# Draft-Final
# Summary Baseline Human Health Risk Assessment
# RSA-67, Operable Unit 15
# Redstone Arsenal, Madison County, Alabama
# EPA ID No. AL7 210 020 742

**Prepared for:**

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

**Prepared by:**

**IT Corporation**
**312 Directors Drive**
**Knoxville, Tennessee 37923**

**Delivery Order 0004**
**Contract No. DACA21-96-D-0018**
**IT Project No. 772650**

**August 1999**

**Revision 0**

# Table of Contents

Page

## List of Tables

## *List of Figures*

## *List of Acronyms*

| | |
|---|---|
| BHHRA | baseline human health risk assessment |
| COC | chemical of concern |
| COPC | chemical of potential concern |
| CSM | conceptual site model |
| DA | dose absorbed |
| EPA | U.S. Environmental Protection Agency |
| FI | fraction exposure |
| GAF | gastrointestinal absorption factor |
| HI | hazard index |
| IEUBK | integrated exposure uptake biokinetic |
| ILCR | incremental lifetime cancer risk |
| IT | IT Corporation |
| MDC | maximum detected concentration |
| MSFC | George C. Marshall Space Flight Center |
| µg/dL | micrograms per deciliter |
| OU | Operable Unit |
| PC | permeability coefficient |
| PEF | particulate emission factor |
| PELA | P.E. LaMoreaux and Associates, Inc. |
| RBC | risk-based concentration |
| RBSC | risk-based screening concentration |
| RfD | reference dose |
| RGO | remedial goal option |
| RI | remedial investigation |
| RME | reasonable maximum exposure |
| RSA | Redstone Arsenal |
| Rust | Rust Environment and Infrastructure, Inc. |
| SF | slope factor |
| UCL | upper confidence limit |
| WP | work plan |

# 1.0 Introduction

This report presents a summary of a baseline human health risk assessment (BHHRA) for RSA-67 at Redstone Arsenal (RSA), Madison County, Alabama. This BHHRA was performed as part of a remedial investigation (RI) initiated by the U.S. Army under the Comprehensive Environmental Response, Compensation, and Liability Act. The BHHRA provides an estimate of potential current and future human health risk associated with hazardous substance releases at this site. The purpose of this report is to summarize the essential elements of a BHHRA for this site to support a complete technical review and risk management decisions. This site is part of Operable Unit (OU)-15 (Figure 1-1); therefore, this report will eventually be incorporated into the RI report for OU-15. The results of the BHHRA support the overall characterization of the site and serve as part of the baseline used to develop, evaluate, and select appropriate remedial alternatives.

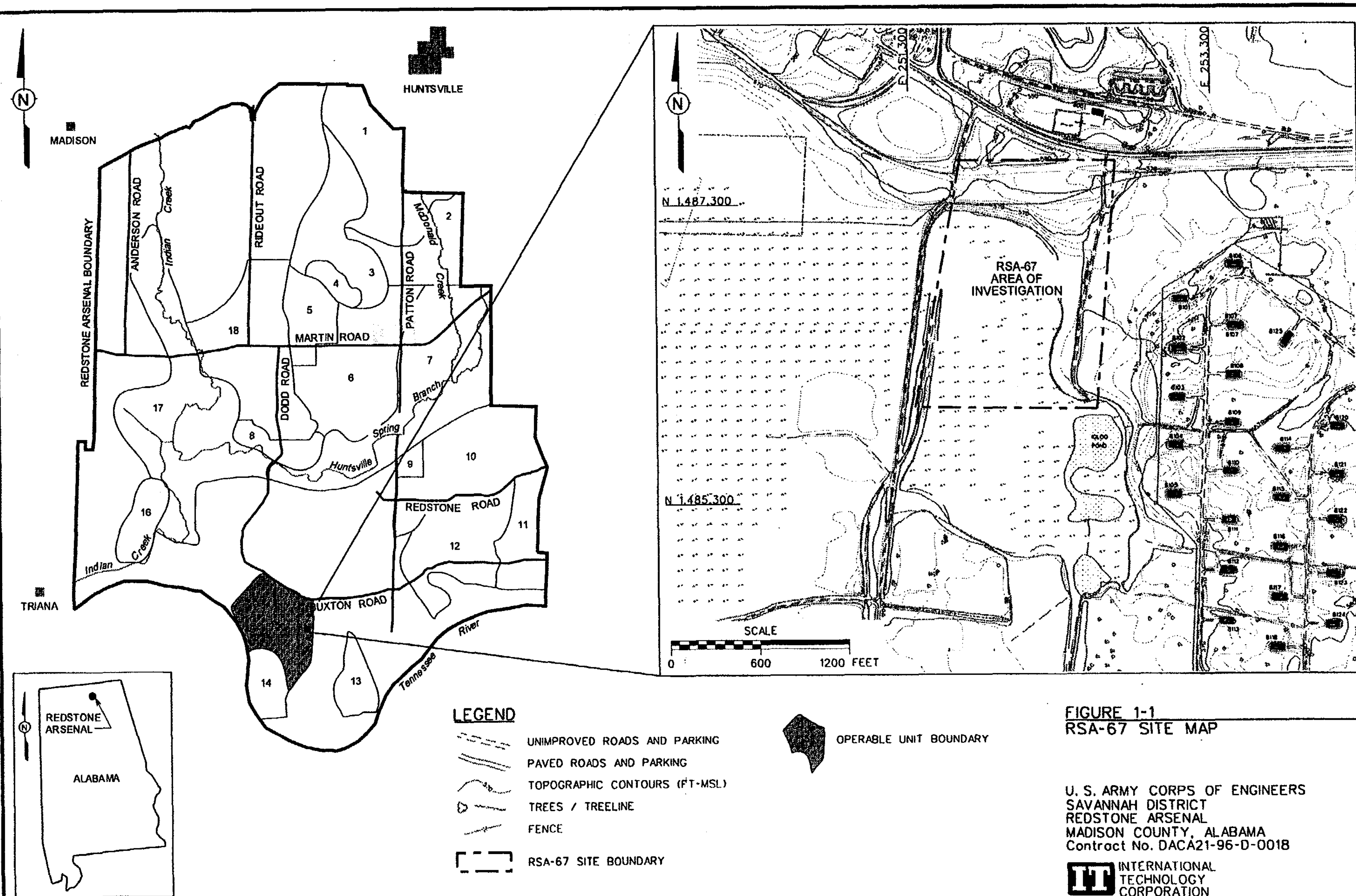
This BHHRA was conducted in accordance with the installation-wide work plan (WP) (IT Corporation [IT], 1997) and the revisions based on response to regulator comments on the WP. The WP was based on U.S. Environmental Protection Agency (EPA) guidance including, but not limited to, the following:

- EPA, 1995, *Supplemental Guidance to RAGS: Region IV Bulletins*, Region 4, Office of Health Assessment, Waste Management Division, EPA Region IV, Atlanta, Georgia, November.

- EPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, Interim Final, Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002.

- EPA, 1991a, *Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Including Revisions to Chapter 4 (November 1992), and Appendix D: Corrections to RAGS-Part B Sections 3.3.1 and 3.3.2 (April 1993)*, Office of Emergency and Remedial Response, Washington, DC, Publication 9285.7-01B.

- EPA, 1992a, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, Interim Final, Office of Emergency and Remedial Response, Washington, DC, Publication 9285.7-081.




## LEGEND

- UNIMPROVED ROADS AND PARKING
- PAVED ROADS AND PARKING
- TOPOGRAPHIC CONTOURS (FT-MSL)
- TREES / TREELINE
- FENCE
- RSA-67 SITE BOUNDARY
- OPERABLE UNIT BOUNDARY

FIGURE 1-1
RSA-67 SITE MAP

U. S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
REDSTONE ARSENAL
MADISON COUNTY, ALABAMA
Contract No. DACA21-96-D-0018

INTERNATIONAL TECHNOLOGY CORPORATION

| | | | | |
|---|---|---|---|---|
| STARTING DATE: 07/31/98 | DATE LAST REV.: | DRAFT. CHCK. BY: K. KINDER | INITIATOR: K. KINDER | DWG. NO.: ...\772650es.825 |
| DRAWN BY: L. STOUT | DRAWN BY: | ENGR. CHCK. BY: | PROJ. MGR.: D.BURTON | PROJ. NO.: 772650 |

01 JUL 99 15:50:01
c:\cadd\design\772650es.825
ctumin

- EPA, 1992b, *Dermal Exposure Assessment: Principles and Applications*, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

- EPA, 1992c, *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26.

- EPA, 1991b, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final*, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.

- EPA, 1997a, *Exposure Factors Handbook*, Volumes 1-3, Office of Research and Development, Washington, D.C., EPA/600/P-95/002F.

This report is organized as follows. A summary of the site history is presented in the remainder of this chapter. Analytical data validation, selection of chemicals of potential concern (COPC) for each medium of interest, and estimation of source-term concentrations for each COPC in each medium are described in Chapter 2.0. The exposure scenarios and the rationale by which plausible receptors are selected, the pathways by which they may be exposed, the exposure-point concentrations of COPC, and the estimated dose or contact rates for each of the COPC are presented in Chapter 3.0. The toxicity assessment and risk characterization methodology discussions are referenced in Chapter 4.0; the toxicity values used in this assessment are presented in this chapter. The toxicity assessment and risk characterization methodology in this BHHRA follows the guidance provided in the WP (IT, 1997); therefore, this summary report does not included a detailed discussion of these subjects. The risk characterization results, Chapter 5.0, combine the output of the exposure analysis and the toxicity analysis to quantify the risk to each receptor. The risk-based remedial goal options (RGO) are presented in Chapter 6.0. Chapter 7.0 presents the uncertainty analysis, where the uncertainties associated with the various assumptions and parameters used in the BHHRA are addressed qualitatively. Conclusions of the BHHRA are presented in Chapter 8.0. References are provided in Chapter 9.0.

***Site History and Description.*** RSA is divided into 18 OUs. Four primary delineation criteria used to define these OUs were: watersheds, critical and sensitive ecological habitats, soil types, and land use patterns. Major watershed boundaries provided the initial delineation of the OUs at RSA. Within these boundaries, additional OUs were established to accommodate critical and sensitive ecological habitats. Different soil types support distinctive vegetation patterns and, where definitive, additional OUs were established to reflect these patterns and to facilitate evaluation of potential contamination impacts on these areas. Locations with high human activity can impact ecological receptors; this played a role in the further refinement of OUs into the current grouping of 18. RSA-67 falls within OU-15, which also includes RSA-32, RSA-65, RSA-66, RSA-68, RAS-69, RSA-70, and RSA-110.

RSA-67 was used for aboveground drum storage of mustard gas in the 1940s and 1950s. The vicinity of RSA-67 is generally flat. The site consists of approximately 30 acres, which are largely inundated with water. The remaining areas are heavily wooded. It is located in the southern part of RSA, south of Buxton Road and within the Tennessee River Flood Plain (Figure 1-1). The site contains numerous square, flat, storage areas, each occupying approximately 200 square feet. These cells are separated by earthen berms, railcar tracks, and trails. The storage cells were used to store drums of chemical agent and create a grid pattern over much of the site.

# 2.0 Selection of Chemicals of Potential Concern

This chapter presents the selection of COPC for all media at RSA-67. The results of the COPC selection will provide risk managers perspective of the overall characterization of the site and serve as part of the baseline used to develop, evaluate, and select appropriate remedial alternatives.

This COPC selection portion of the BHHRA was conducted in accordance with the WP (IT, 1997) and the revisions based on response to regulatory agency comments on the WP.

## 2.1 Data Sources and Usability

The purpose of this section is to describe the sources of data and to evaluate the acceptability of the analytical data to be used in the quantitative risk assessment (EPA, 1989). Data collected during site characterization (P.E. LaMoreaux and Associates, Inc. [PELA], 1988) and during a supplemental investigation (Rust Environment and Infrastructure, Inc. [Rust], 1998) were evaluated for use in the risk assessment.

Definitions for the various data validation qualifiers are provided in Section 5.1 of the WP (IT, 1997). "J" qualified data were used in the risk assessment; "R" qualified data were not. Analytical data results with laboratory "B" qualifiers ("detected in blank") were used if the sample concentration was greater than 5 times the blank concentration for most analytes and greater than 10 times the blank concentration for common laboratory contaminants (acetone, 2-butanone, methylene chloride, toluene, and phthalate esters). Data exceeding these criteria were not "B" qualified following data validation. The handling of "U" qualified data (nondetects) in the COPC selection is described in Section 2.3 of this BHHRA.

### 2.1.1 Site-Related Data

Soil and groundwater samples from the RI (Rust, 1998) and site investigations (PELA, 1988) were used in this BHHRA (Table 2-1). Soil sample 06701 was not included in the risk assessment because it was collected significantly outside the site boundaries and would not be representative of site conditions (Figure 2-1). Subsurface soil is considered to be limited to 6 feet below ground surface due to a shallow groundwater table (i.e., reflecting a reasonable potential maximum depth for construction or other excavations).

## Table 2-1

## Sampling Summary for RSA-67 Sampling Locations
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Location | Sample Number | Date | Depth (ft) | Analyses | Investigation |
|---|---|---|---|---|---|
| **Surface Soil** | | | | | |
| 06701 [a] | 06701-SB-01 | 10/17/96 | 1 | Chem Agents, Thiodiglycol, Metals, Pest, SVOC, VOC | Rust, 1998 |
| PEL-AAS1 | AAS1-A-2 | 3/30/88 | 2 | Metals, SVOC, VOC | PELA, 1988 |
| PEL-AAS2 | AAS2-A-2 | 3/30/88 | 2 | Metals, SVOC, VOC | PELA, 1988 |
| PEL-AAS3 | AAS3-A-2 | 3/30/88 | 2 | Metals, SVOC, VOC | PELA, 1988 |
| **Deep Soil** | | | | | |
| 06701 [a] | 06701-SB-04 | 10/17/96 | 4 | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| PEL-AAS1 | AAS1-B-6 | 3/30/88 | 6 | Metals, SVOC, VOC | PELA, 1988 |
| PEL-AAS2 | AAS2-B-6 | 3/30/88 | 6 | Metals, SVOC, VOC | PELA, 1988 |
| PEL-AAS3 | AAS3-B-6 | 3/30/88 | 6 | Metals, SVOC, VOC | PELA, 1988 |
| **Sediment** | | | | | |
| 06702 | 060702-SD | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06703 | 060703-SD | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06704 | 060704-SD | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06705 | 060705-SD | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06706 | 060706-SD | 10/17/96 | | Chem Agents, Thiodiglycol, Metals, Pest, SVOC, VOC | Rust, 1998 |
| 06707 | 060707-SD | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| **Surface Water** | | | | | |
| 06702 | 060702-SW | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06703 | 060703-SW | 10/17/96 | | Chem Agents, Thiodiglycol, Metals, Pest, SVOC, VOC, Cyanide | Rust, 1998 |
| 06704 | 060704-SW | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06705 | 060705-SW | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06706 | 060706-SW | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| 06707 | 060707-SW | 10/17/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| **Groundwater** | | | | | |
| RS-156 | 067156-MW | 10/2/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| RS-157 | 067157-MW | 10/2/96 | | Chem Agents, Thiodiglycol, Metals, Pest, SVOC, VOC, Cyanide | Rust, 1998 |
| RS-158 | 067158-MW | 10/2/96 | | Chem Agents, Arsenic, Thiodiglycol | Rust, 1998 |
| RS-156 | RS156-88FEB | 2/1/88 | | Metals (unfiltered only), SVOC, VOC | PELA, 1988 |
| RS-157 | RS157-88FEB | 2/1/88 | | Metals (unfiltered only), SVOC, VOC | PELA, 1988 |
| RS-158 | RS158-88FEB | 2/1/88 | | Metals (unfiltered only), SVOC, VOC | PELA, 1988 |

[a] Sample was excluded from the human health baseline risk assessment (see section 2.1.1).

13 JUL 1999 10:31:33
C:\CADD\DESIGN\772650ES.450 SMCCAWLE

| | | | | |
|---|---|---|---|---|
| STARTING DATE: 06APR98 | DATE LAST REV.13 JUL 1999 | DRAFT. CHCK. BY: C.TUMLIN | INITIATOR: S.GUHA | DWG. NO.: \772650ES.450 |
| DRAWN BY: M. CRAFT | DRAWN BY: SMCCAWLE | ENGR. CHCK. BY: | PROJ. MGR.: D.BURTON | PROJ. NO.: 772650 |

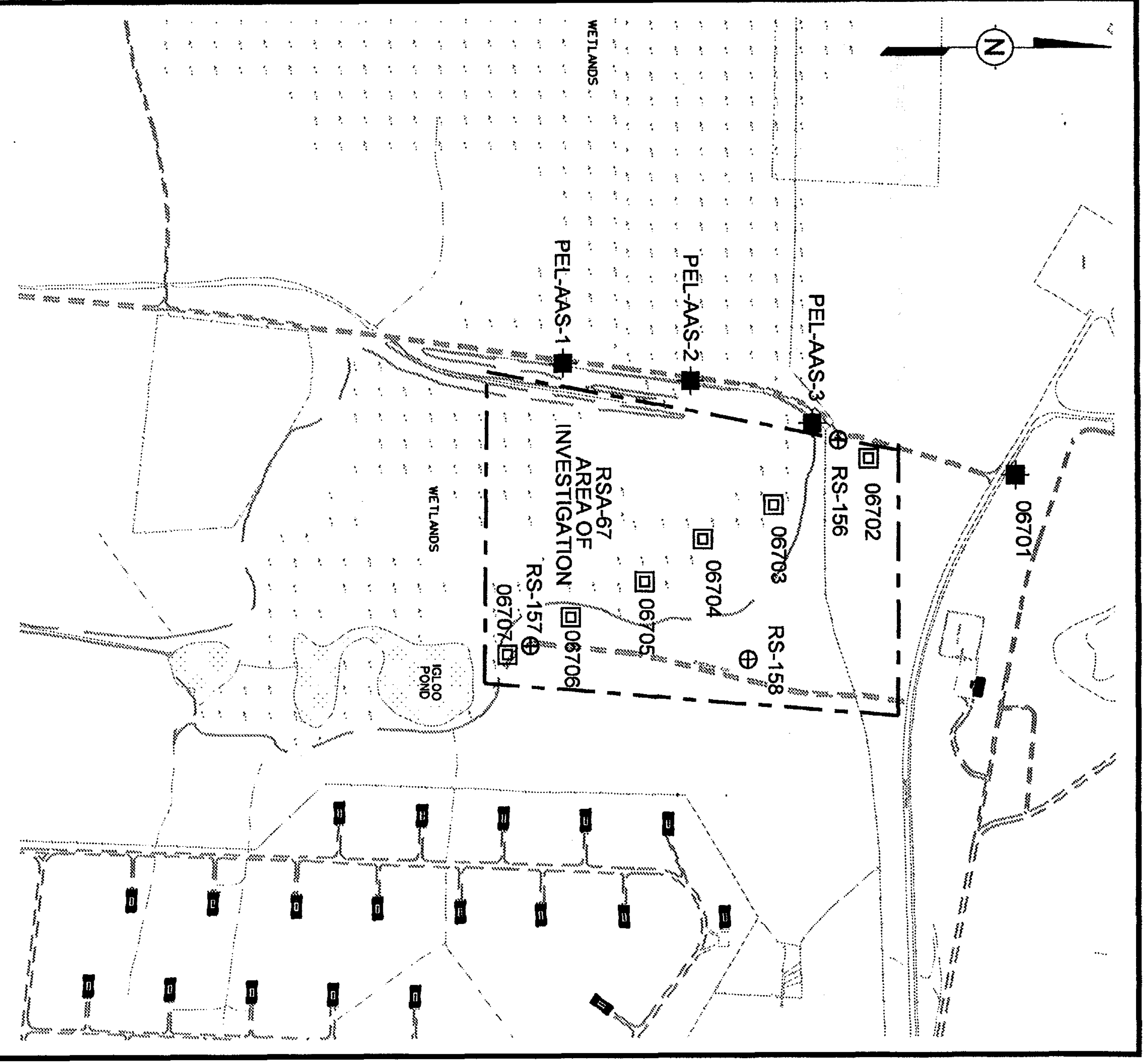



FIGURE 2-1
RSA-67 SAMPLING LOCATIONS

U.S. ARMY CORPS OF ENGINEERS
SAVANNAH DISTRICT
REDSTONE ARSENAL
MADISON COUNTY, ALABAMA
Contract No. DACA21-96-D-0018

INTERNATIONAL TECHNOLOGY CORPORATION

### 2.1.2 Background Data

Background data for surface and subsurface soil were based on the RSA installation-wide background study (IT, 1998). Groundwater background data were based on a background study conducted previously at George C. Marshall Space Flight Center (MSFC) (CH2M Hill, 1997). Surface water and sediment background data were also obtained from a background study conducted at MSFC (CH2M Hill, 1997) and revised as described in the following text.

