consumption or for any nonpotable uses. The Tennessee River is the source of potable water for both consumption and the majority of nonpotable uses on Redstone Arsenal. Local residents and Redstone Arsenal workers receive their potable water from the Huntsville Utilities, where water is derived from the Tennessee River. Redstone Arsenal's installation-wide groundwater IROD prevents the current use of groundwater under Redstone Arsenal for potable purposes and ensures that any nonpotable uses of groundwater are reviewed and evaluated by the Army prior to being permitted (Shaw, 2007b). An installation-wide groundwater LUC remedial design (RD) document has been prepared to document the LUCs to be implemented for groundwater (Shaw, 2009b).

Future Groundwater Use. Under the provisions of the Army's groundwater IROD, future groundwater resources at RSA-122, RSA-056, RSA-139, or elsewhere on Redstone Arsenal may not be developed for potable purposes, and groundwater withdrawals for nonpotable uses must be managed as previously discussed. These LUCs will remain in effect until remedies are selected in the final RODs for the various groundwater sites (e.g., the RSA-147 groundwater site) within Redstone Arsenal. Thus, the IROD and the LUC RD document (Shaw, 2009b; 2007b) apply to any groundwater site for which the final remedy has not been selected in a ROD.

2.7 Site Risks

BHHRAs and screening-level ecological risk assessments (SLERA) were performed to estimate the probability and magnitude of potential adverse human health and environmental effects from exposure to contaminants associated with three sites: RSA-122, RSA-056, and RSA-139. Included within the RSA-122 site boundary are several former chemical manufacturing areas and waste disposal ponds associated with these manufacturing operations. The two waste disposal ponds (RSA-056 and RSA-139) are included in this ROD because they lie within the RSA-122 boundary and also have similar contaminants.

RSA-056 and RSA-139. BHHRAs were completed for RSA-056 and RSA-139 in 1998 (IT, 1998). Results of the BHHRAs demonstrated that risks posed by arsenic to industrial human health receptors were extremely high. Based on these results, an IRA in 1995 and TCRA in 2001 and 2002 were used to address imminent hazards posed by these sites. The IRA and TCRAs conducted at RSA-056 and RSA-139 included capping of the lagoons and soil areas surrounding the lagoons. Fences were installed to completely encompass each site, with signs posted along the fences every 100 feet indicating that each site is a “Restricted Area” with additional “No Dig Area” restrictions. An LUC implementation plan was completed for RSA-056 and RSA-139 during the TCRA activities (IT, 2001) to ensure that caps are maintained and that uses of these sites are limited. These actions resulted in the elimination of human and ecological direct contact exposure pathways. Therefore, although arsenic was disposed of in the lagoons and pond and was found in surrounding site surface soils above acceptable levels, RSA-056 and RSA-139 no longer pose a risk to human health or the environment because the installed caps prevent direct exposure to contaminants. Documentation of the final remedy is needed to ensure that the caps are properly maintained, mowed, and inspected for burrowing animals and that LUCs are implemented to ensure protection from future exposure.

RSA-122. As part of the RI, the Army completed separate BHHRAs and SLERAs for each of five geographical areas at RSA-122 to evaluate potential current and future effects of exposure to chemicals on the human health and environment (Shaw, 2007a). An indoor air vapor intrusion evaluation was also included as part of the human health risk assessment for RSA-122.

The five major geographical areas at RSA-122 include the following:

- 122-Northwest (Former Arsenic Trichloride Manufacturing Plant)
- 122-North (Former Stockpiling Area)
- 122-East (Former Lewisite Plants 5 and 6 Area)
- 122-South (Former Lewisite Plants 3 and 4 Area)

- 122-Creek (North-South Trending Unnamed Creek).

These risk assessments support the need for the Preferred Alternative for RSA-122 soil, which is excavation of arsenic- and mercury-contaminated soil, treatment (if required), backfill with clean soil, off-site disposal, short-term sediment and groundwater monitoring, and institutional controls (Alternative 2). A summary of the aspects of the BHHRAs that support the determination that this remedial action is necessary to ensure the protection of human health and the environment is presented in Section 2.7.1, followed by a summary of the SLERAs in Section 2.7.2. The complete BHHRAs and SLERAs can be found in Chapter 7.0 and Appendices F (BHHRA) and G (SLERA) of the RI report for RSA-122 (Shaw, 2007a).

2.7.1 Baseline Human Health Risk Assessment

The BHHRAs identified unacceptable risks for industrial and residential receptors from exposure to arsenic and mercury in surface media at RSA-122. To reach this conclusion, the BHHRAs calculated the likelihood of health problems occurring if no cleanup actions are taken at this site. The BHHRAs followed a four-step process to estimate the baseline risk for human health: 1) hazard identification, which identified those hazardous substances which, given the specifics of the site, were of significant concern; 2) exposure assessment, which identified actual or potential exposure pathways, characterized the potentially exposed populations, and determined the extent of possible exposure; 3) toxicity assessment, which considered the types and magnitude of adverse health effects associated with exposure to hazardous substances, and 4) risk characterization and uncertainty analysis, which integrated the three previous steps to estimate the potential and actual risks posed by hazardous substances at the site, including carcinogenic risks and noncarcinogenic hazards and a discussion of the uncertainty in the risk estimates.

A summary of these steps of the BHHRA follows.

2.7.1.1 Step 1 - Identification of Chemicals of Potential Concern

Surface media evaluated for RSA-122 in the BHHRA included soil, sediment, and surface water (collected from a north-south-trending unnamed perennial creek and various ephemeral tributaries), and perched groundwater defined as extremely shallow groundwater which could be contacted during construction activities. Chemicals of potential concern (COPC) are chemicals found at the site at concentrations above federal and state risk screening levels. The COPCs were selected to represent potential site-related hazards based on toxicity, concentration, frequency of detection, and mobility and persistence in the environment. A hypothetical medium called total soil was created by combining all soil data from samples with starting depths of 10 feet or less into one data set to evaluate the potential for subsurface soil to be brought to the surface during construction or excavation so that direct contact is plausible.

The soil and perched groundwater data were segregated into four data sets corresponding to four of the major areas (Northwest, North, East, and South) (Figure 3). Evaluating each of the four major areas separately more nearly approximates a reasonable exposure unit. In addition, surface soil, collected in close proximity to the Unnamed Creek, was segregated into a separate Creek Area data set. However, the surface soil data from the Creek Area were also included in the four major data sets described above. Data from sediment and surface water samples collected from the Unnamed Creek were also included in the Creek Area evaluation. The Creek Area was evaluated as a separate exposure unit for a trespasser who visits the site to engage in water play.

East Area. Ten of the 38 chemicals detected in soil and 3 of the 19 chemicals detected in perched groundwater were selected for evaluation in the BHHRA as COPCs. COPCs for surface soil, subsurface soil, and total soil can be found in Tables 7-5 through 7-7, respectively, of the RI report, and COPCs for perched groundwater can be found in Table 7-21 of the RI report (Shaw, 2007a). Estimates of the exposure point concentrations used for all COPCs can be found in Table 7-25 of the RI report (Shaw, 2007a).

North Area. Eleven of the 28 chemicals detected in soil and 4 of the 19 chemicals detected in perched groundwater were selected for evaluation in the BHHRA as COPCs. COPCs for surface soil, subsurface soil, and total soil can be found in Tables 7-8 through 7-10, respectively, of the RI report, and COPCs for perched groundwater can be found in Table 7-22 of the RI report (Shaw, 2007a). Estimates of the exposure point concentrations used for all COPCs can be found in Table 7-25 of the RI report (Shaw, 2007a).

Northwest Area. Eighteen of the 57 chemicals detected in soil and 7 of the 26 chemicals detected in perched groundwater were selected for evaluation in the BHHRA as COPCs. COPCs for surface soil, subsurface soil, and total soil can be found in Tables 7-11 through 7-13, respectively, of the RI report, and COPCs for perched groundwater can be found in Table 7-23 of the RI report (Shaw, 2007a). Estimates of the exposure point concentrations used for all COPCs can be found in Table 7-25 of the RI report (Shaw, 2007a).

South Area. Twelve of the 63 chemicals detected in soil and 7 of the 23 chemicals detected in perched groundwater were selected for evaluation in the BHHRA as COPCs. COPCs for surface soil, subsurface soil, and total soil can be found in Tables 7-14 through 7-16, respectively, of the RI report, and COPCs for perched groundwater can be found in Table 7-24 of the RI report

(Shaw, 2007a). Estimates of the exposure point concentrations used for all COPCs can be found in Table 7-25 of the RI report (Shaw, 2007a).

Creek Area. Seven of the 32 chemicals detected in soil and 7 of the 25 chemicals detected in surface water were selected for evaluation in the BHHRA as COPCs. The COPCs for surface soil, sediment, and surface water can be found in Tables 7-17 through 7-19, respectively, of the RI report (Shaw, 2007a). Six of the 37 chemicals detected in sediment were selected as COPCs; however, these COPCs were not evaluated further in the BHHRA because risks from exposure to sediment perennially covered with water are generally insignificant. Estimates of the exposure point concentrations used for all COPCs can be found in Table 7-25 of the RI report (Shaw, 2007a).

Vapor Intrusion. As presented in Attachment 2 of Appendix F of the RI report (Shaw, 2007a), the maximum detected concentrations of VOCs in groundwater samples were used to evaluate whether vapors originating from groundwater contamination could pose unacceptable risks to an indoor worker exposed in Buildings 5421-Main, 5421-Addition, 5422, 5432, 5435, 5436, 5437, or 5452, or to a resident if residential buildings were constructed on RSA-122 in the future.

2.7.1.2 Step 2 - Exposure Assessment

Potential human health effects associated with exposure to COPCs were estimated quantitatively through the development of several hypothetical receptor scenarios and exposure pathways. These pathways were developed to reflect the potential for receptor exposure to hazardous substances based on the present site uses, potential future site uses, and location of RSA-122. Based on the information from the Department of Public Works Master Planning for Redstone Arsenal (Army, 2006), the current land use of RSA-122 is identified as industrial, with potential future building projects, probably administrative in nature. Future construction at RSA-122 is expected to include two industrial buildings and a parking lot. The Department of Public Works Master Planning has requested flexibility with regard to the precise locations for siting industrial buildings and other support features. Currently there are no plans to use this site for recreational or residential purposes. The future hypothetical residential evaluation provides a basis for establishing some remedial responses, including justification for the selection of LUCs.

The following paragraphs present a brief summary of the exposure pathways evaluated in the BHHRAs. A more thorough description of exposure pathways evaluated can be found in Appendix F, Section F3.2 of the RI report (Shaw, 2007a).

Five types of human receptors were quantitatively evaluated in the exposure assessment that was performed as part of the quantitative risk assessment for RSA-122. The groundskeeper and construction worker are considered industrial receptors; these receptors were evaluated under current and future land-use assumptions. The trespasser is considered a recreational receptor and was evaluated under current and future land use assumptions. A hypothetical residential receptor was evaluated under a potential future site use which assumes that houses are built on RSA-122. An additional receptor, an indoor commercial worker, was used in the evaluation of potential risks posed by indoor air, contaminated via the vapor intrusion transport pathway. Indoor air contamination may occur when VOCs found in soils and groundwater volatilize and are transported into buildings.

Intake of chemicals from potential exposure to surface soil was determined for all human health receptors except the indoor commercial worker. Additionally, the intake of chemicals found in subsurface soil and perched groundwater was determined for the construction worker possibly exposed during excavation or trenching operations. The possible exposure due to contact of chemicals found in surface water was determined for the trespasser while playing, particularly along the perennial creek. It was also assumed that the future groundskeeper, construction worker, and hypothetical residential receptor would be exposed to overburden groundwater developed as a source of potable water in the future. The intake of chemicals found in the total soils medium was determined for the future groundskeeper, future construction worker, and future hypothetical residential receptors.

Receptors could come in contact with contaminants in site media by dermally contacting (touching), ingesting (eating), or inhaling (breathing in) site media. For exposure to soils, all three exposure routes were evaluated for the construction worker, groundskeeper, and trespasser receptors. The trespasser was assumed to come in contact with surface water through dermal contact only. Also, the construction worker may come in contact with perched groundwater through dermal contact during excavation or trenching operations. Hypothetical future residential adults and children were assumed to only come in contact with soils through ingestion and dermal contact because, in a residential setting, soils would be covered by lawns, gardens, or pavement, reducing dust emissions from wind erosion to insignificant levels.

Of the 24 VOCs detected in groundwater, only TCE and vinyl chloride were identified as COPCs for the vapor intrusion migration exposure pathway. To determine the exposure point concentration used to evaluate the vapor intrusion migration exposure pathway, indoor air concentrations were calculated using maximum detected concentrations of VOCs from groundwater samples collected near existing buildings at RSA-122. For the hypothetical residential building, the maximum detected concentration of VOCs from all wells or hydropunch locations throughout RSA-122 was selected for use in vapor intrusion modeling. A three-tiered screening-level vapor intrusion evaluation was performed. The Johnson and Ettinger vapor intrusion model was used to calculate indoor air concentrations based on groundwater sample results (Johnson and Ettinger, 1991). Indoor air concentrations were calculated for a worker in Buildings 5421-Main, 5421-Addition, 5422, 5432, 5435, 5436, 5437, and 5452, and for a hypothetical future residential on-site house.

2.7.1.3 Step 3 - Toxicity Assessment

The possible harmful effects to humans from the COPCs were evaluated. These chemicals were separated into two groups: carcinogens (COPCs that may cause cancer) and noncarcinogens (COPCs that may cause adverse health effects other than cancer). Chemicals classified as carcinogens may also elicit noncarcinogenic adverse health effects; these effects are evaluated as well. Both cancer and noncancer adverse health effects were evaluated for carcinogens, where applicable. Toxicity values used for quantitative evaluation of risks via the oral, dermal, and inhalation pathways are discussed in Appendix F, Chapter F4.0, and presented in Tables 7-26, 7-28, and 7-29 of the RI report (Shaw, 2007a).

Cancer potency factors have been developed by EPA from epidemiological or animal studies to reflect a conservative “upper bound” of the risk posed by potentially carcinogenic compounds. A summary of the current cancer toxicity data relevant to the carcinogens of concern is presented in Table 3. Reference doses (RfD) for noncarcinogen compounds have been developed by EPA and represent a level to which an individual may be exposed that is not expected to result in any deleterious effect. RfDs are derived from epidemiological or animal studies and incorporate uncertainty factors to help ensure that adverse health effects will not occur. A summary of the current noncarcinogenic toxicity data relevant to the noncarcinogens of concern is presented in Table 4.

There is ongoing uncertainty in the regulatory community over the most scientifically valid inhalation slope factor to use for estimating risks from inhalation TCE vapors. Inhalation slope factors for TCE used in the vapor intrusion evaluation were based on two different sources: EPA’s National Center for Environmental Assessment evaluation of TCE (EPA, 2001) and California Environmental Protection Agency’s (2002) guidelines for describing cancer potency factors. Attachment 2 of Appendix F of the RI report (Shaw, 2007a) presents the toxicity assessment performed for the vapor intrusion evaluation.

2.7.1.4 Step 4 - Risk Characterization

The results from the exposure and toxicity assessment were combined to calculate the overall risks from exposure to site COPCs. Excess lifetime cancer risks were determined for each exposure pathway by multiplying a daily intake level with the chemical-specific cancer potency factor.

For potential carcinogens, the risk to human health is expressed in terms of the probability of the chemical causing cancer over an estimated lifetime of 70 years. All risks estimated represent an “excess lifetime cancer risk” or the additional cancer risk on top of that which occurs from other causes. The NCP (EPA, 1990) states, at 40 Code of Federal Regulations 300.430 (e)(2)(i)(A)(*2*), that, for known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 1×10^{-4} and 1×10^{-6}, and that the 1×10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available, or when ARARs are not sufficiently protective because of the presence of multiple contaminants or exposure pathways. In other words, if exposure to a particular carcinogenic chemical creates a 1-in-100,000 chance of causing cancer, then this would be expressed as 1×10^{-5}. In general, calculated risks greater than 1×10^{-4} require consideration of engineering-oriented cleanup alternatives. Cancer risks between 1×10^{-4} and 1×10^{-6} (between 1 in 10,000 and 1 in 1,000,000) fall within a risk management range that Redstone Arsenal Tier 1 Risk Managers may decide is acceptable on a case-by-case basis.

For noncarcinogens, the risk to human health is expressed as a hazard quotient (HQ) for each exposure pathway. The HQ is calculated by dividing the daily intake level by the appropriate exposure pathway RfD (e.g., oral RfD for ingestion pathway). The hazard index (HI) is the sum of all the HQs for all COPCs that affect the same target organ (e.g., liver) within or across those media to which the same individual may reasonably be exposed. An HI greater than 1 suggests that adverse health effects are possible.

For risk management purposes under CERCLA, a total cancer risk of 1×10^{-6} (1 in 1,000,000) is a point of departure below which cancer risks are considered to be insignificant (EPA, 1990). For sites subject to compliance with the Alabama Risk-Based Corrective Action program, a cumulative cancer risk of 1×10^{-5} triggers identification of COCs (ADEM, 2008). However, RSA-122 is not subject to regulation under Alabama Risk-Based Corrective Action based on the start date of the remedial investigation for this site. Where cumulative risks have been found to exceed designated risk thresholds, chemicals with risks exceeding 1×10^{-6} (or an excess lifetime cancer risk of 1 in 1,000,000) or an HI of 0.1 may be selected as COCs. These are chemicals that significantly contribute to unacceptable risks for a pathway in an exposure model for a hypothetical receptor (e.g., a child that resides on the site). Typically, these selected chemicals represent chemicals that may require a response action. However, Redstone Tier 1 Risk Managers may refine the list of COCs selected for action based on site-specific considerations. Final identification of COCs may occur during a removal action or as part of the evaluations performed during the feasibility study (FS) for a site.

Risks presented in the final RI report (Shaw, 2007a) from exposure to each medium and the cumulative risk for each receptor are shown in Table 5. Risk managers for RSA-122 determined that arsenic and mercury were the COCs requiring action for this site. Arsenic and mercury risks exceeding 1×10^{-4} (or an excess lifetime cancer risk of 1 in 10,000) or an HI of 0.1 within a medium are summarized in Table 6. The chronic RfD for arsenic was used in the RI to calculate the noncancer hazard effects for a construction worker's exposure to soil. However, it is appropriate to apply a subchronic RfD to the construction worker because the assumed exposure duration for this receptor is one year, which is considered subchronic exposure by EPA (EPA, 2008). Therefore, noncancer hazards for a construction worker's exposure to arsenic using a subchronic reference dose was assessed in the FS (Shaw, 2009), and these results are presented in Table 6 as well.

A short-term utility corridor worker was also evaluated in the FS (Shaw, 2009c) as a future receptor who may have an acute exposure to arsenic in soil while working within the utility corridor (i.e., 5 feet on either side of the utility and 4 feet bgs). A remedial goal (RG) of 1,500 mg/kg was calculated using the acute toxicity value for arsenic developed by the Agency for Toxic Substances and Disease Registry (2005). Complete calculations and input values are provided in the FS (Shaw, 2009c). The RG of 1,500 mg/kg is protective of a short-term utility worker working in one location for up to 10 days within a 14-day time period. The RG of 1,500 mg/kg is also within the acceptable risk range (e.g., 6.5×10^{-6}) based on a ratio to the cancer-based RGs presented in the FFS (Shaw, 2009a).

Seasonally perched groundwater is contaminated with arsenic in the Northwest and South Areas but cannot be developed as a potable source. Risks to a construction worker exposed to seasonally perched groundwater were found to be acceptable.

