Shaw Environmental, Inc.

312 Directors Drive
Knoxville, TN 37923
865.690.3211
Fax 865.690.3626

Shaw™ Shaw Environmental, Inc.

September 30, 2003

DEPARTMENT OF THE ARMY
Mr. Karl Blankinship
US Army Corps of Engineers
Attn: CESAM-PM-ME
Building 4488, Room A317A, Martin Road
Redstone Arsenal, Alabama 35898

802829-SHAWCHO-0463

Contract: Total Environmental Restoration Contract
Contract DACA21-96-D-0018, Delivery Order 0011

Subject: Submittal of Final Closeout Report Non-Time-Critical Removal Action at RSA-49, Cap Installation Over the Former Arsenic Ponds, Operable Unit 5, Redstone Arsenal, Madison County, Alabama

Dear Mr. Blankinship:

The Final *Closeout Report Non-Time-Critical Removal Action at RSA-49, Cap Installation Over the Former Arsenic Ponds, Operable Unit 5*, Redstone Arsenal, Madison County, Alabama (Shaw, September 2003) is published on ActiveProjects.

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If you have any questions or need additional information regarding this submittal, please do not hesitate to call me at 865-694-7433.

Respectfully submitted,

Don C. Burton
Project Manager
Shaw Environmental, Inc.

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REDSTONE ARSENAL, ALABAMA 35898-5000

REPLY TO
ATTENTION OF

AMSAM-RA-DES-IR

MEMORANDUM FOR Federal Facilities Branch (Ms. Julie Corkran), US Environmental Protection Agency, Waste Management Branch, 61 Forsyth Street, SW, Mail code 4WD-FFB-10th Floor, Atlanta, GA 30303-34013
Government Facilities Section (Mr. Tom Birks), Hazardous Waste Branch, Land Division, Alabama Department of Environmental Management, PO Box 301463, Montgomery, AL 36130-1463

SUBJECT: Final Closeout Report, Non-Time-Critical Removal Action at RSA-49 Cap Installation Over the Former Arsenic Ponds, Operable Unit 5

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

2. This letter transmits one hard copy of subject document. Approval letters have been received from both regulatory agencies and are included with the document.

3. Any questions or concerns regarding this report may be directed to Ms. Terry de la Paz, Installation Restoration Division (AMSAM-RA-DES-IR), e-mail terry.delapaz@redstone.army.mil, 256-955-6968.

Encl

TERRY W. HAZLE
Director, Directorate of Environment
and Safety

CF:
Ground Water Division (Mr. David Lovoy), Alabama Department of Environmental Management, PO Box 301463, Montgomery, AL 36130-1463 (1 hardcopy & 1 CD)
Gannett Fleming, Inc. (Mr. J.E. "Ben" Bentkowski), Suite 700, Peachtree Center Tower, 230 Peachtree St, N, Atlanta, GA 30303 (2 hardcopies & 1 CD)
US Army Environmental Center, Installation Restoration Division, (SFIM-AEC-IRP, Mr. Derek Romitti), Building #E4480, Aberdeen Proving Ground, MD 21010-5401 (1 CD)
US Army Environmental Center (SFIM-AEC-ERA, Ms. Laurie Haines), Building #E4460, Aberdeen Proving Ground, MD 21010-5401 (1 CD)
US Army Center for Health Promotion and Preventative Medicine, (MCHB-TS-THR), Building #E1675, Aberdeen Proving Ground, MD 21010-5401 (1 CD)

AMSAM-RA-DES-IR
SUBJECT: Final Closeout Report, Non-Time-Critical Removal Action at RSA-49 Cap Installation Over the Former Arsenic Ponds, Operable Unit 5

CF (continued):
Environmental Compliance Group (Mr. Jack Milligan), Tennessee Valley Authority, 1101 Market St, CST 17B, Chattanooga, TN 37402-2801 (1 CD)
Wheeler National Wildlife Refuge (Mr. Dwight Cooley), US Fish and Wildlife Service, 2700 Refuge HQ Road, Decatur, AL 35603 (1 CD)
Alabama Department of Public Health (Mr. Kenneth Calhoun), 201 Monroe St, Suite 1450, Montgomery, AL 36104 (1 CD)
Marshall Space Flight Center, Mr. Farley Davis, Building 4200, Mail Code AD-10, Marshall Space Flight Center, AL 35812 (AP)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4

61 Forsyth Street SW
Atlanta, Georgia 30303-3104

September 24, 2003

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

4WD-FFB

Mr. Terry Hazle
Department of the Army
Directorate of Environmental Management
(AMSAM-RA-DEM, Mr. Terry Hazle)
U.S. Army Aviation and Missile Command
Redstone Arsenal Support Activity, Building 4488
Redstone Arsenal, AL. 35898

SUBJ: Redstone Army Arsenal, AL
AL7 210 020 742
Approval: *Closeout Report, Non-Time Critical Removal Action at RSA-049, Cap Installation Over the Former Arsenic Ponds, Operable Unit 5, Draft Final, (October 2002), & Redstone Revised Responses to Comments, (September 23, 2003)*

Dear Mr. Hazle:

The purpose of this correspondence is to provide EPA Region 4's approval of the subject report. This approval is based on Redstone's revised responses (dated September 23, 2003) to EPA's comments on the draft final version (October 2002) of the document. The revised responses to comments were discussed in a conference call between EPA Region 4 and Redstone Arsenal on September 23, 2003, and found by the Agency to be satisfactory. The Alabama Department of Environmental Management has previously approved this report. Therefore, please make the necessary revisions to the report and forward the final version of the document and responses to comments for our files.

Please do not hesitate to contact me at 404/562-8547 or at corkran.julie@epa.gov if you have any questions about this correspondence.

Sincerely,

Julie L. Corkran

Julie L. Corkran
Senior Remedial Project Manager
Waste Management Division
Federal Facilities Branch

cc: Terry de la Paz, Redstone
Tom Birks, ADEM
Ben Bentkowski, Gannett-Fleming

ADEM

ALABAMA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

POST OFFICE BOX 301463 36130-1463 ♦ 1400 COLISEUM BLVD. 36110-2059

MONTGOMERY, ALABAMA

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(334) 271-7700

JAMES W. WARR
DIRECTOR

DON SIEGELMAN
GOVERNOR

Facsimiles: (334)
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December 5,2002

Mr. Terry Hazle
Director
Directorate of Environmental Management
DEPARTMENT OF THE ARMY
Installation Restoration Division
(AMSAM-RA-DEM-IR)
US Army Aviation and Missile Command
Bldg. 4488
Redstone Arsenal, AL 35898

RE: **Notice of Concurrence**
Closeout Report for Non-Time Critical Removal Action (TCRA) at RSA-49: Cap Installation Over the Former Arsenic Ponds, Operable Unit 5, dated October 2002
Redstone Arsenal DSMOA Environmental Restoration Program
Facility ID No. AL7 210 020 742

Dear Mr. Hazle:

The Alabama Department of Environmental Management (ADEM or the Department) has reviewed Redstone Arsenal's closeout report for the TCRA at RSA-49. ADEM understands that this submittal is intended to document past activities taken at the site and to fill administrative gaps in the public record in accordance with the CERCLA process. ADEM concurs that this submittal documents the previous actions at RSA-49.

Unless additional changes are forthcoming to address review comments by other agencies, Redstone should submit appropriate revision pages to update the *Draft-Final* submittal at this time. Please submit *Final* slip-in cover sheets and other appropriate revision pages to make this document final.

If you have any questions please contact Tom Birks at 334/271-7967 or by e-mail at wtb@adem.state.al.us

Sincerely,

Stephen A. Cobb, Chief
Governmental Hazardous Waste Branch
Land Division

cc:
Tom Birks/ADEM
Julie Corkran/EPA Region IV
Jim Grassiano/ADEM

Birmingham Branch
110 Vulcan Road
Birmingham, Alabama 35209-4702
(205) 942-6168
(205) 941-1603 [Fax]

Decatur Branch
2715 Sandlin Road, S.W.
Decatur, Alabama 35603-1333
(256) 353-1713
(256) 340-9359 [Fax]

Mobile Branch
2204 Perimeter Road
Mobile, Alabama 36615-1131
(251) 450-3400
(251) 479-2593 [Fax]

Mobile – Coastal
4171 Commanders Drive
Mobile, Alabama 36615-1421
(251) 432-6533
(251) 432-6598 [Fax]

Final

Closeout Report
Non-Time-Critical Removal Action
at RSA-49
Cap Installation Over the
Former Arsenic Ponds
Operable Unit 5

Redstone Arsenal
Madison County, Alabama
U.S. EPA ID No. AL7 210 020 742

September 2003

Delivery Order 0011
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Alabama Department
of Environmental
Management

Closeout Report Non-Time-Critical Removal Action at RSA-49, Cap Installation Over the Former Arsenic Ponds, Operable Unit 5, Redstone Arsenal, Madison County, Alabama, U.S. EPA ID No. AL7 210 020 742 Final September 2003

Final

Closeout Report
Non-Time-Critical Removal Action at RSA-49
Cap Installation Over the
Former Arsenic Ponds
Operable Unit 5
Redstone Arsenal, Madison County, Alabama

Prepared for:

U.S. Army Corps of Engineers, Mobile District
119 St. Joseph Street
Mobile, Alabama 36662

Prepared by:

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

Delivery Order No. 0011
Contract No. DACA21-96-D-0018
Project No. 802829

September 2003

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List of Acronyms

ADEM	Alabama Department of Environmental Management
AMCOM	U.S. Army Aviation and Missile Command
ASTM	American Society for Testing and Materials
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CL	clay
CMS	corrective measure study
DAF	dilution attenuation factor
EA	environmental assessment
EE/CA	engineering evaluation and cost assessment
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
FONSI	finding of no significant impact
FS	feasibility study
G&M	Geraghty & Miller, Inc.
HEA	health and environmental analysis
HI	hazard index
ICM	interim corrective measure
IRP	Installation Restoration Program
IT	IT Corporation
MCL	maximum contaminant level
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
NCP	National Contingency Plan
NOV	notice of violation
NTCRA	non-time-critical removal action
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PELA	P.E. Lamoreaux and Associates, Inc.
PP	proposed plan
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation

List of Acronyms *(continued)*

RG	remedial goals
ROD	record of decision
RSA	Redstone Arsenal
SSL	soil screening level
TCE	trichloroethene
USACE	U.S. Army Corps of Engineers
USAEHA	U.S. Army Environmental Hygiene Agency
VOC	volatile organic compound

1.0 Introduction

The U.S. Army Corps of Engineers (USACE)-Mobile District has contracted IT Corporation (IT) to prepare a closeout report documenting the construction of a landfill cap at RSA-49, Former Arsenic Ponds, Operable Unit (OU) 5, Redstone Arsenal (RSA), Madison County, Alabama.

The cap was originally constructed as an interim corrective measure (ICM) by the USACE-Mobile District under provisions of the National Oil and Hazardous Substance Pollution Contingency Plan (NCP; Title 40 Code of Federal Regulations Part 300.415 [b][2][iii]). Based on previous investigations, it was determined that contaminants were migrating from the three former arsenic holding ponds located at RSA-49 [U.S. Army Aviation and Missile Command (AMCOM), 1998].

In early 2001, RSA reviewed all Installation Restoration Program (IRP) sites where interim actions or proposed actions have taken place or will take place. For each site, all documentation prepared for any action at that site was listed and reviewed. In reviewing the documentation, the present status of the site was considered, and a plan for completing the administrative record for each action was prepared. Therefore, in order to maintain a proper administrative record under the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA), the ICM at RSA-49 is being considered a non-time-critical removal action (NTCRA). This closeout report will serve as the administrative record that documents the completion of the NTCRA (RSA, 2001).

RSA-49 is located in the north-central portion of RSA (Figure 1) less than 1,000 feet north of the former lewisite manufacturing Plants 1 and 2 (RSA-183). RSA-49 occupies approximately five acres of land and consists of three unlined, closed impoundments or ponds. These ponds were used during the early 1940s for the disposal of a 4 percent arsenic/lime slurry received from the former lewisite manufacturing plants area (RSA-183). Lewisite (dichloro[2-chlorovinyl]arsine) is an arsenic compound that was manufactured for use as a chemical warfare agent. Following the disposal practices of the early 1940s, the ponds were used for the disposal of liquid waste, ash, rubble, and industrial waste resulting from the demilitarization and demolition of sumps and buildings at the lewisite facilities. In 1977, the former arsenic ponds were closed, covered with a soil cap, and revegetated with grass and pine trees.