A review was conducted of the representative background sampling locations for surface water and sediment that were presented in the draft final report of MSFC background sampling (CH2M Hill, 1997) to identify any locations that might be impacted by RSA site contamination. Two locations downgradient of the RSA sites, SWBK-017/SDBK-017 and SWBK-022/SDBK-022, were identified as sites that might have been affected by drainage contamination and not representative candidates to be included in the background data. Two additional locations, SWBK-003/SDBK-003 and SWBK-006/SDBK-006, were not included in the original background data and were excluded from the revised data as well.

The analytical data from SWBK-017/SDBK-017 and SWBK-022/SDBK-022 were eliminated from the original surface water and sediment background data and revised data were compiled from locations. This revised background data for surface water and sediment was used as RSA background data because it presents a more reliable representation of background conditions.

## 2.2 Selection of COPC

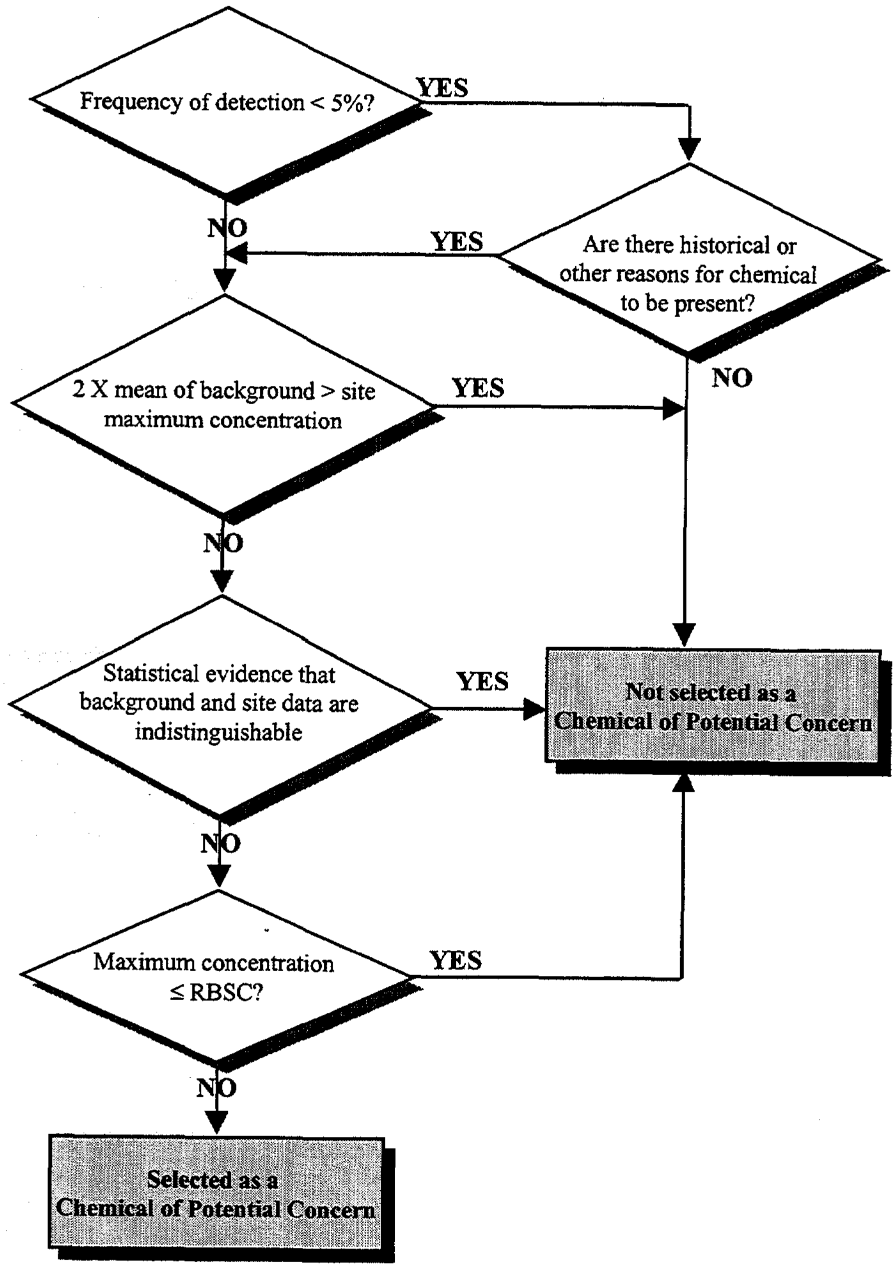
This process includes evaluating the sample collection and analytical methods used, evaluating the quality of the data, and comparing the concentrations to EPA (1998) risk-based criteria and to background concentrations. The process will identify those chemicals potentially harmful to human health if present at the site, and those that are likely to be naturally occurring. Once the data were complete, summary statistics on site and background analytical data were compiled and source-term concentrations for all chemicals were estimated.

***Selection Criteria.*** The process flow for selection of COPC is presented in Figure 2-2. The selection criteria for chemicals to be retained as COPC, as recommended by EPA (1989), include:

- ***Frequency of Detection.*** Chemicals were eliminated if they were detected infrequently (5 percent or lower frequency of detection), providing there was no

## Figure 2-2

## Decision Flow for Selection of Chemicals of Potential Concern Redstone Arsenal Site No. 67, Madison County, Alabama



evidence that infrequent detection reflected a "hot spot" location. Chemicals that are detected infrequently may be artifacts in the data that may not reflect site-related activity or disposal practices. As such, these chemicals should not be included in the risk assessment. Generally, chemicals that are detected only at low concentrations in less than 5 percent of the samples from a given medium are dropped from further consideration, unless their presence is expected based on historical information about the site. Chemicals detected infrequently at high concentrations may identify the existence of "hot spots" and were retained in the evaluation, unless other information exists to suggest that their presence was unlikely to be related to site activities.

- ***Background.*** Chemical concentrations were compared to background concentrations as an indication of whether a chemical is present from site-related activity or as background. This comparison is generally valid for inorganic chemicals, but not usually for organic chemicals, because inorganic chemicals are naturally occurring and most organic chemicals are not. For RSA-67, background was evaluated for inorganic chemicals only. It was assumed that background anthropogenic organic compounds were not applicable to RSA-67. In accordance with Region IV guidance (EPA, 1995) for background screening, maximum detected concentrations (MDC) were compared with two times the mean background concentration; chemicals with concentrations less than the background screen were eliminated from further consideration. If the MDC exceeded two times background, the chemical was retained as a COPC. If the MDC exceeded background marginally, further statistical testing was performed to compare the site with background data.

- ***Risk-Based Screening.*** A risk-based screening step for human health was introduced early in the COPC selection process to focus the assessment on the chemicals that may contribute significantly to overall risk. In this step, concentrations were compared with very conservative levels derived for standard exposure scenarios. Chemicals whose concentrations were below the risk-based screening concentration (RBSC) were not considered further in the risk assessment because it was very unlikely that they would cause significant risk. RBSCs for soil, sediment, and groundwater consisted of EPA (1998) Region III risk-based concentrations (RBC) adjusted, if necessary, to reflect an incremental lifetime cancer risk (ILCR) of $1 \times 10^{-6}$ and a hazard index (HI) of 0.1. One-tenth of the RBSC value was used as a conservative screening criteria for hazard because the initial screening process was not intended to account for additivity between chemicals and/or pathways. Soil contaminant concentrations were compared with "residential soil" RBSCs, and groundwater contaminant concentrations were compared with "tap water" RBSCs. Surface water concentrations were compared with federal ambient water quality criteria for human health based on ingestion of drinking water and aquatic organisms (EPA, 1992d). For chemicals with unpublished ambient water quality criteria, the residential tap water RBSCs were used in the risk screen because they are considered sufficiently conservative.

- ***Nutrients.*** Essential nutrients (i.e., calcium, chloride, iodine, magnesium, phosphorus, potassium, and sodium) were eliminated as COPC. Their presence in a particular medium was judged to be unlikely to cause adverse effects on human health. An oral reference dose (RfD) for iron is available. However, some published standard values that describe the relative carcinogenicity or toxicity of a COPC do not accurately represent the threat posed by that chemical. This reference concentration (RfD) is not considered reliable by EPA Region IV because it is based on inadvertent iron consumption from beer brewed in iron vessels. Based on EPA Region IV recommendation, if iron is selected as a COPC, its hazard to human health will be evaluated in the uncertainty section (Chapter 7.0).

- ***Chemical Specificity.*** Analytical results that were not specific for a particular compound were excluded from further consideration, unless toxicity values were located that sufficiently reflected the toxicity of the constituent.

  Chemicals not eliminated in the COPC selection will be retained for further analysis in a BHHRA.

### *2.3 Summary Statistics of Site-Related Data*

The statistical methods used in data evaluation are discussed in this section, and reflect EPA headquarters guidance (EPA, 1992a). The samples evaluated in this BHHRA and a list of analyses performed on each sample is presented in Table 2-1. The summary statistics on site-related surface soil, subsurface soil, groundwater, surface water and sediment data are listed in Tables 2-2 through 2-6, with the summary of COPC selected presented in Table 2-7. All chemicals that were detected in the chemical analyses are evaluated in these tables. Those chemicals that were detected but not selected as COPC are not considered further.

For each set of data used to describe the concentration of chemicals in a medium, the following information was tabulated:

- Chemical name
- Frequency of detection
- Range of detected concentrations
- Range of detection limits
- Statistical distribution
- Arithmetic mean
- 95 percent upper confidence limit (UCL) on the mean of the concentration
- Two times the arithmetic mean of background concentrations
- Appropriate RBSCs
- Selection as COPC
- Source-term concentration.

**Table 2-2**

**Selection of Chemicals of Potential Concern, Surface Soil[a]**
**RSA-67**
**Redstone Arsenal, Madison County, Alabama**

| Chemical | Detection Frequency | Range of values, mg/kg: Detected Concentration Minimum | Detected Concentration Maximum | Detection Limits Minimum | Detection Limits Maximum | Statistical Distribution [b] | Mean mg/kg | Background Screening Criterion mg/kg [c] | Risk-Based Screening Criterion mg/kg [d] | COPC? [e,f] | Source Term Concentration mg/kg [g] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | |
| Arsenic | 3 / 3 | 4.75E+00 | 5.75E+00 | ND | ND | U | 5.25E+00 | 9.47E+00 | 4.30E-01 | N (a) | --- |
| Barium | 3 / 3 | 5.70E+01 | 6.90E+01 | ND | ND | U | 6.37E+01 | 2.94E+02 | 5.50E+02 | N (a) | --- |
| Chromium (VI) | 3 / 3 | 2.50E+01 | 3.70E+01 | ND | ND | U | 3.17E+01 | 5.78E+01 | 2.30E+01 | N (a) | --- |
| Lead | 3 / 3 | 1.35E+01 | 1.60E+01 | ND | ND | U | 1.44E+01 | 4.51E+01 | 4.00E+02 [h] | N (a) | --- |

[a] Surface soil is defined as the interval less than or equal to 1 foot below the ground surface. Soil samples were classified on the basis of the end depth of the sample.

[b] Statistical Distribution: U = Distribution not determined if sample size is 4 or less.

[c] Background criteria for inorganic constituents are based on 2 times the mean concentration of the background data set (IT, 1998, Installation-Wide Background Soil Study Report).

[d] Based on Region III risk-based concentrations (RBCs) for residential soil ingestion, adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 and a hazard index of 0.1 (EPA, 1998, *Risk-Based Concentration Table*, 1 October, EPA Region III, Philadelphia, PA, on-line).

[e] Rationale for exclusion of chemical as a contaminant of potential concern (COPC):
(a) = within background concentration.

[f] N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.

[g] Concentration used in risk assessment is equal to maximum detected value.

[h] Screening criteria for lead based on the residential soil screening value of 400 mg/kg (EPA, 1994, "Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil," Memorandum from Lynn R. Goldman, Assistant Administrator, to EPA Regional Directors, dated July 14).

ND = No Data.

## Table 2-3

### Selection of Chemicals of Potential Concern, Subsurface Soil[a]
### RSA-67
### Redstone Arsenal, Madison County, Alabama

| Chemical | Detection Frequency | Range of values, mg/kg: Detected Concentration Minimum | | Maximum | Detection Limits Minimum | | Maximum | Statistical Distribution [b] | Mean mg/kg | 95% UCL mg/kg [c] | Background Screening Criterion mg/kg [d] | Risk-Based Screening Criterion mg/kg [e] | COPC? [f,g] | Source Term Concentration mg/kg [h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | | | | |
| Arsenic | 3 / 3 | 2.98E+00 | - | 6.50E+00 | ND | - | ND | U | 5.24E+00 | | 1.25E+01 | 4.30E-01 | N (a) | --- |
| Barium | 3 / 3 | 5.00E+01 | - | 1.21E+02 | ND | - | ND | U | 7.87E+01 | | 1.71E+02 | 5.50E+02 | N (a) | --- |
| Chromium (VI) | 3 / 3 | 2.70E+01 | - | 4.20E+01 | ND | - | ND | U | 3.60E+01 | | 1.11E+02 | 2.30E+01 | N (a) | --- |
| Lead | 3 / 3 | 1.33E+01 | - | 1.67E+01 | ND | - | ND | U | 1.50E+01 | | 3.39E+01 | 4.00E+02 [i] | N (a) | --- |

[a] Subsurface soil is defined as the interval greater than 1 foot and less than 6 feet below the ground surface. Soil samples were classified on the basis of the end depth of the sample.

[b] Statistical Distribution: U = Distribution not determined if sample size is 4 or less.

[c] 95% Upper confidence limit not applicable.

[d] Background criteria for inorganic constituents are based on 2 times the mean concentration of the background data set (IT, 1998, Installation-Wide Background Soil Study Report).

[e] Based on Region III risk-based concentrations (RBCs) for residential soil ingestion, adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 and a hazard index of 0.1 (EPA, 1998, *Risk-Based Concentration Table*, 1 October, EPA Region III, Philadelphia, PA, on-line).

[f] Rationale for exclusion of chemical as a contaminant of potential concern (COPC):
(a) = within background concentration.

[g] N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.

[h] Concentration used in risk assessment is equal to the maximum detected value.

[i] Screening criteria for lead based on the residential soil screening value of 400 mg/kg (EPA, 1994, "Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil," Memorandum from Lynn R. Goldman, Assistant Administrator, to EPA Regional Directors, dated July 14).

ND = No Data.

## Table 2-4

### Selection of Chemicals of Potential Concern, Residuum Groundwater[a]
### RSA-67
### Redstone Arsenal, Madison County, Alabama

| Chemical | Detection Frequency | Range of values, µg/L: Detected Concentration Minimum | Detected Concentration Maximum | Detection Limits Minimum | Detection Limits Maximum | Statistical Distribution [b] | Mean µg/L | 95% UCL µg/L [c] | Background Screening Criterion µg/L [d] | Risk-Based Screening Criterion µg/L [e] | COPC? [f,g] | Source Term Concentration µg/L [h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | | |
| Aluminum | 1 / 1 | 6.67E+03 | 6.67E+03 | ND | ND | U | 6.67E+03 | | 3.44E+03 | 3.70E+03 | Y | 6.67E+03 |
| Arsenic | 2 / 6 | 4.70E+00 | 7.10E+01 | 1.00E+00 | 1.20E+00 | U | 1.30E+01 | | 3.20E+00 | 4.50E-02 | Y | 7.10E+01 |
| Barium | 2 / 4 | 1.19E+02 | 5.20E+02 | 2.00E+00 | 1.00E+02 | U | 1.85E+02 | | 4.28E+01 | 2.60E+02 | Y | 5.20E+02 |
| Cadmium | 2 / 4 | 2.97E+00 | 3.50E+01 | 1.00E-01 | 5.00E+00 | U | 1.07E+01 | | | 1.80E+00 [i] | Y | 3.50E+01 |
| Calcium | 1 / 1 | 6.93E+04 | 6.93E+04 | ND | ND | U | 6.93E+04 | | 8.48E+04 | Nutrient | N (b) | --- |
| Chromium (VI) | 2 / 4 | 2.26E+01 | 2.50E+02 | 1.00E-01 | 4.00E+01 | U | 7.82E+01 | | 7.24E+01 | 1.10E+01 | Y | 2.50E+02 |
| Cobalt | 1 / 1 | 2.30E+01 | 2.30E+01 | ND | ND | U | 2.30E+01 | | 1.08E+01 | 2.20E+02 | N (c) | --- |
| Copper | 1 / 1 | 8.39E+00 | 8.39E+00 | ND | ND | U | 8.39E+00 | | | 1.50E+02 | N (c) | --- |
| Iron | 1 / 1 | 1.51E+04 | 1.51E+04 | ND | ND | U | 1.51E+04 | | 2.54E+04 | 1.10E+03 | N (a) | --- |
| Lead | 3 / 3 | 2.00E+00 | 8.80E+01 | 1.00E-01 | 1.00E-01 | U | 3.20E+01 | | 2.80E+00 | 1.50E+01 [j] | Y | 8.80E+01 |
| Magnesium | 1 / 1 | 2.79E+03 | 2.79E+03 | ND | ND | U | 2.79E+03 | | 7.25E+03 | Nutrient | N (b) | --- |
| Manganese | 1 / 1 | 4.18E+03 | 4.18E+03 | ND | ND | U | 4.18E+03 | | 3.38E+02 | 7.30E+01 | Y | 4.18E+03 |
| Nickel | 1 / 1 | 2.23E+01 | 2.23E+01 | ND | ND | U | 2.23E+01 | | 3.27E+01 | 7.30E+01 | N (a) | --- |
| Potassium | 1 / 1 | 1.16E+03 | 1.16E+03 | ND | ND | U | 1.16E+03 | | 2.74E+03 | Nutrient | N (b) | --- |
| Silver | 1 / 4 | 3.70E+00 | 3.70E+00 | 1.00E+01 | 1.00E+01 | U | 4.68E+00 | | | 1.80E+01 | N (c) | --- |
| Sodium | 1 / 1 | 1.77E+03 | 1.77E+03 | ND | ND | U | 1.77E+03 | | 8.04E+03 | Nutrient | N (b) | --- |
| Vanadium | 1 / 1 | 1.92E+01 | 1.92E+01 | ND | ND | U | 1.92E+01 | | 2.34E+01 | 2.60E+01 | N (a) | --- |
| Zinc | 1 / 1 | 5.06E+01 | 5.06E+01 | ND | ND | U | 5.06E+01 | | 9.38E+01 | 1.10E+03 | N (a) | --- |

[a] Residuum groundwater is defined as water collected from overburden monitoring wells RS156, RS157, and RS158.
[b] Statistical Distribution: U = Distribution not determined if sample size is 4 or less.
[c] 95% Upper confidence limit not applicable.
[d] Background criteria for inorganic constituents are based on 2 times the mean concentration of the background data set (CH2M Hill, 1997, Report of MSFC Background Sampling).
[e] Based on Region III risk-based concentrations (RBCs) for tap water, adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 and a hazard index of 0.1 (EPA, 1998, *Risk-Based Concentration Table*, 1 October, EPA Region III, Philadelphia, PA, on-line).
[f] Rationale for exclusion of chemical as a contaminant of potential concern (COPC):
- (a) = within background concentration.
- (b) = essential nutrient.
- (c) = maximum detection is less than screening criteria.