Results of the vapor intrusion evaluation are presented in Table 7. Risks from VOCs present in groundwater that might migrate into indoor air and might come in contact with a future residential receptor or indoor commercial worker receptors working in the existing site structures were assessed. In Table 7, risks from exposure to modeled concentrations of TCE were found to be acceptable for commercial workers in eight existing buildings. Risks exceeded the EPA (2002) target cancer risk level of 1 x 10^{-6} (1 in 1,000,000) but did not exceed the target risk levels of 1 x 10^{-5} (1 in 100,000) and 1 x 10^{-4} (1 in 10,000). For the residential receptors within a hypothetical future residential building, risks for vinyl chloride exceeded the EPA (2002) target cancer risk level of 1 x 10^{-6} (1 in 1,000,000) but did not exceed the target risk levels of 1 x 10^{-5} (1 in 100,000), while risks for TCE exceeded the EPA (2002) target cancer risk level of 1 x 10^{-4} (1 in 10,000). Risks from exposure to TCE in indoor air were further evaluated for the hypothetical residential receptor using the California Environmental Protection Agency inhalation slope factor. The modeled indoor air concentration of TCE for the residential receptor did not exceed the target cancer risk levels of 1 x 10^{-5} (1 in 100,000) and 1 x 10^{-4} (1 in 10,000) based on the California Environmental Protection Agency inhalation slope factor. Target risk levels based on the California Environmental Protection Agency inhalation slope factor are protective of human health, although these levels are less restrictive than the EPA (2002) target risk levels.

Risks from exposure to groundwater were also characterized in this BHHRA to ensure that cumulative risk requirements of the NCP (EPA, 1990) were met. The risks to a groundskeeper, construction worker, and a future hypothetical residential receptor from exposure to groundwater were found to exceed 1 x 10^{-4} in the BHHRA. Noncancer HIs exceeded 1 for exposure to groundwater by all future receptors. However, potential risks from exposure to groundwater from this site will be addressed with groundwater site RSA-147. In the meantime, LUCs selected in the final installation-wide IROD and implemented in the LUC RD preclude the use of the installation's groundwater as a potable water source and ensure that the nonpotable uses of groundwater are managed to ensure protection of public health (Shaw, 2007b; 2009b).

2.7.1.5 Summary of the Baseline Human Health Risk Assessment

Arsenic and mercury in soil have been identified as COCs warranting action based on the results of the BHHRA. Chemicals in groundwater do pose a human health threat, but these chemicals are being addressed during the RSA-147 groundwater site RI. Risks to an indoor worker in eight existing buildings and a hypothetical future residential receptor from the vapor intrusion pathway do not exceed acceptable levels.

2.7.2 Screening-Level Ecological Risk Assessment

The SLERA included an evaluation of the potential environmental impacts from exposure to chemicals detected in surface soil, sediment, and surface water from the five geographical areas (North, Northwest, South, East, and Creek). The SLERA conducted for RSA-122 concluded that arsenic and mercury in site media have the potential to result in adverse impacts to some individual ecological receptors. Impacts to populations of ecological receptors are not expected. To reach this conclusion, the SLERA was completed in three steps, which are as follows.

2.7.2.1 Step 1 - Screening-Level Problem Formulation and Toxicity Assessment

The primary objective of the ecological risk assessment is to evaluate whether individuals of species designated as having a special administrative status or populations of non-special-status species are potentially adversely impacted when exposed to site-related chemicals at RSA-122. The ecological receptors evaluated for this assessment included the following:

- Terrestrial plant and soil invertebrate communities
- Populations of mammals and birds which feed on soil invertebrates, plants, and other animals
- Aquatic benthic invertebrate communities
- Aquatic water-column invertebrate and water-dwelling amphibian communities.

No special-status species were found to occur at this site, although it is possible that the peregrine falcon could be an occasional site visitor. Similar to the BHHRA, chemicals found in site surface soils, surface water, and sediment at concentrations above federal and state risk-screening levels (and BSVs for metals) were identified as chemicals of potential ecological concern (COPEC).

2.7.2.2 Step 2 - Screening-Level Exposure Estimate and Risk Calculation

Chemicals initially selected as COPECs in surface soil included metals, pesticides, polynuclear aromatic hydrocarbons (PAH), and VOCs. Chemicals initially selected as COPECs in surface water included several metals and four pesticides. Chemicals initially selected as COPECs in sediment included several metals, five pesticides, Aroclor 1254, and total PAHs. Tables G-3 through G-7 of Appendix G of the RI report (Shaw, 2007a) present the results of the selection of COPECs for surface soil in the North, Northwest, East, South, and Creek Areas, respectively. Tables G-8 and G-9 of Appendix G of the RI report (Shaw, 2007a) present the results of the selection of COPECs for sediment and surface water, respectively.

2.7.2.3 Step 3 - Problem Formulation Refinement

Further evaluations were performed during the problem formulation refinement step to determine whether adverse impacts to populations of non-special-status species present at this site would be anticipated. This step consisted of three parts: an assessment of exposure, toxicity assessment, and risk characterization. The exposure assessment was based on measured concentrations of COPECs in site surface soils, surface water, and sediment. These concentrations were used directly to assess the potential for adverse impacts to terrestrial and aquatic plants and invertebrates. Food chain dose calculations were performed using appropriate bioaccumulation factors to estimate chemical concentrations in the food of mammals and birds. COPECs were further eliminated from consideration based on comparison to BSVs, status as an essential nutrient, or low frequency of detection. In contrast, bioaccumulative chemicals which did not exceed ecological screening values were included in the evaluation for potential food chain effects.

Toxicity endpoints concentrations for soil, plant, or invertebrate communities were based on literature-derived soil, surface water, and sediment concentrations identified as posing potential impacts to plants or soil invertebrates. For food chain receptors, toxicity reference values used in the SLERA were based on studies where both no observable adverse effects levels and lowest observable adverse effects levels were determined. The risk characterization was performed by calculating an HQ. The HQ is defined as the exposure (soil, surface water, or sediment concentration or dose) divided by the toxic endpoint concentration. If the HQ is greater than 1.0, a potential adverse impact may occur for particular receptors. Tables 7-86 through 7-92 of Chapter 7.0 of the RI report (Shaw, 2007a) present the results of the comparison to literature-based toxicity values for terrestrial and aquatic plants and invertebrates for each of the five surface soil areas (Northwest, North, East, and South Areas, and the floodplain soils in the Unnamed Creek) and for surface water and sediment. Tables 7-93 through 7-97 of Chapter 7.0 of the RI report (Shaw, 2007a) present the summary of HQs for food chain receptors for soil, and Table 7-98 presents the summary of HQs for food chain receptors in surface water and sediment. These results are summarized and presented in Table 8 of this ROD.

Based on the evaluation of potential adverse impacts to individuals of some community-based ecological receptors, the potential for adverse effects to ecological receptor species from exposure to arsenic and mercury concentrations found at some locations within RSA-122 cannot be discounted. However, impacts to populations of ecological receptors are not expected. In addition, PAHs in the Northwest Area may potentially pose unacceptable risks to a small number of individual receptors in this area. However, the limited habitat available in this highly developed area of the site and limited distribution of contamination would limit the number of individuals which could be impacted and should translate into a negligible impact to receptor populations.

Aquatic community-based ecological site-related COCs selected for surface water at RSA-122 include primarily copper. However, no site-related source for this metal has been identified. For sediments, community-based ecological site-related COCs include arsenic and mercury. The results of the food chain modeling demonstrate that the potential for adverse effects to ecological receptor species from exposure to arsenic and mercury concentrations in sediments found at some locations within the Unnamed Creek at RSA-122 exists.

RSA-056 and RSA-139 Human Health and Ecological Risk. The time-critical removal actions conducted at RSA-056 and RSA-139 included capping of the sites, resulting in the elimination of all human exposure pathways. Therefore, although arsenic was disposed of in the lagoons and pond and was found in surrounding site surface soils above acceptable levels, RSA-056 and RSA-139 no longer pose an unacceptable risk to human health because caps have been installed at the sites.

Similarly, no ecological exposure pathways exist because the RSA-056 and RSA-139 have been capped. No future ecological threat is expected provided the caps are properly maintained, mowed, and inspected for burrowing animals.

2.7.3 Sourcing to Groundwater Summary

The fate and transport evaluation in the RI assessed the potential for soil contaminants to leach to groundwater (Shaw, 2007a). Environmental sampling results have confirmed that materials used in SM, AT, and lewisite manufacturing (primarily arsenic, mercury, and chlorinated solvents) have been released to the environment from the RSA-122 site. In general, most metals detected in site soils at concentrations exceeding the dilution attenuation factor $(DAF)_4$ SSL values are not expected to migrate through the soil column as dissolved components of leachate and negatively impact the underlying groundwater. However, a review of the site history and the existing data for metals in soil suggests that arsenic and mercury have been released to the deep subsurface soils from leaks in the collecting pits (RSA-122S). These two metals are present in relatively high concentrations and have had a widespread impact to site soils and a smaller, more localized impact to the underlying groundwater.

Former surface structures (e.g. AT tanks, trenches) and subsurface structures (e.g. collection pits, blowcase pit, industrial sewer) are considered to be release points. Arsenic and mercury concentrations in site subsurface soils are highest in the area of these below-grade structures. The areas where the highest concentrations of arsenic are present (at approximately 13-14 feet below ground surface) will be addressed by the removal of the contaminated soils in these areas to prevent further sourcing to groundwater.

Prior to capping, arsenic present in wastes at RSA-056 and RSA-139 migrated to groundwater and formed plumes with concentrations in excess of the MCL. However, capping performed as part of the IRA TCRA appear to have achieved the objective of minimizing the migration of soil contaminants to other areas or other media (e.g., surface water or groundwater). As shown in Figure 5-23 of the final RI for RSA-122 (Shaw, 2007), groundwater monitoring data collected beyond the edge of the capped waste management area indicates that these caps are effective in preventing ongoing migration of arsenic and mercury from the former waste ponds to groundwater in the area of attainment, located outside of the capped wastes.

2.7.4 Risk Summary

Arsenic and mercury in surface media at RSA-122 have been identified as COCs or COPECs warranting action based on the results of the conservative exposure scenarios in the BHHRA and SLERA. Chemicals (primarily VOCs) in groundwater may pose a substantial human health threat if exposure should occur, an activity precluded by Redstone Arsenal's installation-wide groundwater IROD (Shaw, 2007b). Risks posed by chemicals present in groundwater will be addressed as part of the RI for the RSA-147 groundwater site. Contaminants in site soil posing an ongoing threat of sourcing to groundwater at RSA-122 include primarily arsenic and mercury. However, elevated concentrations of mercury commonly coexist with the elevated arsenic, forming a single target for remediation.

Results of the human health risk assessment indicate that arsenic in soil is associated with unacceptable cancer risk and noncancer risk to both industrial and residential receptors. Mercury in soil is associated with unacceptable noncancer risk to a residential receptor. Although the ecological risk assessment indicated potential adverse effects to individual ecological receptors from exposure to arsenic and mercury concentrations found at some locations within RSA-122, the limited habitat and limited distribution of the contamination at the site would limit the number of individuals potentially impacted resulting in negligible impacts to ecological populations. At RSA-056 and RSA-139, no unacceptable risks to industrial or ecological receptors are present because caps have been installed at the sites. No future threats to future industrial or ecological receptors are posed by these two sites provided the caps are properly maintained, mowed, and inspected.

Surface media at RSA-122 have been found to pose unacceptable risks to human health or the environment. Based on these results, it is the Army's current judgment that a remedial action is necessary at RSA-122 to ensure protection of public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

2.7.5 Basis for Action

The actual or threatened release of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, will present a current or potential threat to public health, welfare, or the environment.

2.8 Remedial Action Objectives

Remedial action objectives (RAO) are cleanup objectives that are developed during the FS and finalized in the ROD. They consist of medium-specific goals for protecting human health and the environment. RAOs provide the basis for the identification, detailed analysis, and selection of remedial alternatives.

The RAOs for RSA-122, RSA-056, and RSA-139 are as follows:

- Prevent future residential development at RSA-122, RSA-056, and RSA-139.
- Protect a current or future industrial receptor (groundskeeper, construction worker) from exposure to surface soil contaminated with arsenic and mercury.
- Protect a current or future construction worker from exposure to subsurface soil contaminated with arsenic and mercury.
- Protect a current or future construction worker from acute exposure to soil within the utility corridor (i.e., 5 feet on either side of the utility and 4 feet bgs) contaminated with arsenic and mercury.
- Prevent the construction of structures at RSA-056 and RSA-139 that would negatively impact the integrity of the caps.
- Reduce or eliminate the potential for contaminant sourcing to groundwater.
- Minimize the potential for adverse effects to populations of ecological receptors from arsenic and mercury in the surface soil and sediment (mercury contamination in surface soil is collocated with arsenic contamination).

In the human health risk assessment for RSA-122, remedial goal options (RGO) are presented for surface and subsurface soil. These RGOs are calculated using target cancer risk levels of 1E-6, 1E-5, and 1E-4 and target noncancer HIs of 0.1, 1, and 3 for residential and industrial exposure scenarios. In accordance the NCP, the 1×10^{-6} risk level is used as the point of departure for determining remediation goals for alternatives when ARARs are not available, or when ARARs are not sufficiently protective because of the presence of multiple contaminants or exposure pathways. RGOs are initially set at the more protective end of EPA's risk range, that is, at 10^{-6}. However, final RGs can later be changed upon consideration of site-specific or remedy-specific factors. These factors are generally exposure factors, uncertainty factors or technical factors. Although future use of the site as a residential setting is considered unlikely, RGs based on the residential exposure scenario provide the most conservative evaluation for this medium. Remediation of site soil to residential-based RGs would allow the site to be released for unrestricted use. Alternatively, RGs may be calculated for an industrial exposure scenario, because this is the current and expected future use of the site. RGs based on the industrial exposure scenario would be adequately protective of human health as long as the industrial exposure assumptions are not violated. Selection of the appropriate land use on which to base RGs is typically a risk management decision that is informed from a variety of sources, including the land use that is proposed by the federal agency based upon its own projections. For RSA-122, the reasonably anticipated land use is industrial, which is the land use proposed by the Army based upon its projected land use for this site.

Because of the generally conservative assumptions used in the RGO calculations, it is possible for a risk-based RGO to be less than what occurs naturally in unimpacted background soils. Generally, under CERCLA, cleanup levels are not set at concentrations below natural background levels. The reasons for this approach include cost-effectiveness, technical practicability, and the potential for recontamination of remediated areas by surrounding areas with elevated background concentrations (EPA, 2002). For example, some RGOs for residential receptors exposed to arsenic are less than the surface soil background value and would not be recommended. Therefore, the RG (15 mg/kg) is set essentially equivalent to the background value for surface soil (14.5 mg/kg), which essentially corresponds to the concentration protective for the target industrial RGO (15.6 mg/kg). No RGOs were developed for mercury because mercury and arsenic were released by the same process and thus soil contaminated with mercury is also contaminated with arsenic. The co-located nature of these two contaminants provides a single focus for remediation.

Specific arsenic RGs are selected for RSA-122, RSA-056, and RSA-139 as follows:

- An RG equal to 15 mg/kg was selected to protect a current or future industrial receptor (groundskeeper, construction worker) from exposure to surface soil contaminated with arsenic at a maximum risk level of 1E-5. To comply with this RG, the 95 percent upper confidence level of the mean (UCLM) for arsenic in surface soil after the remedial action must be equal to or less than 15 mg/kg.

- An RG equal to 200 mg/kg was selected to protect a current or future industrial receptor (groundskeeper, construction worker) from exposure to subsurface soil or total soil contaminated with arsenic at a maximum risk level of 1E-4. To comply with this RG, the 95 percent UCLM for arsenic in total or subsurface soil after the remedial action must be equal to or less than 200 mg/kg.

- An RG equal to 1,500 mg/kg was selected to protect a current or future utility worker from exposure to any soil within a utility corridor (i.e., 5 feet on either side of the utility and 4 feet bgs) contaminated with arsenic at a maximum HI for acute effects equal to 1. Therefore, this RG represents a not-to-exceed value. All soils with a concentration of arsenic greater than 1,500 mg/kg will be removed even if the UCLM of 200 mg/kg is achieved in total soil or subsurface soil.

The surface soil RG for arsenic of 15 mg/kg is consistent with both the industrial RGO (15.6 mg/kg) and the background concentration (14.5 mg/kg) for arsenic in surface soil. The RG selected for arsenic in surface soil is the BSV for arsenic and as such will ensure that threats to populations and communities of ecological receptors will be minimized to those that would occur from naturally occurring background. In addition, hot spots of mercury in surface soil are co-located with elevated arsenic and will be addressed by the actions planned for arsenic thus minimizing threats to ecological receptors from this COC.

The industrial RGO of 200 mg/kg is selected as the RG for arsenic in subsurface soil. A separate RG was developed to be protective of the future utility worker from acute risk associated with exposure to arsenic. The RG of 200 mg/kg selected for arsenic in subsurface soil will be protective for the soil–to-groundwater migration pathway. Currently, arsenic is not observed to migrate to groundwater except at the very high concentrations of arsenic found in the former lagoons, RSA-056 and RSA-139. Toxicity characteristic leaching procedure (TCLP) testing performed at the adjacent site RSA-057 provides further support that arsenic is only sparingly leachable in site soils. RSA-057 contains the sludge ponds for the former lewisite Plants 5 and 6 which are included in RSA-122. Arsenic concentrations at RSA-057 were found to be similar to those at RSA-122 (see Shaw, 2007c). Therefore, reducing arsenic concentrations to an upper bound average value of 200 mg/kg along with removing collocated mercury concentrations will be sufficient to achieve the RAO selected for the contaminant migration to groundwater pathway.

The RG of 1,500 mg/kg was calculated using the acute toxicity value for arsenic developed by the Agency for Toxic Substances and Disease Registry to be protective of a short-term utility worker working in one location for up to 10 days within a 14-day time period. This RG will be applied as a not-to-be exceeded threshold in conjunction with the industrial RG of 200 mg/kg for arsenic in subsurface soil. The establishment of the short-term exposure RG of 1,500 mg/kg will ensure that a worker is not exposed to arsenic-contaminated soil within the utility corridor.

2.9 Description of Alternatives

A technology screening was performed to evaluate a number of remedial technologies that are potentially applicable to the treatment of arsenic- and mercury-contaminated soil. The following technologies were screened against the criteria of effectiveness, implementability, and cost: institutional controls, capping, excavation, disposal, electrokinetics, chemical stabilization, soil washing, in situ flushing, vitrification, pyrometallurgical recovery, and phytoremediation. Three remedial alternatives were selected for detailed analysis. A summary of the alternatives is presented below.

2.9.1 Alternative 1 –No Action

Regulations under CERCLA require that the "no action" alternative be evaluated to establish a baseline for comparison. Under this alternative, the Army would take no action at the site to prevent exposure to soil contamination or leaching of contamination to groundwater.

2.9.1.1 Description of Remedy Components

Treatment Components. Alternative 1 does not include a treatment component.

Contaminant Components. Alternative 1 does not include additional engineering controls for the low-level source materials constituting an unacceptable risk to human health and the environment.

Land-Use Controls. Alternative 1 does not include LUCs.

Operation and Maintenance. Alternative 1, No Action, requires no O&M to maintain the integrity of the remedy.

Monitoring Requirements. Alternative 1 does not include groundwater monitoring requirements.

2.9.1.2 Common Elements and Distinguishing Features

Applicable or Relevant and Appropriate Requirements. There are no chemical- or location-specific ARARs for any contaminants in soil at RSA-122. Action-specific ARARs do not apply to Alternative 1, No Action, because no remedial measures would be taken.

Long-Term Reliability/Effectiveness. Alternative 1, No Action, does not protect human health and/or the environment at the site and it is not reliable.

Waste. Alternative 1, No Action, does not generate waste to be managed but it leaves approximately 1,775 cubic yards of untreated arsenic- and mercury-contaminated soil in place.