The NTCRA, which was initiated in 1995 and completed in 1997, involved removing existing vegetation at the site and abandonment of some existing monitoring wells to allow for

construction of a Resource Conservation and Recovery Act (RCRA) cap over the former impoundment areas. The term RCRA cap is used to indicate that the cap was constructed per RCRA guidance documents and requirements (EPA, 1991). The RCRA cap was installed to inhibit further contaminant migration from the site (USACE, 1995). In addition, a new chain link fence and locking gate were installed to prevent trespassing onto the capped area. The existing drainage ditches running through the northeast corner and along the southern edge of the site were relocated outside of the area to be capped. Confirmatory sampling data were compared to a value of 9.5 milligrams per kilogram (mg/kg), which is two times (2x) the mean background concentration of 4.74 mg/kg, to ensure that the extent of the cap encompassed all contaminated areas.

The remainder of this report discusses site conditions prior to the NTCRA (Chapter 2.0), cap construction and related activities (Chapter 3.0), current status of the site (Chapter 4.0), and references used in this report (Chapter 5.0).

2.0 Summary of Existing Environmental Studies

In 1970, the U.S. Army Environmental Hygiene Agency (USAEHA) sampled the drainage ditch downstream of RSA-49. Arsenic was detected in the sediments at a concentration of 640 milligrams per kilogram (mg/kg) (USAEHA, 1970). The ditch paralleled the site on the east side. USAEHA recommended that the arsenic ponds be covered by fill material and the drainage ditch be diverted. The ponds were covered with soil and revegetated with trees and grass in 1977. Sediment and surface water were collected from the drainage ditch again in 1978. In 1979, the U.S. Army Toxic and Hazardous Materials Agency hired Testing, Inc. to install four groundwater monitoring wells around the covered ponds (RS052, RS053, RS054, and RS055) as part of the hydrogeology characterization, survey of wells and lysimeter locations, and monitoring well installation program. The wells were sampled in 1980. Figure 2 is a pre-construction site map that includes the former impoundments and existing monitoring wells.

In 1987, P.E. Lamoreaux and Associates, Inc., (PELA) initiated a confirmation study and resampled the four existing monitoring wells, analyzed four groundwater and four soil samples for arsenic, and performed in-situ permeability tests (PELA, 1989). Arsenic was detected in all four wells, but only two samples exceeded the drinking water maximum contaminant level (MCL) (50 micrograms per liter [µg/L]). Unfiltered arsenic concentrations were: well RS052, 2.8 µg/L (1980), 29 µg/L (1987); well RS053, 3.9 µg/L (1980), 184 µg/L (1987); well RS054, less than 1.3 µg/L (1980), 25 µg/L (1987); and well RS055, 11.34 µg/L (1980), 117 µg/L (1987).

Concentrations of arsenic detected in 1987 were considerably higher than the 1980 detected concentrations from wells closest to the covered impoundments.

PELA performed an upgrade to their 1987 confirmation study in 1988 that included collecting filtered and unfiltered groundwater samples from two of the existing wells for volatile organic compounds (VOC), semivolatile organic compounds and metals. Arsenic was the primary contaminant, with concentrations as follows: well RS054, 148 µg/L (unfiltered), 1.0 µg/L (filtered); well RS055, 62 µg/L (unfiltered), 26 µg/L (filtered). The other two wells were dry at the time of sampling. Other noteworthy constituents include minor detections of carbon tetrachloride and trichloroethene (TCE).

In 1989, Geraghty & Miller, Inc. (G&M) summarized the work PELA performed and formulated the preliminary assessment/site investigation for the site. In 1990, G&M went to the field to perform a first-phase RCRA facility investigation (RFI), which confirmed arsenic contamination in both soil and groundwater. G&M excavated three test pits, installed seven groundwater monitoring wells, sampled all wells, and sampled surface and subsurface soil, sediment, and surface water. Surface, subsurface soils, and sediments were contaminated with polynuclear aromatic hydrocarbons (PAH) and metals, primarily arsenic, with concentrations up to 294 mg/kg. Groundwater south of the site was contaminated with carbon tetrachloride at concentrations up to 17 µg/L. From these Phase I findings, a Phase II RFI investigation was recommended to delineate the extent of contamination in these media.

In 1992, G&M returned to the site to complete the RFI (Phase II) that included additional shallow soil sampling, soil borings, subsurface soil sampling, sediment sampling, monitoring well installation, and groundwater sampling. The investigation showed elevated levels of arsenic (up to 45.7 mg/kg), mercury (up to 9.1 mg/kg) and PAHs in surface soils, as well as elevated levels of arsenic (up to 20,100 mg/kg) and mercury (up to 778 mg/kg) in subsurface soils. Elevated arsenic and PAHs were also observed in sediment samples collected from nearby drainage ditches, particularly to the south of RSA-49 in the RSA-183 area. No constituents of potential concern were detected in the one surface water sample collected at the site. Elevated levels of arsenic and chlorinated hydrocarbons (primarily carbon tetrachloride) were detected in groundwater, predominantly in wells located in the pond area and to the south. However, these chemicals were not detected in the subsurface soil samples collected from within the former disposal ponds. Carbon tetrachloride concentrations in the groundwater exceeded the 5 µg/L MCL at several locations. TCE concentrations in the groundwater also exceeded the 5 µg/L MCL at several locations. The source of carbon tetrachloride and TCE in groundwater is unknown. It is quite possible that the former ponds have partially contributed to the solvent

contamination in groundwater at RSA-49. Groundwater analytical data from the Phase I and Phase II investigations, prior to the cap installation, are shown on the figure contained within Appendix A.

The following documents contain a more detailed discussion of previous activities, analytical results, and general information on the site environmental setting and hydrogeologic conditions:

- Confirmation Report, Unit 3 Investigations (PELA, 1988)
- Upgrade Confirmation Report and Assessment of Remedial Alternatives for Selected Unit 3 Sites (PELA, 1989)
- Final Phase I Report, RCRA Facility Investigations at Unit 1, Unit 2, and Selected Unit 3 Areas (G&M, 1992)
- Final Phase II Addendum, RCRA Facility Investigations at Unit 1, Unit 2, and Selected Unit 3 Areas (G&M, 1993).

Health and Environmental Analyses (HEA) were performed in conjunction with both the Phase I and the Phase II RFI activities. The purpose of the HEA was to determine possible human and environmental exposure pathways so as to assess potential contaminant migration. The results of the Phase I HEA indicated that several constituents posed either systemic or carcinogenic human health risks. Three constituents (arsenic, cadmium, and mercury) detected in test pit, surface soil, and/or sediment samples exceeded systemic criteria. Constituents detected in the remaining environmental media (deep soils, surface water, and groundwater) did not exceed systemic criteria. Several PAH constituents detected in soil, sediment, and test pit samples exceeded carcinogenic criteria. The only carcinogenic constituent exceeding the criterion for groundwater was carbon tetrachloride.

The exposure pathway analyses, however, showed that the probability of contact with most media and exposure to site contamination was low. The potential for contact with surface soils was rated moderate. Based upon the available data, arsenic and chlorinated hydrocarbons were the most widely distributed contaminants at RSA-49. The RFI determined that the most significant concentrations of these constituents occurred in groundwater at the center and south of RSA-49, in interface wells RS055, RS258, RS262, and RS263, and in bedrock well RS261. RS052, the only perched well at the site, was reported to be receiving moderate levels of arsenic leachate from the northern closed disposal pond. No contamination was detected in the deep bedrock well RS259 (134 feet deep) installed at the center of the disposal ponds. In summary, the HEA determined that while direct exposure to the contaminated soils was of moderate

concern, elevated arsenic in groundwater posed a greater potential threat to human health and the environment.

The investigations discussed previously were all conducted in accordance with the requirements of RCRA. However, while a draft corrective measure study (CMS) report was being completed for an April 1993 submittal to the U.S. Environmental Protection Agency (EPA) Region IV, RSA was proposed for listing on the CERCLA National Priority List. As a result, EPA Region IV requested that RSA revise the RCRA HEA (G&M, 1992) to meet the requirements for an equivalent document, a Baseline Risk Assessment (BRA), under CERCLA and the NCP. Therefore, in 1994, USACE contracted with Environmental Science and Engineering, Inc. (ESE) to conduct human and ecological BRAs to address contamination detected at 10 study areas at RSA. RSA-49 was addressed in this BRA effort. The BRA was conducted on data available for soil, groundwater, surface water, and sediment to determine if these environmental media require remedial action. Both human health risks and ecological impacts were evaluated for RSA-49.

Table 1 summarizes the constituents of potential concern and corresponding exposure concentrations identified at RSA-49. Cumulative hazard indices (HI) and cancer risks for a current and future worker exposed to various site media are presented in Table 2.
The results of the human risk characterization at RSA-49 indicated that the cumulative HIs and cancer risks associated with current and future worker exposure to surface soil were below a target HI of 1.0 and a cumulative risk of $1x10^{-4}$. However, in the event that groundwater is ever used for potable purposes in the future, it was determined that the cumulative cancer risk would be $3x10^{-4}$, due primarily to the presence of arsenic. Several VOCs (carbon tetrachloride and chloroform) also contributed to groundwater risks. Based on noncarcinogenic effects, potential future use of groundwater would pose excess health hazards as indicated by an HI of 13, due to the presence of mercury, arsenic, and carbon tetrachloride.

The ecological risk characterization for RSA-49 indicated that the surface soil, surface water, and sediments would not cause excess ecological risks (ESE, 1995).

2.1 Remedial Action Objectives

Based upon concentrations of arsenic and PAHs in soils and sediment, RSA decided that an ICM would be necessary to reduce the direct human exposure to contaminated soils and sediment and to minimize water infiltration through the contaminated waste. A conceptual site model for RSA-49 that includes known site conditions at the time of the ICM, contaminants, and receptors is provided in Figure 3. A human health conceptual site exposure model for RSA-49 that includes known site conditions at the time of the ICM, receptors, and potential exposure

pathways is provided in Figure 4. Using the known site conditions and potential for receptor risk, a primary remedial action objective (RAO) was developed for the NTCRA. The primary RAO was to inhibit further contaminant migration from the site (via soil leachate, sediment transport, surface water transport, and groundwater migration). To accomplish this objective, various problems elements of the primary objective (secondary RAOs) and appropriate remedial goals (RG) were established for the principal media of concern. Table 3 presents the various problem elements of the primary RAO, and the actions taken to mitigate each problem element to the appropriate RG.

Ebasco was contracted to complete a CMS for cap installation at RSA-49. An engineering evaluation and cost assessment (EE/CA) was not completed for the NTCRA at RSA-49. However, it was decided that the Finding of No Significant Impact (FONSI) and the Environmental Assessment (EA) would serve as the EE/CA since they document the elements of an EE/CA such as effectiveness, implementability, and public awareness (RSA, 2001). The FONSI and EA discuss the option of capping versus no action in areas of risk, environmental impact, and consequences for mitigation of contaminant migration from RSA-49. A feasibility study (FS) for RSA-49 was completed and submitted in February of 1997 (ESE, 1997). Public awareness was accomplished with the submittal of numerous fact sheets on the ICM, and conductance of a public meeting in October of 1997. The rationale for cap installation as an ICM is summarized below.

It was concluded that the construction of a low-permeability, multilayer RCRA cap over the closed disposal ponds and excavation of contaminated sediments would prevent direct exposure to the contaminated media and provide an effective and long-term reduction in leachate generation. The cap would help in reducing, though not eliminating, the mobility of contaminated leachate entering the onsite groundwater. Although capping the closed disposal ponds would not reduce the contaminant toxicity or volume because no material would be removed from the site or treated, cap installation and sediment excavation would achieve the primary RAO of minimizing contaminant migration from the site.