[g] N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.
[h] Concentration used in risk assessment is equal to maximum detected value.
[i] RBC based on cadmium-water.
[j] Screening criteria for lead based on the action level of 15 µg/L (EPA, 1996, *Drinking Water Regulations and Health Advisories*, Office of Water, Washington, DC, October).
ND = No Data.

## Table 2-5

### Selection of Chemicals of Potential Concern, Surface Water[a]
### RSA-67
### Redstone Arsenal, Madison County, Alabama

| Chemical | Detection Frequency | Range of values, µg/L: Detected Concentration Minimum | Detected Concentration Maximum | Detection Limits Minimum | Detection Limits Maximum | Statistical Distribution [b] | Mean µg/L | Standard Deviation | 95% UCL µg/L [c] | Background Screening Criterion µg/L [d] | Risk-Based Screening Criterion µg/L [e] | COPC? [f,g] | Source Term Concentration µg/L [h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | | | |
| Aluminum | 1 / 1 | 1.09E+03 | 1.09E+03 | ND | ND | U | 1090 | NA | | 8.42E+02 | 3.70E+03 [i] | N (c) | --- |
| Arsenic | 5 / 6 | 1.45E+00 | 4.95E+00 | 1.20E+00 | 1.20E+00 | N | 2.95 | 1.81907 | 4.45E+00 | | 1.80E-02 | Y | 4.45E+00 |
| Barium | 1 / 1 | 6.79E+01 | 6.79E+01 | ND | ND | U | 67.9 | NA | | 6.40E+01 | 2.60E+02 [i] | N (c) | --- |
| Calcium | 1 / 1 | 1.44E+04 | 1.44E+04 | ND | ND | U | 14400 | NA | | 6.93E+04 | Nutrient | N (d) | --- |
| Chromium (VI) | 1 / 1 | 3.75E+00 | 3.75E+00 | ND | ND | U | 3.75 | NA | | | 1.10E+01 [i] | N (c) | --- |
| Copper | 1 / 1 | 2.07E+00 | 2.07E+00 | ND | ND | U | 2.07 | NA | | | 1.50E+02 [i] | N (c) | --- |
| Iron | 1 / 1 | 4.65E+03 | 4.65E+03 | ND | ND | U | 4650 | NA | | 1.51E+03 | 1.10E+03 [i] | Y | 4.65E+03 |
| Magnesium | 1 / 1 | 2.04E+03 | 2.04E+03 | ND | ND | U | 2040 | NA | | 6.94E+03 | Nutrient | N (d) | --- |
| Manganese | 1 / 1 | 1.03E+03 | 1.03E+03 | ND | ND | U | 1030 | NA | | 4.15E+02 | 7.30E+01 [i] | Y | 1.03E+03 |
| Potassium | 1 / 1 | 2.32E+03 | 2.32E+03 | ND | ND | U | 2320 | NA | | 2.48E+03 | Nutrient | N (d) | --- |
| Sodium | 1 / 1 | 2.16E+03 | 2.16E+03 | ND | ND | U | 2160 | NA | | 4.62E+03 | Nutrient | N (d) | --- |
| Vanadium | 1 / 1 | 2.88E+00 | 2.88E+00 | ND | ND | U | 2.88 | NA | | 4.80E+00 | 2.60E+01 [i] | N (a) | --- |

ND = No data; NA = not applicable

[a] Surface water is defined as water collected from poor drainage of site marshy areas and small ponds.

[b] Statistical Distribution: N = Normal distribution; L = Lognormal distribution; NP = Nonparametric distribution for data sets with greater than 50% detects if data set fails normal and lognormal; U = Distribution not determined if sample size is 4 or less, or if maximum concentration < background or screening criteria.

[c] 95% Upper confidence limit calculated for chemicals with maximum detected concentrations greater than screening criteria.

[d] Background criteria for inorganic constituents are based on 2 times the mean concentration of the background data set (CH2M Hill, 1997, Report of MSFC Background Sampling).

[e] Based on 40 CFR Part 131 - Water Quality Standards for Consumption of Water and Organisms for surface water, adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 and a hazard index of 0.1 (EPA, 1997, *Drinking Water Regulations and Health Advisories*, Office of Water, Washington, DC, August).

[f] Rationale for exclusion of chemical as a contaminant of potential concern (COPC):
- (a) = within background concentration.
- (b) = detection frequency less than 5%.
- (c) = maximum detection is less than screening criteria.
- (d) = essential nutrient.

[g] N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.

[h] Concentration used in risk assessment equal to 95% UCL or maximum value, if maximum value is less than UCL or if no UCL is calculated.

[i] Based on the EPA Region III Tap Water risk-based concentrations (EPA, 1998, *Risk-Based Concentration Table*, 1 October, EPA Region III, Philadelphia, PA, on-line).

## Table 2-6

### Selection of Chemicals of Potential Concern, Sediment
### RSA-67
### Redstone Arsenal, Madison County, Alabama

| Chemical | Detection Frequency | Range of values, mg/kg: Detected Concentration Minimum | Detected Concentration Maximum | Detection Limits Minimum | Detection Limits Maximum | Statistical Distribution [a] | Mean mg/kg | 95% UCL mg/kg [b] | Background Screening Criterion mg/kg [c] | Risk-Based Screening Criterion mg/kg [d] | COPC? [e,f] | Source Term Concentration mg/kg [g] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | | |
| Aluminum | 1 / 1 | 4.60E+04 | 4.60E+04 | ND | ND | U | 4.60E+04 | | 2.73E+04 | 7.80E+03 | Y | 4.60E+04 |
| Arsenic | 3 / 3 | 2.08E+00 | 7.64E+00 | ND | ND | U | 4.05E+00 | | 8.79E+00 | 4.30E-01 | N (a) | --- |
| Barium | 1 / 1 | 2.01E+02 | 2.01E+02 | ND | ND | U | 2.01E+02 | | 1.61E+02 | 5.50E+02 | N (c) | --- |
| Beryllium | 1 / 1 | 1.49E+00 | 1.49E+00 | ND | ND | U | 1.49E+00 | | 1.53E+00 | 1.60E+01 | N (a) | --- |
| Chromium (VI) | 1 / 1 | 2.95E+01 | 2.95E+01 | ND | ND | U | 2.95E+01 | | 1.22E+02 | 2.30E+01 | N (a) | --- |
| Cobalt | 1 / 1 | 8.93E+00 | 8.93E+00 | ND | ND | U | 8.93E+00 | | 1.95E+01 | 4.70E+02 | N (a) | --- |
| Copper | 1 / 1 | 1.71E+01 | 1.71E+01 | ND | ND | U | 1.71E+01 | | 1.63E+01 | 3.10E+02 | N (c) | --- |
| Lead | 1 / 1 | 3.58E+01 | 3.58E+01 | ND | ND | U | 3.58E+01 | | 2.21E+01 | 4.00E+02 [h] | N (c) | --- |
| Nickel | 1 / 1 | 2.35E+01 | 2.35E+01 | ND | ND | U | 2.35E+01 | | 2.32E+01 | 1.60E+02 | N (c) | --- |
| Potassium | 1 / 1 | 2.06E+03 | 2.06E+03 | ND | ND | U | 2.06E+03 | | 7.79E+02 | Nutrient | N (b) | --- |
| Silver | 1 / 1 | 6.60E-01 | 6.60E-01 | ND | ND | U | 6.60E-01 | | 7.40E-01 | 3.90E+01 | N (a) | --- |
| Vanadium | 1 / 1 | 5.70E+01 | 5.70E+01 | ND | ND | U | 5.70E+01 | | 1.18E+02 | 5.50E+01 | N (a) | --- |
| Zinc | 1 / 1 | 9.13E+01 | 9.13E+01 | ND | ND | U | 9.13E+01 | | 1.37E+02 | 2.30E+03 | N (a) | --- |
| **Volatile Organics** | | | | | | | | | | | | |
| 2-Butanone | 1 / 1 | 1.00E-02 | 1.00E-02 | ND | ND | U | 1.00E-02 | | | 4.70E+03 | N (c) | --- |
| Carbon disulfide | 1 / 1 | 1.20E-03 | 1.20E-03 | ND | ND | U | 1.20E-03 | | | 7.80E+02 | N (c) | --- |
| Toluene | 1 / 1 | 1.10E-03 | 1.10E-03 | ND | ND | U | 1.10E-03 | | | 1.60E+03 | N (c) | --- |

[a] Statistical Distribution: U = Distribution not determined if sample size is 4 or less.
[b] 95% Upper confidence limit not applicable.
[c] Background criteria for inorganic constituents are based on 2 times the mean concentration of the background data set (IT Background Data for Soils, 1997).
[d] Based on Region III risk-based concentrations (RBCs) for residential soil ingestion, adjusted, if necessary to reflect an incremental lifetime cancer risk of 1E-6 and a hazard index of 0.1 (EPA, 1998, *Risk-Based Concentration Table*, 1 October, EPA Region III, Philadelphia, PA, on-line).
[e] Rationale for exclusion of chemical as a contaminant of potential concern (COPC):
  (a) = within background concentration.
  (b) = essential nutrient.
  (c) = maximum detection is less than screening criteria.
[f] N = Chemical is not chosen as a COPC; Y = Chemical is chosen as a COPC.
[g] Concentration used in risk assessment is equal to maximum detected value.
[h] Screening criteria for lead based on the residential soil screening value of 400 mg/kg (EPA, 1994, "Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil," Memorandum from Lynn R. Goldman, Assistant Administrator, to EPA Regional Directors, dated July 14).
ND = No data.

## Table 2-7

## Summary and Source-Term Concentrations of Selected Chemicals of Potential Concern
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Chemical | Surface Soil mg/kg | Subsurface Soil mg/kg | Residuum Groundwater µg/L | Surface Water µg/L | Sediment mg/kg |
|---|---|---|---|---|---|
| **Inorganics** | | | | | |
| Aluminum | ---- | ---- | 6.67E+03 | --- | 4.60E+04 |
| Arsenic | ---- | ---- | 7.10E+01 | 4.45E+00 | ---- |
| Barium | ---- | ---- | 5.20E+02 | ---- | ---- |
| Cadmium | ---- | ---- | 3.50E+01 | ---- | ---- |
| Chromium (VI) | ---- | ---- | 2.50E+02 | ---- | ---- |
| Iron | ---- | ---- | ---- | 4.65E+03 | ---- |
| Lead | ---- | ---- | 8.80E+01 | ---- | ---- |
| Manganese | ---- | ---- | 4.18E+03 | 1.03E+03 | ---- |

To reduce the complexity of the tables, standard deviations are not displayed, but were calculated.

Footnotes in the tables provide the rationale for selection or rejection of the chemical as a COPC.

Because of the uncertainty associated with characterizing contamination in environmental media, the UCL on the mean was estimated for each chemical in each medium of interest. In general, "outliers" were included in the calculation of the UCL because high values in site-related data are seldom outliers. Inclusion of outliers increased the overall conservatism of the risk estimate. Data are tested for normality and lognormality based on the Shapiro-Wilks test (EPA, 1992e). Statistical analysis is performed only on those chemicals whose MDCs exceed their RBSCs. If statistical tests support the assumption that the data are normally distributed, the UCL for a normal distribution is calculated. If the statistical analysis shows the data to be lognormally distributed, the UCL is calculated for a lognormal distribution. If the data fit both normal and lognormal distributions, the UCL is calculated for the distribution that gives the better fit. Equations 5.1 through 5.3 in the WP (IT, 1997) describe this calculation process.

Analytical results were presented as "nondetects" ("U" qualifier) whenever chemical concentrations in samples did not exceed the detection or quantitation limits for the analytical procedures for those samples. Generally, the detection limit is the lowest concentration of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. To apply the previously mentioned statistical procedures to data with nondetects, a concentration value must be assigned to nondetects. Nondetects were assumed to be present at one-half the sample quantitation limit (EPA, 1989).

The UCL or the MDC, whichever was smaller, was selected as the source-term concentration, and is understood to represent a conservative estimate of average for use in the risk assessment or in various transport models used to estimate exposure-point concentrations.

### *2.4 COPC in Soil*

Surface soil (0 to 1 foot below ground surface) and subsurface soil (1 to 6 feet) are considered separate media.

### 2.4.1 Surface Soil

Summary statistics for chemicals detected in surface soil samples are presented in Table 2-2. No COPC were selected in surface soil.

### 2.4.2 Subsurface Soil

Summary statistics for chemicals detected in subsurface soil samples are presented in Table 2-3. No COPC were selected in subsurface soil.

## 2.5 COPC in Groundwater

Groundwater samples at this site are from the residuum zone. Summary statistics for chemicals detected in residuum groundwater samples are presented in Table 2-4. Seven inorganics (aluminum, arsenic, barium, cadmium, chromium [VI], lead, and manganese) were identified as COPC. For chromium, it is assumed in calculating risk that hexavalent chromium is represented in the data, though in fact, it may be the more common trivalent species.

## 2.6 COPC in Surface Water

Summary statistics for chemicals detected in surface water samples are presented in Table 2-5. Three inorganics (arsenic, iron, and manganese) were identified as COPC. However, EPA Region IV does not consider the RBC for iron to be reliable. Iron's potential threat to human health is discussed in Section 7.4.1 of Chapter 7.0.

## 2.7 COPC in Sediment

Summary statistics for chemicals detected in sediment samples are presented in Table 2-6. Only aluminum was selected as a COPC in sediment.

## 2.8 Summary of COPC Selection

Of the five media evaluated, only groundwater, surface water, and sediment contained chemicals at concentrations sufficient for their selection as COPC. In these media, only metals were selected as COPC.

With respect to the contamination associated with the previous use of the site, no explosive compounds, thiodiglycol, or chemical agents were detected in any sample.

# 3.0 Exposure Assessment

Exposure is the contact of a receptor with a chemical or physical agent. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPC found at or migrating from a site (EPA, 1989). An exposure assessment includes the following steps:

- Characterize the physical setting.
- Identify the contaminant sources, release mechanisms, and migration pathways.
- Identify the potentially exposed receptors.
- Identify the potential exposure pathways.
- Estimate exposure concentrations.
- Estimate chemical intakes or contact rates.

## 3.1 Characterization of Physical Setting

The physical setting of RSA, including its historical and current use, topography, climate, and demographics of the area, is described in detail in the Phase I RI report (Rust, 1998). RSA-67, previously known as Area AA, occupies approximately 30 acres in the southern part of RSA, south of Buxton Road and within the Tennessee River Flood Plain. The area is generally flat; where drainage ways occur, water has been impounded by beavers resulting in the development of small ponds and marshy areas. The site is largely inundated with water and the remaining areas are heavily wooded. RSA-67 was used for the storage of mustard gas in drums until the 1950s. The site contains numerous square, flat, storage areas, each occupying approximately 200 square feet. The storage areas are separated by earthen berms, railcar tracks, and trails create a grid pattern over the entire site, contributing to poorly developed drainage patterns.

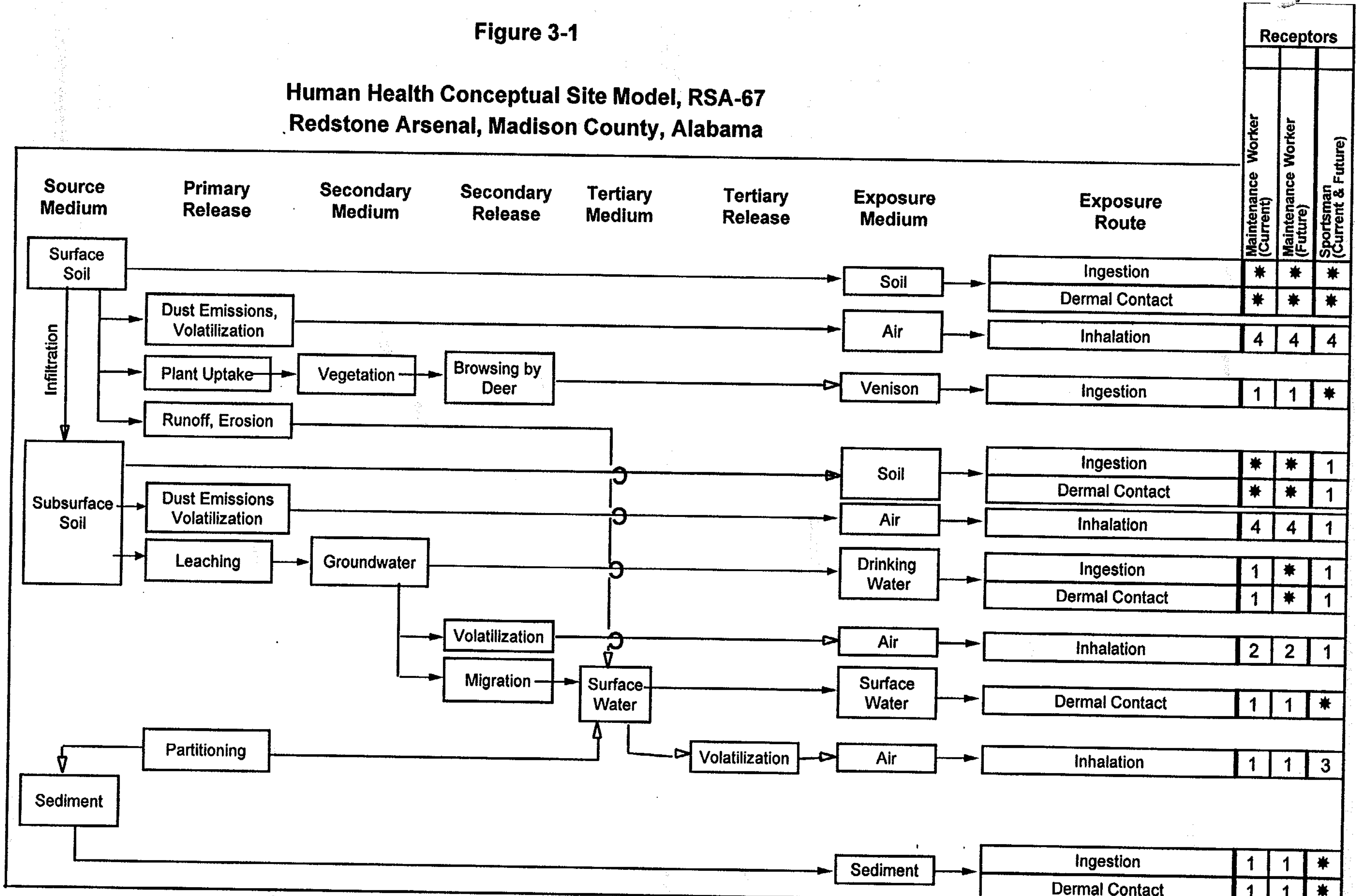
Groundwater is no longer used as a drinking water source for RSA, but provides a large percentage of the rural domestic potable water supply for areas surrounding RSA (Engineering Science, Inc., 1992). The Tennessee River is also a source of drinking water in the region. The radius of influence associated with the wells used by the City of Huntsville and Madison County is not believed to extend into RSA property.

## 3.2 Conceptual Site Model

The conceptual site model (CSM) provides the basis for identifying and evaluating the potential risks to human health in the BHHRA. The CSM (Figure 3-1) includes the receptors appropriate to all plausible scenarios, and the potential exposure pathways. Graphically presenting all possible pathways by which a potential receptor may be exposed, including all sources, release

## Figure 3-1

## Human Health Conceptual Site Model, RSA-67
## Redstone Arsenal, Madison County, Alabama




✱ = Complete exposure pathway evaluated in baseline risk assessment.
1 = Incomplete exposure pathway.
2 = Although theoretically complete pathway, inhalation of volatiles is insignificant compared with ingestion.
3 = Although theoretically complete exposure pathway, large dilution factor of outdoor obviates the need to quantify this pathway.
4 = Because site is mostly marsh, this pathway is insignificant with respect to ingestion or dermal exposures.

KN/3875/RSA-67/RSA67.PPT/7/19/99 3:11 PM and transport pathways, and exposure routes, facilitates consistent and comprehensive evaluation of risk to human health, and helps to ensure that potential pathways are not overlooked. The elements necessary to construct a complete exposure pathway and develop the CSM include:

- Source (i.e., contaminated environmental) media
- Contaminant release mechanisms
- Contaminant transport pathways
- Receptors
- Exposure pathways.