Cost, Construction Times, and Time to Achieve Remedial Action Objectives. Alternative 1, No Action, has the following costs and durations:

- Estimated Capital Cost: $0
- Estimated Annual O&M Cost: $0
- Estimated Present Worth Cost: $0
- Estimated Construction Time Frame: None.

2.9.1.3 Expected Outcomes

Land Use. Alternative 1 would not prohibit any land use at the site.

Other Impacts or Benefits. Alternative 1, No Action, would result in exposure to contaminants posing unacceptable health risks.

2.9.2 Alternative 2 – Soil Excavation, Treatment, Off-Site Disposal, Backfill, Short-Term Sediment and Groundwater Monitoring, and Institutional Controls

Alternative 2 is the Selected Remedy for RSA-122 and includes excavation of arsenic- and mercury-contaminated soil, treatment (if required), backfill with clean soil, off-site disposal, short-term sediment and groundwater monitoring, and institutional controls. Surface soil will be removed from contaminated areas to meet the RG for arsenic (equal to a post-action 95 percent UCLM of 15 mg/kg). Subsurface soil will be removed to meet the RG for arsenic (equal to a post-action 95 percent UCLM of 200 mg/kg). In addition, any soil sample location greater than 1,500 mg/kg will also be removed regardless if the UCLM is met for the surface soil RG of 15 mg/kg and the total soil RG of 200 mg/kg.

2.9.2.1 Description of Remedy Components

Treatment Components. Following characterization of the excavated soil, the soil may require chemical stabilization to treat elevated concentrations of arsenic and mercury. If soil is considered hazardous, soil will be treated with calcium polysulfide and Portland cement.

Containment Components. Under Alternative 2, soil contaminated with arsenic and mercury would be excavated, treated as necessary, and disposed in an off-post disposal facility. The contaminated soil would be excavated to a depth of 20 feet where required. The excavated areas will be backfilled with native soil from an on-post borrow area. The soil will be compacted, regraded, and vegetated.

Land-Use Controls. Alternative 2, will require permanent LUCs to prohibit future residential land use of the site. The performance objectives of the LUCs at RSA-122, RSA-056, and RSA-139 are to ensure no residential use or residential development of the property and to ensure that special handling procedures are in place for future excavation of soils for industrial development at the site. No intrusive activities will be allowed at RSA-056 and RSA-139 that would compromise the effectiveness of the caps unless prior approval is obtained from EPA and ADEM. The entire area within the RSA-122 site boundary (Figures 2 and 3) is included in the LUC.

O&M. O&M will include inspections and reporting to enforce the LUCs as detailed in the LUC RD document. Five-year reviews will be conducted because waste remains in place at the site, preventing unrestricted future use.

Monitoring Requirements. A short-term groundwater and sediment monitoring program will be performed to determine if preferential mobilization of residual arsenic and mercury in soil occurred during the excavation activities. Biennial groundwater and sediment monitoring will be conducted for four years at RSA-122, RSA-056 and RSA-139 following remedial activities at RSA-122.

2.9.2.2 Common Elements and Distinguishing Features

ARARs. There are no chemical- or location-specific ARARs for RSA-122, RSA-056, or RSA-139. Alternative 2 would comply with action-specific ARARs, five-year reviews under CERCLA, and EPA requirements for groundwater monitoring. Table 9 presents the action-specific ARARs. Although no chemical-specific ARARs are identified for RSA-122, RSA-056 or RSA-139, MCLs may be potential chemical-specific ARARs for the groundwater underlying the site. ARARs would be developed specifically for the groundwater with the RSA-147 groundwater site.

Long-Term Reliability/Effectiveness. Alternative 2 is protective of human health and the environment because it prevents exposure to concentrations of arsenic and mercury in soil that pose an unacceptable risk. Alternative 2 will also eliminate or greatly reduce the threat to groundwater from the soil-to-groundwater migration pathway.

Waste. Alternative 2 will excavate approximately 1,775 cubic yards of soil contaminated with arsenic and mercury, treat any soil classified as hazardous, and dispose of it in an off-site treatment, storage, and disposal facility.

Cost, Construction Times, and Time to Achieve Remedial Action Objectives. Alternative 2 has the following costs and durations:

- Estimated Capital Cost: $893,000.00
- Estimated Annual O&M Cost: $50,270.00
- Estimated Present Worth Cost: $1,716,000.00
- Estimated Construction Time Frame: 1 month
- Estimated Time to Achieve RAOs: 11-15 months.

2.9.2.3 Expected Outcomes

Land Use. Alternative 2 would ensure that the Army and any subsequent land owner would not perform intrusive activities or building construction that could disturb the existing caps at RSA-056 and RSA-139 and expose underlying wastes and contaminated soils. Development and use of the property for residential housing, elementary and secondary schools, child care facilities, and playgrounds would not be permitted at RSA-122, RSA-056, or RSA-139. Use restrictions would be further specified in the LUC RD document.

Other Impacts and Benefits. Alternative 2 achieves the RGs for arsenic in a short period of time. It also minimizes the amount of contamination left at the site, reducing the future routes for exposure and the unacceptable risks at the site. However, LUCs will be required at the site to ensure the remedy is protective under current and reasonably anticipated land use. Any changes to the LUCs required for RSA-122, RSA-056 and RSA-139 would be evaluated during the five-year reviews with EPA and ADEM.

2.9.3 Alternative 3 – Hot Spot Excavation, Treatment, On-Site Disposal, Backfill, Capping, Short-Term Sediment and Groundwater Monitoring, and Institutional Controls

Alternative 3 includes hot spot excavation of arsenic- and mercury-contaminated soil, treatment (if required), backfill with clean soil, on-site disposal, short-term sediment and groundwater monitoring, and institutional controls. Surface and subsurface soil with arsenic concentrations exceeding 1,000 mg/kg will be removed from contaminated areas.

2.9.3.1 Description of Remedy Components

Treatment Components. Following characterization of the excavated soil, the soil may require chemical stabilization to treat elevated concentrations of arsenic and mercury. If soil is considered hazardous, soil will be treated with calcium polysulfide and Portland cement.

Containment Components. Under Alternative 3, soil contaminated with arsenic would be excavated, and treated as necessary. Nonhazardous excavated soil will be used as subsurface backfill in the excavated hot spot areas. Hazardous excavated soil will be treated on site with calcium polysulfide and portland cement to meet the Universal Treatment Standard prior to reuse as backfill in the excavated hot spots. The soil will be compacted, regraded, and vegetated.

Land-Use Controls. Alternative 3 will require permanent LUCs to prohibit future residential land use of the site. The performance objectives of the LUCs at RSA-122, RSA-056, and RSA-139 are to ensure no residential use or residential development of the property and to ensure that special handling procedures are in place for future excavation of soils for industrial development at the site. No intrusive activities will be allowed at RSA-056 and RSA-139 that would compromise the effectiveness of the caps unless prior approval is obtained from EPA and ADEM. The entire area within the RSA-122 site boundary (Figures 2 and 3) is included in the LUC.

O&M. O&M will include inspections and reporting to enforce the LUCs as detailed in the LUC RD document. Five-year reviews will be conducted because waste remains in place at the site, preventing unrestricted future use.

Monitoring Requirements. A short-term groundwater and sediment monitoring program will be performed to determine if preferential mobilization of residual arsenic and mercury in soil occurred during the excavation activities. Biennial groundwater and sediment monitoring will be conducted for four years at RSA-122, RSA-056 and RSA-139 following remedial activities at RSA-122.

2.9.3.2 Common Elements and Distinguishing Features

ARARs. There are no chemical- or location-specific ARARs for RSA-122, RSA-056, and RSA-139. Alternative 3 would comply with action-specific ARARs, five-year reviews under CERCLA, and EPA requirements for groundwater monitoring. Table 9 presents the action-specific ARARs. Although no chemical-specific ARARs are identified for RSA-122, RSA-056 or RSA-139, MCLs may be potential chemical-specific ARARs for the groundwater underlying the site. ARARs would be developed specifically for the groundwater with the RSA-147 groundwater site.

Long-Term Reliability/Effectiveness. Alternative 3 is protective of human health and the environment because it prevents exposure to concentrations of arsenic and mercury in soil that pose an unacceptable risk.

Waste. Alternative 3 will excavate approximately 2,105 cubic yards of soil contaminated with arsenic and mercury, treat any soil classified as hazardous, and dispose of it in an off-site treatment, storage, and disposal facility.

Cost, Construction Times, and Time to Achieve Remedial Action Objectives.
Alternative 2 has the following costs and durations:

- Estimated Capital Cost: $1,262,000.00
- Estimated Annual O&M Cost: $60,270.00
- Estimated Present Worth Cost: $2,287,000.00
- Estimated Construction Time Frame: 2 months
- Estimated Time to Achieve RAOs: 11-15 months.

2.9.3.3 Expected Outcomes

Land Use. Alternative 3 would ensure that the Army and any subsequent land owner would not perform intrusive activities or building construction that could disturb the existing caps at RSA-056 and RSA-139 and expose underlying wastes and contaminated soils. Development and use of the property for residential housing, elementary and secondary schools, child care facilities, and playgrounds would not be permitted at RSA-122, RSA-056, and RSA-139. Use restrictions would be further specified in the LUC RD document.

Other Impacts and Benefits. Alternative 3 achieves the RGs for arsenic in a short period of time. It also minimizes the amount of contamination left at the site, reducing the future routes for exposure and the unacceptable risks at the site. However, LUCs will be required at the site to ensure the remedy is protective under current and reasonably anticipated land use. Any changes to the LUCs required for RSA-122, RSA-056 and RSA-139 would be evaluated during the five-year reviews with EPA and ADEM.

2.10 Comparative Analysis of Alternatives

The three alternatives have been evaluated against the nine CERCLA criteria which provide the basis for evaluating the alternatives and selecting a remedy. The nine criteria are categorized into three groups: threshold criteria, primary balancing criteria, and modifying criteria, which are discussed in Table 10. An evaluation of each remedial alternative is documented in the FS (Shaw, 2009c). A brief discussion summarizing the overall conclusions resulting from the detailed CERCLA nine-criteria evaluation is provided below and summarized in Table 11.

1. ***Overall Protection of Human Health and the Environment.*** Alternative 2 (excavation, treatment, off-site disposal, backfill, short-term sediment and groundwater monitoring, and institutional controls) provides adequate protection of human health and ecological receptors under an industrial scenario by the excavation and off-facility disposal of arsenic- and mercury-contaminated soil (based on the interactive and truncation method using the 95 percent UCLM arsenic concentration). Further, Alternative 2 would be protective of the future utility worker because the COC concentrations in the utility corridors do not exceed the acute risk RG. The existing caps at RSA-056 and RSA-139 would protect human health and the environment by creating a physical barrier to contact with contaminated soil. Similarly, Alternative 3 (hot spot excavation, treatment, on-site disposal, backfill, capping, short-term sediment and groundwater monitoring, and institutional controls) protects human health and the environment by creating a physical barrier to contact with the contaminated soil at RSA-122 and maintaining the existing caps at RSA-056 and RSA-139. Alternative 3 also protects human health and the environment by excavation of hot spots (soil with arsenic concentrations exceeding 1,000 mg/kg). Both alternatives are protective as long as the caps exist, the institutional controls remain in force, and periodic groundwater monitoring is conducted. Alternative 1 (No Action) is not protective under any exposure scenario.

2. ***Compliance with ARARs.*** There are no chemical- or location-specific ARARs for soil. Both Alternative 2 and Alternative 3 would comply with all the action-specific ARARs.

3. ***Long-Term Effectiveness and Permanence.*** Alternative 2 provides the highest degree of long-term effectiveness by removing arsenic- and mercury-

contaminated soil at RSA-122 such that the 95 percent UCLM average arsenic concentration in the surface and subsurface soil at the site is below the RGs, thus protecting all potential future industrial receptors by reducing the residual risk to acceptable levels. Although soil with arsenic concentrations exceeding 1,000 mg/kg at RSA-122 would be removed under Alternative 3, it does not present the same degree of long-term effectiveness as Alternative 2 because the 95 percent UCLM arsenic concentration would likely exceed the surface and subsurface soil RGs. For RSA-122, Alternative 3 primarily relies on a barrier technology, groundwater monitoring, and institutional controls to manage the residual risk. Therefore, it is only effective as long as these components of the alternative are operative. Alternative 1 (No Action) does not reduce the residual risk to potential future residential receptors or implement any controls to manage this risk. As a result, it is ineffective.

4. ***Reduction of Toxicity, Mobility, or Volume through Treatment.*** Alternatives 2 and 3 would include on-site treatment of excavated soil classified as hazardous waste to comply with the land disposal restrictions, if required. This treatment would reduce the mobility of the arsenic and mercury in the excavated soil prior to off-site disposal and the threat of soil contamination migrating to groundwater. Alternative 1 provides no reduction in toxicity, mobility, or volume of the arsenic and mercury in soil.

5. ***Short-Term Effectiveness.*** There are no adverse short-term impacts to the community, site workers, or the environment from Alternative 1 (No Action), because no active remedial measures would be taken at the site. Implementation of Alternative 2 or Alternative 3 presents no particularly significant short-term threats that cannot be mitigated through routine health and safety practices normally observed on a remediation project, such as dust suppression, appropriate use of personal protective equipment, storm water controls, and decontamination procedures for equipment and personnel. Alternative 2 and 3 should take approximately 11 to 15 months.

6. ***Implementability.*** There are no technical or administrative difficulties associated with the implementation of Alternative 1 (No Action), because no action would be taken. Alternative 2 consists of well established and uncomplicated technology options and, therefore, does not present any problems in terms of the availability of personnel or equipment. ADEM and EPA Region 4 must approve the disposal facility for waste materials managed off site, but adequate disposal capacity exists within the state. ADEM and EPA Region 4 must also approve the details of the post-remedial monitoring required. The technology requirements of Alternative 3 are also relatively uncomplicated, and the availability of personnel and equipment should not be a concern. ADEM and EPA Region 4 must approve the design of the permeable cover, the long-term monitoring plan, and the implementation plan for institutional controls. None of the alternatives would preclude additional action at the site, although the caps included in Alternative 3 may need to be removed in part or in whole if additional remedial action should be required for either soil or groundwater.

7. ***Cost.*** There are no costs associated with Alternative 1 (No Action). The total capital cost of Alternative 2 is $893,000 and the present value O&M cost is $823,000, corresponding to a total present value cost of $1,716,000. Alternative 3 is the highest-cost alternative, with a total capital cost of $1,262,000, a present value O&M cost of $1,025,000, and a total present value cost of $2,287,000.

8. ***State Support/Agency Acceptance.*** EPA and ADEM are in agreement with Alternative 2, the Preferred Alternative.

9. ***Community Acceptance.*** Community acceptance of the Preferred Alternative will be evaluated after the public comment period ends and will be addressed in the Responsiveness Summary prepared for the ROD for RSA-122.

2.11 Selected Remedy

This section describes the Selected Remedy for RSA-122, RSA-056, and RSA-139.

2.11.1 Detailed Description of the Selected Remedy

Based upon the characterization data and risk assessments in the RSA-122 documents, the RAOs, and the detailed evaluation of alternatives, the Preferred Alternative for RSA-122 soil is excavation of arsenic- and mercury-contaminated soil constituting a low-level threat waste, treatment (if required), backfill with clean soil, off-site disposal, short-term sediment and groundwater monitoring, and institutional controls (Alternative 2). Surface soil will be removed from contaminated areas to meet the RG for arsenic (equal to a post-action 95 percent UCLM of 15 mg/kg). Subsurface soil will be removed to meet the RG for arsenic (equal to a post-action 95 percent UCLM of 200 mg/kg) (Figure 5). In addition, any soil sample location greater than 1,500 mg/kg will also be removed regardless if the UCLM is met for the surface soil RG of 15 mg/kg and the total soil RG of 200 mg/kg.

The RG selected for arsenic in surface soil is the BSV for arsenic and as such will ensure that threats to populations and communities of ecological receptors will be minimized to those that would occur from naturally occurring background. In addition, hot spots of mercury in surface soil are co-located with elevated arsenic and will be addressed by the actions planned for arsenic thus minimizing threats to ecological receptors from this COC. RGs for arsenic are more stringent such that the areas to be excavated to address arsenic contamination will also address the elevated levels of mercury in site soils. This remedy addresses both direct contact risk and threats from soil contamination migrating to groundwater.

As necessary, the removed soil will be treated on site with calcium polysulfide and Portland cement to render the soil nonhazardous for waste disposal purposes, and then shipped to an appropriate off-site disposal facility. Biennial post-action monitoring of sediments and groundwater will be conducted at RSA-122, RSA-056 and RSA-139 for four years to confirm the effectiveness of this remedy for potential migration pathways. This information will be included in the first five-year review.

This Selected Remedy was selected over the other alternatives because it provides permanent removal of contaminants in soil and is expected to allow the land to be reused for future Army redevelopment plans. This alternative will provide adequate protection of human health and the environment for all receptors under a continued industrial scenario. The groundwater beneath RSA-122 is contaminated, and there is unacceptable noncancer hazard and cancer risk if the groundwater should be used for drinking or bathing. Because the groundwater contamination under RSA-122 is not believed to be from former site activities and it is part of a bigger solvent plume in this area of Redstone Arsenal, the groundwater will be addressed as part of the RSA-147 groundwater site for further investigation and remediation. Any public concerns about the Preferred Alternative that are received during the public comment period could result in the selection of a final remedy that differs from the alternative currently recommended.

Based on information currently available, the Selected Remedy provides the best balance of trade-offs among the other alternatives with respect to the evaluation criteria. The Army, EPA, and ADEM expect the Preferred Alternative to satisfy the statutory requirements in CERCLA Section 121(b) to (1) provide adequate protection of human health and the environment, (2) comply with federal and state ARARs, (3) be a cost-effective use of public funds for the site, (4) utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent possible, and (5) satisfy the preference for treatment as a principal element.

LUC Performance Objectives

The LUC performance objectives for RSA-122, RSA-056 and RSA-139 include:

- Prohibit residential use of the site, including use for residential housing, elementary and secondary schools, child care facilities and playgrounds;
- Prevent intrusive activities or excavation that may compromise the remedial caps unless prior approval is obtained from EPA and ADEM; and
- Maintain the integrity of any current or future remedial or monitoring system.

A LUC RD will be prepared as the land use component of the Remedial Design. Within 90 days of ROD signature, the Army shall prepare and submit to EPA for review and approval a LUC

RD that shall contain implementation and maintenance actions, including periodic inspections. The document will also specify the LUC duration, requirements for changes, and maintenance and reporting responsibilities as follows:

- LUC Duration – The LUCs will be maintained until the concentrations of hazardous substances in the soil are at such levels to allow for unrestricted use and exposure.
- LUC Maintenance and Reporting – The Army is responsible for implementing, maintaining, reporting on, and enforcing the LUCs described in this ROD.

As specified in the Alabama Uniform Environmental Covenant Act, Code of Alabama §§ 35-19-1 to 35-19-14 and in the ADEM Uniform Environmental Covenant Program regulations, AAC 335-5, ADEM may require a person conducting an environmental response project to enter into an environmental covenant with ADEM as specified in 335-5-1.07(2) after the remediation plan is accepted. The Army will coordinate with GSA and ADEM during the development of the LUC RD implementation document, which will describe short and long-term implementation actions for the site LUCs (U.S. Department of Defense, 2003). Actions to implement the requirements of ADEM's Uniform Environmental Covenant program will be specified in the LUC RD.

The Army will be responsible for implementing the LUCs through the use of tools such as the site access control program (Army, 2008) to perform ongoing tracking and review of site use and specific limitations.