The rationale for installing a RCRA cap at RSA-49 was also influenced, in part, by past activities at similar facilities at RSA. In 1992, RSA received a notice of violation (NOV) from the Alabama Department of Environmental Management (ADEM) for groundwater violations related to two closed sites, former arsenic ponds south (RSA-56) and an arsenic waste lagoon (RSA-139). In response to the NOV, RSA determined that an ICM involving construction of RCRA caps at RSA-56 and RSA-139 should be implemented. Based on the similarities in

historical use and waste types between these two sites and RSA-49, RSA determined that a similar ICM should be implemented at RSA-49.

Therefore, cap installation and sediment excavation was a presumptive measure to minimize risk to potential human receptors and reduce contaminant leaching to groundwater.

3.0 Cap Construction and Related Activities

3.1 Limits of the Clay Cap

Existing soil analytical data obtained during the RFI and other previous investigations was not sufficient to establish the lateral limits of soil contamination at the site. To address this lack of data, Ebasco and the USACE-Savannah District conducted further sampling efforts.

To define the extent of contamination and determine the approximate limits of the cap, Ebasco conducted a soil sampling effort on May 2 through 20, 1994. The sampling effort was based on a grid with inner and outer ring samples. The inner ring soil borings were installed next to the existing chain-link fence approximately every 90 feet. An outer ring of borings was established 35 feet from the inner ring and boreholes were installed approximately every 90 feet. An on-site laboratory was used to analyze for arsenic and additional borings were established if screening results indicated arsenic contamination above 10 mg/kg. While the background level of arsenic was 8.8 mg/kg a value of 10 mg/kg used because 10 mg/kg was the detection limit of the on-site X-ray fluorescence screening method. It is assumed that the 10 mg/kg limit was used as an approximation to the background concentration to determine whether or not a result was above the background level. A total of 52 soil borings were installed. Samples were collected from 51 boreholes at depths of 0 to 2 feet, 2 to 4 feet, and 4 to 6 feet and analyzed for arsenic. One boring was installed and sampled at depths of 0 to 2 feet and 2 to 4 feet. The USACE collected additional surface (0 to 1 feet) and subsurface (2 to 4 feet and 4 to 6 feet) samples on July 5 through 6, 1994 and analyzed them for arsenic. The USACE sampling was conducted to supplement work done by Ebasco and to obtain further analytical information in the southwest corner of the site and in the ditch to the south of RSA-49.

The proposed soil clean-up level for arsenic in soil at the time of the cap construction was 80 mg/kg (RCRA Corrective Action Proposed Rule 57FR30708). Due to the potential non-homogeneous nature of the contamination, it was decided to consider 40 mg/kg (1/2 of 80 mg/kg) as the action level for arsenic in soils at RSA-49. To cover possible contaminated areas, the RCRA cap was extended to encompass the outer ring of the Ebasco samples to the north,

west, and east portions of the site, and extended to encompass areas in the southern portion of the site that were above 40 mg/kg. Soils and sediments in the south drainage ditch with concentrations of arsenic greater than 40 mg/kg were excavated and placed under the cap. Soils and sediments located outside the limits of the cap were sampled every 50 feet and, if contaminated, were excavated up to a depth of 2 feet and placed under the cap. A figure displaying the aerial extent of surface and subsurface soils equal to or exceeding the 40 mg/kg RG along with a figure of the portions of the drainage ditches affected by re-routing are included in Appendix B.

3.2 Site Preparation

Prior to construction of the multilayer RCRA cap at RSA-49, numerous activities were completed to prepare the work areas for capping and associated construction. The existing chain link fence with barbed wire that surrounded the arsenic impoundment area was removed. Fence posts were cut-off at ground level and the concrete footings were left in place to minimize contact with arsenic contaminated soil.

Nine monitoring wells (RS052, RS053, RS055, RS256, RS257, RS258, RS259, RS260, and RS261) located within the area to be capped were abandoned with a neat bentonite, grout, and water mixture prior to the clearing activities. The mixture was thoroughly mixed with a mechanical grout mixer and pumped through a tremie pipe into the wells. Proper steps were taken to ensure that air voids or bridging did not occur during abandonment.

The entire area to be capped was cleared of vegetation. All tree trunks within the area were trimmed to three inches above the ground surface. Grubbing was not allowed within the former impoundment and all reasonable precautions were taken not to disturb the existing ground surface. Tree bark and leaves were tested for arsenic and were found to be uncontaminated. All vegetation was chipped and disposed of in the RSA-10 landfill in accordance with all state and other applicable requirements.

To facilitate maintenance activities, a level, approximately 15 feet wide area was created that extended beyond the toe of the cap to a new chain-link fence. Trees and other vegetation were cleared and disposed of in the same manner as those within the impoundment areas. Clearing, stripping, and grubbing were also performed in certain work areas outside the capping area.

The existing drainage ditches located at the northeast and southwest corners of the former impoundment area were relocated to the east and south, respectively, of the capped area to prevent erosion of the cap (Appendix B).

3.3 Cap Construction

Construction of the RCRA cap was conducted in accordance with the Ebasco *95 Percent Submittal – Installation and Maintenance Plan/Health and Safety Design Analysis for the Interim Corrective Measure Design at RSA-49, RSA, Alabama* (Ebasco, 1994).
Figure 5 shows the intended design of this RCRA cap. As shown in this figure, all trees within the former impoundment area were cut down to within three inches of the surface prior to installation of the RCRA cap. Significant grading was required to establish the subgrade design. The subgrade contours were established by placement of a general fill. No grubbing was allowed within this area.

Fill material consisted of locally available material which was clean and free of deleterious material such as large rocks, boulders, trash, construction debris, and organic matter. All fill material was tested and certified as clean prior to its arrival on site. A minimum height of 6 inches of compacted fill material was required to cover all site features, with the exception of tree stumps that required a minimum covering of 3 inches. A maximum design slope of 2 percent was selected for the top of the cap for two reasons: (1) the effect of erosion from stormwater run-off was determined to be manageable with shallow root surface vegetation; and (2) a greater slope would have required more fill at this site and could have potentially resulted in excessive settlement due to greater loads. Side slopes of the cap were designed to be a ratio of five horizontals to one vertical (5:1) for several reasons:

- To minimize the potentially damaging effects of stormwater runoff that increase with the slope angle
- To promote long-term slope stability
- To enable construction equipment to place a well-compacted clay cap on the side slopes
- For ease of maintenance (i.e., mowing).

All subgrade contours were designed to promote positive drainage during and after placement of the RCRA cap.

All subgrade material was compacted to at least the same density as required for the clay layer above it. All fill placed as part of the subgrade was constructed in thin lifts of less than 8 inches in loose measure. Any boulders or rock fragments larger than 3/8 inch in nominal size was segregated from the fill and discarded prior to arrival on site. The organic content of fill soils

was maintained at less than 1 percent by weight of soil. Any tree stumps, logs, trash and other deleterious material was removed from the fill material prior to arrival on site.

Fill placement was supervised by an experienced soils technician, and frequent fill density and moisture tests were performed to verify that the specified degree of compaction was achieved.

The clay used to construct the clay layer was low plasticity clay (CL) material that was free of deleterious debris such as trash, roots, stumps, sand, and rock larger than 3/8 inch in any dimension. Every effort was made to minimize the use of silty or sandy soils in the cap material. The organic content of the clay material was maintained at less than 1 percent by weight of soil. The clay material was selected from a borrow source (northwest corner of RSA-49) that was tested for hydraulic conductivity for a range of soil densities. Acceptable material had a hydraulic conductivity of $1x10^{-7}$ centimeters per second or less from a remolded soil sample compacted to 93 percent of the Modified Proctor maximum dry density as determined by American Society for Testing and Materials (ASTM) D-1557 procedures. The moisture content of the clay material was maintained between 1 and 5 percent above optimum as determined by the same test.

The surface of the clay layer was finished approximately 0.15 feet above or below the design grade. The surface of the clay layer was not allowed to dry or desiccate prior to placement of the topsoil cover. Soil density compaction tests and moisture testing of the placed clay were performed at the same frequency as the subgrade material. Any areas that did not pass the moisture and density requirements of ASTM D-1557 were reworked and retested.

A 40-mil flexible membrane liner was then installed over the clay layer. A drainage layer (geonet with attached geotextile filter layer) was placed on top of the flexible membrane liner. In addition, 18 inches of cover material and six inches of topsoil were placed on top of the drainage layer and graded to a 2 percent slope.

Seeding, fertilizing, and mulching of the topsoil were completed immediately after topsoil density and moisture test results were available. Groundcover maintenance (i.e., mowing), visual inspection for damage, and damage restoration have occurred at regular intervals since the cap was completed in May 1997.

In keeping with the EPA requirements for construction of a RCRA cap, the final thickness of the clay layer was 2 feet. Although this cap has been considered an ICM, the cap meets the EPA guidance for final covers for hazardous waste landfills with the exception of cap slope. The cap

slope was designed at a 2 percent slope to limit the required fill material. To date, there has been no noticeable integrity compromise (ponding, cracking, excessive erosion, etc.) of the cap as a result of the slope deviation.

Straw bale ditch checks and a staked silt fence were used for general sediment and erosion control at RSA-49 during the cap installation and until a suitable stand of grass was produced. The existing access road to the impoundment area from the parking area south of the site (lewisite manufacturing area) was upgraded for vehicle access during construction and maintenance. Following construction of the cap, the access road was extended up the cap side slope to provide vehicle access for maintenance of the cap. The side slope in the vicinity of this ramp is 5:1. The access road consists of an 8-inch minimum crushed stone surface/base course and an eight ounce woven geotextile underlying the base course. The subgrade beneath the geotextile has been compacted to 90 percent of the Modified Proctor maximum dry density. The width of the road is approximately 12 feet with a slope of 1/3 inch per foot away from the crown center of the cap for drainage. All crushed aggregate paving was compacted to 98 percent of the Modified Proctor in accordance with ASTM D1557.

3.4 Ditch Relocation

The existing drainage ditch on the east side of the former impoundment area was relocated outside of the cap to promote free drainage of surface runoff from the cap. The new ditch was tied into an existing drainage further to the south. This allowed for effective drainage of other perimeter areas. The section of the existing drainage ditch that was formerly located within the extent of the cap was cleared and stripped (not grubbed) and filled in with general fill material. Sediments stripped from the ditch were disposed of under the cap. Erosion control, such as rip rap was placed along the sides of the new ditch to maintain stability. Surface contours were gradually tied into the existing terrain to prevent ponding of water and the formation of erosion gullies. The size of the new drainage ditch was greater than the average width and depth of the former ditch in order to facilitate the same capacity flows.

The existing drainage ditch located on the southwest corner of the site area was relocated south of the capped area to prevent erosion of the cap. The existing drainage ditch was cleared and stripped (not grubbed, since there was the potential for contact with contaminated soil), and then filled to promote drainage towards the new drainage ditch location. The new ditch was shaped to permit drainage and grass seeded for erosion prevention.

As previously stated in Section 3.1, sediments in the south drainage ditch with concentrations of arsenic greater than 40 mg/kg were excavated and placed under the cap. Sediments located

outside the limits of the cap were reportedly sampled every 50 feet and, if contaminated, were excavated up to a depth of 2 feet and placed under the cap.

A figure and aerial photos of the drainage ditch relocations are provided in Appendix B.

3.5 Access Limitation

A 6-foot high chain-link fence with three-strand barbed wire along the top was erected around the perimeter of the capped area. The minimum distance between the new fence and the toe of the cap is 5 feet. The fence has the appropriate warning signs, legible from a distance of 25 feet, posed on it every 100 feet. There is one locking gate at the southwest corner of the capped area where the access road enters the site. This fence effectively limits access to the site.

A new cow fence consisting of five strands of barbed wire were reinstalled along the roads to the north and northeast of the cap. The new cow fencing was installed to confine the cows to the area between the chain-link fence and the cow fence.

A post-construction site map that displays cap extent, ditch relocation, and fencing is presented in Figure 6.

Appendix C contains the final as-built drawing and topographic survey that was completed in 1997 by Vector Enterprises, Inc. This figure displays the ICM RCRA cap, borrow area, relocated ditches, and newly installed fences at RSA-49.