Contaminant release mechanisms and transport pathways are not relevant for direct receptor contact with a contaminated source medium. The receptors and pathways in Figure 3-1 reflect plausible scenarios developed from information regarding site background and history, topography, climate, and demographics from Section 3.1 of this BHHRA and the Phase I RI report (Rust, 1998). The asterisks indicate the exposure pathways that are complete and addressed in the BHHRA. Justification for exclusion of pathways is provided in the footnotes and in Section 3.4.

### *3.3 Contaminant Sources, Release Mechanisms, and Migration Pathways*

Contaminant sources, release mechanisms, and migration pathways are presented in Figure 3-1. Briefly, waste on the surface or buried in the ground may contaminate surface and subsurface soil. Contaminants buried in subsurface soil or leached from surface soil to subsurface soil may leach to groundwater. Runoff and erosion may move contaminants to surface water and sediment. At RSA-67, contaminated groundwater may discharge to the surface, contaminating surface water. Most of RSA-67 is shallow marsh that contains water much, if not most, of the time. The connection between groundwater and surface water is probably continuous over most of the site and the direction of water flow is unknown. Potential sources and exposure media at RSA-67 include the following:

- Surface soil
- Subsurface soil
- Groundwater
- Surface water
- Sediment.

COPC were not selected in soil.

## 3.4 Receptor Scenarios for RSA-67

The objective of this assessment is to identify potential human receptors that may be exposed to site-related chemicals at RSA-67 under current and future land-use scenarios. The assessment also identifies the potential pathways by which the receptors are exposed to site-related chemicals. Receptors selected to represent all potentially exposed groups of people at the site, and the pathways by which they may be exposed to contaminants are summarized in Table 3-1 and Figure 3-1. Receptors addressed in the WP (IT, 1997) but not quantified here are not included in Table 3-1 or Figure 3-1. Exposure parameters for this risk assessment are specified in Table 3-2.

Based on the noted factors and the WP (IT, 1997), the following exposure scenarios are proposed for a BHHRA at RSA-67:

- Maintenance worker (current and future land use)
- Sportsman (current and future land use).

### 3.4.1 Maintenance Worker

The site is partially fenced, with no regularly scheduled activity. Surface water at this site consists of marsh ponds, which would not support any future construction or development for industrial use (office complexes, etc.) without extensive backfilling. Thus, many activities and exposures associated with the groundskeeper and construction worker scenarios are not appropriate for this site. Thus, a maintenance worker scenario, which was not included in the WP, was developed for RSA-67. This maintenance worker represents an upper-bound limit for the industrial exposure scenarios for this site because it combines exposure pathways for the groundskeeper and construction worker that are described in the WP. Under current land use, the maintenance worker is exposed to site soil, and is not expected to be exposed to surface water and sediment because no structures or equipment requiring maintenance are present in the marshy areas. Under future land use scenarios, ingestion of groundwater from a groundwater well on RSA-67 is evaluated as an exposure pathway.

### 3.4.2 Sportsman

RSA-67 is known to be deer habitat; therefore, a sportsman hunting scenario is evaluated for this site if surface soil contamination is present. Surface water at this site would not support development of fish of edible size; therefore, exposure to the sportsman via the fish pathway is not quantified. Due to the marsh ponds, direct exposure to sediment at these sites for the sportsman is added as an exposure pathway to those previously defined in the WP.

## Table 3-1

## Potential Receptors, Media, and Exposure Pathways
## RSA-67
## Redstone Arsenal, Madison County, Alabama



| Source Medium | Model | Exposure Medium | Exposure Pathway | Comment (Reference equation) |
|---|---|---|---|---|
| MAINTENANCE WORKER | | | | |
| Surface and subsurface soil ( future conditions) | None | Soil | Incidental ingestion | Complete pathway but no COPCs selected. |
| | None | Soil | Dermal contact | Complete pathway but no COPCs selected. |
| | Volatilization of VOCs | Air | Inhalation | Complete pathway but no COPCs selected. Insignificant because of small dry land area. |
| | Dust emissions based on activity | Air | Inhalation | Complete pathway but no COPCs selected. |
| | Dust | | | Insignificant risk because of dry land area |
| Groundwater (future conditions) | None | Drinking water | Ingestion | Quantified (Eq 3.12) |
| | None | Water | Dermal contact | Quantified (Eq. 3.13-17) |
| | Volatilization of VOCs | Air | Inhalation | Insignificant, compared with other pathways, because of infrequent and short-term exposure, and large dilution factor of ambient air; not quantified. |
| SPORTSMAN | | | | |
| Surface soil (current and future conditions) | None | Soil | Incidental ingestion | Complete pathway but no COPCs selected. |
| | None | Soil | Dermal contact | Complete pathway but no COPCs selected. |
| | Volatilization of VOCs | Air | Inhalation | Volatilization from surface soil deemed insignificant; large dilution factor of outdoor air; not quantified. |
| | Dust emissions from wind erosion | Air | Inhalation | Complete pathway but no COPCs selected. |

## Table 3-1

## Potential Receptors, Media, and Exposure Pathways
## RSA-67
## Redstone Arsenal, Madison County, Alabama

(Page 2 of 2)

| Source Medium | Model | Exposure Medium | Exposure Pathway | Comment (Reference equation) |
|---|---|---|---|---|
| | Dust | | | Insignificant risk because of dry land area |
| | Uptake from soil by vegetation; deer eat vegetation | Venison | Ingestion | Complete pathway but no COPCs selected. |
| Surface water (current and future conditions)[a] | None | Water | Dermal contact | Quantified (Eq. 3.13-17) |
| | Volatilization of VOCs | Air | Inhalation | Insignificant risk because of large dilution factor of outdoor air; not quantified. |
| | Bioconcentration | Fish | Ingestion | Fish habitat not supported by marsh ponds; not quantified. |
| Sediment (current and future conditions)[a] | None | Sediment | Incidental ingestion | Quantified |
| | None | Sediment | Dermal contact | Quantified. |
| Sediment (current and future conditions)[a] | Biota-to-sediment-accumulation factor | Fish | Ingestion | Fish habitat not supported by marsh ponds; not quantified. |

[a]Evaluated at on- and off-site locations.

## Table 3-2

## Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
## RSA-67
## Redstone Arsenal, Madison County, Alabama



| Pathway Variable | Maintenance Worker | Sportsman |
|---|---|---|
| **General Parameters Used in All Intake Models** | | |
| Exposure frequency - except game & fish (days/year) | 28 | 52 |
| Exposure frequency - game & fish (days/year) | NA | 365 |
| Exposure duration (years) | 25 | 30 |
| Body weight (kg) | 70 | 70 |
| Averaging time - noncancer (days) | 9125 | 10950 |
| Averaging time - cancer (days) | 25550 | 25550 |
| **Inhalation of VOCs and Resuspended Dust (5.19)** | | |
| Inhalation rate ($m^3$/hour) | 2.5 | 2.1 |
| Fraction exposed to contaminated medium, soil (unitless) | 0.7 | 0.5 |
| Fraction exposed to contaminated medium, surface soil (unitless) | 0.3 | |
| Fraction exposed to contaminated medium, sediment (unitless) | | 0.15 |
| Exposure time (hours/day) | 8 | 8 |
| Conversion factor (g->kg) | 1.00E-03 | |
| Dust Load Factor (h->s) | 2.00E-04 | |
| Inverse of mean.... (g/m2-s) (kg/m3) | | |
| Conversion factor h->s | | |
| Fraction covered w/vegetation (unitless) | | |
| Mean annual wind speed (m/s) | | |
| Equivalent....of wind speed at 7 m (m/s) | | |
| Function dependent on Um/Ut (unitless) | | |
| **Dermal Contact with Soil/Sediment (5.20)** | | |
| Incidental ingestion rate (mg/day) | 200 | 100 |
| Fraction exposed to contaminated medium, soil (unitless) | 0.7 | 0.25 |
| Fraction exposed to contaminated medium, surface soil (unitless) | 0.3 | |
| Fraction exposed to contaminated medium, sediment (unitless) | 5000 | 0.08 |
| Conversion Factor (kg->mg) | 1.00E-06 | |
| **Dermal Contact with Soil/Sediment (5.24)** | | |
| Fraction exposed to contaminated medium, sediment (unitless) | 0.7 | 0.5 |

## Table 3-2

## Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors
## RSA-67
## Redstone Arsenal, Madison County, Alabama



| Pathway Variable | Maintenance Worker | Sportsman |
|---|---|---|
| Fraction exposed to contaminated medium, surface soil | 0.3 | |
| Fraction exposed to contaminated medium, sediment | NA | 0.15 |
| Body surface area exposed | 5000 | 5000 |
| Soil-to-skin adherence factor | 0.2 | 0.2 |
| Conversion Factor | 1.00E-06 | |
| **Drinking Water Ingestion of Groundwater (5.29)** | | |
| Drinking Water Ingestion rate (L/day) | 1 | |
| Fraction exposed to contaminated medium (unitless) | 1 | |
| **Dermal Contact with Surface Water/Groundwater (5.25, 5.26)** | | |
| Body surface area exposed ($cm^2$) | 4100 | 4100 |
| Exposure Time (hours/day) | 1 | 4 |
| Fraction exposed to contaminated medium (unitless) | 1 | 0.7 |
| **Ingestion of Beef (5.21)** | | |
| Ingestion rate (kg/day) | | |
| Fraction exposed to contaminated medium (unitless) | | |
| **Ingestion of Venison** | | |
| Areal fraction of site contained... (unitless) | | 6.77E-02 |
| Conversion Factor to adjust for soil moisture (unitless) | | 1.25 |
| Contaminated browse ingestion rate (kg DM/day) | | 0.87 |
| Ingestion rate (kg/day) | | 0.03 |
| Fraction exposed to contaminated medium (unitless) | | 1 |

### *3.4.3 Additional Receptors Not Evaluated*

***Trespasser.*** The trespasser is assumed to be a nearby resident, age 13, who makes sporadic visits to accessible areas on RSA. However, there are no residential or industrial areas for many miles in any direction from RSA-67. The only incentive a trespasser would have to visit this site would be to hunt and this scenario is covered under the sportsman scenario. Based on the demographics of the area, the distances from centers of population to RSA-67, and the lack of any attractive features on the site, the partial fencing, and the remote location, a trespasser scenario is not appropriate for this site. Therefore, exposures to the trespasser are not quantified.

***On-Site Resident.*** An on-site residential receptor is not evaluated as a plausible scenario under future land-use assumptions because residential development is highly unlikely in a marsh.

***Off-Site Residents.*** Surface water at this site is an unlikely pathway for off-site migration of contaminants; therefore, off-site exposure of a youthful child to surface water is not quantified for this site. The residential receptors evaluated for off-site is a farmer, a 70-kilogram adult who lives nearby and pastures beef cattle on RSA (IT, 1997). Because RSA-67 is largely marsh and not suitable for grazing cattle, off-site exposure via beef ingestion is not evaluated.

## *3.5 Quantification of Chemical Intake*

This section describes the models used to quantify doses or intakes of the COPC by the exposure pathways identified. Models were taken or modified from EPA (1989) unless otherwise indicated. To enable a detailed technical review, the equations are listed in this section. Models for media in which COPC were not selected are not described. The specific equations used for the exposure pathways for each receptor are listed Table 3-1. A detailed description, justification, and reference for these equations are provided in the WP (IT, 1997).

### *3.5.1 Incidental Ingestion of COPC in Sediment*

$$I_s = \frac{(C_s)(IR_s)(FI_s)(EF_T)(ED)(CF4)}{(BW)(AT)} \qquad \text{Eq. 3.1}$$

where:

$I_s$ = ingested dose of COPC in soil/sediment (mg/kg-day, calculated)

| | | |
|---|---|---|
| $C_s$ | = | concentration of COPC in soil/sediment (mg/kg) |
| $IR_s$ | = | ingestion rate of soil/sediment (milligrams per day [mg/day]) |
| $FI_s$ | = | fraction of exposure attributed to site soil/sediment (unitless) |
| $EF_T$ | = | exposure frequency (days/year) |
| ED | = | exposure duration (years) |
| CF4 | = | conversion factor ($10^{-6}$ kg/mg) |
| BW | = | body weight (kg) |
| AT | = | averaging time (days). |

### 3.5.2 Ingestion of COPC in Water

$$I_w = \frac{(C_w)\ (IR)\ (FI_w)\ (ED)\ (EF)}{(BW)\ (AT)} \qquad \text{Eq. 3.2}$$

where:

| | | |
|---|---|---|
| $I_w$ | = | intake of COPC from drinking water (mg/kg-day) |
| $C_w$ | = | concentration of COPC in water (mg/L) |
| IR | = | ingestion rate (L/day) |
| $FI_w$ | = | fraction of exposure attributed to groundwater (unitless) |
| ED | = | exposure duration (years) |
| EF | = | exposure frequency (days/year) |
| BW | = | body weight (kg) |
| AT | = | averaging time (days; for noncarcinogens, AT equals [(ED)(365 days/year)], for chemical carcinogens, AT equals [(70 years)(365 days/year)]). |

### 3.5.3 Dermal Contact with COPC in Water and Sediment

$$DAD = \frac{(DA)(FI_w)(SA)(EF_T)(ED)}{(BW)(AT)} \qquad \text{Eq. 3.3}$$

where:

| | | |
|---|---|---|
| DAD | = | average dermally absorbed dose of COPC (mg/kg-day, calculated) |
| DA | = | dose absorbed per unit body surface area per day ($mg/cm^2$-day) |
| $FI_w$ | = | fraction of exposure attributed to contaminated medium surface water, sediment, and groundwater) |
| SA | = | surface area of the skin available for contact with soil ($cm^2$) |
| $EF_T$ | = | exposure frequency (days/year) |
| ED | = | exposure duration (years) |

| | | |
|---|---|---|
| BW | = | body weight (kg) |
| AT | = | averaging time (days). |

Dose absorbed (DA) for water exposure is given by:

$$DA_{event} = (C_w)(PC)(ET_w)(CF5) \qquad \text{Eq. 3.4}$$

where:

| | | |
|---|---|---|
| $DA_{event}$ | = | dose absorbed per unit body surface area per day (mg/cm$^2$-day, calculated) |
| $C_w$ | = | concentration of COPC in water (mg/L) |
| PC | = | permeability coefficient (cm/hour) |
| $ET_w$ | = | time of exposure (hours/event) |
| CF5 | = | conversion factor (0.001 L/cm$^3$). |

For short exposure times (0.25 hrs), $DA_{event}$ is calculated from:

$$DA_{event} = 2(PC)(C_w)(CF5)\sqrt{\left(\frac{6\tau\,(ET_w)}{\pi}\right)} \qquad \text{Eq. 3.5}$$

where:

| | | |
|---|---|---|
| $DA_{event}$ | = | dose absorbed per unit body surface area per day (mg/cm$^2$-day, calculated) |
| PC | = | permeability coefficient (cm/hour) |
| $C_w$ | = | concentration of COPC in water (mg/L) |
| CF5 | = | conversion factor (0.001 L/cm$^3$) |
| $\tau$ | = | time for concentration of COPC in stratum corneum to reach steady state (hours) |
| $Et_w$ | = | exposure time (hours/day). |

If permeability coefficient (PC) values were not available, they were calculated from the formula (EPA, 1992b):

$$\mathrm{Log}(PC) = -2.72 + 0.71(\log K_{ow}) - 0.0061(MW) \qquad \text{Eq. 3.6}$$

where:

| | | |
|---|---|---|
| PC | = | permeability coefficient (cm/hour, calculated) |
| $\log K_{ow}$ | = | log of the octanol/water partition coefficient (unitless) |
| MW | = | molecular weight. |

If values for $\tau$ were not available, they were calculated from:

$$\tau = \frac{L_{sc}}{6x\,10^{(-2.72-0.0061*MW)}} \qquad \text{Eq.3.7}$$

where:

| | | |
|---|---|---|
| $\tau$ | = | time for concentration of COPC in stratum corneum to reach steady state (hours, calculated) |
| $L_{sc}$ | = | effective thickness of the stratum corneum ($10^{-3}$ cm) |
| MW | = | molecular weight. |

DA for soil and sediment exposure is given by:

$$DA = (C_s)(CF4)(AF)(ABS) \qquad \text{Eq. 3.8}$$

where:

| | | |
|---|---|---|
| DA | = | dose absorbed per unit body surface area per day ($mg/cm^2$-day, calculated) |
| $C_s$ | = | concentration of COPC in soil (mg/kg) |
| CF4 | = | conversion factor ($10^{-6}$ kg/mg) |
| AF | = | soil-to-skin adherence factor ($mg/cm^2$-day) |
| ABS | = | absorption fraction (unitless, chemical-specific). |

Based on EPA (1995) guidance, the absorption factor for inorganics is assumed to be 0.001.

### 3.6 Justification of Intake Variables

Most BHHRAs are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure level that could reasonably be expected to occur, but not necessarily the worst possible case (EPA, 1989, 1991b). It is interpreted as reflecting the 90 to 95th percentile on exposure. In keeping with EPA (1991b) guidance, variables chosen for a baseline RME scenario for intake rate, exposure frequency, and exposure duration are generally upperbounds. Other variables, e.g., body weight and exposed skin surface area, are generally central or average values. In the case of contact rates consisting of multiple components, e.g., dermal contact with soil or water, which consists of a dermal absorption factor and soil-to-skin adherence factor for soil, and PC and exposure time for water, only one variable, absorption factor or PC, needs to be an upperbound. The conservatism built into the individual variables ensures that the entire estimate for the contact rate is more than sufficiently conservative.

The scenarios described in the following sections assume that 100 percent of the maintenance worker's time of exposure to a given medium is spent in contact with contaminated media at the site. For example, it is assumed that the maintenance worker spends eight hours per day, four weeks per year exposed to contaminated surface soil on a given site.

The average time for noncancer evaluation is computed as the product of exposure duration (years) times 365 days per year, to estimate an average daily dose over the entire exposure period (EPA, 1989). For cancer evaluation, average time is computed as the product of 70 years, the assumed human lifetime, times 365 days per year, to estimate an average daily dose prorated over a lifetime, regardless of the frequency or duration of exposure. This methodology assumes that the risk from short-term exposure to a high dose of a given carcinogen is equivalent to long-term exposure to a correspondingly lower dose, provided that the total lifetime doses are equivalent. This approach is consistent with current EPA (1986) policy of carcinogen evaluation, although it introduces considerable uncertainty into the cancer risk assessment.

The exposure variable values used in the contaminant intake models are compiled in Table 3-2. Exposure variables are listed only for pathways that were quantified (Table 3-1).

### 3.6.1 Maintenance Worker

To appropriately evaluate exposures at this site, a scenario for a maintenance worker was developed that incorporates appropriate portions of the groundskeeper and construction worker scenarios. The maintenance worker is assumed to be a 70-kilogram adult who works 8 hours per day, approximately 7 days per week for a total of 4 weeks (28 days) per year (2 weeks in the spring and 2 weeks in the fall) for 25 years. Because no COPC were selected for surface and subsurface soil, these media were not quantified for this site. The WP (IT, 1997) provides a detailed description of the quantification of contaminants for these media.

It is assumed that the maintenance worker will be exposed to the ingestion of groundwater from a well that does not currently exist, but may exist sometime in the future. His drinking water ingestion rate is assumed to be one liter per day (EPA, 1991a). He may also experience dermal contact with groundwater used to clean equipment and to rinse dust or perspiration from his body. For this evaluation, it is assumed that the head, arms, and hands, or approximately 4,100 square centimeters (EPA, 1992b), are exposed intermittently throughout the day for up to an hour per day.

### 3.6.2 Sportsman

The sportsman is normally assumed to be a nearby resident who makes regular visits to the unrestricted areas on RSA for hunting game. The marsh environment does not support a fish population for recreational fishing. In spite of the demographics of the area and the distances from centers of population to various sites on RSA, it is assumed that the sportsman makes one visit per week (52 days per year), and spends 8 hours per day in the unrestricted areas. Of those 52 days, it is assumed that 8 hours per day are spent in contact with soil at RSA-67.