The SAC program provides a procedure to control and manage the Redstone Arsenal IRP sites in order to prevent any activities that might cause a worker or visitor to be exposed to site contamination or other hazardous conditions. The program is administered accordance with Redstone Arsenal Regulation 200-7 which clearly defines responsibilities. Physical site control is provided through the use of signage at all sites and fencing where appropriate. Administrative controls include worker training and a work request process which is reviewed by the Environmental Office. All requests for new construction and building projects, repairs and maintenance of existing facilities, landscaping, and land use changes are submitted to the Directorate of Public Works for review and approval. A work plan evaluation checklist is also completed so that the IRP staff in the Environmental Office can review the proposed activities, evaluate worker safety, determine potential impact on the investigation and cleanup plans for the site, evaluate potential waste that will be generated, and determine what site controls will be required. As part of the review process, coordination is conducted with the Base Master Planning Office. Specifically, the Redstone Arsenal Base Master Plan controls current land use and future development installation-wide. Any restrictions on land use such as LUCs (e.g., fencing, no dig) are designated in the base master plan so that future land use will be consistent/in compliance with any property restrictions.

These LUCs will be legally enforceable by EPA under CERCLA and by ADEM in accordance with the facility's RCRA Part B permit. Details regarding LUC implementation will be presented in the LUC RD document. To the extent required by law, RSA-122, RSA-056, and RSA-139 will be reviewed at least once every five years after the initiation of remedial action since contaminants would remain at these sites above levels that permit unrestricted use. The reviews will assure that the remedial action continued to protect human health and the environment.

Any changes to the remedy described in this ROD will be documented in a technical memorandum in the Administrative Record for the site, an explanation of significant difference, or a ROD amendment, as appropriate.

The Army and EPA have selected Alternative 2 as the Selected Remedy, and ADEM concurs.

2.11.2 Cost Estimate for the Selected Remedy

The costs associated with the Selected Remedy are detailed in Table 12. The information in this cost estimate summary is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the Administrative Record file, an explanation of significant difference, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

2.11.3 Expected Outcomes of the Selected Remedy

The results of the BHHRA summarized in the final RI report (Shaw, 2007a) indicate that the existing conditions at RSA-122 present an unacceptable cancer risk and noncancer hazard from exposure to arsenic in surface and subsurface soils. It is anticipated that RGs selected on the basis of human health protection will minimize potential impacts to the populations and communities of ecological receptors.

When implemented, the Selected Remedy will result in the following major outcomes:

- The Selected Remedy will reduce soil concentrations to levels acceptable for current and future land use.
- The Selected Remedy will minimize the risks to ecological receptors.
- The excavation of contaminated surface and subsurface soil will minimize the leaching of soil contamination to groundwater.
- The site will be available for industrial land use following completion of the remedial action. Future construction at RSA-122 is expected to include two industrial buildings and a parking lot.
- The groundwater, other than perched groundwater, under RSA-122 is not part of the surface media at RSA-122 and will be further investigated and remediated as necessary under the RSA-147 groundwater site effort.
- The Selected Remedy will prevent future residential development.

Soil cleanup levels for COCs in soil exhibiting an unacceptable cancer risk or HI have been established such that they are protective of human health and the environment.

Arsenic in Surface Soils. The surface soil cleanup level for arsenic has been selected to equal an RG of 15 mg/kg, which is based on the installation-wide background screening concentration for arsenic at Redstone Arsenal. The background screening concentration for arsenic was established based on the 95 percent upper tolerance limit for this metal in the background data set. This RG represents a value equal to a 1 x 10^{-5} risk threshold concentration for a groundskeeper receptor. Although this value exceeds the residential-based RGO at 1 x 10^{-5}, it would still allow for an unrestricted closure for surface soils because CERCLA does not support the use of cleanup goals less than background. Thus, the life cycle costs associated with the maintenance of LUCs at this site should be reduced. In addition, establishment of this goal ensures that any potential for risk to ecological receptors has been addressed.

For arsenic in surface soil, an RG equal to 15 mg/kg was selected to protect a current or future industrial receptor (groundskeeper, construction worker) from exposure to surface soil contaminated with arsenic at a maximum risk level of 1 x 10^{-5}. This value was used in the iterative truncation evaluation to delineate the extent of contamination to be removed in surface soils. Because this value represents a 95 percent upper tolerance limit based on the background data set, it is likely that 5 percent of the confirmatory samples may have concentrations greater than 15 mg/kg. Therefore, the performance standard for the surface soil removal includes the provision that up to 5 percent of the confirmatory samples for the surface soil action may exceed 15 mg/kg RG. No further excavation will be required if the confirmatory soil samples meet this performance standard. For further details regarding how this RG was selected please refer to Appendix A of the FS (Shaw, 2009c).

Arsenic in Subsurface Soils. The subsurface soil cleanup level for arsenic has been selected to equal a RG of 200 mg/kg, which is based on a risk of 1 x 10^{-4} for the groundskeeper. A separate RG was developed to be protective of the future utility worker from acute risk associated with exposure to arsenic. The RG of 200 mg/kg selected for arsenic in subsurface soil will be protective for the soil–to-groundwater migration pathway. This value was used in the iterative truncation evaluation to delineate the extent of subsurface soil contamination location within the RSA-122 site boundary. The provisions for meeting the confirmatory sampling requirements for subsurface soil will be presented in detail in the RD for this action.

The RG of 1,500 mg/kg is a pick up value that was calculated using the acute toxicity value for arsenic developed by the Agency for Toxic Substances and Disease Registry to be protective of a short-term utility worker working in one location for up to 10 days within a 14-day time period. This RG will be applied as a not-to-be exceeded threshold in conjunction with the industrial RG of 200 mg/kg for arsenic in subsurface soil. The establishment of the short-term exposure RG of 1,500 mg/kg will ensure that a worker is not exposed to arsenic-contaminated soil within the utility corridor.

For further details regarding how these RGs were selected please refer to Appendix A of the FS (Shaw, 2009c).

Mercury in Soil. Elevated mercury and arsenic concentrations were released by the same process and thus soil contaminated with mercury is also contaminated with arsenic. The collocated nature of these two contaminants provides a single focus for remediation. This action will further reduce the potential for mercury in surface soil to pose an adverse impact to populations of ecological receptors which may use this site. Mercury currently does not pose unacceptable risks to industrial receptors at RSA-122. Residential use of this site will be precluded by LUCs to be implemented as part of this remedy.

2.12 Statutory Determination

Under CERCLA Section 121, the Army and EPA must select a remedy for RSA-122 that is protective of human health and the environment, complies with ARARs (unless a statutory waiver is justified), is cost effective, and utilizes permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable. Under RCRA, ADEM requires that similar criteria bet such as ensuring the protectiveness of human health. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces volume, toxicity, or mobility of hazardous waste as their principal element. The following sections describe how the Selected Remedy for RSA-122 meets the statutory requirements.

2.12.1 Protection of Human Health and the Environment

The remedy would adequately protect human health by controlling exposure to all potential site receptors through LUCs at RSA-122, RSA-056, and RSA-139. A short-term sediment and groundwater monitoring program would ensure prevention of additional leaching of contaminants to groundwater. The Selected Remedy includes excavation and treatment of contaminated soil, short-term groundwater monitoring (four years), and five-year reviews.

2.12.2 Compliance with ARARs

The Selected Remedy would comply with all federal and state ARARs, as summarized in Table 9. These ARARs include RCRA corrective actions and CERCLA requirements.

2.12.3 Cost Effectiveness

In the lead agency's judgment, the Selected Remedy is cost effective because the remedy's costs are proportional to its overall effectiveness (see 40 Code of Federal Regulations 300.430[f][1][ii][D]). This determination was made by evaluating the overall effectiveness of those alternatives that satisfied the threshold criteria. Overall effectiveness was evaluated by assessing three of the five balancing criteria (long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness) in combination. The overall effectiveness was then compared to the alternative's costs to determine cost effectiveness. The relationship of the overall effectiveness of this remedial alternative was determined to be proportional to its costs and, hence, represents a reasonable value for the money to be spent.

2.12.4 Utilization of Permanent Solutions and Alternative Treatment Technologies (or Resource Recovery Technologies) to the Maximum Extent Practicable

Based on information currently available, the Selected Remedy provides the best balance of trade-offs among the other alternatives with respect to the evaluation criteria. The Selected Remedy provides the highest degree of long-term effectiveness by removing arsenic- and mercury-contaminated soil at RSA-122, thus permanently protecting current and future industrial receptors, ecological receptors and groundwater through reducing residual risks and threats to acceptable levels. The remedy provides for cap inspection and maintenance at RSA-056 and RSA-139 to ensure the long term integrity of this component of the remedy.

2.12.5 Preference for Treatment as a Principal Element

The principal elements of the selected remedy include the removal of soils which contain elevated concentrations of arsenic and mercury, the implementation of LUCs, and short-term monitoring to ensure remedy effectiveness. These elements address the primary threat at RSA-122/056/139. The Selected Remedy does not meet the statutory preference for treatment as a principal element of the remedy since no cost-effective or technically viable commercial treatment technologies are available for the site conditions and contaminants at the site. However, no principal threat source material is present at RSA-122 or outside of caps at RSA-056 and RSA-139.

2.12.6 Need for Five-year Reviews

Because the remedy will result in contaminants remaining onsite in subsurface soil above levels that allow for unlimited use and unrestricted exposure, as required by the NCP Section 300.430(f)(4)(ii), a review will be conducted within five years after initiation of the remedial action to ensure that the remedy continues to provide adequate protection of human health and the environment.

2.13 Documentation of Significant Change

No significant change has been made to the preferred alternative presented in the SB/PP for RSA-122, RSA-056, and RSA-139.

3.0 Responsiveness Summary

The Responsiveness Summary serves three primary purposes. First, it provides the Army, EPA Region 4, and ADEM with information about community concerns with the site and preferences about the Preferred Alternative presented in the SB/PP (Shaw, 2009a). Second, it shows how the public's comments were factored into the decision-making process for selection of the final remedy. Third, it provides a formal mechanism for the Army to respond to public comments.

This Responsiveness Summary documents the formal public comments received on the RSA-122, RSA-056, and RSA-139 SB/PP and the Army's responses to the comments. However, no comments were received during the 30-day public comment period that began on August 1, 2009 and ended on August 30, 2009.

Alternative 2 (Excavation of arsenic- and mercury-contaminated soil, treatment (if required), backfill with clean soil, off-site disposal, short-term sediment and groundwater monitoring, and institutional controls), which was presented as the Preferred Alternative in the SB/PP (Shaw, 2009b), is the Selected Remedy for RSA-122, RSA-056, and RSA-139 surface media. This decision is based on the Administrative Record file for all three sites, including the site characterization documents, risk assessments, FS, and other related documents contained in the file for this site, as well as on the fact that no public comments were received on the Preferred Alternative during the public comment period. The Army and EPA have selected Alternative 2 as the Selected Remedy and ADEM concurs.

4.0 References

Alabama Department of Environmental Management (ADEM), 2008, ***Alabama Risk-Based Corrective Action Guidance Manual***, April.

Agency for Toxic Substances and Disease Registry, 2005, ***Update Toxicological Profile for Arsenic***, Draft for Public Comment, U.S. Department of Health and Human Services, Atlanta, Georgia, September, on line.

California Environmental Protection Agency, 2002, ***Air Toxics Hot Spot Program Risk Assessment Guidelines, Part II, Technical Support for Describing Available Cancer Potency Factors***, December.

Department of Defense, 2003, ***Principles and Procedures for Specifying, Monitoring and Enforcement of Land Use Controls and Other Post-ROD Actions [Navy Principles]***, Letter from Daymond F. DuBois, Deputy Under Secretary of Defense to Honorable Marianne Lamont Horinko, Action Administrator, EPA, October.

Environmental Science and Engineering (ESE), 1996, ***Final Site Characterization Report for Solid Waste Management Units RSA-46, RSA-47, RSA-51, RSA-56, RSA-122, and RSA-139 at Redstone Arsenal, Alabama***, prepared for U.S. Army Corps of Engineers, Huntsville Division, January.

Geraghty & Miller, Inc., 1991, ***Final Identification and Evaluation of Potential Solid Waste Management Units and Areas of Concern***, prepared for the U.S. Army Corps of Engineers, February.
-

IT Corporation (IT), 2002, ***Internal Draft Closure Report, Time Critical Removal Action, Cap Installation Over the Closed Arsenic Waste Ponds at RSA-56 and the Former Arsenic Trichloride Manufacturing and Disposal Area, RSA-139, Operable Unit 6b, Redstone Arsenal, Madison County, Alabama***, prepared for U.S. Army Corps of Engineers, Savannah District, February.

IT Corporation (IT), 2001, ***Internal-Draft Time Critical Removal Action Construction Report, RSA-56, Closed Arsenic Waste Ponds, and RSA-139, Former Arsenic Trichloride Manufacturing and Disposal Area, Operable Unit 6b, Redstone Arsenal, Madison County, Alabama***, prepared for the U.S. Army Corps of Engineers, Savannah District, June.

IT Corporation (IT), 2000, ***Draft-Final Action Memorandum and Work Plan, Time Critical Removal for RSA-56, Closed Arsenic Waste Ponds, and RSA-139, Former Arsenic Trichloride Manufacturing Area, Operable Unit 6b, Redstone Arsenal, Madison County, Alabama***, prepared for the U.S. Army Corps of Engineers, Savannah District, December.

IT Corporation (IT), 1998, ***Baseline Human Health Risk Assessment, RSA-56, RSA-122, and RSA-139, Redstone Arsenal, Madison County, Alabama,*** prepared for U.S. Army Corps of Engineers, Savannah District, February.

IT Corporation (IT), 1997, ***Internal Draft Supplemental Investigation Report for RSA-56, -122, - and 139, Redstone Arsenal, Madison County, Alabama***, prepared for U.S. Army Corps of Engineers, Savannah District, August.

Johnson, P.C. and R. A. Ettinger, 1991, ***Heuristic model for predicting the intrusion rate of contaminant vapors in buildings***, Environ. Sci. Technol. 25: 1445-1452.

Shaw Environmental, Inc. (Shaw), 2009a, ***Draft Statement of Basis/Proposed Plan RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6, Redstone Arsenal, Madison County, Alabama***, April.

Shaw Environmental, Inc. (Shaw), 2009b, ***Draft-Final Installation-Wide Groundwater Land-Use Control Remedial Design, Redstone Arsenal, Madison County, Alabama,*** prepared for the U.S. Army Corps of Engineers, Savannah District, February.

Shaw Environmental, Inc. (Shaw), 2009c, ***Final Feasibility Study, RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6***, prepared for U.S. Army Corps of Engineers, Savannah District, in preparation.

Shaw Environmental, Inc. (Shaw), 2007a, ***Final Phase II Remedial Investigation Report, Baseline Human Health Risk Assessment and Screening-Level Ecological Risk Assessment for RSA-122, Dismantled Lewisite Manufacturing Plan, Operable Unit 6***, prepared for U.S. Army Corps of Engineers, Savannah District, August.

Shaw Environmental, Inc. (Shaw), 2007b, ***Final Record of Decision, Interim Remedial Action for Installation-Wide Groundwater, Redstone Arsenal, Madison County, Alabama, Revision 0,*** prepared for U.S. Army Corps of Engineers, Savannah District, September.

Shaw Environmental, Inc. (Shaw), 2007c, ***Final Record of Decision for Surface Media at RSA-057, Inactive Arsenic Waste Lagoons- East, Operable Unit 6, , Redstone Arsenal, Madison County, Alabama,*** prepared for U.S. Army Corps of Engineers, Savannah District, August.

Shaw Environmental, Inc. (Shaw), 2006, ***Community Relations Plan, Redstone Arsenal, Madison County, Alabama***, prepared for the U.S. Army Corps of Engineers, Savannah District, March.

Shaw Environmental, Inc. (Shaw) 2003, ***Time-Critical Removal Action Close Out Report, Fencing and Trench Marker Installation, Select Sites in Operable Units 4 through 8, 12, 15, and 17***, prepared for U.S. Army Corps of Engineers, Savannah District.

U.S. Army Garrison – Redstone (Army), 2006, ***Real Property Master Plan Digest.***

U.S. Army Garrison-Redstone (Army), 2008, ***Redstone Arsenal Environmental Site Access Control Program,*** Redstone Arsenal Regulation 200-7, February.

U.S. Army Missile Command Environmental Office, 1996, ***Installation Action Plan for Redstone Arsenal, Alabama***, May.

U.S. Army Missile Command, 1983, ***Groundwater and Surface Water Monitoring Program***, March.

U.S. Environmental Protection Agency (EPA), 2008, ***Integrated Risk Information System (IRIS), IRIS Glossary***, on line, http://www.epa.gov/ncea/iris/help_gloss.htm .

U.S. Environmental Protection Agency (EPA), 2004, ***Region 9 Preliminary Remediation Goals***, Annual Update, San Francisco, California, November.

U.S. Environmental Protection Agency (EPA), 2002, ***OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)***, EPA 530-D-02-004, November.

U.S. Environmental Protection Agency (EPA), 2002, ***Role of Background in the CERCLA Cleanup Program***, OSWER 9285.6-07P, Office of Solid Waste and Emergency Response, April.

U.S. Environmental Protection Agency (EPA), 2001, ***Trichloroethylene Health Risk Assessment: Synthesis and Characterization,*** External Review Draft, Office of Research and Development, Washington, DC, EPA/600/P-01/002A, August.

U.S. Environmental Protection Agency (EPA), 1995, ***Improving RCRA/CERCLA Coordination at Federal Facilities***, ***OSWER Directive 9272.0-22***, December.

U.S. Environmental Protection Agency (EPA), 1991a, ***A Guide to Principal Threat and Low Level Threat Wastes,*** 9380.3-06FS, Office of Solid Waste and Emergency Response, November.

U.S. Environmental Protection Agency (EPA), 1991b, ***Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions***, Directive 9355.0-30, Office of Solid Waste and Emergency Response, April.

U.S. Environmental Protection Agency (EPA), 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," ***Federal Register*** 55(46): 8666-8865.

TABLES

Table 1

History of Site Investigations
RSA-122, RSA-056, RSA-139
Redstone Arsenal, Madison County, Alabama

Contractor/Date/ Investigation or Report	Media Sampled	Description
Testing, Inc. - 1979 Drill and Encase Monitoring Wells	Groundwater	Constructed and sampled 4 monitoring wells around RSA-056 and RSA-139 (RS048 through RS051).
P.E. LaMoreaux and Associates, Inc. – 1988 Confirmation Report	Surface soil Groundwater	Collected 4 subsurface soil and groundwater samples at RSA-056. Performed in-situ permeability tests on existing monitoring wells.
Geraghty & Miller, Inc. – 1991 Preliminary Assessment and Visual Site Inspection	Soil	Collected 2 soil samples.
ESE – 1994 Site Characterization (RSA-056 and RSA-139)	Surface soil Subsurface soil Groundwater Surface Water Sediment	Seven monitoring wells were installed and sampled. Numerous surface and subsurface soil samples were collected around the disposal ponds, former Plants 3 and 4 area. Surface water and sediment samples were collected from the main creek.
IT Corporation – 1997/2000 RI/SRI	Surface soil Subsurface soil Groundwater Surface Water Sediment	Collected soil, ground and surface water, and sediment samples in Plants areas, stockpiling area, former AT plant area, and main creek area.
IT Corporation – 2004/2005 Phase II RI	Surface soil Subsurface soil Groundwater Surface Water Sediment	199 surface soil samples and 790 subsurface soil samples from 209 locations were collected. 22 collocated surface water/sediment samples were collected from the main creek. Numerous groundwater samples collected from monitoring wells and piezometers around RSA-122.

AT – Arsenic Trichloride.
RI – Remedial Investigation.
SRI – Supplemental Remedial Investigation.