4.0 Current Status of the Site

The NTCRA at RSA-49 involved the installation of a RCRA cap over all contaminated soils associated with the former arsenic disposal ponds and excavation of contaminated sediments from a nearby drainage ditch. A sampling program (IT, 1997a, 1999) confirmed that the majority of arsenic contaminated surface and subsurface soils were covered by the cap. A figure showing the spatial distribution of surface and subsurface soil results compared to current screening criteria versus the extent of the cap is provided in Appendix D. The present screening criteria for surface soil is the current background value of 14.5 mg/kg. Subsurface soil results have been compared to dilution attenuation factor of four [$(DAF)_4$] soil screening level (SSL) of 1.168 mg/kg.

A remedial investigation for RSA-49 was initiated in the spring of 2000 under an OU-5-wide investigation and continues to the present. Media sampled to date includes surface and subsurface soil, sediment, and surface water. Nine groundwater monitoring wells were installed in the overburden and sixteen were installed in the bedrock throughout OU-5 in late 2000. Sampling of these wells was completed in April through May 2001. The OU-5 field effort is described in the *Draft Site Specific Field Sampling Plan Attachment, Supplemental Remedial Investigation*, OU-5 (IT, 2000). Current groundwater conditions at RSA-49 and the immediate area surrounding the cap are depicted in a figure contained within Appendix E.

Pursuant to a decision in 2001 to investigate groundwater separately from surface media, the groundwater at RSA-49 will be further investigated under RSA-148 (GW-04). Data collected for the surface media at RSA-49 will be reported in an RI/FS report. A draft FS (ESE, 1997) and a final proposed plan (PP) (IT, 1997b) prepared for the site documented cap maintenance, institutional controls, and groundwater monitoring as components of the final preferred remedial alternative for addressing soil contamination at the arsenic disposal area within RSA-49. These documents will be revised. The aforementioned FS (ESE, 1997) will be revised for inclusion in the future RI/FS surface media report. Following RI/FS reports, a proposed plan and a record of decision will be prepared, documenting the preferred alternative(s) for the entire site.

4.1 Data Gaps and Uncertainties

Because the site boundary of RSA-49 has changed over time, it is important to note what data gaps will be included in future investigations at RSA-49 and what data gaps will be resolved through investigation of RSA-183. While the earlier RSA-49 boundary included portions of the lewisite manufacturing area and a nearby drainage ditch, the site boundary of RSA-49 has recently (2003) been limited to include only the capped disposal ponds. As shown on Figure 1, a new site (RSA-183) was identified to address contamination issues related to the former lewisite plants and portions of the adjacent drainage ditch.

While the cap construction and sediment excavation address direct exposure to contaminated soil and sediment and source control of arsenic within the RSA-49 impoundment area it also has helped to minimize contaminant migration to the groundwater. However, several data gaps remain unresolved following the NTCRA at RSA-49. Each identified data gap will be approached in the following manner.

- **Data Gap #1: Cap construction may not have covered all of the contaminated soil to the south of the site.** If identified, soil locations within the site boundary of RSA-49 with elevated concentrations of arsenic or mercury will

be further sampled to complete the RI and support risk evaluations for inclusion in the FS, PP/ROD, and final remedy decisions at RSA-49. Soil locations outside of the RSA-49 site boundary where elevated arsenic and mercury were detected have been included within the RSA-183 site boundary and were identified for confirmation sampling during the extensive RI soil sampling effort. Please see maps in Appendix F. Sampling data collected during this investigation will be used for risk evaluations in support of a FS, PP/ROD, and ultimately will support decisions for a final remedy at RSA-183.

- **Data Gap #2: Was sediment contamination in the adjacent drainage ditches fully addressed during the NTCRA.** Because so much is unknown about the details of the actual process for sediment removal during the NTCRA, sediment contamination in the adjacent drainage ditches has not been addressed. Therefore, both the eastern and southern drainage ditches that bound RSA-49 have been included within the RSA-183 site boundary and will be sampled as part of the RSA-183 RI. Please see maps in Appendix F. Sampling data collected during this investigation will be used for risk evaluations in support of a FS, PP/ROD, and ultimately will support decisions for a final remedy at RSA-183.

- **Data Gap #3: Has the hydraulic conductivity of the constructed RCRA cap at RSA-49 been determined.** At this time, the hydraulic conductivity of the cap has not been determined, however a Hydrologic Evaluation of Landfill Performance (HELP) evaluation was performed prior to the construction of the cap by EBASCO in 1994. This HELP model will be reviewed and comparisons of available data to SSLs will be conducted as part of the on-going RI to assess if additional data collection is required. Results of the evaluation of the effectiveness and hydraulic conductivity of the cap will be used for preparation of the ROD.

- **Data Gap #4: Has the impact to groundwater from the capped former impoundment ponds at RSA-49 been fully characterized.** At this time, it has been determined that concentrations of arsenic and other metals have decreased in groundwater since construction of the cap in 1995. However, elevated detections of solvents are unresolved as of the writing of this Closure Report. As previously mentioned, separation of surface media and groundwater was decided in 2001. Therefore, characterization of groundwater at RSA-49 will be covered under the investigation of RSA-148 (GW-04). Essentially, RSA-49 will remain a point source for groundwater contamination within RSA-148 and any sampling data collected during future investigations will be used for risk evaluations in support of a FS, PP/ROD, and ultimately will support decisions for a final remedy at RSA-148.

Even with the aforementioned data gaps, the immediate potential threats to human health and the environment from the presence of arsenic contaminated surface soils and sediment at RSA-49 have been eliminated through this NTCRA. In addition, the potential for the arsenic

contaminated leachate from the disposal pits to contaminate the underlying groundwater at the site has been reduced. While the site is proceeding through the CERCLA stages of RI/FS and ROD, land use controls at the cap will be implemented through a RSA site-access program document. This document is currently under preparation.

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TABLES

Table 1

Summary of COPCs and Exposure Concentrations Evaluated in the BRA for RSA-49 Redstone Arsenal, Madison County, Alabama

COPC	Soil (mg/kg)	Groundwater (mg/L)	Surface Water (mg/L)	Sediment (mg/kg)
Inorganics				
Arsenic	7.10E-02	4.00E-02		4.00E-02
Barium		9.10E-02	3.20E-02	2.30E-01
Cadmium	4.60E-04	3.70E-03		6.80E-04
Chromium		6.90E-03		1.10E-01
Lead		1.30E-02		1.10E-01
Mercury	3.60E-03	3.30E-01		4.00E-03
SVOCs				
Bis-(2-ethylhexyl)phthalate	3.10E+00			
Acenaphthene	9.10E-01			
Anthracene	9.00E-01			
Benzo(a)anthracene	2.00E+00			3.30E-01
Benzo(a)pyrene	1.40E+00			3.40E-01
Benzo(b)fluoranthene	2.00E+00			3.00E-01
Benzo(ghi)perylene	1.00E+00			
Chrysene	1.60E+00			3.30E-01
Dibenz(ah)anthracene	8.50E-01			
Fluoranthene	3.40E+00			2.90E-01
Fluorene	9.50E-01			
Indeno(123cd)pyrene	1.10E+00			
Naphthalene	7.80E-01			
Phenanthrene	2.20E+00			3.60E-01
Pyrene	3.00E+00			3.00E-01
VOCs				
Acetone	8.00E-02	3.20E-02		
Carbon tetrachloride		8.00E-03		3.00E-03
Chloroform		6.00E-03		
Methylene chloride	1.70E-02			2.30E-02
Trichloroethene		3.30E-03		

Notes: Exposure Concentrations are either the UCL 95 or the maximum detected value, whichever is less.

Source: ESE, 1997

Table 2

Sumamry of Human Health
Hazard Indices and Cancer Risks
for RSA-49
Redstone Arsenal, Madison County, Alabama

Area	Scenario	Medium	Exposure Route	HI		Cancer Risk
				Adult	Child	
RSA-49	Current Worker	Soil	Ingestion	< 0.1	NA	3.0E-06
			Dermal	< 0.1	NA	2.0E-06
			Inhalation	< 0.1	NA	3.0E-06
			TOTAL	< 0.1	NA	5.0E-06
	Future Worker	Groundwater	Ingestion	12	NA	3.0E-04
			Dermal	< 0.1	NA	1.0E-06
			Inhalation	0.3	NA	7.0E-06
			Subtotal	13	NA	3.0E-04
		Soil	Ingestion	< 0.1	NA	4.0E-06
			Dermal	< 0.1	NA	2.0E-06
			Inhalation	< 0.1	NA	3.0E-08
			Subtotal	< 0.1	NA	5.0E-06
			TOTAL	13	NA	3.0E-04

Table 3

RSA-49 NTCRA
Remedial Action Objectives and Remedial Goals
Redstone Arsenal, Madison County, Alabama

Problem Element	RAO	RG	Action(s) Taken
Arsenic concentrations in soils (both surface and subsurface) present an unacceptable risk when screened against the 40 mg/kg screening criteria.	Prevent unacceptable human exposures to arsenic-contaminated soils.	An RG of 40 mg/kg was the value selected for soils as the screening criteria (value is 1/2 of the 80 mg/kg value prescribed in the RCRA Corrective Action Rule 57FR30798.	1. Install fencing and a locking gate to prevent trespassing. 2. Implement construction of a RCRA cap over the former impoundment areas, and 3. Relocation of the existing drainage ditches located at the northeast and southwest corners of the former impoundment areas to prevent cap erosion.
Arsenic concentrations in sediments of the southern and eastern drainage ditchs present an unacceptable risk when screened against the 40 mg/kg screening criteria.	Prevent unacceptable human exposures to arsenic-contaminated sediments in the southern and eastern drainage ditches.	An RG of 40 mg/kg was the value selected for sediments as the screening criteria (value is 1/2 of the 80 mg/kg value prescribed in the RCRA Corrective Action Rule 57FR30798.	1. Excavation and placement under the cap of arsenic-contaminated sediments exceeding the RG.
Groundwater concentrations at RSA-49 are indicative of contaminant leaching from the waste materials and soils to the groundwater.	Protect groundwater from additional contributions of arsenic leaching from surface and subsurface soils.	A separate RG for protection of groundwater was not used in cap design. However, the extent of the cap may be evaluated relative to the current soil screening level (SSL) of 29 mg/kg (20 DAF) for the protection of groundwater (EPA, 1996).	1. Construction of a RCRA cap over the former impoundment area and contaminated soils to minimize infiltration to groundwater.
Wastes left in place at RSA-49 upon implementation of the cleanup actions may pose unacceptable risk under the unrestricted future land use scenario.	Prevent unacceptable human exposure to arsenic-contaminated wastes within the impoundments under unrestricted future land use scenarios.	A numerical RG is not applicable for this particular RAO. The goal of this RAO is to assure that institutional and land use control elements applied to this site are continued until a final remedy is implemented.	1. Incorporate a land use control implementation plan (LUCIP) into the final remedy of the site, if necessary. 2. Until a final remedial alternative is developed for the site, access to the capped area will be managed through the Redstone Site Access Control Program.