The sportsman is assumed to be a 70-kilogram adult with a respiratory rate of 2.1 cubic meters per hour associated with moderate activity (EPA, 1990). Because the site is largely covered with water, it is assumed that the sportsman is exposed to sediment. The sediment incidental ingestion rate is assumed to be a portion of the soil ingestion rate, which is estimated as 100 milligrams per day (EPA, 1991b), because the activities responsible for incidental ingestion of soil may result in similar ingestion of sediment. Dermal uptake of COPC from sediment is also estimated with the variable values being the same as previously defined for soil, except for the fraction exposure term.

During wading in surface water, the sportsman is assumed to expose his feet, lower legs, and hands to surface water. These body regions constitute approximately 21 percent of the body SA of an adult, or 4,100 square centimeters (EPA, 1992b).

The sportsman is assumed to hunt at RSA-67. Because much of the RSA is wooded interspersed with pasture land, it is a favorable habitat for deer, and the sportsman is assumed to harvest a deer each year. There are dry land portions of RSA-67 that would provide forage for deer. However, since no COPC were selected from surface soil at RSA-67, there is no exposure for deer and this pathway is not quantified.

***Fraction Exposure.*** EPA (1989) permits the development of a fraction term to reflect the proportion of his total daily exposure that a receptor obtains from the contaminated media. Data for Huntsville, Alabama, the city where RSA is located, suggest that the area receives an average of 30 percent of possible sunshine (Bair, 1992). Therefore, it is assumed that 70 percent of the time, the surface water in the marsh is available for exposure, and 30 percent of the time, the sediment is available for exposure, i.e., not covered with water.

The fraction exposure term of the sportsman for the ingestion pathway is based on the proportion of a 16 waking hours-per-day time period spent at the site, assuming an overall soil, sediment and dust ingestion rate of 100 milligrams per day (EPA, 1989; IT, 1997). The ingestion pathway FI term is calculated as the number of hours that the sportsman is at the site, divided by 16 hours. Of the 8 hours (Table 3-2) that the sportsman spends at the site, it is assumed that 4 are spent in the marsh. This represents 25 percent of his daily soil, sediment, and dust ingestion exposure. This factor of 25 percent is further multiplied by 30 percent, the fraction of time in a year that the sediment is assumed as not covered by surface water and, thus, available for exposure. Therefore, the sportsman FI term for sediment ingestion is 0.08.

Unlike the case of ingestion, there is no average rate of dermal contact with soil, sediment, and dust assumed over a 16-hour time period (EPA, 1996; IT, 1997). Therefore, the level of exposure experienced by the sportsman is described in terms of the 8 hours spent hunting. It is assumed that of these 8 hours during a hunting day, the sportsman spends 4 hours (50 percent of his time) in the marsh. This 50 percent is further multiplied by 30 percent, the fraction of time in a year that the sediment is assumed as not covered by surface water and, thus, available for exposure. Therefore, the sportsman FI term for dermal contact with sediment is 0.15. It is assumed that the sediment is too wet and too heavily vegetated for the inhalation of sediment to be a complete pathway, even during the 30 percent of the year when the site is not inundated.

For dermal exposure to surface water, an FI of 70 percent is used. This factor represents the percentage of time in a given year that surface water is available for exposure, based on weather conditions previously described.

# 4.0 Toxicity Assessment and Risk Characterization Methodology

## 4.1 Methodology

The toxicity assessment and risk characterization methodology in this BHHRA follows the guidance provided in the WP (IT, 1997); therefore, this summary report does not include a detailed discussion of these subjects. The toxicity assessment for selected COPC are presented in Tables 4-1 and 4-2. The cancer toxicity assessment is summarized in Table 4-1, including the following information for each COPC:

- Chemical name
- Gastrointestinal absorption factor (GAF)
- Cancer weight-of-evidence classification
- Oral slope factor (SF)
- Inhalation SF
- Dermal SF (=oral SF/GAF).

The noncancer toxicity assessment is summarized in Table 4-2, including the following information for each COPC:

- Chemical name
- GAF
- Oral reference dose (RfD)
- Target organ for oral exposure
- Inhalation RfD
- Target organ for inhalation exposure
- Dermal RfD (=oral RfD × GAF).

## 4.2 Evaluation of Noncarcinogenic Effect for Lead

Lead has been identified as a COPC for groundwater at RSA-67. Because no threshold dose has been established for lead, an RfD is not available for evaluation of the toxicity of exposure to lead. However, the EPA (1994) Integrated Exposure Uptake Biokinetic Model (IEUBK) is designed to integrate exposure to lead from various sources to estimate mean blood lead concentrations for the first 7 years of a child's life, and to predict variation about the mean. Although no child receptor is assumed for RSA-67, it is generally agreed that the young child is the most sensitive receptor for exposure to lead. Therefore, the IEUBK was used for RSA-67 to provide a conservative estimate of potential human health impacts of lead. This approach, in effect, uses the young child as a surrogate lead receptor for the maintenance worker (Section 3.4).

## Table 4-1

### Summary of the Cancer Evaluation for Chemicals of Potential Concern
### RSA-67
### Redstone Arsenal, Madison County, Alabama

| Chemicals | Gastrointestinal Absorption Factors (unitless) | Reference | Cancer Weight-of-Evidence Group | Reference | Oral Slope Factor (per mg/kg-day) | Reference | Inhalation Slope Factor (per mg/kg-day) | Reference | Dermal Slope Factor (per mg/kg-day) |
|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | |
| Aluminum | 0.27 | 1 | ND | | ND | | ND | | ND |
| Arsenic | 0.95 | 2 | A | 3 | 1.50E+00 | 3 | 1.51E+01 | 3 | 1.58E+00 |
| Barium | 0.91 | 4 | D | 5 | ND | | ND | | ND |
| Cadmium-Water | 0.05 | 3 | B1 | 3 | ND | | 6.30E+00 | 3 | ND |
| Chromium (VI) | 0.05 | 6 | A | 3 | ND | | 4.10E+01 | 7 | ND |
| Iron | 0.15 | 8 | D | 9 | ND | | ND | | ND |
| Lead | 0.1 | 6 | B2 | 3 | ND | | ND | | ND |
| Manganese | 0.03 | 10 | D | 3 | ND | | ND | | ND |

ND = No Data.

References:


1. U.S. Environmental Protection Agency (EPA), 1994, ***Risk Assessment Issue Paper for: Derivation of a Provisional Oral RfD for Aluminum*** (CASRN 7429-90-5), National Center for Environmental Assessment, Cincinnati, OH, June 20.
2. U.S. Environmental Protection Agency (EPA), 1992, ***Risk Assessment Issue Paper for: Oral Absorption for Arsenic*** (CASRN 7440-38-2), National Center for Environmental Assessment, Cincinnati, OH, October 9.
3. U.S. Environmental Protection Agency (EPA), 1998, Integrated Risk Information System (IRIS), Environmental Criteria and Assessment Office, Cincinnati, OH, on-line.
4. U.S. Environmental Protection Agency (EPA), 1993, ***Risk Assessment Issue Paper for: Provisional Oral Absorption Factors for Barium*** (CASRN 7440-39-3), National Center for Environmental Assessment, Cincinnati, OH, August 5.
5. U.S. Environmental Protection Agency (EPA), 1996, ***Drinking Water Regulations and Health Advisories***, Office of Water, Washington, DC, October.
6. Jones, TD. and BA Owen, 1989, ***Health Risks from Mixtures of Radionuclides and Chemicals in Drinking Water***, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-6533.
7. U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables*** (HEAST), FY 1997 Update, Office of Solid Waste and Emergency Response, Washington, D.C., 9200.6-303 (97-1), EPA/540/R-97/036, NTIS No. PB97-921199.
8. U.S. Environmental Protection Agency (EPA), 1996, "Dermal Risk Values Derived by Calculation from Gastrointestinal (GI) Absorption Data in Chemical Order," Table 6 of unidentified document suggested by EPA Region IV as a reliable source of gastrointestinal absorption factors.
9. U.S. Environmental Protection Agency (EPA), no date, ***Risk Assessment Issue Paper for: Provisional RfD and Interim Oral Slope Factor for Iron (CASRN 7439-89-6)***, National Center for Environmental Assessment, Cincinnati, OH, July 7.
10. Keen and Leach, 1988, "Manganese," in Seiler, H.G. and H. Sigel, eds., 1988, ***Handbook on Toxicity of Inorganic Compounds***, Marcel Dekker, Inc., New York, pp. 405-415.


Weight-of-Evidence:

Group A - Human Carcinogen: Human data are sufficient to identify the chemical as a human carcinogen.

Group B1 - Probable Human Carcinogen: Human data indicate that a causal association is credible, but alternative explanations cannot be dismissed.

Group B2 - Probable Human Carcinogen: Human data are insufficient to support a causal association, but testing data in animals support a causal association.

Group C - Possible Human Carcinogen: Human data are inadequate or lacking, but animal data suggest a causal association, although the studies have deficiencies that limit interpretation.

Group D - Not Classifiable as to Human Carcinogenicity: Human and animal data are lacking or inadequate.

Group E - Evidence of Noncarcinogenicity to Humans: Human data are negative or lacking, and adequate animal data indicate no association with cancer.

# Table 4-2

## Summary of the Noncancer Evaluation of the Chemicals of Potential Concern
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Chemicals | Gastrointestinal Absorption Factors (unitless) | Reference | Oral Reference Dose (mg/kg-day) | Reference | Oral Target Organ | Reference | Inhalation Reference Dose (mg/kg-day) | Reference | Inhalation Target Organ | Reference | Dermal Reference Dose (mg/kg-day) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | |
| Aluminum | 0.27 | 1 | 1.00E+00 | 1 | NS | 1 | 1.40E-03 | 2 | NS | 2 | 2.70E-01 |
| Arsenic | 0.95 | 3 | 3.00E-04 | 4 | S | 4 | ND | | NA | | 2.85E-04 |
| Barium | 0.91 | 5 | 7.00E-02 | 4 | CV | 4 | 1.40E-04 | 6 | F | 6 | 6.37E-02 |
| Cadmium-Water | 0.05 | 4 | 5.00E-04 | 4 | K | 4 | ND | | NA | | 2.50E-05 |
| Chromium (VI) | 0.05 | 8 | 3.00E-03 | 4 | ND | 4 | 3.00E-05 | 4 | LNG | 4 | 1.50E-04 |
| Iron | 0.15 | 9 | 3.00E-01 | 10 | L | 10 | ND | | NA | | 4.50E-02 |
| Lead | 0.1 | 8 | ND | | ND | | ND | | NA | | NA |
| Manganese | 0.03 | 11 | 2.00E-02 | 4 | NS | 4 | 1.43E-05 | 4 | NS | 4 | 6.00E-04 |

ND = No Data; NA = Not Applicable.

References:


1. U.S. Environmental Protection Agency (EPA), 1994, ***Risk Assessment Issue Paper for: Derivation of a Provisional Oral RfD for Aluminum (CASRN 7429-90-5)***, National Center for Environmental Assessment, Cincinnati, OH, June 20.
2. U.S. Environmental Protection Agency (EPA), 1997, ***Risk Assessment Issue Paper for: Derivation of a Provisional Inhalation RfC for Aluminum (CASRN 7429-90-5)***, National Center for Environmental Assessment, Cincinnati, OH, June 20.
3. U.S. Environmental Protection Agency (EPA), 1992, ***Risk Assessment Issue Paper for: Oral Absorption for Arsenic (CASRN 7440-38-2)***, National Center for Environmental Assessment, Cincinnati, OH, October 9.
4. U.S. Environmental Protection Agency (EPA), 1998, Integrated Risk Information System (IRIS), Environmental Criteria and Assessment Office, Cincinnati, OH, on-line.
5. U.S. Environmental Protection Agency (EPA), 1993, ***Risk Assessment Issue Paper for: Provisional Oral Absorption Factors for Barium*** (CASRN 7440-39-3), National Center for Environmental Assessment, Cincinnati, OH, August 5.
6. U.S. Environmental Protection Agency (EPA), 1997, ***Health Effects Assessment Summary Tables*** (HEAST), FY 1997 Update, Office of Solid Waste and Emergency Response, Washington, D.C., 9200.6-303 (97-1), EPA/540/R-97/036, NTIS No. PB97-921199.
7. U.S. Environmental Protection Agency (EPA), 1996, ***Risk Assessment Issue Paper for: Derivation of a Provisional Subchronic RfC for Cadmium (CASRN 7440-43-9),*** National Center for Environmental Assessment, Cincinnati, OH, March 20.
8. Jones, TD. and BA Owen, 1989, ***Health Risks from Mixtures of Radionuclides and Chemicals in Drinking Water***, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-6533.
9. U.S. Environmental Protection Agency (EPA), 1996, "Dermal Risk Values Derived by Calculation from Gastrointestinal (GI) Absorption Data in Chemical Order," Table 6 of unidentified document suggested by EPA Region IV as a reliable source of gastrointestinal absorption factors.
10. U.S. Environmental Protection Agency (EPA), 1993, ***Risk Assessment Issue Paper for: Derivation of a Provisional RfD for Iron (CASRN 7439-89-6),*** National Center for Environmental Assessment, Cincinnati, OH, July 7.
11. Keen and Leach, 1988, "Manganese," in Seiler, H.G. and H. Sigel, eds., 1988, ***Handbook on Toxicity of Inorganic Compounds***, Marcel Dekker, Inc., New York, pp. 405-415.


Target Organs:

CV = Cardiovascular; E = Erythrocyte; F = Fetus or offspring; H = Hematopoietic System; I = Immune System; K = Kidney; L = Liver; LNG = Lung; NS = Nervous System; S = Skin; URT = Upper Respiratory Tract

Because the IEUBK represents a multimedia approach, lead exposure is evaluated for a variety of media, even though lead is a COPC for groundwater only.

# 5.0 Risk Characterization Results and Discussion

The risk characterization results combine the output of the exposure analysis and the toxicity analysis to quantify the risk to each receptor. The results and discussion of the risk characterization for the receptors at RSA-67 are presented in the following sections. The risk characterization results are discussed on a site-specific basis. Total ILCRs and HIs are summarized for each receptor by pathway in Table 5-1. The site ILCRs and HIs listed for the maintenance worker and sportsman are based on exposure to the residuum aquifer. The cancer intakes, ILCRs, noncancer intakes, and HIs for individual COPC by media, receptor, and site are summarized by receptor and pathway in Appendix A.

## 5.1 Maintenance Worker

As explained in Section 3.4, a maintenance worker has been substituted in place of a groundskeeper and a construction worker for this site. This worker is exposed to surface and subsurface soil and to groundwater. Total site ILCRs and HI for this receptor are presented in Table 5-1. From Table 5-1, it can be seen that the total site ILCR is $4.\ 2 \times 10^{-5}$, within the range of $10^{-6}$ to $10^{-4}$ generally considered to be acceptable to the EPA (1986). The total site HI is $7 \times 10^{-1}$ (Table 5-1), lower than the acceptable limit of 1.0 (EPA, 1989). Therefore, it can be concluded that contamination at this site does not pose an unacceptable risk or hazard to a maintenance worker at the site.

## 5.2 Sportsman

As explained in Section 3.4, under the future land-use scenario, the sportsman is exposed to surface soil, surface water, and sediment. Total site ILCRs and HIs for this receptor are presented in Table 5-1. From Table 5-1, it can be seen that the total site ILCR is $7.0 \times 10^{-8}$, below the range of $10^{-6}$ to $10^{-4}$ generally considered to be acceptable to EPA (1986). The total site HI is $4 \times 10^{-2}$ (Table 5-1), below the acceptable limit of 1.0 (EPA, 1989). Therefore, it can be concluded that contamination at this site does not pose an unacceptable risk or hazard to a sportsman visiting the site.

## 5.3 Noncancer Effects of Chemicals

As noted in Section 4.2, the IEUBK model for estimating blood lead levels in young children (EPA, 1994) was used to evaluate the effects of lead in the various media as RSA-67. This approach, in effect, represents an overestimate of potential lead exposure to groundwater because

## Table 5-1

## Summary of Incremental Lifetime Cancer Risks and Noncancer Hazards
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Receptors | Surface Soil ILCR | Subsurface Soil ILCR | Surface Water ILCR | Sediment ILCR | Residuum Groundwater ILCR | **ILCR All Pathways** |
|---|---|---|---|---|---|---|
| **RSA-67** | | | | | | |
| Maintenance Worker | NA | NA | NA | NA | 4.19E-05 | **4.19E-05** |
| Sportsman | NA | NA | 7.03E-08 | NA | NA | **7.03E-08** |

ILCR - Incremental Lifetime Cancer Risk.
NA - Not Applicable.

| Receptors | Surface Soil HI | Subsurface Soil HI | Surface Water HI | Sediment HI | Residuum Groundwater HI | **HI All Pathways** |
|---|---|---|---|---|---|---|
| **RSA-67** | | | | | | |
| Maintenance Worker | NA | NA | NA | NA | 7.26E-01 | **7.26E-01** |
| Sportsman | NA | NA | 4.05E-02 | 8.01E-04 | NA | **4.13E-02** |

HI - Hazard Index.
NA - Not Applicable.

the child resident is considered the most sensitive receptor to lead exposure, and for RSA-67 is an incomplete pathway. The evaluation consists of estimating blood lead concentrations and comparing them to the generally accepted cutoff level of 10 micrograms per deciliter (µg/dL). The IEUBK model estimates blood lead concentrations for each of the first 7 years of a child's life. It also applies descriptive statistics to estimate the probability density of blood lead concentration, and estimates the percent of the population expected to exceed the cutoff level.

Lead is somewhat unique in that it is a naturally occurring metal, it is ubiquitous (i.e., present usually at low, background levels in all media to which a receptor may be exposed), effects are not route-specific (i.e., the effects of contact via different media and exposure pathways are additive), and effects occur at levels sufficiently low so that establishing a threshold or benchmark dose is not practical.

Although lead was identified as a COPC in groundwater only, the IEUBK is designed to quantify the multimedia, multipathway human health impacts of exposure to lead. Therefore, because lead was identified as a COPC in groundwater only, the IEUBK model was run for RSA-67 primarily to evaluate the potential impacts of lead in groundwater to human receptors, and the source-term concentration of groundwater was used as the input concentration for groundwater (88 µg/L). Default values were used for other IEUBK input parameters (Tables 5-2 and 5-3).

***Results***. The inputs and outputs of the IEUBK lead model are presented in Appendix B and the probability graph output is presented in Figure 5-1. From Figure 5-1, it can be seen that groundwater is the major contributor to blood lead, with background dietary concentrations providing the next greatest contribution. The geometric mean blood lead concentration for the on-site child resident is estimated at 7.4 µg/dL, with 25.29 percent of the population potentially experiencing concentrations above the 10 µg/dL level below which adverse manifestations are not expected. Therefore, it can be concluded that lead at RSA-67 will not pose an unacceptable hazard to human health. Considering the proposed land use for RSA, the exposure pathway is also implausible.

## Table 5-2

### Default Variable Values Used in the Integrated Exposure Uptake Biokinetic Model[a] for Predicting Blood Lead Levels in Children Redstone Arsenal Site No. 67, Madison County, Alabama

| Variable | Age of Child (Years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0-1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 |
| Outdoor air concentration (μg/m$^3$) | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Indoor air concentration | 30 Percent of indoor air concentration | | | | | | |
| Time outdoors (hours/day) | 1 | 2 | 3 | 4 | 4 | 4 | 4 |
| Ventillation rate (m$^3$/day) | 2.0 | 3.0 | 5.0 | 5.0 | 5.0 | 7.0 | 7.0 |
| Pulmonary absorption | 30 percent of inhaled dose | | | | | | |
| Dietary lead intake (μg/day) | 5.53 | 5.78 | 6.49 | 6.24 | 6.01 | 6.34 | 7.00 |
| Drinking water intake (L/day)[b] | 0.20 | 0.50 | 0.52 | 0.53 | 0.55 | 0.58 | 0.59 |
| Bioavailability of lead in ingested diet and water | 50 Percent of ingested dose | | | | | | |
| Bioavailability of lead in ingested soil and dust | 30 Percent of ingested dose | | | | | | |
| Contribution of lead in soil to lead in indoor dust | 70 Percent | | | | | | |
| Contribution of airborne lead to lead in indoor dust | 100 Percent | | | | | | |

[a]U.S. Environmental Protection Agency (EPA), 1994, ***Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children***, Office of Emergency and Remedial Response, Publ. No. 9285-7-15-1, EPA/540/R-93/081, NTIS No. PB93-963510.
[b]Fifteen percent consumed from other sources with a lead concentration of 10 μg/L.