Table 2

Surface Media Data Summary for Arsenic and Mercury
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Chemical	Unit	Frequency of Detection	Detected Concentrations Minimum Value	VQ	Maximum Value	VQ	Arithmetic Average	95% UCL	Exposure Point Concentration	Basis of Exposure Point Concentration
EAST AREA										
Surface Soil										
Arsenic	mg/kg	30 / 30	5.5		220		1.85E+01	4.93E+01	4.93E+01	95% UCL
Mercury	mg/kg	30 / 30	0.017	J	3.5		3.35E-01	1.62E+00	1.62E+00	95% UCL
Subsurface Soil										
Arsenic	mg/kg	53 / 53	0.723		471		2.44E+01	6.43E+01	6.43E+01	95% UCL
Total Soil										
Arsenic	mg/kg	83 / 83	0.723		220		2.23E+01	5.00E+01	5.00E+01	95% UCL
Mercury	mg/kg	80 / 84	0.014	J	5.4		3.74E-01	1.02E+00	1.02E+00	95% UCL
NORTH AREA										
Surface Soil										
Arsenic	mg/kg	25 / 25	6.4		21.7		1.05E+01	1.15E+01	1.15E+01	95% UCL
Subsurface Soil										
Arsenic	mg/kg	51 / 51	4.4		29.4		1.16E+01	1.26E+01	1.26E+01	95% UCL
Total Soil										
Arsenic	mg/kg	76 / 76	4.4		29.4		1.12E+01	1.20E+01	1.20E+01	95% UCL
NORTHWEST AREA										
Surface Soil										
Arsenic	mg/kg	49 / 49	3		1290		1.06E+02	4.70E+02	4.70E+02	95% UCL
Mercury	mg/kg	39 / 39	0.023	J	15.1		6.06E-01	4.48E+00	4.48E+00	95% UCL
Subsurface Soil										
Arsenic	mg/kg	109 / 109	1.6	J	1540	J	8.13E+01	2.12E+02	2.12E+02	95% UCL
Total Soil										
Arsenic	mg/kg	158 / 158	1.6	J	1540	J	8.90E+01	2.03E+02	2.03E+02	95% UCL
Mercury	mg/kg	128 / 132	0.011	J	15.1		2.22E-01	7.27E-01	7.27E-01	95% UCL

Table 2

Surface Media Data Summary for Arsenic and Mercury
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Chemical	Unit	Frequency of Detection	Detected Concentrations Minimum Value	VQ	Maximum Value	VQ	Arithmetic Average	95% UCL	Exposure Point Concentration	Basis of Exposure Point Concentration
SOUTH AREA										
Surface Soil										
Arsenic	mg/kg	140 / 140	2.9		641		2.27E+01	4.64E+01	4.64E+01	95% UCL
Mercury	mg/kg	128 / 128	0.018	J	67.7		1.45E+00	5.24E+00	5.24E+00	95% UCL
Subsurface Soil										
Arsenic	mg/kg	271 / 271	0.764		1920		6.12E+01	1.46E+02	1.46E+02	95% UCL
Mercury	mg/kg	255 / 259	0.016	J	80.7		1.09E+00	3.35E+00	3.35E+00	95% UCL
Total Soil										
Arsenic	mg/kg	411 / 411	0.764		1920		4.81E+01	1.06E+02	1.06E+02	95% UCL
Mercury	mg/kg	383 / 387	0.016	J	80.7		1.21E+00	3.17E+00	3.17E+00	95% UCL
CREEK AREA										
Surface Soil										
Arsenic	mg/kg	13 / 13	6.6	J	303	J	7.38E+01	1.34E+02	1.34E+02	95% UCL
Mercury	mg/kg	12 / 12	0.05		22.5		3.52E+00	1.27E+01	1.27E+01	95% UCL
Sediment										
Arsenic	mg/kg	31 / 31	8.1	J	5630	J	2.41E+02	2.03E+03	2.03E+03	95% UCL
Surface Water										
Arsenic	µg/L	25 / 32	4.3	J	76.2		2.21E+01	2.88E+01	2.88E+01	95% UCL

J - The compound/analyte was positively identified; the reported result is the estimated concentration of the compound/analyte detected in the sample analyzed.
95% UCL - 95 Percent upper confidence limit.
VQ - Validation qualifier.
COPC - Chemical of potential concern.
mg/kg - Milligrams per kilogram.
µg/L - Micrograms per liter.

Table 3

Cancer Toxicity Data Summary for Chemicals of Concern
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Pathway: Ingestion, Dermal							
Chemical of Concern	**GAF**	**Oral Cancer Slope Factor**	**Dermal Cancer Slope Factor**	**Slope Factor Units**	**Weight of Evidence/Cancer Guideline Description**	**Source**	**Date**
Arsenic	NA	1.5	1.5	mg/kg-day^{-1}	A	IRIS	5/13/2009
Mercury	0.07	ND	NA	---	D	IRIS	5/13/2009
Pathway: Inhalation							
Chemical of Concern	**Unit Risk**	**Units**	**Inhalation Cancer Slope Factor**	**Units**	**Weight of Evidence/Cancer Guideline Description**	**Source**	**Date**
Arsenic	0.0043	µg/m^3	15	mg/kg-day^{-1}	A	IRIS	5/13/2009
Mercury	---	---	ND	---	D	IRIS	5/13/2009

GAF - Gastrointestinal absorption factor (unitless).
IRIS - Integrated Risk Information System, EPA.
NA - Not applicable; adjustment not applied.
ND - No data.
mg/kg - Milligrams per kilogram.
µg/m^3 - Micrograms per cubic meter.

A - Human carcinogen.
B1 - Probable human carcinogen - indicates that limited human data are available.
B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans.
C - Possible human carcinogen.
D - Not classifiable as a human carcinogen.
E - Evidence of noncarcinogenicity.

Table 4

Noncancer Toxicity Data Summary for Chemicals of Concern
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Pathway: Ingestion, Dermal									
Chemical of Concern	**Chronic/ Subchronic**	**Oral RfD**	**Oral RfD Units**	**Dermal RfD**	**Dermal RfD Units**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Sources of RfD: Target Organ**	**Dates of Rfd: Target Organ**
Arsenic	Chronic	3.00×10^{-4}	mg/kg-day	3.00×10^{-4}	mg/kg-day	Skin	3	IRIS	5/13/2009
Mercury	Chronic	3.00×10^{-4}	mg/kg-day	2.10×10^{-5}	mg/kg-day	Kidney	1000	IRIS	5/13/2009
Pathway: Inhalation									
Chemical of Concern	**Unit Risk**	**Inhalation RfC**	**Inhalation RfC Units**	**Inhalation RfD**	**Inhalation RfD Units**	**Primary Target Organ**	**Combined Uncertainty/ Modifying Factors**	**Sources of RfC:RfD: Target Organ**	**Dates**
Arsenic	Chronic	ND	---	ND	---	NA	---	---	---
Mercury	Chronic	3.00×10^{-4}	mg/m^3	8.60×10^{-5}	mg/kg-day	Nervous System	30	IRIS	5/13/2009

--- - No information necessary.
IRIS - Integrated Risk Information System, EPA.
NA - Not applicable.
ND - No data.
RfC - Reference concentration.
RfD - Reference dose.
mg/kg - Milligrams per kilogram.
µg/m^3 - Micrograms per cubic meter.

Table 5

Total Cancer Risks and Noncancer Hazards for Current and Future Site Receptors Including Background-Related Metals[1]
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

	Current Site Use	Future Site Use		
Receptors	Soil and Perched Groundwater [a]	Soil and Perched Groundwater [a]	Groundwater (Potable Source) [b]	Total Risk [c]
EAST AREA				
CANCER RISK				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	2.53×10^{-5}	2.53×10^{-5}	**1.08×10^{-2}**	**1.08×10^{-2}**
Groundskeeper (Alternative) [e]	NE	5.13×10^{-5}	**1.08×10^{-2}**	**1.08×10^{-2}**
Construction Worker (Conventional) [d]	5.03×10^{-6}	5.03×10^{-6}	**4.79×10^{-4}**	**4.84×10^{-4}**
Construction Worker (Alternative) [e]	NE	6.50×10^{-6}	**4.79×10^{-4}**	**4.86×10^{-4}**
Hypothetical Residential Receptor:				
Lifetime (Conventional) [d]	NE	**1.37×10^{-4}**	**2.57×10^{-2}**	**2.58×10^{-2}**
Lifetime (Alternative) [e]	NE	**1.37×10^{-4}**	**2.57×10^{-2}**	**2.58×10^{-2}**
NONCANCER HAZARD [f]				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	0.313	0.313	**109**	**110**
Groundskeeper (Alternative) [e]	NE	0.387	**109**	**110**
Construction Worker (Conventional) [d]	1.63 [g]	1.63 [g]	**121**	**123**
Construction Worker (Alternative) [e]	NE	**5.56**	**121**	**127**
Hypothetical Residential Receptor:				
Child (Conventional) [d]	NE	**4.68**	**399**	**404**
Child (Alternative) [e]	NE	**4.90**	**399**	**404**
NORTH AREA				
CANCER RISK				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	5.55×10^{-6}	5.55×10^{-6}	**1.08×10^{-2}**	**1.08×10^{-2}**
Groundskeeper (Alternative) [e]	NE	5.97×10^{-6}	**1.08×10^{-2}**	**1.08×10^{-2}**
Construction Worker (Conventional) [d]	9.93×10^{-7}	9.93×10^{-7}	**4.79×10^{-4}**	**4.80×10^{-4}**
Construction Worker (Alternative) [e]	NE	3.17×10^{-6}	**4.79×10^{-4}**	**4.82×10^{-4}**
Hypothetical Residential Receptor:				
Lifetime (Conventional) [d]	NE	2.96×10^{-5}	**2.57×10^{-2}**	**2.57×10^{-2}**
Lifetime (Alternative) [e]	NE	3.08×10^{-5}	**2.57×10^{-2}**	**2.57×10^{-2}**
NONCANCER HAZARD [f]				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	0.134	0.134	**109**	**109**
Groundskeeper (Alternative) [e]	NE	0.245	**109**	**109**
Construction Worker (Conventional) [d]	1.11 [g]	1.11 [g]	**121**	**122**
Construction Worker (Alternative) [e]	NE	**7.62**	**121**	**129**
Hypothetical Residential Receptor:				
Child (Conventional) [d]	NE	**1.99**	**399**	**401**
Child (Alternative) [e]	NE	**3.58**	**399**	**403**

Table 5

Total Cancer Risks and Noncancer Hazards for Current and Future Site Receptors Including Background-Related Metals[1]
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

	Current Site Use	Future Site Use		
Receptors	**Soil and Perched Groundwater [a]**	**Soil and Perched Groundwater [a]**	**Groundwater (Potable Source) [b]**	**Total Risk [c]**
NORTHWEST AREA				
CANCER RISK				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	**2.87×10^{-4}**	**2.87×10^{-4}**	**1.08×10^{-2}**	**1.11×10^{-2}**
Groundskeeper (Alternative) [e]	NE	**1.13×10^{-4}**	**1.08×10^{-2}**	**1.09×10^{-2}**
Construction Worker (Conventional) [d]	1.99×10^{-5}	1.99×10^{-5}	**4.79×10^{-4}**	**4.99×10^{-4}**
Construction Worker (Alternative) [e]	NE	2.05×10^{-5}	**4.79×10^{-4}**	**5.00×10^{-4}**
Hypothetical Residential Receptor:				
Lifetime (Conventional) [d]	NE	**1.60×10^{-3}**	**2.57×10^{-2}**	**2.73×10^{-2}**
Lifetime (Alternative) [e]	NE	**6.16×10^{-4}**	**2.57×10^{-2}**	**2.63×10^{-2}**
NONCANCER HAZARD [f]				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	**2.02**	**2.02**	**109**	**111**
Groundskeeper (Alternative) [e]	NE	0.889	**109**	**110**
Construction Worker (Conventional) [d]	**6.93**	**6.93**	**121**	**128**
Construction Worker (Alternative) [e]	NE	**13.7**	**121**	**135**
Hypothetical Residential Receptor:				
Child (Conventional) [d]	NE	**30.6**	**399**	**430**
Child (Alternative) [e]	NE	**13.5**	**399**	**413**
SOUTH AREA				
CANCER RISK				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	2.48×10^{-5}	2.48×10^{-5}	**1.08×10^{-2}**	**1.08×10^{-2}**
Groundskeeper (Alternative) [e]	NE	5.37×10^{-5}	**1.08×10^{-2}**	**1.08×10^{-2}**
Construction Worker (Conventional) [d]	1.15×10^{-5}	1.15×10^{-5}	**4.79×10^{-4}**	**4.91×10^{-4}**
Construction Worker (Alternative) [e]	NE	1.06×10^{-5}	**4.79×10^{-4}**	**4.90×10^{-4}**
Hypothetical Residential Receptor:				
Lifetime (Conventional) [d]	NE	**1.35×10^{-4}**	**2.57×10^{-2}**	**2.58×10^{-2}**
Lifetime (Alternative) [e]	NE	**2.89×10^{-4}**	**2.57×10^{-2}**	**2.60×10^{-2}**
NONCANCER HAZARD [f]				
Industrial Receptors:				
Groundskeeper (Conventional) [d]	0.26	0.26	**109**	**109**
Groundskeeper (Alternative) [e]	NE	0.447	**109**	**110**
Construction Worker (Conventional) [d]	**1.91**	**1.91**	**121**	**123**
Construction Worker (Alternative) [e]	NE	**2.34**	**121**	**124**
Hypothetical Residential Receptor:				
Child (Conventional) [d]	NE	**3.89**	**399**	**403**
Child (Alternative) [e]	NE	**6.77**	**399**	**406**

Table 5

Total Cancer Risks and Noncancer Hazards for Current and Future Site Receptors Including Background-Related Metals[1]
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

CREEK AREA				
	Current Site Use	**Future Site Use**		
Receptors	**Soil and Surface Water [h]**	**Soil and Surface Water [h]**	**Groundwater (Potable Source) [b]**	**Total Risk [h]**
CANCER RISK				
Recreational Receptors:				
Trespasser	2.62×10^{-6}	2.62×10^{-6}	NE	2.62×10^{-6}
NONCANCER HAZARD [f]				
Recreational Receptors:				
Trespasser	0.0777	0.0777	NE	0.0777

[1]Includes the cancer risks and noncancer hazaards from the background-related metals aluminum, chromium, manganese, and vanadium

NE - Not evaluated.

Bold font entries represent cancer risk values that exceed 1×10^{-4} or noncancer hazard index values that exceed the threshold level of 1 and are unacceptable.

[a] Includes cancer risks and noncancer hazards from exposure to the following media and receptors:
Surface soil - groundskeeper, construction worker, and hypothetical residential receptor.
Subsurface soil - construction worker.
Perched groundwater - construction worker.
Total soil - groundskeeper, construction worker, and hypothetical residential receptor.

[b] An independent investigation will be conducted for RSA-122 groundwater under the RSA-147 groundwater unit to determine the extent of contamination in the groundwater and to assist with the development of remedial alternatives for the volatile organic compound plume beneath the RSA-147 area. This SBPP does not develop remedial alternatives for the groundwater contamination at RSA-122, RSA-056, or RSA-139.

[c] The total risk cancer estimates and noncancer hazards include the receptor's exposure to groundwater. However, as footnote "b" states, groundwater is included in RSA-147 and not included as a part of the remedial alternatives for RSA-122.

[d] Conventional - Exposure to surface soil except for construction worker where exposure is to surface soil and subsurface soil.

[e] Alternative - Total soils. Total soil hypothetically assumes surface and subsurface soil are mixed during future development.

[f] The noncancer hazard is expressed as a hazard index.

[g] Although the noncancer hazard for this receptor exceeds the threshold of 1, no target organ hazard index exceeds 1.

[h] Includes cancer risks and noncancer hazards from exposure to surface soil and surface water.
Exposure to sediment perennially covered with water is generally insignificant and therefore is not quantified.

Table 6

Summary of Arsenic and Mercury Risks Based on the BHHRA at RSA-122
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Receptor	Potential COCs	Cancer Risk	Critical Exposure Pathway	Noncancer HI	Critical Exposure Pathway
EAST AREA					
SURFACE SOIL					
Residential					
Hypothetical Resident	Arsenic	**1.27×10^{-4}**	Ingestion	**2.28**	Ingestion
TOTAL SOIL					
Residential					
Hypothetical Resident	Arsenic	**1.28×10^{-4}**	Ingestion	**2.31**	Ingestion
NORTHWEST AREA					
SURFACE SOIL					
Industrial					
Groundskeeper	Arsenic	**2.26×10^{-4}**	Ingestion	**1.41**	Ingestion
Construction Worker (Chronic) [a]	Arsenic			0.521	Ingestion
Construction Worker (Subchronic) [b]	Arsenic			0.312 [c]	Ingestion
Residential					
Hypothetical Resident	Arsenic	**1.21×10^{-3}**	Ingestion	**21.7**	Ingestion, Dermal Contact
	Mercury			0.191	Ingestion
SUBSURFACE SOIL					
Industrial					
Construction Worker (Chronic) [a]	Arsenic			**2.11**	Ingestion
Construction Worker (Subchronic) [b]	Arsenic			0.141 [c]	Ingestion
TOTAL SOIL					
Industrial					
Construction Worker (Chronic) [a]	Arsenic			**2.25**	Ingestion
Construction Worker (Subchronic) [b]	Arsenic			0.135 [c]	Ingestion
Residential					
Hypothetical Resident	Arsenic	**5.22×10^{-4}**	Ingestion	**9.39**	Ingestion, Dermal Contact
SOUTH AREA					
SURFACE SOIL					
Residential					
Hypothetical Resident	Arsenic	**1.19×10^{-4}**	Ingestion	**2.14**	Ingestion
	Mercury			0.223	Ingestion
SUBSURFACE SOIL					
Industrial					
Construction Worker (Chronic) [a]	Arsenic			**1.46**	Ingestion
Construction Worker (Subchronic) [b]	Arsenic			0.0875 [c]	Ingestion
TOTAL SOIL					
Industrial					
Construction Worker (Chronic) [a]	Arsenic			**1.17**	Ingestion
Construction Worker (Subchronic) [b]	Arsenic			0.0702 [c]	Ingestion
Residential					
Hypothetical Resident	Arsenic	**2.71×10^{-4}**	Ingestion	**4.88**	Ingestion
	Mercury			0.135	Ingestion

Bold font entries represent cancer risk values that exceed 1×10^{-4} or noncancer hazard index values that exceed the threshold level of 1 and are unacceptable.

[a] The construction worker's chronic exposure to arsenic was presented in the Final Remedial Investigation Report (Shaw, 2007).
[b] The construction worker's subchronic exposure to arsenic was not presented in the Final Remedial Investigation Report (Shaw, 2007) but was included in the Draft Final Focused Feasibility Study in support of Region 4's acceptance of the subchronic oral reference dose (Shaw, 2009).
[c] The HI asssociated with subchronic exposure does not exceed 1; therefore, soil poses no unacceptable health threat to the construction worker.
BHHRA - Baseline Human Health Risk Assessment
COC - Chemical of concern.
HI - Hazard index.

References:
Shaw Environmental, Inc. (Shaw), 2009, *Final Feasibility Study, RSA-122, Dismantled Lewisite Manufacturing Plant Sites; RSA-056, Closed Arsenic Waste Ponds; and RSA-139, Former Arsenic Trichloride Manufacturing Disposal Area, Operable Unit 6*, prepared for U.S. Army Corps of Engineers, Savannah District, in preparation.

Shaw Environmental, Inc. (Shaw), 2007, *Final Phase II Remedial Investigation Report, Baseline Human Health Risk Assessment and Screening-Level Ecological Risk Assessment for RSA-122, Dismantled Lewisite Manufacturing Plant, Operable Unit 6, prepared for U.S. Army Corps of Engineers,* Savannah District, August.