FIGURES

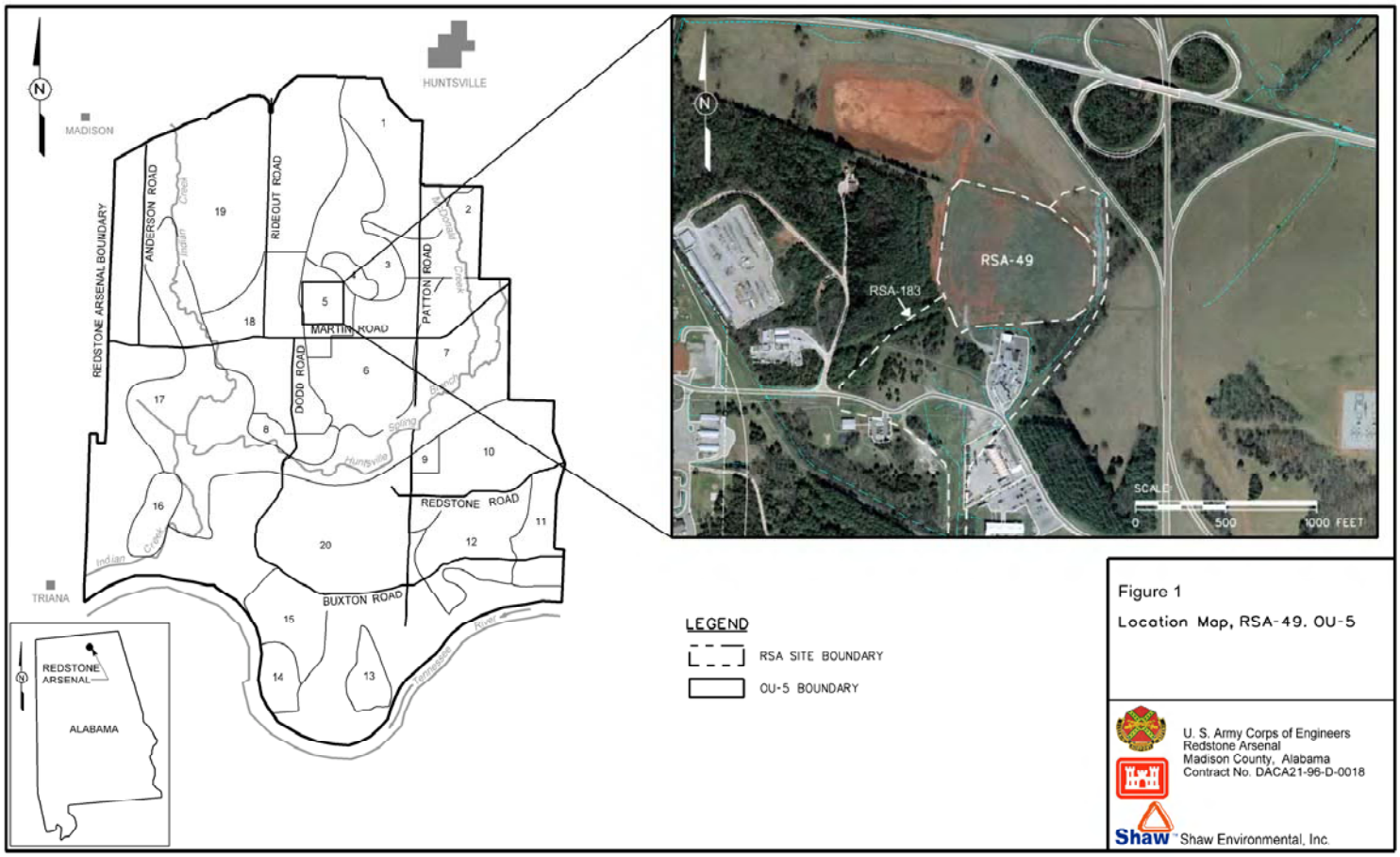

Figure 1

Location Map, RSA-49, OU-5

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.

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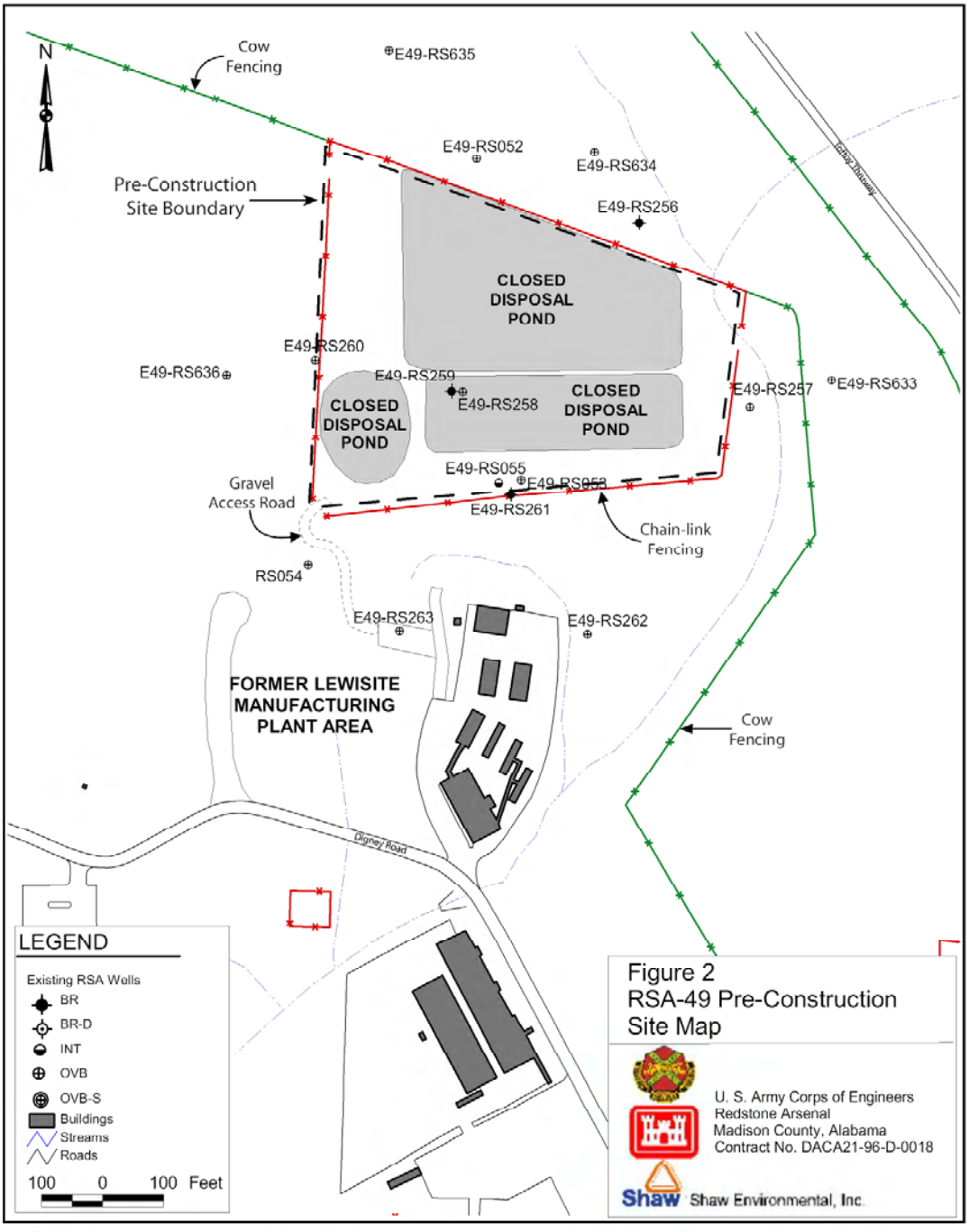

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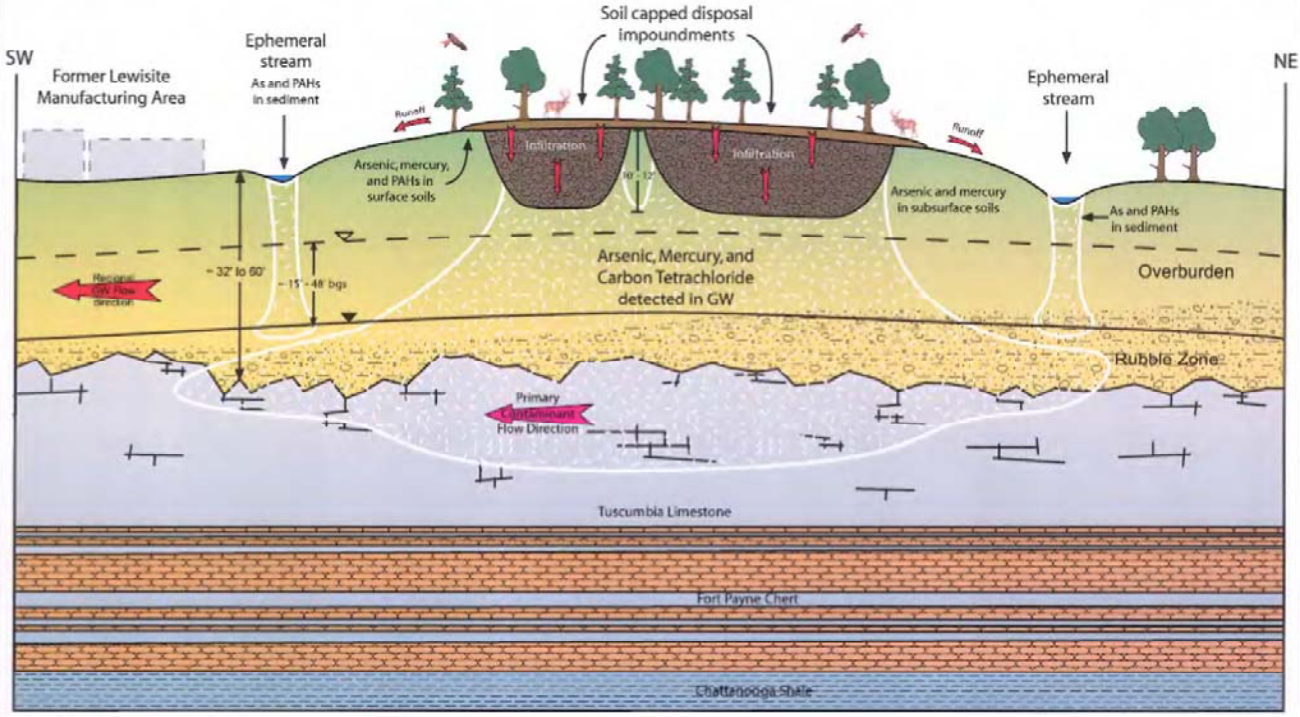
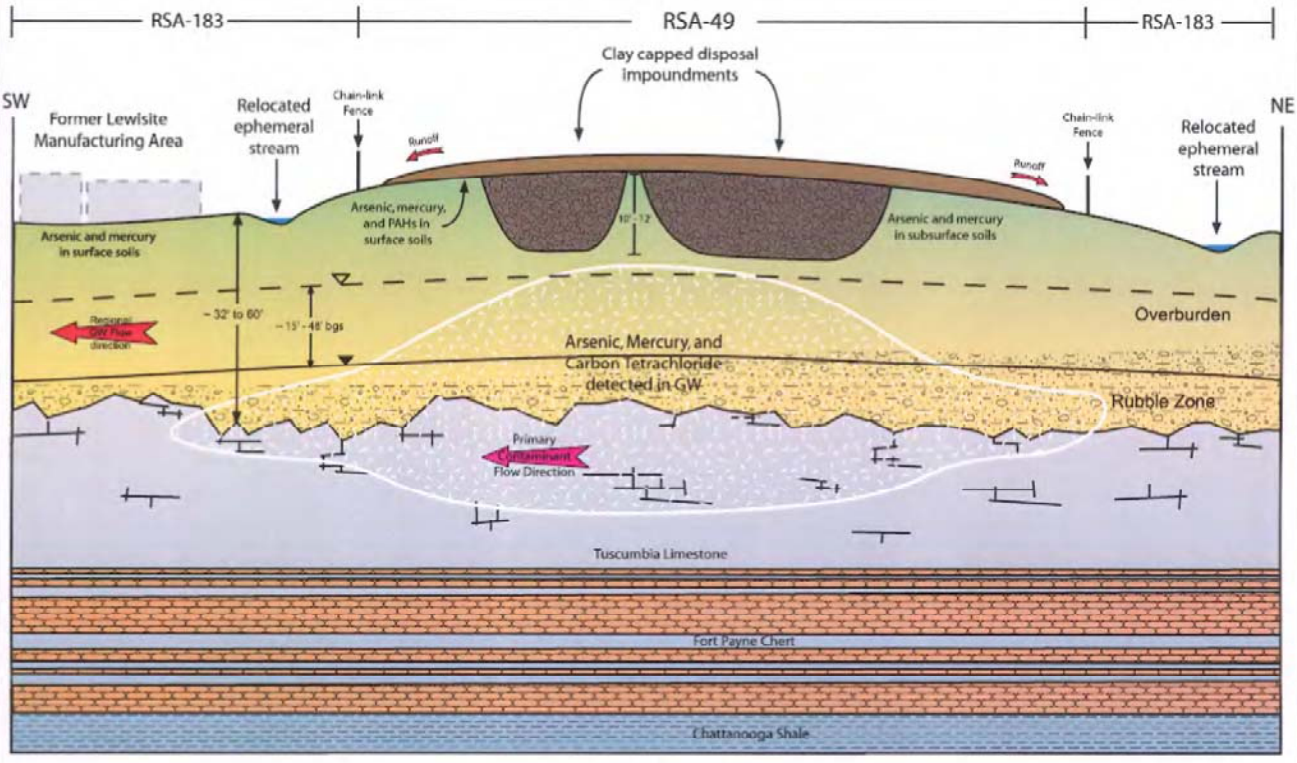


Ecological receptors present at surface.