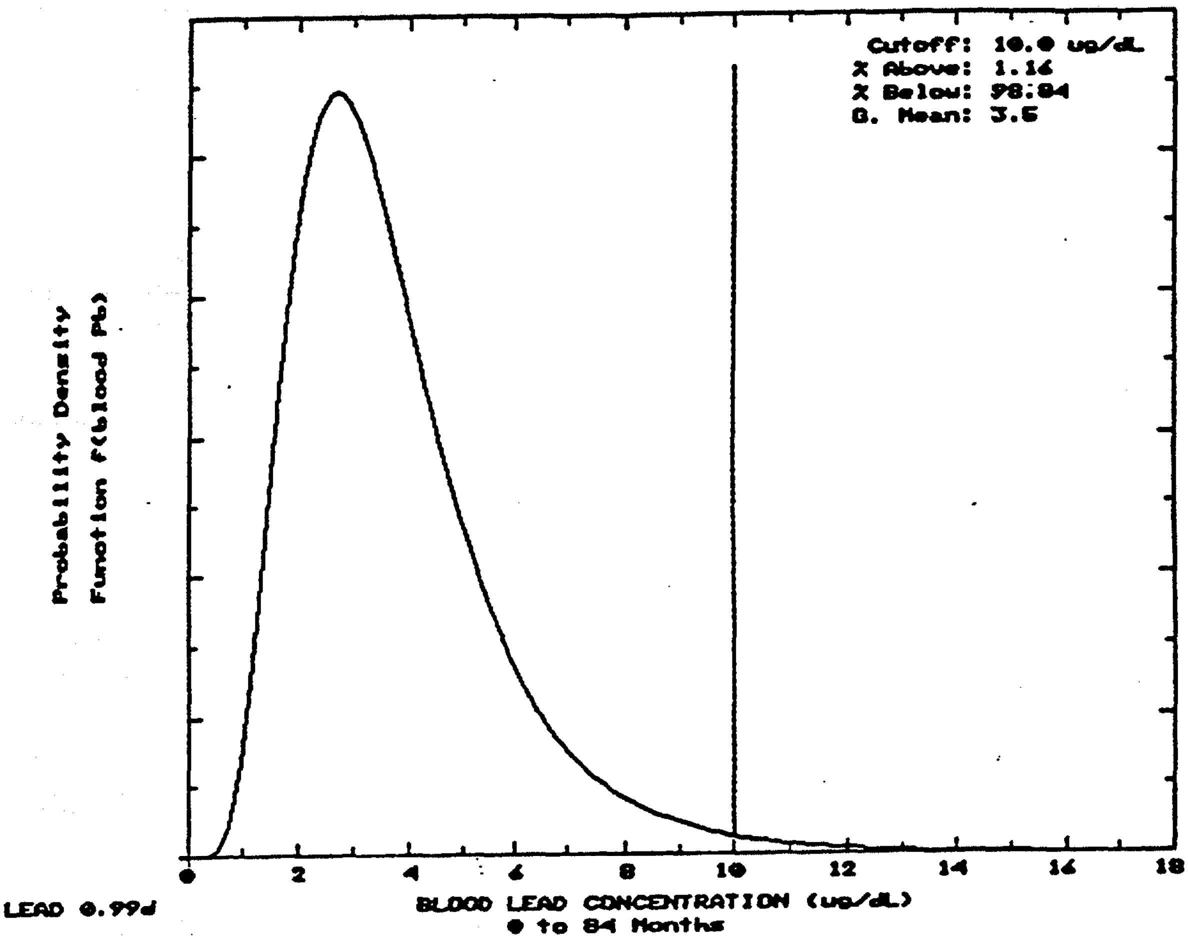
**Table 5-3**

**Lead Concentration and Dose Data Used in the Integrated Exposure Uptake Biokinetic Blood Lead Model Redstone Arsenal Site No. 67, Madison County, Alabama**

| Data Input Parameter | Value |
|---|---|
| Soil concentration (mg/kg [μg/g]) | 0.0 |
| Groundwater concentration (μg/L) | 88.0 |
| Ingested Pb in venison (mg/kg-day) | NA |
| Ingested Pb in beef (mg/kg-day) | NA |
| Contribution of Pb via venison and beef (μg/day) | NA |

**Figure 5-1**

**Integrated Exposure Uptake Biokinetic Model Results**
**Redstone Arsenal Site No. 67, Madison County, Alabama**



# 6.0 Remedial Goal Option Development

EPA Region IV requires development of RGOs as part of the BHHRA (EPA, 1995). RHOS are site-specific RBCs that reflect the exposure and toxicity assumptions applied in the BHHRA assessment. Consequently, the risk-based RGOs are source medium-, receptor-, and chemical-specific. RGOs were estimated only for the nonresidential scenario and not the residential scenario because the on-site resident is not a likely future land-use scenario at RSA (as discussed in the January 17, 1997 RSA risk managers' project review meeting).

## 6.1 Selection of Chemicals of Concern

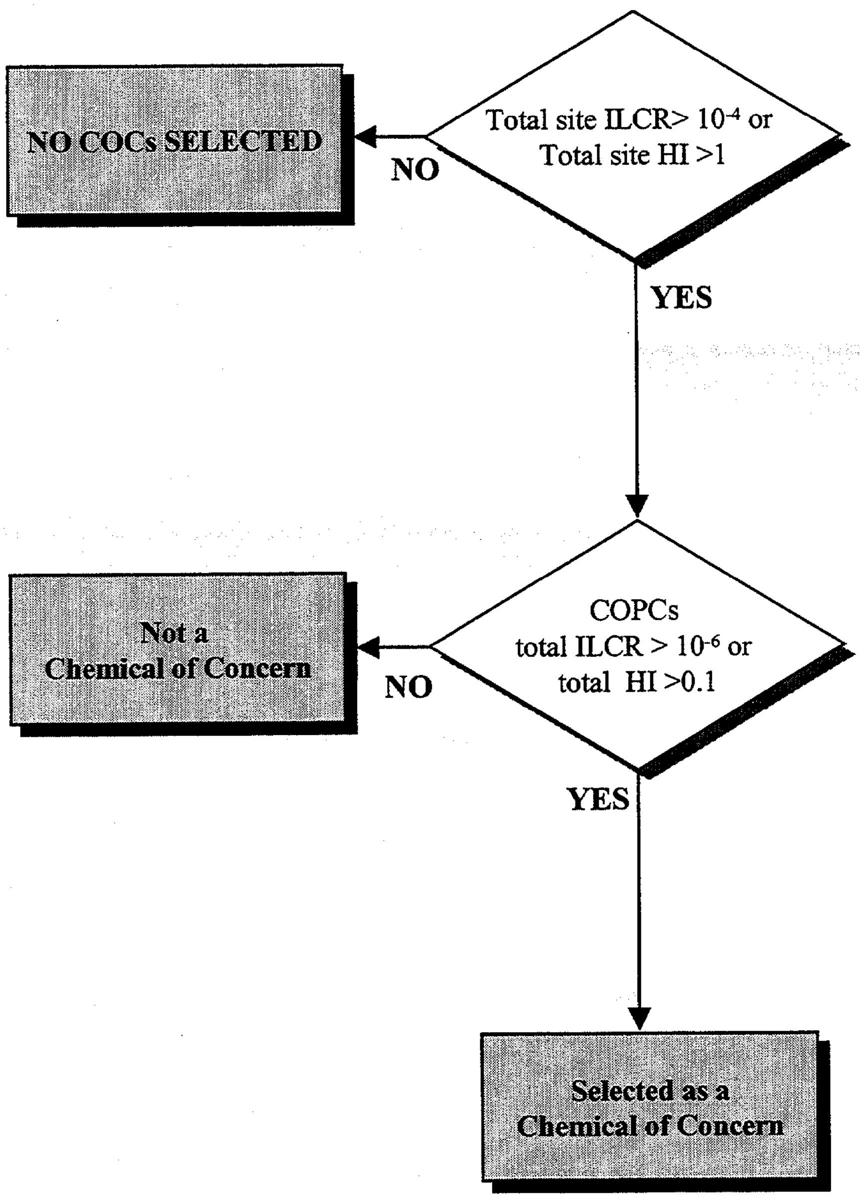
The first step in RGO development is selection of chemicals of concern (COC) (Figure 6-1). No COC were selected at RSA-67 for any of the media because total site ILCRs and HIs were within acceptable limits for all receptors.

## 6.2 Remedial Goal Options

RGOs were not estimated because total site ILCRs and HIs were within acceptable limits for all receptors.

# Figure 6-1

## Decision Flow for Selection of Chemicals of Concern
## Redstone Arsenal Site No. 67, Madison County, Alabama




COPC: Chemical of Potential Concern

HI : Hazard Index

ILCR: Incremental Lifetime Cancer Risk

# 7.0 Uncertainty Analysis

This chapter evaluates uncertainties associated with the BHHRA presented in this report. There are many uncertainties inherent in a risk assessment process, and a lengthy discussion of these issues are provided in the WP (IT, 1997). Because this is a summary report, this chapter focuses on uncertainties that are site-specific and relevant to this assessment.

## 7.1 Analytical Data

It is not possible to completely characterize the nature and extent of contamination on any site. Uncertainties arise from the limits on the number and locations that can be sampled to characterize the site and the elimination of constituents that are infrequently detected.

There is also some uncertainty associated with combining the two groups of data that were collected by different investigators during different time frames. The quality of the data from the site characterization (PELA, 1988) and supplemental investigation (Rust, 1997) may not be identical. An additional consideration is that the background data for groundwater was compiled by a third investigator (CH2M, 1997).

Inorganics were the only COPC identified for groundwater and surface water (Sections 2.5 and 2.6). It is possible that these levels of inorganics are associated with high turbidity in the samples, based on the method of sample collection.

## 7.2 Selection and Quantification of COPC

Uncertainty associated with the selection process used to determine the COPC and estimation of source-term concentrations arises from a combination of the following factors:

- Estimated source-term concentrations are uncertain. For statistical purposes, if a constituent is positively identified at a site and has at least a single positive hit, all the samples with nondetects are assumed to have a value equal to half the detection limit and are included in the data. These procedures introduce a conservative bias into the risk assessment.

- A limited number of samples may lead to the calculation of wide confidence intervals on the mean concentration and high source-term concentrations. In some cases, the 95 percent UCL, was greater than the maximum values; thus, the maximum value was chosen as the source-term concentration. High confidence limits introduce a conservative bias into the risk assessment.

- A limited number of samples may not completely characterize the site.

- Laboratory analytical techniques have a degree of uncertainty associated with them. These uncertainties are documented by using data qualifiers to reflect the degree of certainty of measurement. For example, some data were estimated (e.g., J-qualified), while other data were rejected (i.e., R-qualified). The direction of bias is unclear.

- UCLs are used for source-term concentrations according to EPA (1992a). This means that 95 percent of the time, the actual mean concentration can be less than the value used in the exposure assessment. Conversely, 5 percent of the time the actual mean concentration can be greater than the value used in the exposure assessment. Therefore, the exposure assessment may underestimate the exposures in 5 percent of the cases, and overestimate exposures 95 percent of the time, imparting an overall conservative bias to the risk assessment.

## *7.3 Selection of Hypothetical Receptors and Potential Exposure Pathways*

Generally, the hypothetical receptors and exposure pathways are chosen to "cover" the most highly exposed individual or subpopulation, introducing a conservative bias to the risk results.

Another area of uncertainty is the selection of land-use scenarios, particularly for future land use. For example, the assumptions that groundwater at RSA-67 will be used as a drinking water source in the future is likely to reflect an overestimation of risk and hazard. The soil exposure pathways are overly conservative because the soil matrix at this site is limited to a small fraction of the site; however, it is assumed that the maintenance worker is exposed to soil at this site (8 hours per day).

Additionally, because the site is essentially a marsh, it was assumed that future use would be highly limited, thus, a residential receptor was not evaluated at this site. The industrial exposure evaluated also assumed limited maintenance work. If this site was to be developed for office or residential use, it would need to be backfilled with clean soil because construction would not be permitted in a marsh. Therefore, the exposure scenarios evaluated here introduce a conservative bias to the assessment.

## *7.4 Risk Characterization*

EPA (1995) recommends a central tendency evaluation for receptors whose risks exceed acceptable levels. Therefore, since no receptor risks were identified, no central tendency risks were performed.

***Effects of Iron.*** An oral RFD for iron is now available (EPA, 1989). Based on this value, iron in surface water poses an HI of $2.4 \times 10^{-3}$, considerably less than the 1.0 upper limit (Table 7-1). However, the published standard values that describe the relative carcinogenicity or toxicity of some COPC do not accurately represent the threat posed by that chemical. This RfD is not considered reliable by EPA Region IV because it is based on inadvertent iron consumption from beer brewed in iron vessels (EPA, 1997b). Iron concentrations in soil at RSA-67 do not represent levels that would be expected to cause toxicity in mammals.

## Table 7-1

## Sportsman Intake Doses and Risk for Exposure to Surface Water for Iron
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Chemical | Source-Term Concentration (µg/L) | Source-Term Concentration (mg/L) | Dermally Absorbed Dose of COPC Cancer (mg/kg-day) | Dermally Absorbed Dose of COPC Noncancer (mg/kg-day) | ILCR from Dermal Contact | HQ from Dermal Contact | **Sum ILCR** | **Sum HI** |
|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | |
| Iron | 4.65E+03 | 4.65E+00 | 4.66E-05 | 1.09E-04 | NA | 2.41E-03 | **NA** | **2.41E-03** |
| **Total of ILCR and HI** | | | | | | | **NA** | **2.41E-03** |

COPC = Chemical of Potential Concern.
ILCR =Incremental Lifetime Cancer Risk.
HQ = Hazard Quotient.
HI = Hazard Index.

# 8.0 Summary and Conclusion of the Baseline Human Health Risk Assessment

A BHHRA was performed following EPA methodology (1989, 1995) and subsequent guidance. Using highly conservative receptor exposure scenarios, two hypothetical receptors (a maintenance worker and a sportsman) were theoretically exposed to some or all of the contaminated media at this site, either directly or indirectly. The groundskeeper, construction worker, off-site resident, and future on-site resident scenarios proposed in the WP were not evaluated at this site because it is a marshy area that would not support any industrial or residential development. Total ILCR and HI estimates for this site are summarized in Table 5-1. No COPC were identified for soils; only inorganics were identified as COPC in groundwater and surface water.

Explosives, thiodiglycol, and "chemical agents," chemicals associated with previous site activity, were not detected in any of the samples, for any medium. These results indicate that environmental media at RSA-67 have not been impacted by past practices (storage of mustard gas drums) at the site.

No risks to human health, either present or future, were identified for this site.

# 9.0 References

Bair, F. E., 1992, ***Weather of U.S. Cities***, Gale Research Inc., Detroit, Michigan.

CH2M Hill, 1997, ***Report of MSFC Background Sampling***, Draft Final, National Aeronautics and Space Administration, George C. Marshall Space Flight Center, February.

Engineering-Science, Inc., 1992, ***RCRA Facility Investigation Work Plan for RSA-58, RSA-115, RSA-116, RSA-129, G, and Target-Seeker Area***.

EPA, 1997a, ***Exposure Factors Handbook***, Volumes 1-3, Office of Research and Development, Washington, DC, EPA/600/P-95/002F.

IT Corporation (IT), 1998, ***Installation-Wide Background Soil Study Report, Alabama, Internal Draft***, Prepared for U.S. Army Corps of Engineers, Savannah District, Savannah, Georgia, April.

IT Corporation (IT), 1997, ***Installation-Wide Work Plan, Redstone Arsenal, Madison County, Alabama***, Prepared for U.S. Army Corps of Engineers, Savannah District, Savannah, Georgia, June 1996.

P.E. LaMoreaux and Associates Inc., 1988, ***Confirmation Reports, Unit 3 Investigations, Arsenal, Alabama***, Tuscaloosa, Alabama, July.

Rust Environment and Infrastructure, 1998, ***Draft Phase I Remedial Investigation Report, RSA-50, 52, 57, 61, 62, 63, 65, 67, 109, 110, 112, 113, 114, and 128, Redstone Arsenal, Madison County, Alabama***, Prepared for U.S. Army Corps of Engineers, Savannah District, Savannah, Georgia, February 1996.

U.S. Environmental Protection Agency (EPA), 1998, ***Risk-Based Concentration Tables***, EPA Region III, Philadelphia, Pennsylvania, dated October 1.

U.S. Environmental Protection Agency (EPA), 1997a, ***Exposure Factors Handbook***, Volumes 1-3, Office of Research and Development, Washington, DC, EPA/600/P-95/002F.

U.S. Environmental Protection Agency (EPA), 1997b, ***Summary of Risk Contractors TQM Meeting***, June 17, 1997, Memorandum from J. Barksdale, Project Manager, EPA Region IV, to D. Burton, Project Manager, IT, 6/27/97.

U.S. Environmental Protection Agency (EPA), 1996, ***Soil Screening Guidance: Technical Background Document***, Office of Solid Waste and Emergency Response, EPA/540/R-95/128, NTIS No. PBS96-963502.

U.S. Environmental Protection Agency (EPA), 1995, ***Supplemental Guidance to RAGS: Region IV Bulletins, Human Health Risk Assessment***, Waste Management Division, EPA Region IV, Atlanta, Georgia, November.

U.S. Environmental Protection Agency (EPA), 1994, "Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil," Memorandum from L. R. Goldman, Assistant Administrator, to EPA Regional Directors, dated July 14, 1994.

U.S. Environmental Protection Agency (EPA), 1992a, ***Supplemental Guidance to RAGS: Calculating the Concentration Term***, Interim Final, Office of Emergency and Remedial Response, Washington, DC, Publication 9285.7-081.

U.S. Environmental Protection Agency (EPA), 1992b, ***Dermal Exposure Assessment: Principles and Applications***, Interim Report, Office of Research and Development, Washington, DC, EPA/600/8-91/011B, including Supplemental Guidance dated August 18, 1992.

U.S. Environmental Protection Agency (EPA), 1992c, ***Guidance on Risk Characterization for Risk Managers and Risk Assessors***, Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant Administrators, Regional Administrators, February 26.

U.S. Environmental Protection Agency (EPA), 1992d, ***40 CFR Part 131, "Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance; Final Rule,"*** Federal Register 57 (246): 60911-60916.

U.S. Environmental Protection Agency (EPA), 1992e, ***Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Independent Interim Final Guidance,*** Office of Solid Waste, EPA/530/R-93/003.

U.S. Environmental Protection Agency (EPA), 1991a, ***Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Including Revisions to Chapter 4 (November 1992), and Appendix D: Corrections to RAGS-Part B Sections 3.3.1 and 3.3.2 (April 1993)***, Office of Emergency and Remedial Response, Washington, DC, Publication 9285.7-01B.

U.S. Environmental Protection Agency (EPA), 1991b, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final***, Office of Solid Waste and Emergency Response, OSWER Directive: 9285.6-03.

U.S. Environmental Protection Agency (EPA), 1990, ***Exposure Factors Handbook***, Office of Health and Environmental Assessment, Washington, DC, EPA/600/8-89/043.

U.S. Environmental Protection Agency (EPA), 1989, ***Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)***, Interim Final, Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002.

U.S. Environmental Protection Agency (EPA), 1986, "***Guidelines for Carcinogen Risk Assessment,***" Federal Register, 51(185): 33992-34003.