Table 7

Results of the Vapor Intrusion Evaluation
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Receptor	Structure Evaluated	Detected VOCs [a]	Groundwater Concentration [b] (µg/L)	Modeled Indoor Air Concentration (µg/m^3)	Modeled Indoor Air Results Compared to Target Indoor Air Concentrations — EPA Target Indoor Air Concentrations: [c]						CalEPA Target Indoor Air Concentrations: [d]					
					At 1×10^{-6} (µg/m^3)	Exceeds 1×10^{-6} (Yes / No)	At 1×10^{-5} (µg/m^3)	Exceeds 1×10^{-5} (Yes / No)	At 1×10^{-4} (µg/m^3)	Exceeds 1×10^{-4} (Yes / No)	At 1×10^{-6} (µg/m^3)	Exceeds 1×10^{-6} (Yes / No)	At 1×10^{-5} (µg/m^3)	Exceeds 1×10^{-5} (Yes / No)	At 1×10^{-4} (µg/m^3)	Exceeds 1×10^{-4} (Yes / No)
Indoor Commercial Worker	Building 5421-Main [e,f]	TCE	160	3.02E-01	2.20E-02	Yes	2.20E-01	**Yes**	2.20E+00	No	1.3E+00	No	1.30E+01	No	1.30E+02	No
			80.2 [h]	1.51E-01	2.20E-02	Yes	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5421-Addition [e,f,g]	TCE	160	3.98E-01	2.20E-02	Yes	2.20E-01	**Yes**	2.20E+00	No	1.3E+00	No	1.30E+01	No	1.30E+02	No
			80.2 [h]	2.00E-01	2.20E-02	Yes	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5422 [e,f,g]	TCE	160	2.16E-01	2.20E-02	Yes	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5432	TCE	4.3	1.11E-02	2.20E-02	No	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5435 [e,f,g]	TCE	45	2.91E-02	2.20E-02	Yes	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5436 [e,f]	TCE	4.3	7.54E-03	2.20E-02	No	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5437 [e,f]	TCE	8.9	1.66E-02	2.20E-02	No	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
	Building 5452	TCE	21	6.08E-02	2.20E-02	Yes	2.20E-01	No	2.20E+00	No	NA	NA	NA	NA	NA	NA
Hypothetical Future Resident	Hypothetical Future Residential Building	TCE	750	1.08E+01	2.20E-02	Yes	2.20E-01	**Yes**	2.20E+00	**Yes**	1.30E+00	**Yes**	1.30E+01	No	1.30E+02	No
		VC	31	1.32E+00	2.80E-01	Yes	2.80E+00	No	2.80E+01	No	NA	NA	NA	NA	NA	NA

[a] The maximum concentration of two VOCs detected in groundwater exceeded the initial screening concentration and were carried forward for further evaluation.

[b] Maximum detected concentration in groundwater (except where noted) at RSA-122 from samples collected between 2000 and 2005.

[c] Residential target indoor air concentrations of 1×10^{-6}, 1×10^{-5}, and 1×10^{-4} (from Tables 2c, 2b, and 2a, respectively [EPA, 2002]).

[d] California-modified PRG for trichloroethene in ambient air from EPA Region 9 PRG table (EPA, 2004) using the inhalation slope factor from CalEPA (CalEPA, 2002). The indoor air concentration of trichloroethene reflecting a cancer risk of 1×10^{-6} equals 1.30 µg/m^3.

[e] Building contains an HVAC system with an exchange rate of approximately once per hour.

[f] Building system maintains a positive pressure.

[g] Building has foundation vapor barrier.

[h] Average concentration in groundwater at RSA-122 from samples collected between 2000 and 2005.

NA - Not applicable.
TCE- Trichloroethene.
VC - Vinyl chloride.
VOC - Volatile organic compound.
µg/m^3 - Micrograms per cubic meter.
µg/L - Micrograms per liter.

References:

California Environmental Protection Agency (CalEPA), 2002, *Air Toxics Hot Spot Program Risk Assessment Guidelines, Part II, Technical Support for Describing Available Cancer Potency Factors*, December 2002).

U.S. Environmental Protection Agency (EPA), 2002, *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils [Subsurface Vapor Intrusion Guidance*¸, Office of Solid Waste, EPA530-F-02-052, November).

U.S. Environmental Protection Agency.EPA, 2004, *Preliminary Remediation Goals Table*, October, EPA Region 9, San Francisco, California, on-line)

Table 8

Summary of Screening-Level Ecological Risk Evaluation Results
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

(Page 1 of 4)

Step 3a COPEC	Results of Food Chain Modeling				Results of Community-Based Evaluations--Mean HQ over 1	Retain as a COC?	Rationale Code
	Max-NOAEL HQ greater than 1 and Max-LOAEL HQ less than 1	Max-NOAEL HQ greater than 1 and Max-LOAEL HQ over 1	Mean-NOAEL HQ greater than 1 and Mean-LOAEL HQ less than 1	Mean-LOAEL HQ over 1			
NORTHWEST							
Inorganic Analytes							
Aluminum		X		X	X	N	BKG
Antimony		X	X			N	LOW HQs
Arsenic		X	X		X	**Y**	
Barium		X				N	LOW HQs
Cadmium	X					N	LOW HQs
Chromium III		X	X		X	N	BKG
Chromium VI	X				X	N	BKG
Cobalt						N	LOW HQs
Copper						N	LOW HQs
Lead	X		X			N	LOW HQs
Manganese	X				X	**Y**	
Mercury	X				X	**Y**	
Nickel						N	LOW HQs
Selenium	X					N	LOW HQs
Vanadium	X		X		X	N	BKG
Zinc	X		X		X	**Y**	
Polynuclear Aromatic Hydrocarbons							
2-Methylnaphthalene					NSV	N	LOW HQs
Acenaphthene						N	LOW HQs
Acenaphthylene					NSV	N	LOW HQs
Anthracene					NSV	N	LOW HQs
Benzo(a)anthracene	X				NSV	N	LOW HQs
Benzo(a)pyrene	X				NSV	N	LOW HQs
Benzo(b)fluoranthene		X			NSV	N	LOW HQs
Benzo(ghi)perylene	X				NSV	N	LOW HQs
Benzo(k)fluoranthene		X			NSV	N	LOW HQs
Butyl benzyl phthalate		X	X		NSV	N	LOW HQs
Carbazole		X	X		NSV	N	LOW HQs
Chrysene		X			NSV	N	LOW HQs
Dibenz(a,h)anthracene					NSV	N	LOW HQs
Fluoranthene		X			NSV	N	LOW HQs
Fluorene		X	X		NSV	N	LOW HQs
Indeno(1,2,3-cd)pyrene	X				NSV	N	LOW HQs
Naphthalene					NSV	N	LOW HQs
Phenanthrene		X	X			N	LOW HQs
Pyrene		X			NSV	N	LOW HQs
Total PAHs		X		X	NSV	N	LOW HQs
Organochlorine Pesticides							
4,4'-DDE	X		X		NSV	N	LOW HQs
4,4'-DDT	X		X		NSV	N	LOW HQs
NORTH							
Inorganic Analytes							
Arsenic	X		X		X	**Y**	
Cadmium	X					N	LOW HQs
Chromium III		X	X		X	N	BKG
Chromium VI	X				X	N	BKG
Cobalt						N	LOW HQs
Copper						N	LOW HQs
Lead		X	X		X	N	BKG
Mercury					X	**Y**	
Nickel						N	LOW HQs
Selenium						N	LOW HQs
Vanadium	X		X		X	N	BKG
Zinc	X		X		X	**Y**	

Table 8

Summary of Screening-Level Ecological Risk Evaluation Results
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

(Page 2 of 4)

Step 3a COPEC	Results of Food Chain Modeling: Max-NOAEL HQ greater than 1 and Max-LOAEL HQ less than 1	Max-NOAEL HQ greater than 1 and Max-LOAEL HQ over 1	Mean-NOAEL HQ greater than 1 and Mean-LOAEL HQ less than 1	Mean-LOAEL HQ over 1	Results of Community-Based Evaluations--Mean HQ over 1	Retain as a COC?	Rationale Code
EAST							
Inorganic Analytes							
Arsenic		X	X		X	**Y**	
Barium	X					N	LOW HQs
Cadmium						N	LOW HQs
Chromium III		X	X		X	N	BKG
Chromium VI	X				X	N	BKG
Cobalt						N	LOW HQs
Copper						N	LOW HQs
Manganese					X	**Y**	
Mercury					X	**Y**	
Nickel						N	LOW HQs
Vanadium	X		X		X	N	BKG
Zinc	X		X		X	**Y**	
Polynuclear Aromatic Hydrocarbons							
Benzo(a)anthracene					NSV	N	LOW HQs
Benzo(a)pyrene					NSV	N	LOW HQs
Benzo(b)fluoranthene					NSV	N	LOW HQs
Benzo(ghi)perylene					NSV	N	LOW HQs
Benzo(k)fluoranthene					NSV	N	LOW HQs
bis(2-Ethylhexyl)phthalate					NSV	N	LOW HQs
Chrysene					NSV	N	LOW HQs
Fluoranthene					NSV	N	LOW HQs
Indeno(1,2,3-cd)pyrene					NSV	N	LOW HQs
Phenanthrene						N	LOW HQs
Pyrene					NSV	N	LOW HQs
Total PAHs	X		X		NSV	N	LOW HQs
Organochlorine Pesticides							
4,4'-DDE					NSV	N	LOW HQs
SOUTH							
Inorganic Analytes							
Antimony		X	X			N	LOW HQs
Arsenic		X	X		X	**Y**	
Cadmium						N	LOW HQs
Chromium III		X	X		X	N	BKG
Chromium VI	X				X	N	BKG
Copper						N	LOW HQs
Mercury		X			X	**Y**	
Nickel						N	LOW HQs
Selenium		X				N	LOW HQs
Vanadium	X		X		X	N	BKG
Zinc	X		X		X	**Y**	
Polynuclear Aromatic Hydrocarbons							
Acenaphthylene					NSV	N	LOW HQs
Anthracene					NSV	N	LOW HQs
Benzo(a)anthracene					NSV	N	LOW HQs
Benzo(a)pyrene					NSV	N	LOW HQs
Benzo(b)fluoranthene					NSV	N	LOW HQs
Benzo(ghi)perylene					NSV	N	LOW HQs
Benzo(k)fluoranthene					NSV	N	LOW HQs
Chrysene					NSV	N	LOW HQs
Dibenz(a,h)anthracene					NSV	N	LOW HQs
Fluoranthene					NSV	N	LOW HQs
Indeno(1,2,3-cd)pyrene					NSV	N	LOW HQs
Phenanthrene						N	LOW HQs
Pyrene					NSV	N	LOW HQs
Total PAHs	X		X		NSV	N	LOW HQs
Organochlorine Pesticides							
4,4'-DDD	X		X		NSV	N	LOW HQs
4,4'-DDE		X	X		NSV	N	LOW HQs
4,4'-DDT		X		X	NSV	N	LOW HQs
alpha-Chlordane					NSV	N	LOW HQs
beta-BHC					NSV	N	LOW HQs
Dieldrin					NSV	N	LOW HQs
Endrin ketone					NSV	N	LOW HQs
gamma-Chlordane					NSV	N	LOW HQs
Heptachlor					NSV	N	LOW HQs
Heptachlor epoxide					NSV	N	LOW HQs
Methoxychlor					NSV	N	LOW HQs

Table 8

Summary of Screening-Level Ecological Risk Evaluation Results
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

	Results of Food Chain Modeling				Results of		
Step 3a COPEC	Max-NOAEL HQ greater than 1 and Max-LOAEL HQ less than 1	Max-NOAEL HQ greater than 1 and Max-LOAEL HQ over 1	Mean-NOAEL HQ greater than 1 and Mean-LOAEL HQ less than 1	Mean-LOAEL HQ over 1	Community-Based Evaluations-- Mean HQ over 1	Retain as a COC?	Rationale Code
UNNAMED CREEK FLOODPLAIN							
Inorganic Analytes							
Antimony	X		X		X	N	LOW HQs
Arsenic		X	X		X	**Y**	
Barium	X					N	LOW HQs
Cadmium	X					N	LOW HQs
Chromium III		X	X		X	N	BKG
Chromium VI					X	N	BKG
Cobalt						N	LOW HQs
Copper						N	LOW HQs
Lead						N	LOW HQs
Manganese					X	**Y**	
Mercury		X			X	**Y**	
Nickel						N	LOW HQs
Selenium	X				X	N	LOW HQs
Vanadium	X		X		X	N	BKG
Zinc	X		X		X	N	LOW HQs
Organochlorine Pesticides							
4,4'-DDD		X	X		NSV	N	LOW HQs
4,4'-DDE		X		X	NSV	N	LOW HQs
4,4'-DDT		X		X	NSV	N	LOW HQs
alpha-Chlordane					NSV	N	LOW HQs
beta-BHC					NSV	N	LOW HQs
Dieldrin					NSV	N	LOW HQs
Endrin ketone					NSV	N	LOW HQs
gamma-Chlordane					NSV	N	LOW HQs
Heptachlor					NSV	N	LOW HQs
Heptachlor epoxide					NSV	N	LOW HQs

Table 8

Summary of Screening-Level Ecological Risk Evaluation Results
RSA-122, Operable Unit 6
Redstone Arsenal, Madison County, Alabama

Step 3a COPEC	Results of Food Chain Modeling: Max-NOAEL HQ greater than 1 and Max-LOAEL HQ less than 1	Max-NOAEL HQ greater than 1 and Max-LOAEL HQ over 1	Mean-NOAEL HQ greater than 1 and Mean-LOAEL HQ less than 1	Mean-LOAEL HQ over 1	Results of Community-Based Evaluations--Mean HQ over 1	Retain as a COC?	Rationale Code
UNNAMED CREEK							
Inorganic Analytes							
Aluminum		X		X	NSV	N	BKG
Antimony						N	LOW HQs
Arsenic		X		X	X (SD)	**Y**	
Barium	X					N	LOW HQs
Cadmium						N	LOW HQs
Chromium III	X				X (SD)	N	LOW HQs
Chromium VI						N	LOW HQs
Cobalt					NSV	N	LOW HQs
Copper					X (SW)	N	NSR
Iron					NSV	N	LOW HQs
Lead						N	LOW HQs
Manganese	X					**Y**	
Mercury		X			X (SD)	**Y**	
Methylmercury		X		X		**Y**	
Nickel						N	LOW HQs
Selenium						N	LOW HQs
Silver					X (SD)	N	LOW HQs
Vanadium	X		X			N	BKG
Zinc	X		X			N	BKG
Semivolatile Organic Compounds							
2-Methylnaphthalene					X (SD)	N	LOW HQs
bis(2-Ethylhexyl)phthalate						N	LOW HQs
Chrysene						N	LOW HQs
Fluoranthene						N	LOW HQs
Pentachlorophenol					X (SD)	N	LOW HQs
Pyrene						N	LOW HQs
Total PAHs						N	LOW HQs
Organochlorine Pesticides							
4,4'-DDD					X (SD)	N	LOW HQs
4,4'-DDE		X	X		X (SD)	N	LOW HQs
4,4'-DDT		X		X	X (SW & SD)	N	NSR
alpha-BHC						N	LOW HQs
alpha-Chlordane					X (SD)	N	LOW HQs
beta-BHC						N	LOW HQs
Dieldrin					NSV	N	LOW HQs
Endrin ketone					NSV	N	LOW HQs
gamma-Chlordane					X (SD)	N	LOW HQs
Heptchlor					X (SW)	N	LOW HQs
Heptchlor epoxide						N	LOW HQs
Polychlorinated Biphenyls							
Aroclor 1254					X (SD)	N	LOW HQs

Notes:
X - Range of HQ based on the results of the screening-level ecological risk assessment.
HQ - Hazard quotient based on mean or maximum concentration compared to toxicity reference value.
COC - Chemical of concern.
COPEC - Chemical of potential ecological concern.
LOAEL - Lowest-observed-adverse-effect level.
NOAEL - No-observed-adverse-effect level.
Max - Maximum detected value.
Mean - Arithmetic average concentration.
N - COPEC is not retained as a COC.
NSR - Not a site-related chemical.
NSV - No screening value available.
SD - Sediment.
SW - Surface water.
mg/kg - Milligrams per kilogram.

Rationale Codes:
BKG - Aluminum, chromium, lead, and vanadium were determined to be background related, as well as zinc in surface water and sediment. Observed concentrations of these metals have been determined to not occur from a site-related release.
LOW HQs - HQs were less than 1 for most receptors, or had slightly elevated HQs above 1 which were determined to not pose a potential for adverse impacts to populations of ecological receptors.
WOE - Weight of evidence; iron was determined to not be bioavailable in soils at this site.

Table 9

Applicable or Relevant and Appropriate Requirements
RSA-122, RSA-56, and RSA-139
Redstone Arsenal, Madison County, Alabama

	Citation	Description	Prerequisite	Designation
LOCATION-SPECIFIC REQUIREMENTS				
Floodplains	EO 11988	Floodplain protection	Site located in a floodplain.	TBC. The main production areas at RSA-122, RSA-56, and RSA-139 are approximately 1,800 feet north of the nearest 100-year floodplain. Approximately 4,500 feet of the southern portion of the main creek is within the 100-year floodplain boundary.
ACTION-SPECIFIC REQUIREMENTS				
Waste	AAC r. 335-14-3-.01(2)	Hazardous Waste Determination	RDW meets the criteria as a RCRA hazardous waste.	**Applicable** to hazardous RDW.
	AAC r. 335-14-9-.01(7)			
	AAC r. 335-14-3-.03(1)-(4)	Pre-Transport Requirements		
	AAC r. 335-14-9-.04(9)	Alternative LDR Treatment Standards for Contaminated Soil		
	AAC r. 335-14-5-.19(3)(a)(3)	Corrective Action Management Units; Prohibition on placing liquid in CAMUs	Treatment and/or storage of hazardous remediation waste.	**Applicable** to temporary on-site storage and/or treatment of contaminated soil.
	AAC r. 335-14-5-.19(3)(f) and (g)	Corrective Action Management Units		
	EPA Region 4 guidance document	"Management of Contaminated Media", 1999.	On- or off-site management of contaminated media.	TBC

Table 9

Applicable or Relevant and Appropriate Requirements
RSA-122, RSA-56, and RSA-139
Redstone Arsenal, Madison County, Alabama

	Citation	Description	Prerequisite	Designation
Water	AAC r. 335-6-12-.05(2) and (3)	Requires operator to fully implement and regularly maintain effective management practices (BMP) and regularly evaluate construction activities at their site.	Land disturbance > 1 acre.	**Applicable** to construction activities that disturb > 1 acre.
	AAC r. 335-6-12-.06(4)	Requires operator to take all reasonable steps to prevent and/or minimize, to the maximum extent practicable, any discharge in violation of the regulations or which has a reasonable likelihood of adversely affecting the quality of groundwater or surface water receiving the discharge(s).		
	AAC r. 335-6-12-.21	Stormwater Discharges for Construction Activities; CBMPPs, Other Plan, Specifications, BMPs, and Technical Requirements		
	AAC r. 335-6-12-.26(5)-(8)	Stormwater Discharges for Construction Activities; Discharge and Receiving Water Evaluation Requirements		
	AAC r. 335-6-12-.28(1)-(4)	Stormwater Discharges for Construction Activities; Inspection Requirements		
	AAC r. 335-6-12-.33(4)	Requires operators to take all reasonable precautions to prevent the discharge of water contaminated with hazardous or toxic chemicals to the receiving water.		
	AAC r. 335-6-12-.35(1), (10(a)), and (11)	Requires proper operation and maintenance of all BMPs. Confers a duty to mitigate and remediate adverse impacts resulting from noncompliance. Requires cessation, suspension, reduction or otherwise control of construction operations upon the loss or failure of BMPs.		
	Alabama Soil and Water Conservation Committee	"Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management of Construction Sites and Urban Areas", June 2003	Construction activity (e.g., excavation, clearing).	TBC

AAC - Alabama Administrative Code
EO - Executive Order
EPA - Environmental Protection Agency
RCRA - Resource Conservation and Recovery Act
RDW - Remediation Derived Waste
TBC - To be considered

Table 10

Evaluation Criteria for Remedial Alternatives[1]
RSA-122, RSA-056, RSA-139
Redstone Arsenal, Madison County, Alabama

Threshold Criteria:

Overall Protectiveness of Human Health and the Environment determines whether an alternative eliminates, reduces, or controls threats to public health and the environment through institutional controls, engineering controls, or treatment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) evaluates whether the alternative meets Federal and State environmental statutes, regulations, and other requirements that pertain to the site. ARARs may be waived under certain circumstances. ARARs are divided into chemical-specific, location-specific, and action-specific criteria.