**Not to Scale

Pre-Construction
Conceptual Site Model



**Not to Scale

Post-Construction
Conceptual Site Model

Figure 3
Conceptual Site Model
for RSA-49

U.S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21 96-D-0018

Shaw Shaw Environmental, Inc.

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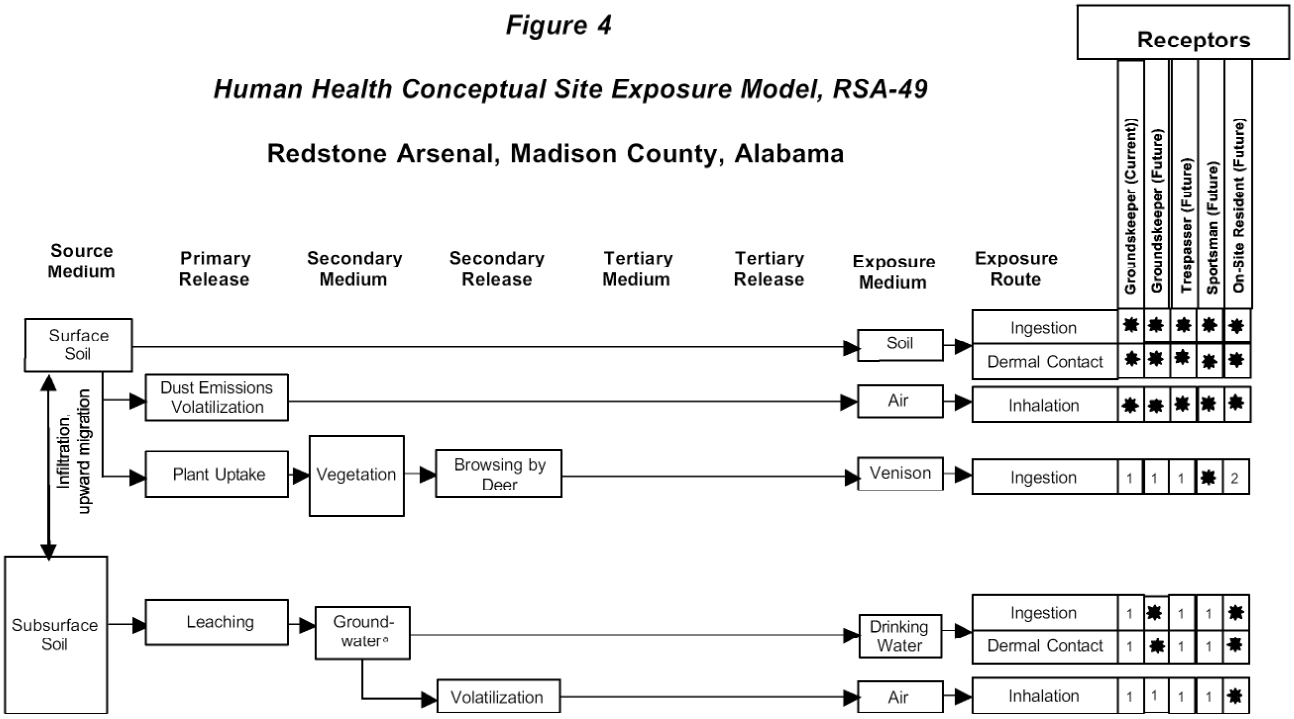
Figure 4

Human Health Conceptual Site Exposure Model, RSA-49

Redstone Arsenal, Madison County, Alabama



* = Complete exposure pathway quantified in risk assessment.

1 = Incomplete exposure pathway.

2 = Residential development precludes this pathway.

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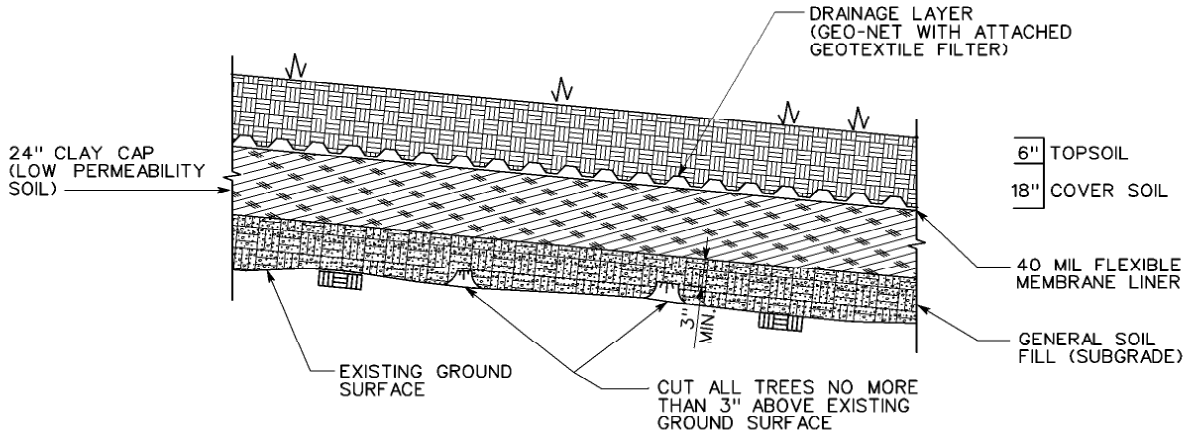
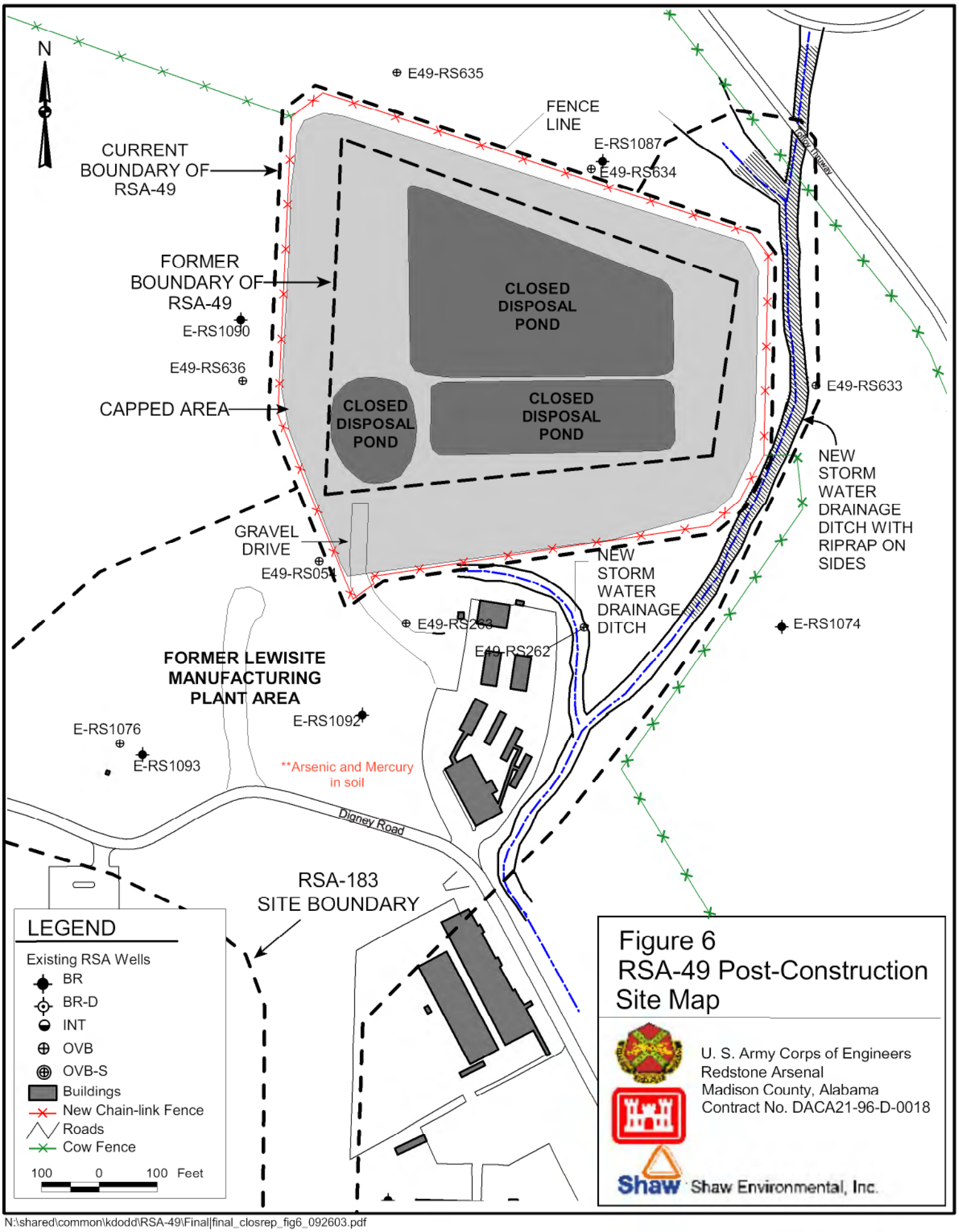


DETAIL
NOT TO SCALE

FIGURE 5
RSA-49, FORMER ARSENIC PONDS
TYPICAL RCRA CAP CROSS SECTION

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

Shaw™ Shaw Environmental, Inc.



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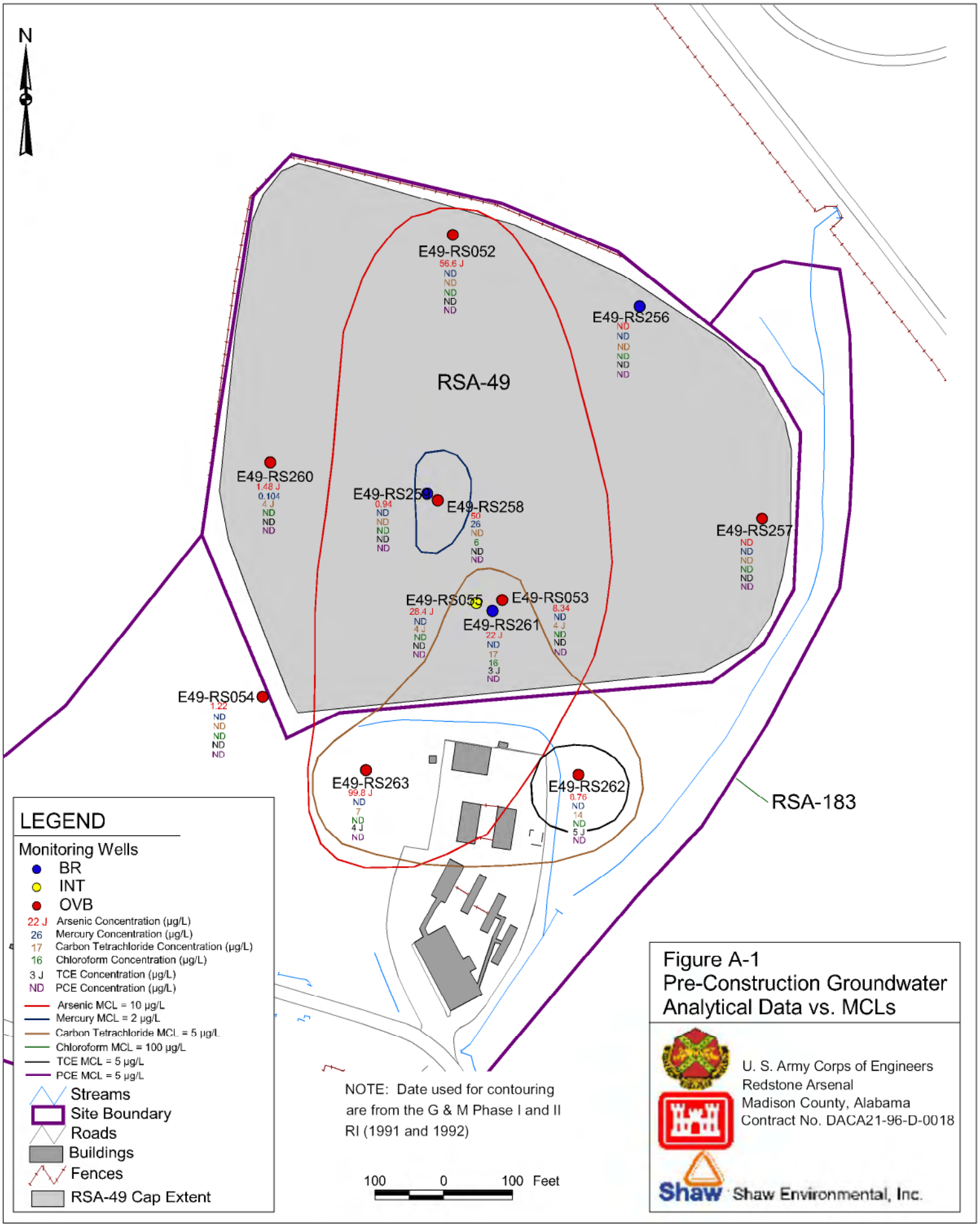
APPENDIX A