# APPENDIX A

# RISK CHARACTERIZATION TABLES

## Table A-1

## Sportsman Intake Doses and Risk for Exposure to Sediment
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Chemical | Source-Term Concentration (mg/kg) | Dermally Absorbed Dose of COPC | | ILCR from Dermal Contact | HQ from Dermal Contact | Ingestion of COPC | | ILCR from Incidental Ingestion | HQ from Incidental Ingestion |
|---|---|---|---|---|---|---|---|---|---|
| | | Cancer (mg/kg-day) | Noncancer (mg/kg-day) | | | Cancer (mg/kg-day) | Noncancer (mg/kg-day) | | |
| **Inorganics** | | | | | | | | | |
| Aluminum | 4.60E+04 | 6.02E-06 | 1.40E-05 | NA | 5.20E-05 | 3.21E-04 | 7.49E-04 | NA | 7.49E-04 |
| **Sum of ILCR and HI** | | | | **NA** | **5.20E-05** | | | **NA** | **7.49E-04** |
| **Total of ILCR and HI** | | | | | | | | **NA** | **8.01E-04** |

COPC = Chemical of Potential Concern.
ILCR =Incremental Lifetime Cancer Risk.
HQ = Hazard Quotient.
HI = Hazard Index.

## Table A-2

## Maintenance Worker Intake Doses and Risk for Exposure to Residuum Groundwater
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Chemical | Source-Term Concentration (µg/L) | Source-Term Concentration (mg/L) | Ingestion of COPC in Groundwater Cancer (mg/kg-day) | Ingestion of COPC in Groundwater Noncancer (mg/kg-day) | ILCR from Groundwater Ingestion | HQ from Groundwater Ingestion | Dermally Absorbed Dose of COPC Cancer (mg/kg-day) | Dermally Absorbed Dose of COPC Noncancer (mg/kg-day) | ILCR from Dermal Contact | HQ from Dermal Contact | Sum ILCR | Sum HI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | | | | | |
| Aluminum | 6.67E+03 | 6.67E+00 | 2.61E-03 | 7.31E-03 | NA | 7.31E-03 | 1.07E-05 | 3.00E-05 | NA | 1.11E-04 | **NA** | **7.42E-03** |
| Arsenic | 7.10E+01 | 7.10E-02 | 2.78E-05 | 7.78E-05 | 4.17E-05 | 2.59E-01 | 1.14E-07 | 3.19E-07 | 1.80E-07 | 1.12E-03 | **4.19E-05** | **2.60E-01** |
| Barium | 5.20E+02 | 5.20E-01 | 2.04E-04 | 5.70E-04 | NA | 8.14E-03 | 8.34E-07 | 2.34E-06 | NA | 3.67E-05 | **NA** | **8.18E-03** |
| Cadmium | 3.50E+01 | 3.50E-02 | 1.37E-05 | 3.84E-05 | NA | 7.67E-02 | 5.62E-08 | 1.57E-07 | NA | 6.29E-03 | **NA** | **8.30E-02** |
| Chromium (VI) | 2.50E+02 | 2.50E-01 | 9.78E-05 | 2.74E-04 | NA | 9.13E-02 | 8.02E-07 | 2.25E-06 | NA | 1.50E-02 | **NA** | **1.06E-01** |
| Lead | 8.80E+01 | 8.80E-02 | 3.44E-05 | 9.64E-05 | NA | NA | 5.65E-10 | 1.58E-09 | NA | NA | **NA** | **NA** |
| Manganese | 4.18E+03 | 4.18E+00 | 1.64E-03 | 4.58E-03 | NA | 2.29E-01 | 6.71E-06 | 1.88E-05 | NA | 3.13E-02 | **NA** | **2.60E-01** |
| **Sum of ILCR and HI** | | | | | **4.17E-05** | **6.72E-01** | | | **1.80E-07** | **5.38E-02** | | |
| **Total ILCR and HI** | | | | | | | | | | | **4.19E-05** | **7.26E-01** |

COPC = Chemical of Potential Concern.
ILCR =Incremental Lifetime Cancer Risk.
HQ = Hazard Quotient.
HI = Hazard Index.

## Table A-3

## Sportsman Intake Doses and Risk for Exposure to Surface Water
## RSA-67
## Redstone Arsenal, Madison County, Alabama

| Chemical | Source-Term Concentration (µg/L) | Source-Term Concentration (mg/L) | Dermally Absorbed Dose of COPC Cancer (mg/kg-day) | Dermally Absorbed Dose of COPC Noncancer (mg/kg-day) | ILCR from Dermal Contact | HQ from Dermal Contact | **Sum ILCR** | **Sum HI** |
|---|---|---|---|---|---|---|---|---|
| **Inorganics** | | | | | | | | |
| Arsenic | 4.45E+00 | 4.45E-03 | 4.45E-08 | 1.04E-07 | 7.03E-08 | 3.65E-04 | **7.03E-08** | **3.65E-04** |
| Manganese | 1.03E+03 | 1.03E+00 | 1.03E-05 | 2.41E-05 | NA | 4.01E-02 | **NA** | **4.01E-02** |
| **Total of ILCR and HI** | | | | | | | **7.03E-08** | **4.05E-02** |

COPC = Chemical of Potential Concern.
ILCR =Incremental Lifetime Cancer Risk.
HQ = Hazard Quotient.
HI = Hazard Index.

# APPENDIX B

# INTEGRATED EXPOSURE UPTAKE BIOKINETIC MODEL RESULTS

# Appendix B

## Integrated Exposure Uptake Biokinetic Model Results
## Redstone Arsenal Site No. 67, Madison County, Alabama



LEAD MODEL Version 0.99d

AIR CONCENTRATION: 0.100 ug Pb/m3 DEFAULT
Indoor AIR Pb Conc: 30.0 percent of outdoor.
Other AIR Parameters:

| Age | Time Outdoors (hr) | Vent. Rate (m3/day) | Lung Abs. (%) |
|---|---|---|---|
| 0-1 | 1.0 | 2.0 | 32.0 |
| 1-2 | 2.0 | 3.0 | 32.0 |
| 2-3 | 3.0 | 5.0 | 32.0 |
| 3-4 | 4.0 | 5.0 | 32.0 |
| 4-5 | 4.0 | 5.0 | 32.0 |
| 5-6 | 4.0 | 7.0 | 32.0 |
| 6-7 | 4.0 | 7.0 | 32.0 |

DIET: DEFAULT

DRINKING WATER Conc: 88.00 ug Pb/L
WATER Consumption: DEFAULT

SOIL & DUST:
Soil: constant conc.
Dust: Multiple Source Analysis

| Age | Soil (ug Pb/g) | House Dust (ug Pb/g) |
|---|---|---|
| 0-1 | 0.0 | 0.0 |
| 1-2 | 0.0 | 0.0 |
| 2-3 | 0.0 | 0.0 |
| 3-4 | 0.0 | 0.0 |
| 4-5 | 0.0 | 0.0 |
| 5-6 | 0.0 | 0.0 |
| 6-7 | 0.0 | 0.0 |

Additional Dust Sources: None DEFAULT
Soil contribution conversion factor: 0.00
Air contribution conversion factor: 0.0

## Appendix B

## Integrated Exposure Uptake Biokinetic Model Results
## Redstone Arsenal Site No. 67, Madison County, Alabama



PAINT Intake: 0.00 ug Pb/day DEFAULT

MATERNAL CONTRIBUTION: Infant Model
Maternal Blood Conc: 2.50 ug Pb/dL

CALCULATED BLOOD Pb and Pb UPTAKES:

| YEAR | Blood Level (ug/dL) | Total Uptake (ug/day) | Soil+Dust Uptake (ug/day) |
|---|---|---|---|
| 0.5-1: | 5.5 | 10.30 | 0.00 |
| 1-2: | 8.1 | 20.71 | 0.00 |
| 2-3: | 8.1 | 22.15 | 0.00 |
| 3-4: | 7.9 | 22.87 | 0.00 |
| 4-5: | 7.7 | 23.89 | 0.00 |
| 5-6: | 7.6 | 25.41 | 0.00 |
| 6-7: | 7.3 | 26.26 | 0.00 |

| YEAR | Diet Uptake (ug/day) | Water Uptake (ug/day) | Paint Uptake (ug/day) | Air Uptake (ug/day) |
|---|---|---|---|---|
| 0.5-1: | 2.46 | 7.82 | 0.00 | 0.02 |
| 1-2: | 2.40 | 18.27 | 0.00 | 0.03 |
| 2-3: | 2.74 | 19.34 | 0.00 | 0.06 |
| 3-4: | 2.69 | 20.12 | 0.00 | 0.07 |
| 4-5: | 2.63 | 21.19 | 0.00 | 0.07 |
| 5-6: | 2.80 | 22.52 | 0.00 | 0.09 |
| 6-7: | 3.11 | 23.06 | 0.00 | 0.09 |

Comments

**Response to U.S. Environmental Protection Agency**
**Comments on**
Draft Summary Baseline Human Health Risk Assessment
RSA-67, Operable Unit 15
December 1998
Redstone Arsenal, Alabama

---

*Comments received from Mr. Jim Barksdale, EPA, on May 11, 1999.*

**General Comments**

**Comment 1:** **Evaluation of lead exposure may be confusing as presented in the document. The exposure assessment pointedly does not evaluate any exposure scenarios that include a child receptor. However, childhood exposure to lead is evaluated in the risk characterization section through the use of the IEUBK model. Although this approach is more conservative than evaluating lead exposure through the use of the "adult lead model" (EPA, 1996), evaluation of lead based upon childhood exposure may be confusing given the absence of a child exposure scenario. The text should be modified to more fully explain that the IEUBK model is used to most conservatively estimate lead risks at the site and to reiterate that there are no child receptors at the site.**

**Response 1:** The following changes have been made to the text to clarify the use of the IEUBK child lead model as a conservative estimate of lead exposure to the adult maintenance worker scenario.

**A.** The text of Section 4.2 has been replaced as follows:

**4.2 Evaluation of Noncarcinogenic Effects for Lead**
Lead has been identified as a COPC for groundwater at RSA-67. Because no threshold dose has been established for lead, an RfD is not available for evaluation of the toxicity of exposure to lead. However, the EPA (1994) Integrated Exposure Uptake Biokinetic Model (IEUBK) is designed to integrate exposure to lead from various sources to estimate mean blood lead concentrations for the first 7 years of a child's life, and to predict variation about the mean. Although no child receptor is assumed for RSA-67, it is generally agreed that the young child is the most sensitive receptor for exposure to lead. Therefore, the IEUBK was used for RSA-67 to provide a conservative estimate of potential human health impacts of lead. This approach, in effect, uses the young child as a surrogate lead receptor for the maintenance worker (Section 3.4). Because the IEUBK represents a multimedia approach, lead exposure is evaluated for a variety of media, even though lead is a COPC for groundwater only.

**B.** Section 5.3, 2nd sentence has been added:

This approach, in effect, represents an overestimate of potential lead exposure to groundwater because the child resident is considered the most sensitive receptor to lead exposure, and for RSA-67 is an incomplete pathway.

**C.** The 3rd paragraph of Section 5.3 has been replaced as follows:

Although lead was identified as a COPC in groundwater only, the IEUBK is designed to quantify the multimedia, multipathway human health impacts of exposure to lead. Therefore, because lead was identified as a COPC in groundwater only, the IEUBK model was run for RSA-67 primarily to evaluate the potential impacts of lead in groundwater to human receptors, and the source-term concentration of groundwater was used as the input concentration for groundwater (88 µg/L). Default values were used for other IEUBK input parameters (Tables 5-2 and 5-3).

**Specific Comments**

**Comment 1:** **Figure 2-1. The figure does not present the location of surface and subsurface soil locations (PEL-AAS1, PEL-AAS2, and PEL-AAS3). These locations should be presented so that the soil data can be evaluated in context.**

**Response 1:** Figure 2-1 has been modified to include soil sampling locations PEL-AAS-1, PEL-AAS-2, and PEL-AAS-3.

Response to Comments

**Response to U.S. Corps of Engineers**
**Comments on**
Draft Summary Baseline Human Health Risk Assessment
RSA-67, Operable Unit 15
December 1998
Redstone Arsenal, Alabama

---

*Comments received from Mead, USACE Missouri River Division; received 4/6/99.*

**Comment 1:** **Comment 6720581-53, Page 1-2, Paragraph 1.0. Please use exposure factors in the EPA August 1997 Exposure Factors Handbook (EPA/600/P-95/002Fa) if acceptable to Region IV.**

**Response 1:** The Exposure Factors Handbook (EFH) was considered as guidance in developing the site-specific receptors and parameter values for the RSA-67 Summary BHHRA. The Region IV guidance was, likewise, considered as was the Installation-wide Work Plan (IT, 1997). The EFH has been added to the list of documents in Section 1.0.

**Comment 2:** **Comment 6720581-54, Page 2-1, Paragraph 2.1. Please consult RAGS A Volume 1, Section 5.5 on appropriate treatment of data with a AB@ data qualifier, which is not automatically excluded from a quantitative risk assessment. If the blank contains detectable levels of common laboratory contaminants, then the sample result should be considered positive only if the concentrations in the sample exceed ten times the maximum amount detected in any blank. If the blank contains detectable levels of one or more organic or inorganic chemicals that are not considered by the EPA to be common laboratory contaminants, then consider site sample results as positive only if the concentration of the chemical in the site sample exceeds five times the maximum amount detected in any blank.**

**Response 2:** The text has been changed to reflect that the data evaluation was performed as is described in RAGS. The description of the use of the "B" qualifier has been modified to indicate that this description applies to the data validation "B" qualifier rather than a laboratory qualifier. In the validation process, the 5X and 10X rules are applied to blank contaminants. If a contaminant exceeds the appropriate rule, the "B" is removed and that value is considered a valid detection in data received for evaluation by risk assessors. Any "B"s that remain on data evaluated for risk have had these rules applied and do not warrant consideration representative of site conditions. The following changes have been made to the second paragraph in Section 2.1:

- "... and "B" ... " has been removed from the second sentence.
- The second sentence was expanded to include a description for determining the blank concentration for common laboratory

contaminants (e.g., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters).

**Comment 3:** **Comment 6720581-62, Page 2-1, Paragraph 2.1.1 Site-Related Data, 2.1.2 Background Data, 2.5 COPC in Groundwater, and 2.6 COPC in Surface Water. Based on the site history, RSA-67 was used for drum storage of mustard gas. Please address here and/or in the uncertainty analysis if the COPCs identified for groundwater, surface water and sediment are consistent with site use, and/or if sampling techniques (i.e., bailer vs. low-flow sampling) used for background and site samples might account for the presence of these constituents in surface and groundwater when they were not present in either surface or subsurface soils.**

**Response 3:** Mention of association of inorganic COPCs with turbidity related to the sampling techniques has been added in Section 7.1 of the Uncertainty Analysis. The following statement has been added as the third paragraph to Section 7.1:

> "Inorganics were the only COPCs identified for groundwater and surface water (Sections 2.5 and 2.6). It is possible that these levels of inorganics are associated with high turbidity in the samples, based on the method of sample collection."

Discussion concerning site relatedness has been added to Section 8.0, Summary and Conclusion of the Baseline Human Health Risk Assessment. The following sentences have been added to the end of Section 8.0: "No COPC were identified for soils; only inorganics were identified as COPC in groundwater and surface water. Explosives, thiodiglycol, and "chemical agents," chemicals associated with previous site activity, were not detected in any of the samples, for any medium. These results indicate that environmental media at RSA-67 have not been impacted by past practices (storage of mustard gas drums) at the site."

**Comment 4:** **Comment 6720581-55, Page 3-3, Paragraph 3.4. Please explicitly describe the activities and exposures expected for the maintenance worker, and explain why no exposure to surface water and sediment would be expected.**

**Response 4:** The activities of the maintenance worker scenario are described in the new Section 3.4.1. As described therein, the RSA-67 maintenance worker incorporates appropriate activities associated with the groundskeeper and construction worker scenarios. No maintenance is assumed to be needed in the marshy areas, as no infrastructure exists or is anticipated to be constructed in the foreseeable future. Therefore, the maintenance worker would not be expected to be exposed to sediment and surface water. The sportsman, however, would be expected to wade through this area which serves as potential deer habitat and, thus, would be potentially exposed to contaminants in the sediment and surface water.

**Comment 5:** **Comment 6720581-57, Page 3-2, Paragraph 3.4. Please consult a biologist/ecologist familiar with the Redstone Arsenal Area to determine if the characterization of the physical setting, conceptual site model, migration pathways, activities, and intake variables of the sportsman scenario are realistic and consistent, and revise these section if appropriate. (See other comments, including Comments 7, 9, 13, and 14 for examples of discrepancies to be resolved.)**

**Response 5:** The sportsman scenario for RSA-67 is based on that described in the Installation-Wide Work Plan (IT, 1997), portions of which were prepared by ecologists that had visited this site and other sites at Redstone Arsenal. Section 3.4 has been revised to provide additional discussion of the receptor scenarios and to correct any discrepancies.

**Comment 6:** **Comment 6720581-58, Page 3-4, Paragraph 3.5, Exposure-Point Concentrations in Ambient Air. If there were no COPC identified in soil and sediments are assumed to be wet, please clarify why inhalation exposure to particulates (dust) are quantified rather than concluding that no further evaluation is warranted.**

**Response 6:** No COPC were found in surface soil, so the inhalation pathway was not evaluated for this medium. Because sediment is covered with water most of the year and the area not covered with marsh is heavily vegetated, it is assumed that sediment would not be suspended in the air as particulates. Also, no volatile COPC were identified. Therefore, the discussion in Section 3.5, *Exposure-Point Concentrations in Ambient Air*, has been deleted.

**Comment 7:** **Comment 6720581-59, Page 3-6, Paragraph 3.5, Exposure-Point Concentration for Consumption of Games. If there were no COPCs identified in soils, and only that one pathway (surface soil-plant uptake-vegetation-browsing by deer-venison-ingestions) is evaluated, please clarify why exposure point concentrations are quantified rather than concluding that further evaluation is not warranted.**

**Please explain why pathways involving other media were not considered when evaluating consumption of game. Figure 4-1 shows a complete exposure pathway for the sportsman ingesting venison. The pathway shown is for surface soil – plant uptake – vegetation – browsing by deer – venison – ingestion), but no pathway is shown for plant uptake from sediment, surface water or groundwater or for ingestion of surface water by deer. No COPCs were identified in surface soil, but COPCs were found in the other three media.**

**Response 7:** The discussion of *Exposure-Point Consumption of Game* has been deleted. For information, studies on bioaccumulation in cattle and, to a lesser degree, on deer indicate that the origin of most bioaccumulation is the animal=s feed, rather than from other sources of exposure.

**Comment 8:** **Comment 6720581-60, Page 37, Paragraph 3.6.1. If there were no COPCs identified in soils, sediments are assumed to be wet, and volatiles are not present as COPCs in surface water, please clarify why inhalation of COPC in air is quantified here rather than concluding that further evaluation of this pathway is not warranted.**

**Response 8:** Please see response to Comment 6. It is acknowledged that no COPCs were found in surface soil and that no volatile organic compounds were detected in sediments. The previous Section 3.6.1, Inhalation of COPC in Air, has been deleted.

**Comment 9:** **Comment 6720581-61, Page 3-11, Paragraph 3.6.5, Ingestion of COPC in Venison. If there were no COPCs identified in soils, and only that one pathway (surface soil-plant uptake-vegetation-browsing by deer-venison-ingestions) is evaluated, please clarify why ingestion of venison is discussed. Para. 3.7.3 states that since no COPC were selected**

**from surface soil, there is no exposure for deer and this pathway is not quantified. (Note previous comment that it may be appropriate to consider pathways involving other media when evaluating consumption of game).**

**Response 9:** Section 3.6.5 has been deleted.

**Comment 10:** **Comment 6720581-63, Page 3-11, Paragraph 3.7, Justification of Intake Variables. Please use exposure factors in the EPA August 1997 Exposure Factors Handbook (EPA/600/P-95-002Fa) if acceptable to Region 4 EPA.**

**Response 10:** Information from the EFH as well as from other sources was considered in developing the intake assumption described in the Work Plan and the RSA-67 BHHRA.

**Comment 11:** **Comment 6720581-64, Page 3-12, Paragraph 3.7.1. Since there were no organic COPCs, please delete the last sentence in the second paragraph.**

**Response 11:** This last sentence has been deleted (now Section 3.6.1).

**Comment 12:** **Comment 6720581-65, Page 3-13, Sections 3.7.2, 3.7.4, 3.7.5. Please clarify that although the workplan proposed evaluation of these scenarios, they are not appropriate for the site, or delete these sections, as the topic was addressed in Para 3.4.**

**Response 12:** Sections 3.7.2, 3.7.4, and 3.7.5 have been deleted. The information found in these sections has been moved to the end of Section 3.4 into a Section 3.4.3 titled Additional Receptors Not Evaluated.