Primary Balancing Criteria:

Long-Term Effectiveness and Permanence considers the ability of an alternative to maintain protection of human health and the environment over time. It evaluates magnitude of residual risk and adequacy of reliability of controls.

Reduction of Toxicity, Mobility, or Volume of Contaminants through Treatment evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contamination present.

Short-Term Effectiveness considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation.

Implementability considers the technical and administrative feasibility of implementing the alternative, including factors such as the relative availability of goods and services.

Cost includes estimated capital and annual operations and maintenance costs, as well as present worth cost. Present worth cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates are expected to be accurate within a range of +50 to -30 percent.

Modifying Criteria:

State Support/Agency Acceptance considers whether EPA and ADEM agree with the analyses and recommendations by the Army, as described in the RI/FS and SB/PP.

Community Acceptance considers whether the local community agrees with the Preferred Alternative. Comments received on the SB/PP during the public comment period are an important indicator of community acceptance.

[1]RCRA criteria are similar to these CERCLA criteria. The threshold RCRA criteria are that the remedy must (1) be protective of human health and the environment; (2) attain media cleanup standards; (3) control the source(s) of releases so as to reduce or eliminate, to the extent practicable, further releases of hazardous waste that might pose threats to human health and the environment; and (4) comply with applicable standards for waste management. The balancing criteria for choosing among alternatives that meet the threshold criteria are (1) long-term reliability and effectiveness; (2) reduction of toxicity, mobility, or volume of wastes; (3) short-term effectiveness; (4) implementability; and (5) cost. See EPA Proposed Rule for Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities, 61 *Federal Register* 19431 (May 1, 1996). The proposed remedy meets the RCRA threshold criteria.

Table 11

Evaluation of Alternatives Summary Table
RSA-122, RSA-056, RSA-139
Redstone Arsenal, Madison County, Alabama

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Implementability	Cost (Total Present Worth)
No Action - Alternative 1	Not Protective	Not Applicable	Not Effective	None	Not Applicable	Readily Implementable	$0
Soil Excavation, Treatment, Off-Site Disposal, Backfill, Short-Term Sediment and Groundwater Monitoring, and Institutional Controls - Alternative 2	Protective as long as institutional controls maintained	Complies	Effective	An on-site treatment component is included, if needed.	Effective	Implementable	$1,716,000
Soil Excavation, Treatment, On-Site Disposal, Backfill, Short-Term Sediment and Groundwater Monitoring, Institutional Controls, and Capping - Alternative 3	Protective as long as land use controls maintained	Complies	Effective	An on-site treatment component is included, if needed.	Effective	Implementable	$2,287,000

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2 **Excavation/Treatment/Off Site Disposal/** **Sediment & Groundwater Monitoring/** **Cap Maintenance/ICs** **Capital, O&M, and Present Value Cost Estimate**	**Site:** RSA-122/56/139 Redstone Arsenal **Date:** 06/2008

Scope:
1. Prepare remedial action work plan and closeout report
2. Prepare site for remediation
3. Excavate contaminated soil to meet As RGs (15 mg/kg, 200 mg/kg)
4. Treat contaminated soil
5. Off-site disposal of treated soil at RSA non-hazardous landfill
6. Backfill and revegetate excavated areas
7. Implement institutional controls (IC)
8. Annual operation and maintenance including cap maintenance

1.0 RA Work Plans and Close-out Report

Includes:
1. Complete RA work plan (including construction QA plan and H&S Plan)
2. Procure equipment and materials
3. Complete remedial action work plan and close-out report
4. Conduct site historical and archaeological survey

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor:					
RA Work Plan	1	$85,000.00	/ea	$85,000.00	
Site Close-out Report	1	$85,000.00	/ea	$85,000.00	
Subcontractor:					
Historical/Archeological Survey	1	$10,000.00	/ea	$10,000.00	
				Subtotal	**$180,000.00**

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2
Excavation/Treatment/Off Site Disposal/
Sediment & Groundwater Monitoring/
Cap Maintenance/ICs
Capital, O&M, and Present Value Cost Estimate

Site: RSA-122/56/139
Redstone Arsenal
Date: 06/2008

2.0 Site Preparation

Includes:
1. Survey and mark proposed remediation area
2. Vegetation removal (trees and shrubs) of approximately 50% of excavation area
3. Construction and Maintenance of Erosion and Sediment Controls

Assumptions:

1. Approximate Area to be cleared (acres) =	0.55
2. Clearing & Grub (mild density $/acre) =	25225
3. Daily output clearing crew (acre/day) =	0.6
4. Days clearing contractor in field =	1
5. Silt Fence to be installed (lf) =	500
6. Daily output silt fencing crew (lf/day) =	500
7. Days fencing crew in field =	1
8. Silt Fencing Cost ($/lf)=	1.6
9. Number of Hay Bales=	25
10. Cost per Hay Bale=	5

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor:					
Field Supervisor	30	$75.00	/hr	$2,250.00	
Field Technician	30	$50.00	/hr	$1,500.00	
Subcontractor:					
Surveying crew	3	$1,027.00	/day	$3,081.00	
Clear, grub, and chip trees & brush	0.55	$25,224.00	/acre	$13,873.00	
Materials:					
Field Instruments (air monitor)	1	$400.00	/wk	$400.00	
Silt Fencing	500	$1.60	/lf	$800.00	
Hay Bales	25	$5.00	ea	$125.00	
Travel for Contractor Crew:					
Per diem	6	$38.00	/day	$228.00	
Lodging	6	$80.00	/day	$480.00	
P/U Truck	3	$52.00	/day	$156.00	
				Subtotal	**$22,893.00**

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2
Excavation/Treatment/Off Site Disposal/
Sediment & Groundwater Monitoring/
Cap Maintenance/ICs
Capital, O&M, and Present Value Cost Estimate

Site: RSA-122/56/139
Redstone Arsenal
Date: 06/2008

3.0 Excavation of Contaminated Soil

Includes:
1. Excavate soil to achieve 95% Upper Confidence Level of the Mean Concentration Below RGs
2. Collect and analyze confirmatory samples to verify removal of contaminated soil
3. Stage and characterize waste stream

Assumptions and Calculations:

1. Cubic yards of soil excavated (assumes 20% swelling) =	2130
2. Density of excavated soil (tons/cy) =	1.5
3. Mass of excavated soil (tons) =	3195
4. Estimated Output (limited by treatment & disposal) (tons/day)	600
5. Days to excavate soil =	6
6. Days on site =	6
7. Excavator & operator ($/hr.) =	$229.00
8. Loader & operator ($/hr.) =	$87.00
9. Samples collected for waste characterization (cy/sample) =	100
10. No. of soil samples collected for waste characterization =	21
11. Excavation area (sf) =	46140
12. Samples collected for confirmation (sf/sample) =	1000
13. No. of confirmation samples from excavation area =	47
14. No. of confirmation QC samples =	3
15. Number of personnel in field crew (including subcontracted = excavator and loader operator)	5

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor:					
Field Supervisor	70	$75.00	/hr	$5,250.00	
Sample Coordinator	70	$50.00	/hr	$3,500.00	
Field Technician	70	$50.00	/hr	$3,500.00	
Subcontractor:					
Excavator & operator	60	$229.00	/hr	$13,740.00	
Wheel loader & operator	60	$87.00	/hr	$5,220.00	
Equipment:					
Field instruments (air monitor)	2	$400.00	/wk	$800.00	
Analytical:					
Soil confirmation:					
TAL metals	50	$235.00	/ea	$11,750.00	
Waste characterization:					
TCLP Metals	21	$165.00	/ea	$3,465.00	
Travel for Remediation Crew:					
Per diem	21	$38.00	/day	$798.00	
Lodging	21	$80.00	/day	$1,680.00	
Rental Car	14	$40.00	/day	$560.00	
				Subtotal	**$50,263.00**

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2
Excavation/Treatment/Off Site Disposal/
Sediment & Groundwater Monitoring/
Cap Maintenance/ICs
Capital, O&M, and Present Value Cost Estimate

Site: RSA-122/56/139
Redstone Arsenal
Date: 06/2008

4.0 Treatment of Contaminated Soil

Includes:
1. Preparation of Site Stabilization Area
2. Stabilization of hazardous soil with Portland Cement and Calcium Polysulfide
3. Confirmatory sampling of treated soil

Assumptions and Calculations:

1. Preparation of Site Stabilization Area =	$30,000
Assumes 10,000 square foot HD polyethylene liner, 6 days of work	
2. Volume of total hazardous soil - assuming all haz (cy) =	2130
3. Density of consolidated soil (tons/cy) =	1.50
4. Mass of excavated soil (tons) =	3195
5. Mix ratio of calcium polysulfide =	0.04
6. Mass of calcium polysulfide (tons) =	128
7. Mix ratio of lime =	0.10
8. Mass of lime (tons) =	320
9. Mix ratio of water =	0.06
10. Mass of water (tons) =	192
11. Volume of water (gallons) =	45971
12. Mass of treated soil (tons) =	3834
13. Additional Mass from 5% retreatment of soil (tons) =	31
14. Treated mass of soil requiring non-haz disposal (tons) =	3865
15. Treatment Rate (tons/day) =	600

Service/Materials	Unit	Unit Cost		Subtotal	
Stabilization Area:					
10,000 square ft stabilization area	1	$30,000.00	/ea	$30,000.00	
Contractor:					
Field Supervisor	80	$75.00	/hr	$6,000.00	
Sample Coordinator	80	$50.00	/hr	$4,000.00	
Field Technician	80	$50.00	/hr	$4,000.00	
Subcontractor:					
Excavator & operator	70	$229.00	/hr	$16,030.00	
Equipment:					
Field instruments	2	$400.00	/wk	$800.00	
Lime, Calcium Polysulfide and Water Costs:					
Lime	335	$125.00	/ton	$41,875	
Calcium Polysulfide	134	$160.38	/ton	$21,491	
Water Truck Rental w/ operator	2	$1,800.00	/wk	$3,600.00	
Analytical:					
Waste confirmation:					
TCLP Metals	26	$165.00	/ea	$4,290.00	
Full TCLP	2	$1,150.00	/ea	$2,300.00	
Travel for contractor crew:					
Lodging	24	$80.00	/day	$1,920.00	
Perdiem	24	$38.00	/day	$912.00	
Rental Car	12	$40.00	/day	$480.00	
				Subtotal	**$137,698.00**

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2
Excavation/Treatment/Off Site Disposal/
Sediment & Groundwater Monitoring/
Cap Maintenance/ICs
Capital, O&M, and Present Value Cost Estimate

Site: RSA-122/56/139
Redstone Arsenal
Date: 06/2008

5.0 Off-Site Disposal

Includes:
1. Load treated soil in trucks for transport & disposal
2. Dispose of non-hazardous soil at nonhazardous waste landfill located outside of RSA
3. Conducted concurrently with excavation and stabilization activities

Assumptions and Calculations:

1. Total mass of treated soil (tons) =	3865
2. Disposal Rate (tons/day) =	600
3. Disposal of Soil at Non-hazardous Landfill ($/ton) =	15

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor:					
Field Technician	80	$50.00	/hr	$4,000.00	
Subcontractor:					
Wheel loader & operator	70	$87.00	/hr	$6,090.00	
Equipment:					
Field instruments	2	$400.00	/wk	$800.00	
Disposal Costs:					
Non-haz waste transportation	3865	$19.25	/ton	$74,401.25	
Non-haz waste direct disposal	3865	$15.00	/ton	$57,975.00	
Travel for contractor crew:					
Lodging	8	$80.00	/day	$640.00	
Perdiem	8	$38.00	/day	$304.00	
Rental Car	8	$40.00	/day	$320.00	
				Subtotal	**$144,530.00**

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2
Excavation/Treatment/Off Site Disposal/
Sediment & Groundwater Monitoring/
Cap Maintenance/ICs
Capital, O&M, and Present Value Cost Estimate

Site: RSA-122/56/139
Redstone Arsenal
Date: 06/2008

6.0 Backfill Excavation and Site Restoration

Includes:
1. Backfill & compact excavated areas with borrow material from RSA
2. Spread chipped wood across the site
3. Reseed disturbed areas

Assumptions and Calculations:

1. Volume of consolidated soil excavated (cy) =	2130	
2. Compaction factor =	1.3	
3. Volume of soil required for backfill (cy) =	2769	
4. Dozer output, 200 hp (cy/day) =	600	
5. Cost of low-permeability soil ($/cy)=	5	transported to site
6. Compaction ($/cy) =	2.5	
7. Field days required to restore site =	5	
8. No. of personnel in contractor field crew =	1	
9. Hydroseed & Mulch ($/acre) =	4100	
10. Hydroseed & Mulch Area (total excavation area -acres) =	1.1	

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor:					
Field Supervisor	60	$75.00	/hr	$4,500.00	
Subcontractor:					
Backfill & compacted	2769	$7.50	/cy	$20,767.50	delivered to site
Dozer & operator	5	$1,150.00	/day	$5,750.00	
Travel for contractor crew:					
Lodging	6	$80.00	/day	$480.00	
Perdiem	6	$38.00	/day	$228.00	
Rental Car	6	$40.00	/day	$240.00	
Subcontract:					
Hydroseed & Mulch	1.1	$4,100.00	/acre	$4,510.00	
				Subtotal	**$36,476.00**

7.0 Institutional Controls

Includes:
1. Development of a Land Use Control Implementation Plan (LUCIP)
2. Incorporation of Institutional Controls into Base Master Plan and GIS-based maps in the Site Access Control program
3. Placement of warning signs

Assumptions and Calculations:

1. Number of warning signs =	45
2. Size of warning sign (s.f.) =	6
3. Cost of signage ($/s.f.) =	12
4. Cost to install sign ($/sign)	120

Service/Materials	Unit	Unit Cost		Subtotal	
Contractor:					
LUCIP	1	$15,000.00	/ea	$15,000.00	
Base Master Plan/GIS maps	1	$10,000.00	/ea	$10,000.00	
Warning Sign Installation	45	$192.00	/ea	$8,640.00	
				Subtotal	**$33,640.00**

Total Capital Cost

Capital Cost	**$605,500.00**
Contingency (30%)*	**$181,650.00**
PM Multiplier (7.5%)*	**$45,413.00**
Fee/Profit (10%)*	**$60,550.00**
Total Capital Cost	**$893,000.00**

* The contingency, PM Multiplier, and Fee/Profit was extracted from the RSA-057 cost estimate (Shaw, 2006b)

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2
Excavation/Treatment/Off Site Disposal/
Sediment & Groundwater Monitoring/
Cap Maintenance/ICs
Capital, O&M, and Present Value Cost Estimate

Site: RSA-122/56/139
Redstone Arsenal
Date: 06/2008

8.0 Average Annual Operation & Maintenance Cost

Includes:
1. Site inspection (quarterly)
2. Prepare annual certification
3. Five-year reviews (annualized cost averaged over 5 years)
4. Biannual groundwater and sediment monitoring (for 2 events over 4 years)
5. Replacement of warning signs (annualized cost averaged over 10 years)
6. Maintenance of RSA-56/RSA-139 Cap and Fenceline

Assumptions:

1. Useful life of warning signs (years) =	10
2. Number of warning signs =	45
3. Cost of 5-year review =	$20,000
4. Number of wells to be sampled =	7
5. Number of sediment locations to be sampled =	2
6. Number of sampling events per year =	0.5
7. Duration of sampling event (incl. travel) =	5
8. Cost of sampling crew including home office support ($/day) =	$2,700
9. Maintenance of fenceline and cap ($/year) =	$12,500

Contractor:					
Site Inspection	32	$75.00	/hr.	$2,400.00	
Annual Report	80	$75.00	/hr.	$6,000.00	
Sampling & Analytical:					
Sampling crew	3	$2,700.00	/day	$8,100.00	
TAL metals	9	$235.00	/ea.	$2,115.00	
Data management & reporting	0.5	$2,500.00	/ea.	$1,250.00	
Annualized Costs:					
5-Year Review	0.2	$20,000.00	/ea.	$4,000.00	
Warning Sign Replacement	4.5	$312.00	/ea.	$1,404.00	
Maintenance of Fenceline and Caps	2.0	$12,500.00	/ea.	$25,000.00	
				Subtotal	**$50,270.00**

Present Value Cost

Assumptions:
1. Duration of alternative = 30 years
for cost estimating purposes (n)
2. Duration of sampling (n) = 4 years
3. Discount rate (i) = 0.028
4. Contingency = 0 %

Note:
The Present Value of the O&M Costs for Alternative 2 = the Present Value of the Sampling Cost (4 years) + the Present Value of the remainng maintenance costs (30 years)*

Total Capital Cost	**$893,000.00**
Present Value of O&M Cost	**$823,000.00**
Total Present Value Cost	**$1,716,000.00**

* Present Value = A* $[(1+i)^n - 1]/[i*(1+i)^n]$ where A = the annual cost, i=the discount rate and n=the duration

This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

Table 12

Cost Estimate for Selected Remedy
RSA-122/56/139
Redstone Arsenal, Madison County, Alabama

Alternative 2	**Site:**	RSA-122/56/139
Excavation/Treatment/Off Site Disposal/		Redstone Arsenal
Sediment & Groundwater Monitoring/	**Date:**	**06/2008**
Cap Maintenance/ICs		
Capital, O&M, and Present Value Cost Estimate		

As - arsenic
ea - each
GIS - geographical information system
H&S - health and safety
hr - hour
lf - linear feet
mg/kg - mg/kg
O&M - operation and maintenance
P/U - pickup truck
RA - remedial action
RG - remedial goal
RSA -Redstone Arsenal
s.f. - square foot
TAL - target analyte list
wk - week

FIGURES

Tennessee

Tennessee

N

Madison
County

Tennessee River

Mississippi

Georgia

Alabama

Florida

Madison
County

Limestone
County

Huntsville

Jackson
County

Madison

Redstone Arsenal

Triana

Tennessee River

Morgan
County

Marshall
County

0 2.5 5 10
Miles

Figure 1

Location of Redstone Arsenal and Surrounding Cities of Madison County, Alabama

U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. W91ZLK-05-D-0017

Shaw® Shaw Environmental, Inc.