GROUNDWATER ANALYTICAL RESULTS FROM THE PHASE I AND PHASE II RFI



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APPENDIX B

DRAINAGE REROUTING (EBASCO, 1994A) AND SOIL ANALYTICALSAMPLING LOCATIONS FOR CAP DESIGN

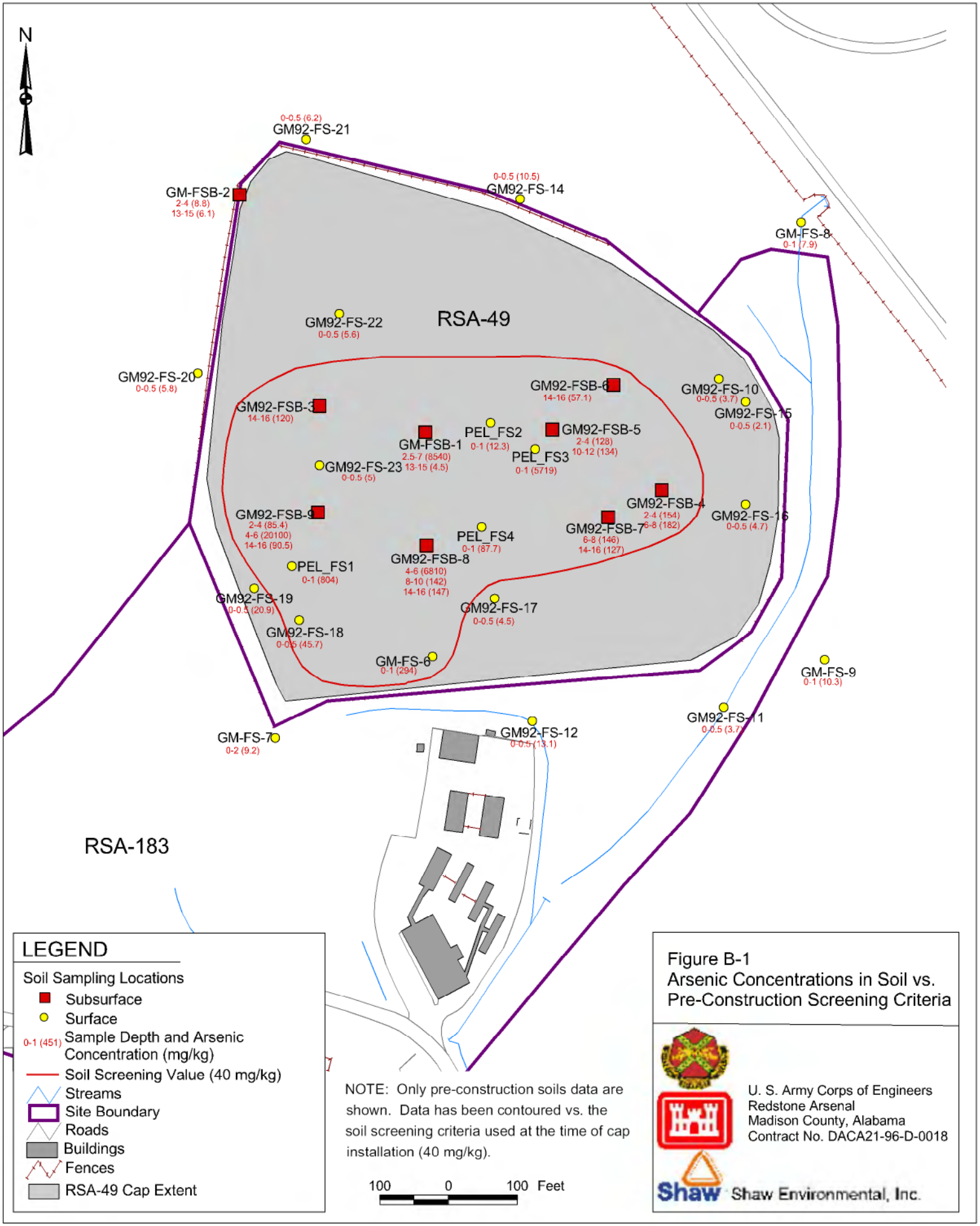

Figure B-1
Arsenic Concentrations in Soil vs. Pre-Construction Screening Criteria

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Environmental, Inc.

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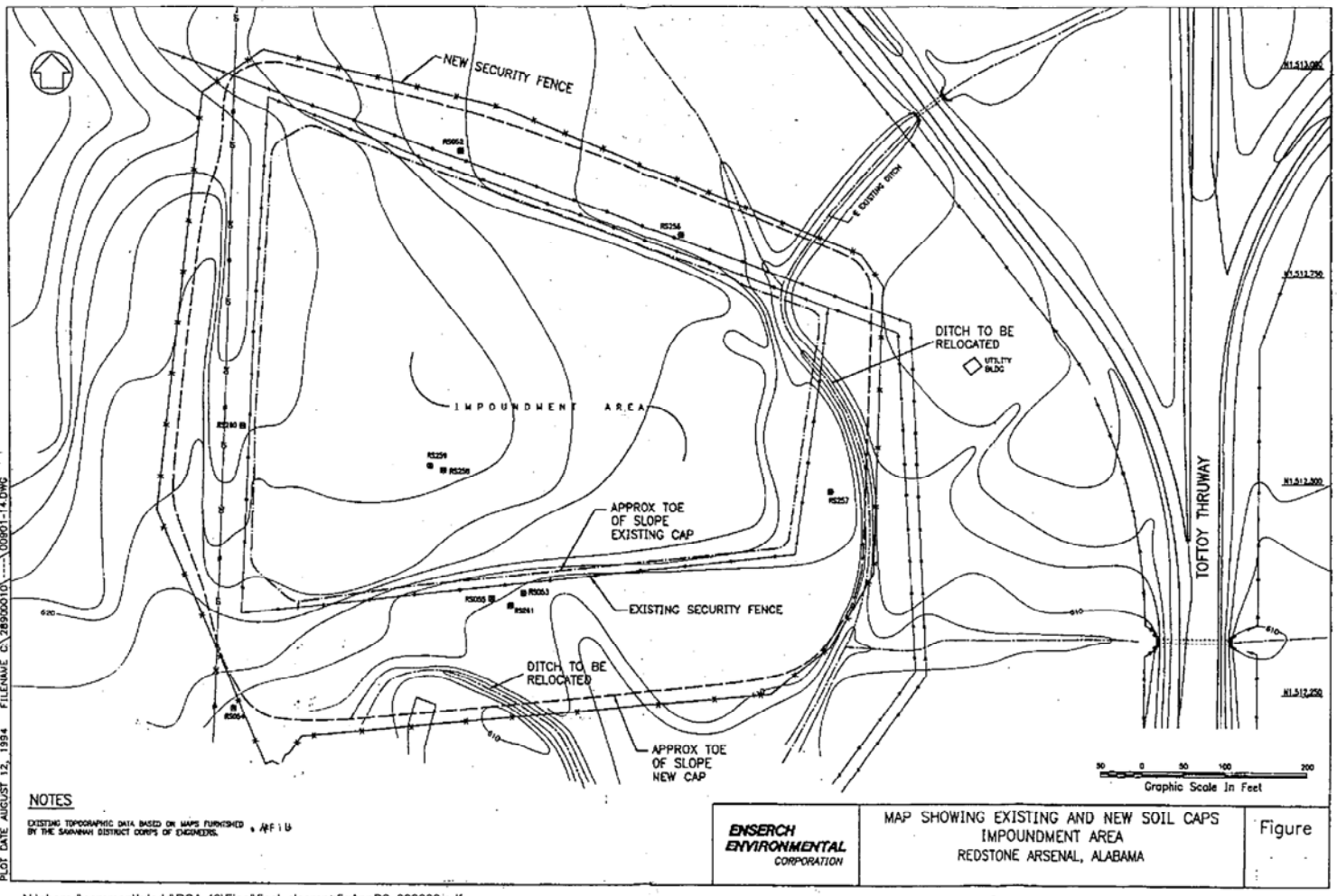

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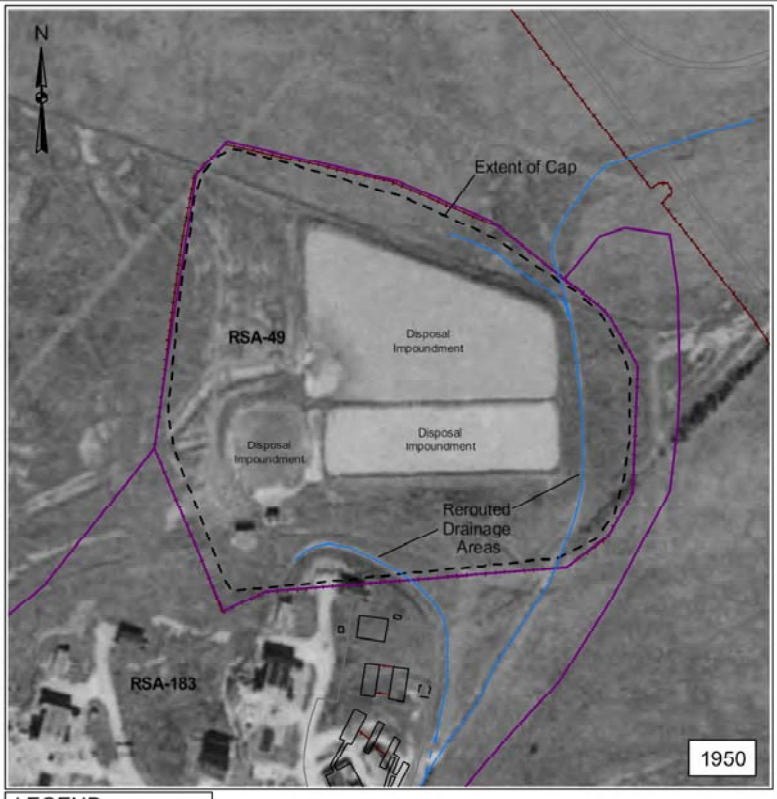
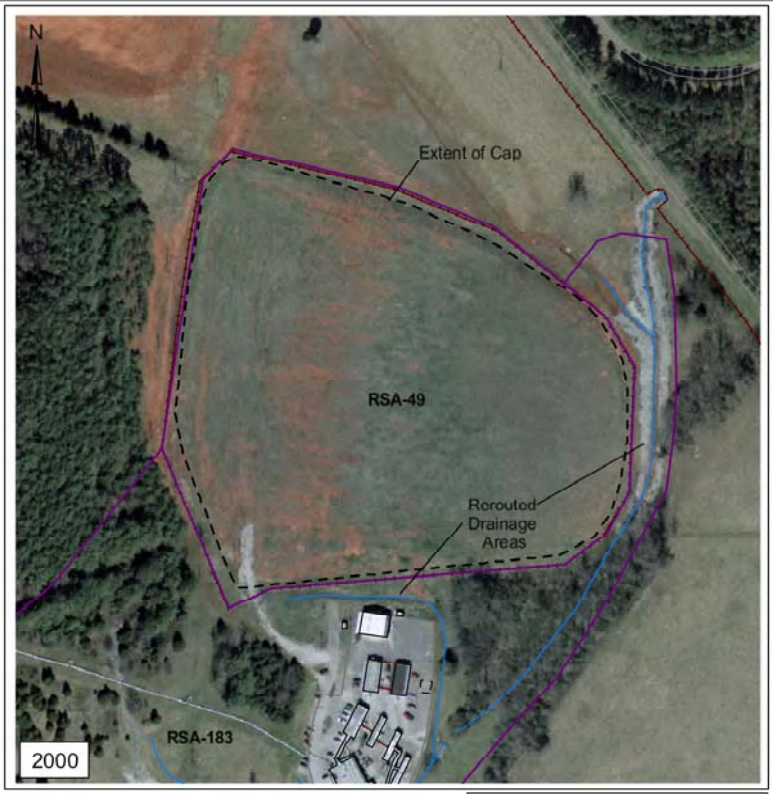
Figure B-2





LEGEND

- CERCLA Site Boundaries
- Buildings
- Streams
- Fences
- Roads

100 0 100 Feet

Figure B-3
Drainage Areas Subject to Rerouting
as part of the NTCRA at RSA-49

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Shaw Environmental, Inc.