**Comment 13:** **Comment 6720581-66, Page 3-13, Paragraph 3.7.3. Please revise this section to be consistent with previous information. Para 3.4 states that surface water at this site would not support development of fish of edible size, so exposure to the sportsman via the fish pathway was not quantified. Para. 3.7.3. also states that the site is largely covered with water. Based on this information, hiking and fishing would not be activities expected at RSA-67. Please revise estimated exposure based on time allowed for deer hunting season at RSA. The normal time of year for deer hunting (late fall) and the fact that the site is largely water-covered supports an assumption that the hunter would be wearing waterproof boots and long pants on most, if not all occasions, so please**

**consider revising the body area exposed to surface water and sediment.**

**Response 13:** Reference to fishing and hiking has been deleted in Section 3.7.3 (new Section 3.6.2). The exposure frequency of 52 days per year for the sportsman is provided in the Work Plan (IT, 1997). While it is true that deer hunting is seasonal, it is conceivable that a sportsman may hunt other game within RSA-65 at various times of the year. While we agree that 52 days per year is likely a conservative assumption for this scenario, we see no compelling reason to modify the accepted value in the Work Plan. Although most hunters would probably wear rubber boots if planning to hunt in this area, it seems plausible to us that a hunter on occasion may not have his boot with him or the boots may leak. Therefore, we used the Work Plan assumption that the sportsman's feet and lower legs are dermally exposed to contaminants in surface water. Concerning exposure to sediment, please see the response to Comment 6.

**Comment 14:** **Comment 6720581-67, Page 3-13, Paragraph 3.7.3, Fraction Exposure. Please justify the use of percent sunshine to estimate the presence or absence of surface water at the site or base this estimate on observations made by site personnel or other climatic (rainfall) statistics. Para. 3.1 states that the site is largely inundated with water and the remaining areas are heavily wooded. Para 3.3 states that most of RSA-67 is shallow marsh that contains water much, if not most of the time. Please include additional information to justify the determination of Fraction Ingested and dermal exposure.**

**Response 14:** The use of percent sunshine is admittedly a crude estimate for the presence of ephemeral surface water, but it is a figure that is consistent, independently developed, and probably sufficiently accurate for the level of risk estimations. Use of personal observations is subject to bias and seasonality, and is not likely to be consistent from site to site or from individual to individual, except to verify that surface water might be present at all times. Rainfall statistics would not provide much improvement because the correlation between percent inundation and rainfall amounts at the site would have to be assumed.

Previous Section 3.7.3, second paragraph (new Section 3.6.2) under Fraction Exposure, has been replaced by the following two paragraphs:

"The fraction exposure term of the sportsman for the ingestion pathway is based on the proportion of a 16 waking hours-per-day time period spent at the site, assuming an overall soil, sediment and dust ingestion rate of 100 mg per day (EPA, 1989; IT, 1997). The ingestion pathway FI term is calculated as the number of hours that the sportsman is at the site, divided by 16 hours. Of the 8 hours (Table 3-2) that the sportsman spends at the site, it is assumed that 4 are spent in the marsh. This represents 25 percent of his daily soil, sediment, and dust ingestion exposure. This factor of 25 percent is further multiplied by 30 percent, the fraction of time in a year that the sediment is assumed as not covered by surface water and, thus, available for exposure. Therefore, the sportsman FI term for sediment ingestion is 0.08.

Unlike the case of ingestion, there is no average rate of dermal contact with soil, sediment, and dust assumed over a 16-hour time period (EPA, 1996; IT, 1997). Therefore, the level of exposure experienced by the sportsman is described in terms of the 8 hours spent hunting. It is assumed that of these 8 hours during a hunting day, the sportsman spends 4 hours (50 percent of his time) in the marsh. This 50 percent is further multiplied by 30 percent, the fraction of time in a year that the sediment is assumed as not covered by surface water and, thus, available for exposure. Therefore, the sportsman FI term for dermal contact with sediment is 0.15. It is assumed that the sediment is too wet and too heavily vegetated for the inhalation of sediment to be a complete pathway, even during the 30 percent of the year when the site is not inundated."

**Comment 15:** **Comment 6720581-68, Page 3-13, Paragraph 3.7.3, Fraction Exposure (FI). Since there were no organic COPCs, please delete the last sentence in the first paragraph.**

**Response 15:** Because no COPCs were found in surface soil, this last sentence under fractional exposure has been deleted (new Section 3.6.2).

**Comment 16:** **Comment 6720581-69, Page 4-1, Paragraph 4.2. Since Paragraph 3.7.5 states that evaluation of an on-site resident exposed to groundwater under future land-use conditions did not merit evaluation because the site is mostly covered with water and not suitable for housing, please explain why the IEUBK was used to evaluate an on-site child resident's exposure to lead.**

**Response 16:** This section has been revised to indicate that, in the case of the lead model, the child is being used as a conservative surrogate for all exposures at the site, rather than as part of the on-site resident scenario. See response to Jim Barksdale, EPA General Comment 1.

***Comments received from Dr. Charles W. Belin, Jr., Ph.D., USACE-Savannah District, dated 1/21/99 (received 4/6/99).***

**Comment 1:** **General. A few typographical errors were located, e.g., use of a singular verb with a plural subject. See the second line down on page 2-2. "...data was..."**

**Response 1:** The document has been scanned and corrected for the correct verb use with the word "data."

**Comment 2:** **Figure 2-1. Why is the icon for the Bedrock Monitoring Well Location included in the legend? I find no location on the map.**

**Response 2:** The icon for a bedrock monitoring well location has been deleted.

**Comment 3:** **Paragraph 3.5. In Table 2-7 you indicate there are no COPCs for both Surface Soil and for Subsurface Soil. You also infer that they will nearly always be wet due to its elevation from the river and the wetland characteristics of the site. Yet in Paragraph 3.5 you launch into detail about Exposure-Point Concentrations in Ambient Air. I would have thought you would have merely stated that this was not necessary. Comment?**

**Response 3:** The vast majority of the site is wet, but there is a dry-land fringe along the northern edge of the site and a road bed along the western boundary of the site between RSA-65 and RSA-67. The dry areas were sampled and, to the extent that construction or regular activity are possible on this site, we would expect human activity and consequently, exposure to be more frequent in the dryer areas. This is why we proposed a maintenance worker (electrical poles, road work, ...) rather than a traditional groundskeeper for this site. Exposure via inhalation has not been quantified, as described in the response to Mead, USACE-MRD, Comment 6.

**Comment 4:** **Paragraph 3.5. Same as Comment #3 above for the Exposure-Point Concentrations for Consumption of Game. The habitat No COPCs for soils yet you complete the quantitation for consumption of venison. Comment?**

**Response 4:** The calculations for the consumption of game have been removed from the document.

**Comment 5:** **Paragraph 3.6.1. Again, the soils have no COPCs; and the soils and sediments are assumed to be constantly wet.**

**Response 5:** See response to Mead, USACE-MRD, Comment 6

**Comment 6:** **Paragraph 3.7.3. If the scenario for the trespasser is established in the Workplan, why is it considered inappropriate here. Perhaps it should be deleted here.**

**Response 6:** Following EPA guidance, the trespasser is assumed to be a youth not yet old enough to drive that visits a site repeatedly over an extended period of time. This site is located a great distance from any residential areas and, while not totally restricted, is located in an area of the reservation that is patrolled. Children on bicycles or wandering around would be directed to leave the area. As part of the general approach approved in the work plan, it is appropriate to mention that the trespasser scenario was considered but not adopted for this particular site. However, Section 3.7.2 has been deleted and this information has been is incorporated into Section 3.4.

**Comment 7:** **Paragraph 3.7.3. If there are no organic COPCs, I recommend that the last sentence of the Fraction Exposure be deleted.**

**Response 7:** The sentence has been removed.

**Comment 8:** **Paragraph 3.7.4. If the scenario for an Off-site Resident was established in the workplan, why is it considered inappropriate here. Perhaps it should be deleted here.**

**Response 8:** Following the work plan, exposure of off-site individuals is considered for two limited exposure pathways. Where a surface water body, such as a stream, passes through a site, it is considered possible that a child living adjacent to the stream at the point that it left the reservation might wade and play in the water and, consequently, be exposed. Little, if any, surface water runs off from this site and there are no residential areas anywhere near this location. A second scenario involves beef cattle feeding on contaminated forage and subsequently, being part of the diet of an off-site farmer. This site is totally unsuitable for grazing beef cattle and further, no contamination in the surface soil was detected. Because these scenarios are in the work plan, it is considered appropriate to mention that they were considered for RSA-67 but were not found to be applicable. Section 3.7.4 has been deleted, and appropriate information from Section 3.7.4 was incorporated, as appropriate, into Section 3.4.

**Comment 9:** **Paragraph 3.7.5. If the scenario for an On-site Resident was established in the Workplan, why is it considered inappropriate here. Perhaps it should be deleted here.**

**Response 9:** A calculation of the risks and hazards for hypothetical on-site residents (a child and adult) is usually provided for information and for use by the risk managers for comparison to other scenarios. By consensus agreement, no remedial decisions will be based on these calculations. At RSA-67, the remote location, limited dry land, and general unsuitability of the area for housing compared to other near-by areas led to the decision not to include the on-site residential scenario in this case. However, because these scenarios are in the work plan, it is considered appropriate to mention that they were considered for RSA-67 but not evaluated. Section 3.7.5 has been deleted and this information was incorporated into Section 3.4.

**Comment 10:** **Paragraphs 4.2 and 3.7.5. These two paragraphs seem to be contradictory. In the earlier, an on-site resident exposed to groundwater under future land-use conditions does not merit evaluation since they are not considered buildable. Yet in Para. 4.2, you evaluate the lead concentrations in a child on-site resident. Perhaps you could explain this further.**

**Response 10:** Additional text has been added to explain that the child in the lead model is used as a surrogate for other workers on the site (see response to Jim Barksdale, EPA, General Comment 1). Although overly conservative in its result, the child lead model is a frequently used model that provides a basis of comparison between site assessments where lead is present.

**Response to U.S. Army Corps of Engineers**
**Comments on**
Draft Summary Baseline Human Health Risk Assessment
RSA-67, Operable Unit 15
December, 1998
Redstone Arsenal , Alabama

---

*Comments from Porter Morgan, USACE Savannah District, dated 1/25/99 (received 4/6/99).*

**Comment 1:** **Section 1.0, Page 1-3. Provide a short "current condition" description of the site. Suggest some verbiage from paragraph 3.1. This would help "picture" the site through time.**

**Response 1:** The following information has been added to Section 1.0, Page 1-3: "The vicinity of RSA-67 is generally flat. The site itself consists of approximately 30 acres, which are largely inundated with water. The remaining areas are heavily wooded."

**Comment 2:** **Section 3.7.3, Fraction Exposure, 2nd paragraph, Page 3-14. It would seem that the "16" hours waking time in the first sentence is incorrect. The Sportsman is only at the site for a total of 8 hours. Therefore, there should be a 50 percent time factor here. If this is not correct, how do we justify using 50 percent for the inhalation calculation at the bottom of the same paragraph. These exposures appear to be one-and-the-same.**

**Response 2:** See response to Mead, USACE-MRD, Comment 14.

**Response to U.S. Army Center for Health Promotion and Preventive Medicine**
**Comments on**
Draft Summary Baseline Human Health Risk Assessment
RSA-67, Operable Unit 15
December 1998
Redstone Arsenal, Alabama

---

***Comments received from Dr. C. Weese, M.D. and Dr. M. Johnson, Ph.D., dated February 10, 1999 (received February 16, 1999).***

**GeneralComment**

**Comment 1:** **(Item 2): We reviewed the subject document and have comments (see Paragraph 3). We cannot concur with the outcome of the risk assessment because we have not yet received the referenced report (which presumably contains the risk assessment) for our review. However, comments are enclosed for your consideration.**

**Response 1:** The subject document (Draft-Final RI Report for RSA-50, 52, 57, 61, 62, 63, 65, 67, 109, 110, 112, 113, 114, and 128) was prepared by Rust Environment and Infrastructure, Inc. and submitted to the ACHPPHM on February 27, 1998. At least one copy should be in your files.

**Specific Comments**

**Comment 1:** **Section 2 Tables, C. Weese. Although a frequency of detection cut-off of 5% is stated as a screening criteria, it appears that the number of samples available from the variety of media were quite small. In this way, any detection would require retention as a COPC on this basis. Why were so few samples taken?**
**<u>Recommendation</u>: Please clarify.**

**Response 1:** A 5% frequency of detection screening criterion indicates that for sample sets less than n=20, any detection will pass this step of the COPC screening process; only nondetected analytes will be eliminated by this step. Although this is a COPC screening criterion employed at Redstone Arsenal and other sites, it is not uncommon to collect less than 20 samples of a given medium at a site. The number of samples selected for an investigation is based on a number of factors that include the size of the site, range of site activity, and other requirements that extend beyond the field of risk assessment.

**Comment 2:** **Table 3-2, C. Weese. The units for the variables (days, kg) are not provided.**
**<u>Recommendation</u>: Please provide these values.**

---

**Response 2:** Units for the variables have been added to Table 3-2.

**Comment 3:** **Figure 2-2, M. Johnson, Decision Flow for Selection of Potential Contaminants of Concern. Why does Region IV require a 2x background comparison? What is the significance of doubling a 95 percent UCL of the mean? Further, the first and third diamonds appear to be identical (i.e., testing the statistical probability that substance detection is not due to Type I error).**
**<u>Recommendation</u>: Please clarify why a doubling of an upper bound confidence level is required, not sufficient in itself for comparison purposes to background and either clarify or remove one of the two diamonds in question.**

**Response 3:** EPA Region IV recognizes that the practice of collecting background and site data sets that are substantially large to perform statistically appropriate comparisons is not always feasible. Therefore, Region IV has taken the approach of using twice the mean concentration of the site-specific background data set as a means of screening out site background concentrations of inorganic constituents that are not related to site activities. This approach considers natural variability in the distribution of inorganics (EPA, 1995, Supplemental Guidance to RAGS: Region IV Bulletins, Human Health Risk Assessment). As stated in Section 2.2, twice the mean background concentration was used for COPC screening, not twice the 95th% UCL of the mean. This is consistent with EPA Region IV guidance (EPA, 1995).

The first and third diamonds of Figure 2-2 are significantly different. The first diamond refers to a basic screening of all analytes on the basis of a 5% frequency of detection. Analytes detected in ≤5% are generally regarded as insignificant contributors to risk (except for "hot spots", etc.). The third diamond refers to statistical analyses used to discern whether a site data set and a background data set (of inorganics) are distinguishable. These analyses are performed only on those analytes whose maximum detected concentrations exceed twice background (See Section 5.1 of the Installation-Wide Work Plan for Redstone Arsenal [IT, 1997]).

**Comment 4:** **Page 2-3, Section 2.2, M. Johnson, Risk-Based Screening. It is not clear how 1/10$^{th}$ the HI accounts for additivity; this appears to be arbitrary.**

**<u>Recommendation</u>: More information is needed how 1/10th was extrapolated (if at all).**

**Response 4:** Adjusting the target HI to 0.1 is the method used by EPA Region IV to adapt the Region III RBCs to the COPC screening process (EPA, 1995, Supplemental Guidance to RAGS: Region IV Bulletins, Human Health Risk Assessment). This method is conservative for RSA-67 based on the number of COPCs (=1) and the level of exposure for the receptors as compared to that assumed by the Region III tables.

**Comment 5:** **Page 2-4, Section 2.2, M. Johnson, Nutrients. The fifth sentence is incorrect: iron *can* be a toxic substance and as such, the dose at which toxicity occurs can be determined in humans and laboratory animals.**
**<u>Recommendation</u>: State that the (based on the data) iron concentrations in the soil approximate background concentrations and do not represent concentrations that could result in exposures that would cause toxicity in mammals (i.e., the calculated dose would be closer to the RDA than that which would cause toxicity).**

**Response 5:** The text has been changed to indicate that EPA Region IV considers the RfD for iron unreliable. Therefore, even if iron were selected as a COPC (it was not), the selection of iron would be discussed in the Uncertainty Analysis section of the BHHRA (Section 7.0).

**Comment 6:** **Table 3-1, M. Johnson, Variables Used to Estimate Potential Chemical Intakes and Contact Rates for Receptors. Without the unit of measurements, the variables in this table are difficult to compare.**
**<u>Recommendation</u>: Include the units for each variable.**

**Response 6:** It is inferred that this comment is for Table 3-2 and units for each variable have been added to Table 3-2.

**Comment 7:** **Table 4-1, M. Johnson, Summary of the Cancer Evaluation for Chemicals of Potential Concern. What is a dermal slope factor? Where was this value found?**
**<u>Recommendation</u>: Present the reference where this value was found and or the logic on its derivation.**

**Response 7:** A dermal slope factor is derived as the quotient of the oral slope factor (numerator) and the gastrointestinal absorption efficiency (denominator). This methodology is described in Section 5.2.2.4 of the Installation-Wide Work Plan (IT, 1997) and follows the approach found in Appendix A.1 of RAGS Volume I, Part A. Mathematical explanations of the dermal SF and dermal RfD have been added to the "bullet" lists in Section 4.1. Also, the derivation of the dermal SF and dermal RfD have been added as footnotes to Tables 4-1 and 4-2, respectively.

**Comment 8:** **Table 4-2, M. Johnson, Summary of the Noncancer Evaluation for Chemicals of Potential Concern. The Region III RBC tables report an inhalation RfD for aluminum of 1.0E-03; why is this inconsistent with the value in this table?**
**Recommendation: Review each source and present the most defensible or use the Region III value.**

**Response 8:** The value shown on Table 4-2 (1.4E-03) is the most recent value recommended by EPA's National Center for Environmental Assessment. Region III may have selected an alternate value (1.0E-03) intentionally, or this value may be less current or reflect an error. Regardless, neither value would change the results of the RSA-67 BHHRA.

**Comment 9:** **General Comment, M. Johnson. Table 2-1 presents many samples with levels of thiodiglycol (and other chemical agents) yet are not mentioned elsewhere. In addition, this BHHRA concludes that there are no health risks associated with exposure at these sites. How can this be so if thiodiglycol (and potentially other substances for which there are no reported toxicity values) were never evaluated? This point, at a minimum it should be presented in Section 7.0 (Uncertainty Analysis) that these and other substances were not evaluated and thus the potential risk from exposure could have been underestimated. Moreover, our lab has just conducted a 90-d (sub-chronic) rat feeding study with thiodiglycol and has reported a NOAEL of 500 mg/kg/d. Using this study, an interim RfD can be calculated (UF = 1000) resulting in 5.0E-01 mg/kg/d. It would be beneficial to use this RfD to determine if thiodiglycol presents a risk.**

**Response 9:** Table 2-1 lists those constituents which were analyzed for in the various site media and does not include analytical results. An initial screening step of the COPC selection is the frequency of detection. Explosives, thiodiglycol, and "chemical agents" were not detected in any of the samples and were, therefore, eliminated during the COPC screening process. The following statement has been added to Section 8.0, Summary and Conclusion of the Baseline Human Health Risk Assessment: "No COPC were identified for soils; only inorganics were identified as COPC in groundwater and surface water. Explosives, thiodiglycol, and "chemical agents" were not detected in any of the samples, for any medium. These results indicate that environmental media at RSA-67 have not been impacted by past practices (storage of mustard gas drums) at the site."

**Response to AMCOM**
**Comments on**
Draft Summary Baseline Human Health Risk Assessment
RSA-67, Operable Unit 15
December 1998
Redstone Arsenal, Alabama

---

***Comments received from Mr. Ken Hewitt, REM, AMCOM, on April 12, 1999.***

**Comment 1:** **The report is good. However, there is no mention of RAGS Part D. Shouldn't we address them in the tables section (Appendix A)?**

**Response 1:** The RAGS D tables have been prepared for this document. The exact RAGS D submission criteria are not yet firmly established. We anticipate providing the RAGS D tables as a separate submission so that questions with these tables will not influence the acceptance of the risk assessment for RSA-67.