X:\Redstone\GIS_Documents\Project_maps\Miscellaneous\RSA_Madison_Co_Alabama_pbc_contract_no.mxd

N

0 0.5 1
Miles

Legend

RSA Installation Boundary

Roads

Surface Water Drainage (some emphemeral)

Surface Water Body

RSA-122 Site Boundary/LUC Boundary

Figure 2

Site Location Map, RSA-122, RSA-056 and RSA-139

U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. W91ZLK-05-D-0017

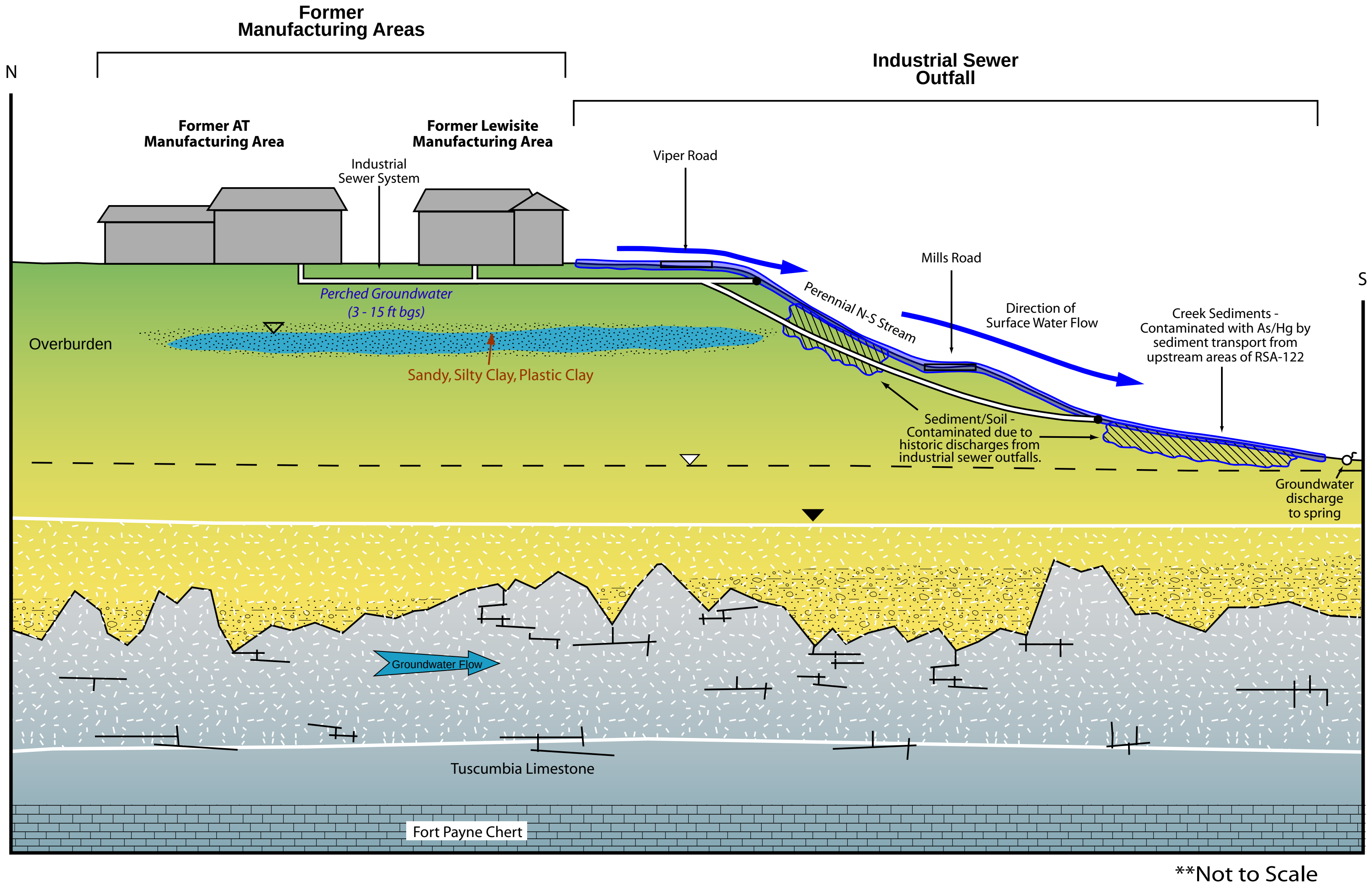
Shaw Environmental, Inc.

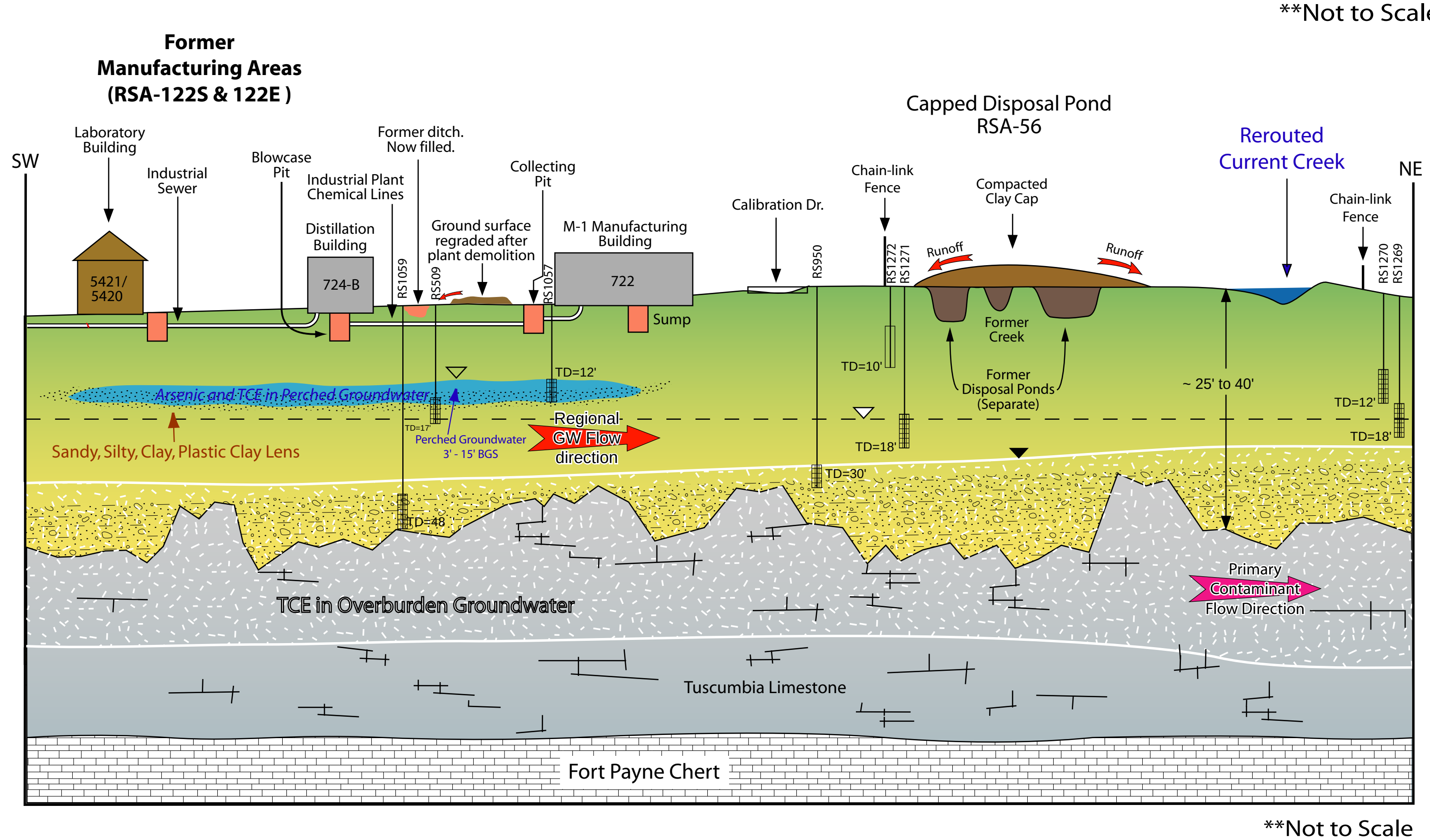
Figure 3

Site Map, RSA-122, RSA-56, RSA-139

U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. W91ZLK-05-D-0017

Shaw Shaw Environmental, Inc.





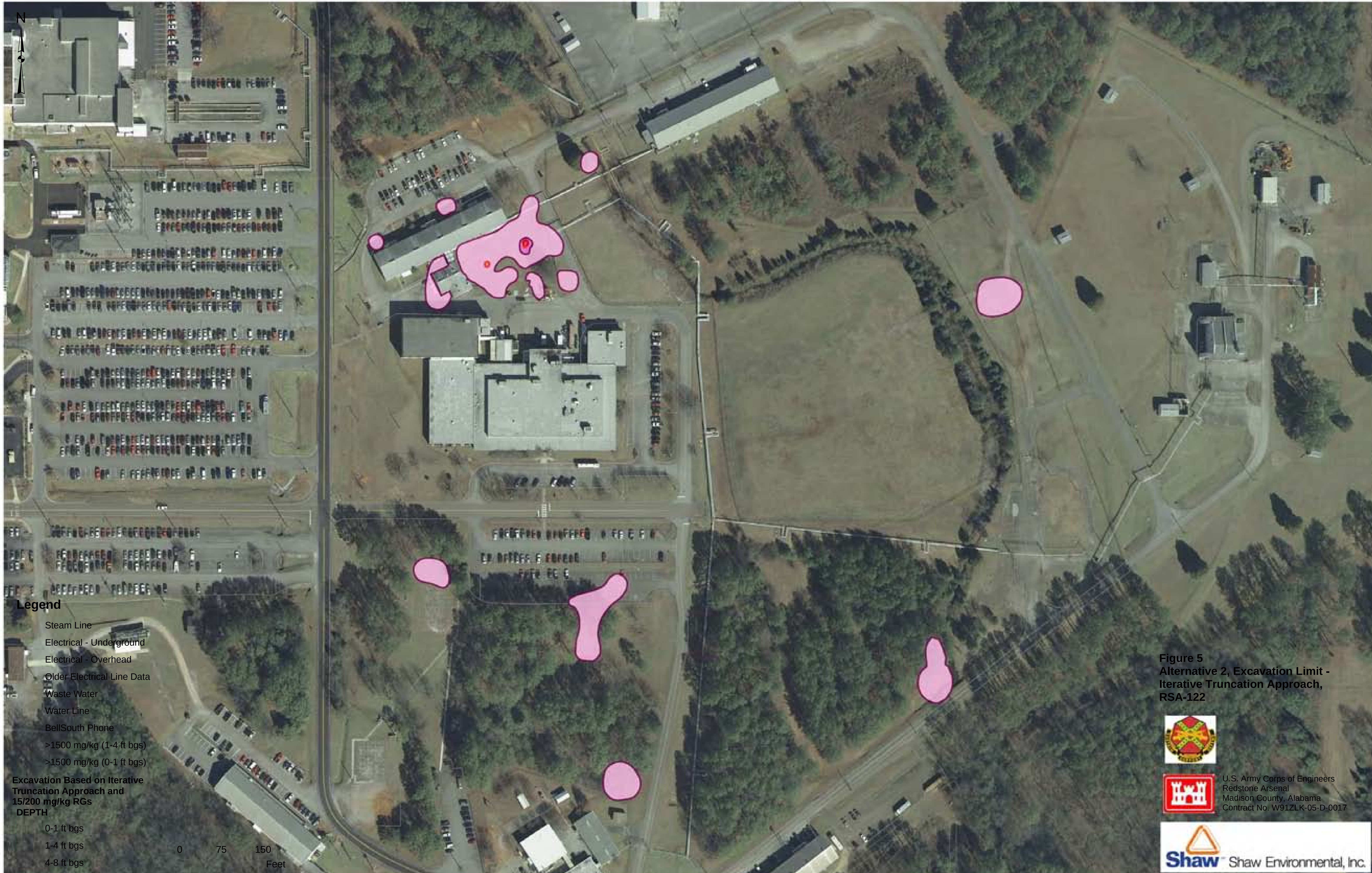
Legend

▽	Upper Range of Perched Groundwater
▽	Upper Range of Overburden Depth to Groundwater
▼	Lower Range of Overburden Depth to Groundwater
	TCE in Overburden Groundwater
TD	Total Depth
BGS	Below Ground Surface

Figure 4
Conceptual Site Model
for RSA-122

U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. W91ZLK-05-D-0017

Shaw Environmental, Inc.


N
Legend
Steam Line
Electrical - Underground
Electrical - Overhead
Older Electrical Line Data
Waste Water
Water Line
BellSouth Phone
>1500 mg/kg (1-4 ft bgs)
>1500 mg/kg (0-1 ft bgs)
Excavation Based on Iterative Truncation Approach and 15/200 mg/kg RGs
DEPTH
0-1 ft bgs
1-4 ft bgs
4-8 ft bgs
0 75 150
Feet
Figure 5
Alternative 2, Excavation Limit - Iterative Truncation Approach, RSA-122
U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. W91ZLK-05-D-0017
Shaw Shaw Environmental, Inc.

APPENDIX A

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Administrative Record File – The body of reports, official correspondence, and other documents that establish the official record of analysis, cleanup, and final closure of a CERCLA or RCRA site.

Applicable or Relevant and Appropriate Requirements (ARAR) – Evaluates whether an alternative will satisfy promulgated substantive standards, requirements, criteria, or limitations pertaining to the COCs that require response actions as established in federal environmental laws or regulations and state environmental or facility siting laws or regulations. ARARs may be waived under certain circumstances.

Arsenic – Arsenic is a naturally occurring metal-like element widely distributed in soils and rocks. Arsenic can also be released as a contaminant at hazardous waste sites. At Redstone Arsenal, arsenic was used to manufacture lewisite, a chemical warfare material.

Background Levels – Ambient concentrations of inorganic elements (metals) that are present in the environment and have not been altered by human activity.

Baseline Human Health Risk Assessment (BHHRA) – Analysis of the potential adverse human health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases.

Characterization – The compilation of all available data about the waste unit to determine the rate and extent of contaminant migration resulting from the waste site, and the concentrations of any contaminants that may be present.

Chemicals of Concern (COC) – Where cumulative risks have been found to exceed designated risk thresholds, chemicals with risks exceeding $1x\ 10^{-6}$ (or an excess lifetime cancer risk of 1 in 1,000,000) or a hazard index of 0.1 may be selected as COCs. These are chemicals that significantly contribute to unacceptable risks for a pathway in an exposure model for a hypothetical receptor (e.g., a child that resides on the site).

Chemicals of Potential Concern (COPC) – Chemicals whose concentrations exceed federal and state risk-screening levels as well as background screening levels for metals.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – Enacted by Congress in 1980 and was amended by the Superfund Amendments and Reauthorization Act in 1986. CERCLA provides federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites and established the Superfund Trust Fund. The Army is funding the investigation and clean up of RSA-122.

Dilution Attenuation Factor 4 (DAF_4) Soil Screening Level (SSL) – DAF_4 SSLs are soil threshold concentrations calculated using methodology developed by the U.S. Environmental Protection Agency (EPA) below which there is not a concern for migration of residual contaminants in soil to groundwater at concentrations above maximum contaminant levels (MCL) or risk-based screening concentrations. Dilution attenuation factors represent the reduction in the contaminant concentrations through soil. A DAF_1 means there is no dilution or attenuation through the soil column. A high DAF value means there is a high degree of dilution or attenuation. The Army in conjunction with EPA and the Alabama Department of Environmental Management has determined that a DAF_4 best matches the site-specific fate and transport processes at RSA-122.

Exposure – Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) and available for absorption.

Feasibility Study (FS) – A development and evaluation of remedial alternatives to address environmental contamination.

Groundwater – Underground water that fills pores in soil or openings in rocks to the point of saturation. Groundwater is often used as a source of drinking water via municipal or domestic wells. Groundwater that comes to the earth's surface, such as streams and springs, is considered surface water. At Redstone, the groundwater is not a source of drinking water.

Groundwater Site –Constitute sub-watersheds defined at Redstone Arsenal from a sitewide hydrogeologic investigation. Each groundwater site will proceed through a separate CERCLA investigation to get to closure of the site.

Interim Record of Decision (IROD) – Document prepared when a quick action is needed to protect human health and the environment or when a temporary measure to stabilize the site and/ or prevent contamination migration is needed. A final ROD must follow an IROD.

Land-Use Controls (LUC) – Any restriction or control, which protects human health and the environment, and limits use of and/or exposure to any portion of a property. LUCs can include engineering controls such as maintaining a cap and institutional controls which are legal and administrative restrictions.

Lewisite – An organic, arsenic based, strong blistering agent (vesicant) with the chemical name and formula of dichloro(2-chlorovinyl)arsine ($C_2H_2AsCl_3$). It was manufactured at Redstone Arsenal in the early 1940s.

Maximum Contaminant Level (MCL) – National standards for acceptable concentrations in drinking water in treatment plants producing potable water. These standards are legally enforceable standards set by the U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act.

Mercury – A metal that occurs naturally in the environment at low levels. Mercury can also be released as a contaminant at hazardous waste sites. At Redstone Arsenal, mercury was used to manufacture lewisite, a chemical warfare material.

National Priorities List (NPL) – The EPA's list of the most serious uncontrolled or abandoned waste sites, identified for possible long-term remedial response action under Superfund. EPA is required to update the NPL at least once a year. A site must be on the NPL to receive money from the Trust Fund for remedial action. The Army funds the cleanup of RSA-122.

Non-Time-Critical Removal Action – A type of cleanup that can be conducted at any time during the CERCLA process to address threats to human health or the environment. Generally conducted when there is more than 6 months available before site activities must be initiated. An engineering evaluation/cost analysis and an action memorandum are prepared to authorize and outline the removal action (e.g., installation of a cap).

Operable Unit (OU) – A discrete portion of a remedial response that comprises an incremental step toward addressing site problems. It can be a geographic area and can address an environmental medium at the site (e.g., groundwater). At Redstone Arsenal, OUs are distinguished primarily from topographic/watershed and ecological habitat/range standpoints.

Operation and Maintenance (O&M) – Activities conducted at a site after a response action occurs to ensure that the cleanup and/or systems are functioning properly.

Overall Protection of Human Health and the Environment – The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment.

Potential Threat Source Material – Materials that have a high toxicity or mobility and cannot be reliably contained or present significant risk to human health or the environment. They include liquids and other highly mobile materials or materials having high concentrations of toxic compounds.

Present Worth – A method of evaluating expenditures that occur over different time periods. By discounting all costs to a common base year, the costs for different remedial alternatives can be compared on the basis of a single figure for each alternative.

Record of Decision (ROD) – A legal document presenting the remedial action selected for a site or operable unit. It is based on information and technical analyses generated during the remedial investigation, risk assessments, feasibility study, and consideration of public comments on the proposed plan and community concerns.

Remedial Investigation (RI) – A study designed to gather data needed to determine the nature and extent of contamination at a Superfund site. The RI at Redstone includes a baseline human health risk assessment and a screening-level ecological risk assessment.

Resource Conservation and Recovery Act (RCRA), 1976 – A federal law that gives EPA the authority to control the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA focuses only on active and future facilities and does not address abandoned or historical sites.

Responsiveness Summary – A summary of oral and/or written comments received during the proposed plan comment period and includes responses to those comments. The Responsiveness Summary is a key part of the ROD, highlighting community concerns.

Soil Vapor – Vapor that resides in the interstitial pores between soil particles.

Solid Waste Management Unit (SWMU) – Site at which solid wastes have been placed at any time, regardless of whether the unit was intended for the management of solid or hazardous waste and from which contaminants may migrate.

Statement of Basis/Proposed Plan (SB/PP) – A plan for site cleanup that proposes a recommended or preferred remedial alternative. The SB/PP is available to the public for review and comment and the Preferred Alternative may change based on public and other stakeholder input. The SB is prepared to satisfy RCRA and the PP is prepared to satisfy CERCLA.

Subsurface Soil – Soil that is below 1 foot from the ground surface.

Superfund Amendments and Reauthorization Act (SARA) – Amended CERCLA in 1986. SARA resulted in more emphasis on permanent remedies for cleaning up hazardous waste sites, increased the focus on human health problems posed by hazardous waste sites, and encouraged citizen participation in making decisions on how sites should be cleaned up.

Surface Media – The soil (surface and subsurface) and soil vapor at RSA-122.

Surface Soil – Soil that is 0 to 1 feet below ground surface.

Trichloroethene (TCE) – TCE is a colorless or blue liquid with an odor similar to ether. It is man-made and does not occur naturally in the environment. TCE was once commonly used to remove oils and grease from metal parts and has been used in the dry cleaning industry.

Unrestricted Use – Use of land is without restrictions (e.g., residential homes could be built on the site) because the surface media do not have unacceptable risk from site contaminants.