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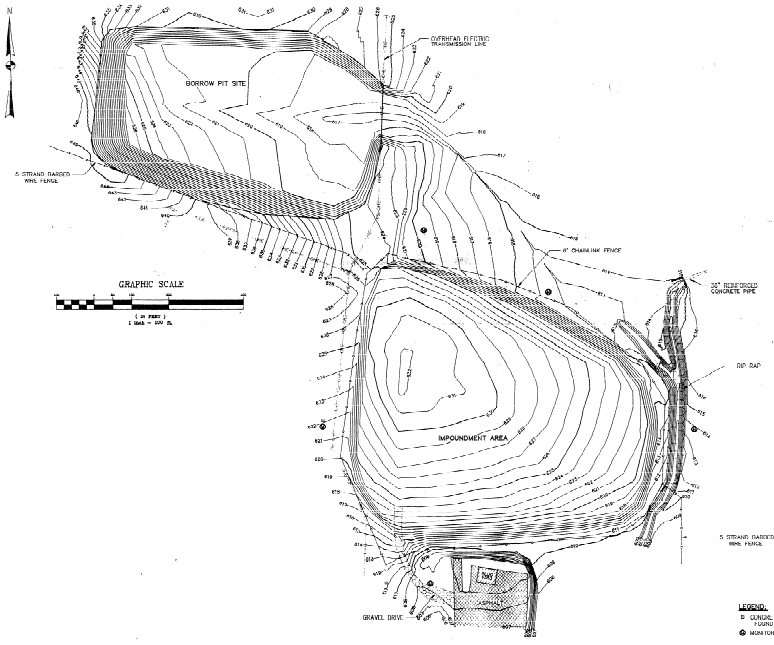
APPENDIX C

IMPOUNDMENT AREA AND BORROW PIT, AS CONSTRUCTED TOPOGRAPHIC SURVEY FIGURE



LEGEND:
- ⊡ CONCRETE MONUMENT FOUND
- ⊕ MONITORING WELL

FINAL FIELD SURVEY DATED 4 09 97.

AS CONSTRUCTED TOPOGRAPHIC SURVEY

Vector Enterprises, Inc.
1050 Cooper Road
Grayson, Georgia 30221

IMPOUNDMENT AREA & BORROW PIT
VM DESIGN AT RSA-45
REDSTONE ARSENAL, ALABAMA

VALLEY SURVEY ASSOCIATES
ROUTE 10 BOX 493
DECATUR, ALABAMA 35603
(205) 584-8118

DRAWN BY:	RWW
DATE:	5-28-97
JOB NO.	134
SHEET NO.	1
SCALE: 1" = 100'	

APPENDIX D

SPATIAL DISTRIBUTION OF SOIL ANALYTICAL RESULTS COMPARED TO CURRENT SCREENING CRITERIA

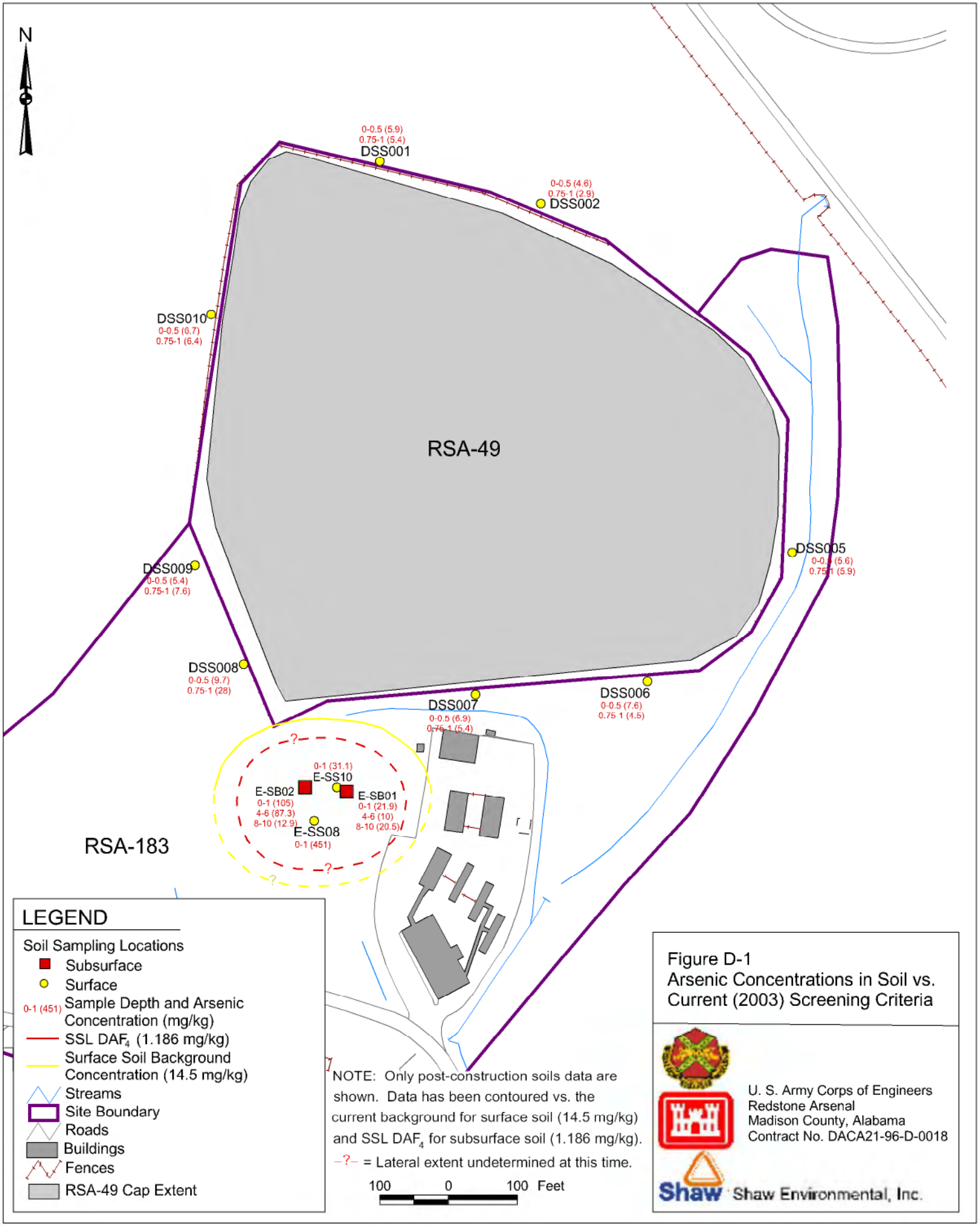


Figure D-1
Arsenic Concentrations in Soil vs. Current (2003) Screening Criteria

U. S. Army Corps of Engineers
Redstone Arsenal
Madison County, Alabama
Contract No. DACA21-96-D-0018

Shaw Shaw Environmental, Inc.

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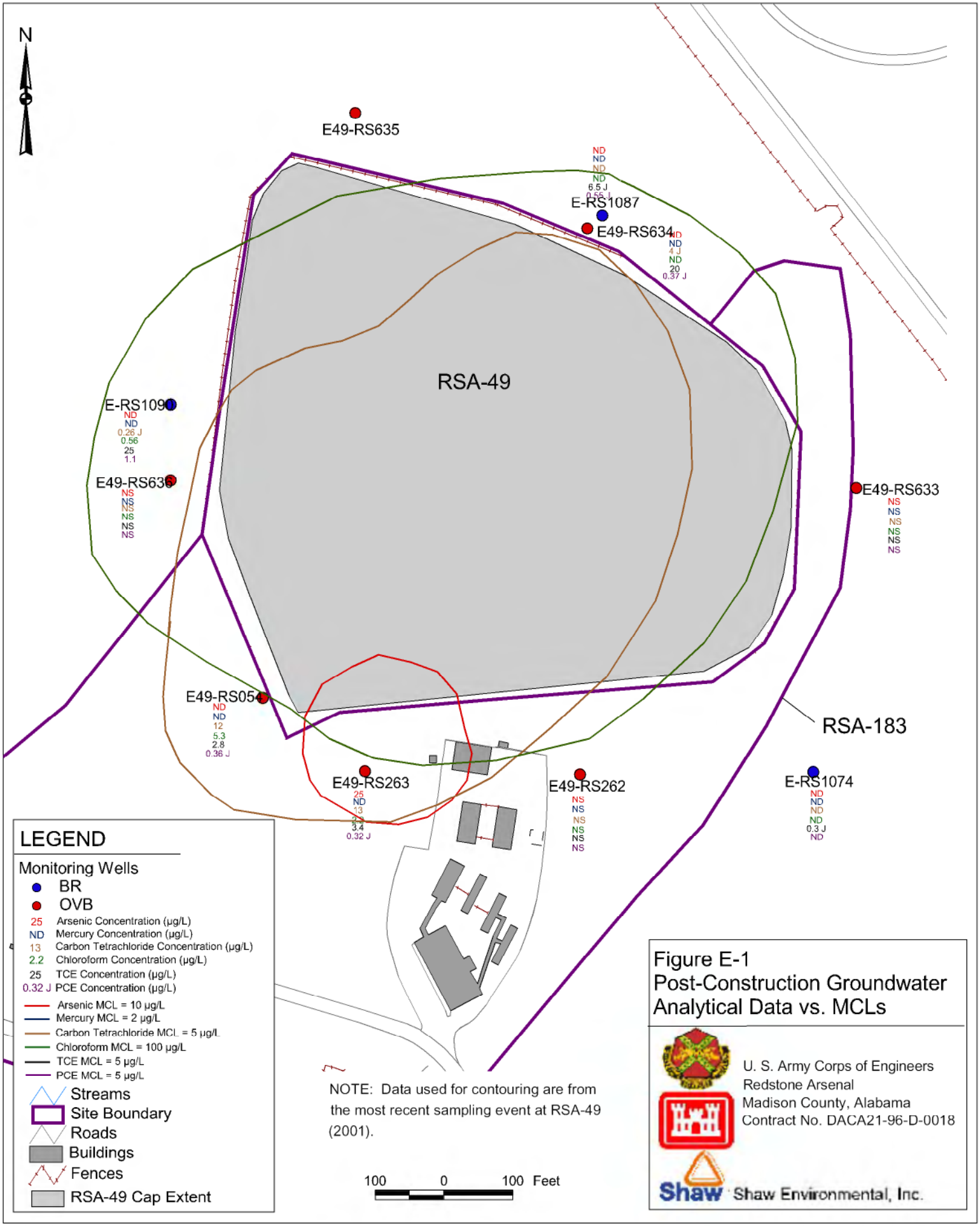
APPENDIX E

SPATIAL DISTRIBUTION OF GROUNDWATER ANALYTICAL RESULTS COMPARED TO CURRENT SCREENING CRITERIA



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