

RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Army Reserve Small Arms Range (ARSAR) RCRA Facility Investigation/ Interim Measures Completion Report



Prepared for:

USACE Baltimore District
10 S. Howard St.
Baltimore, MD 21201



Prepared by:

Shaw Environmental, Inc.
(A CB&I Company)
4696 Millennium Drive, Suite 320
Belcamp, MD 21017

Final Document

November 2013



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

January 14, 2014

Commander,
Radford Army Ammunition Plant
Attn: SJMRF-OP-EQ (Jim McKenna)
P.O. Box 2
Radford, VA 24141-0099

Bob Winstead
Environmental Manager
BAE Systems Ordnance Systems, Inc.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24141-0100

VIA Electronic Mail

Re: Radford Army Ammunition Plant, VA
Army Reserve Small Arms Range
RCRA Facility Investigation/
Interim Measures Completion Report

Dear Mr. McKenna and Mr. Winstead:

The U.S. Environmental Protection Agency (EPA) and Virginia Department of Environmental Quality (VDEQ) have reviewed the U.S. Army's (Army's) Army Reserve Small Arms Range (ARSAR), RCRA Facility Investigation/Interim Measures Completion Report (RFI/IM). The ARSAR is located at the Radford Army Ammunition Plant (RFAAP) in Radford, Virginia. Based upon our review, the RFI/IM Report is approved, and in accordance with Part II. (E)(5) of RFAAP's Corrective Action Permit, the RFI/IM Report is considered final. If you have any questions, please call me at 410-305-2779.

Sincerely,

A handwritten signature in cursive script that reads "Erich Weissbart".

Erich Weissbart, P.G.
RCRA Project Manager
Office of Remediation (3LC20)

c: James Cutler, VDEQ



ORDNANCE SYSTEMS INC.

Radford Army Ammunition Plant
4050 Peppers Ferry Road, P.O. Box 1
Radford, VA 24143
Telephone (540) 639-7631

BAE SYSTEMS

December 11, 2013

Mr. Erich Weissbart, P.G.
U. S. Environmental Protection Agency, Region III
Land and Chemicals Division (3LC20)
1650 Arch Street
Philadelphia, PA 19103-2029

Mr. James L. Cutler, Jr.
Virginia Department of Environmental Quality
629 East Main Street
Richmond, VA 23219

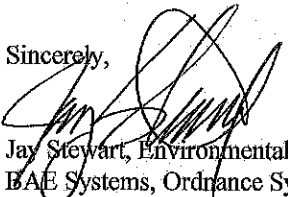
Subject: With Certification, Army Reserve Small Arms Range (ARSAR), RCRA Facility
Investigation/Interim Measures Completion Report, Final Document, November 2013
EPA ID# VA1210020730

Dear Mr. Weissbart and Mr. Cutler:

Enclosed is the certification for the subject documents that were sent to you on December 5, 2013. Also enclosed is the December 5, 2013 transmittal email.

Please coordinate with and provide any questions or comments to myself at 540 639 7785 or Mr. Jim McKenna, ACO Staff at 540 731 5782.

Sincerely,



Jay Stewart, Environmental Manager
BAE Systems, Ordnance Systems Inc

c: E. A. Lohman
Virginia Department of Environmental Quality
Blue Ridge Regional Office
3019 Peters Creek Road
Roanoke, VA 24019

Rich Mendoza
U.S. Army Environmental Command
Cleanup and Munitions Response Division
2450 Connell Road, Bldg 2264, 1st Floor, Room 126
Fort Sam Houston, TX 78234-7664

Tom Meyer
Corps of Engineers, Baltimore District
ATTN: CENAB-EN-HM
10 South Howard Street
Baltimore, MD 21201

bc: Administrative File
J. McKenna, ACO Staff
Rob Davie-ACO Staff

Coordination:

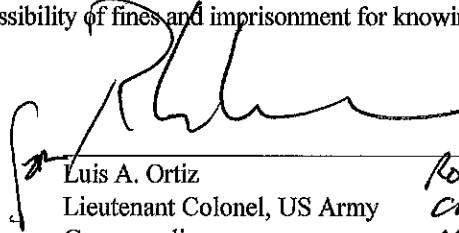

J. McKenna

Concerning the following:

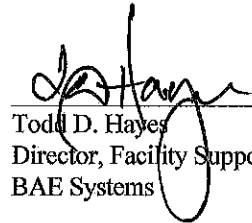
Radford Army Ammunition Plant
Army Reserve Small Arms Range (ARSAR)
RCRA Facility Investigation/Interim Measures Completion Report
Final Document, November 2013

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

SIGNATURE:
PRINTED NAME:
TITLE:


Luis A. Ortiz
Lieutenant Colonel, US Army
Commanding
ROBERT N DAVIE
CHIEF OPERATIONS
ARMY STAFF

SIGNATURE:
PRINTED NAME:
TITLE:

 12 Dec 2013
Todd D. Hayes
Director, Facility Support Services
BAE Systems

Bland, Kaye (US SSA)

From: McKenna, James J CIV (US) <james.j.mckenna16.civ@mail.mil>
Sent: Thursday, December 05, 2013 1:37 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler,Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA); Alberts, Matt (US SSA); Bogucki, MaryAnn (US SSA); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Davie, Robert N.; Ortiz, Luis (RFAAP); Leahy, Timothy
Subject: Final ARSAR RFI/ Completion Report (UNCLASSIFIED)

Classification: UNCLASSIFIED

Caveats: FOUO

Erich, Jim C., All:

Note the contractor will ship the subject document with a copy of this email to the POCs and tracking numbers below. Certification will follow by separate letter.

Jim McKenna	1Z66V7420191053752
Thomas Meyer	1Z66V7420192077761
Jim Bressette	1Z66V7420191517779
Susan M. Ryan	1Z66V7420193045794
Erich Weissbart	1Z66V7420191333806
JIM CUTLER	1Z66V7420190437812
E.A. LOHMAN	1Z66V7420190957822
Jay Stewart	1Z66V7420193493836
Rich Mendoza	1Z66V7420194973780

Thank you for your support of the Radford Army Ammunition Plant Installation Restoration Program.

Jim McKenna

Confidentiality Note: This e-mail is Official Correspondence and is For Official Use Only, it is intended only for the person or entity to which it is addressed, and may contain information that is privileged, confidential, sensitive, or otherwise protected from disclosure. If you receive this email in error please notify the sender immediately.

Classification: UNCLASSIFIED

Caveats: FOUO

Leahy, Timothy

From: Weissbart, Erich [Weissbart.Erich@epa.gov]
Sent: Tuesday, November 12, 2013 6:23 AM
To: McKenna, James J CIV (US); Cutler, Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA); Alberts, Matt (US SSA); MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US); Bressette, James W CIV USARMY MEDCOM PHC (US); Leahy, Timothy
Subject: RE: ARSAR RTCs (UNCLASSIFIED)

Jim,
The RTP for the ARSAR are acceptable. Finalize the report. That makes it two reports (SWMUS 48/49 and ARSAR) that need to be finalized and submitted.

Erich Weissbart, P.G.

Remedial Project Manager

Land and Chemicals Division

US EPA Region III

1650 Arch Street, Philadelphia PA

215 814-3284

weissbart.erich@epa.gov

From: McKenna, James J CIV (US) <james.j.mckenna16.civ@mail.mil>
Sent: Wednesday, November 06, 2013 12:54 PM
To: Weissbart, Erich; Cutler, Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA); Alberts, Matt (US SSA); MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US); Bressette, James W CIV USARMY MEDCOM PHC (US); Leahy, Timothy
Subject: RE: ARSAR RTCs (UNCLASSIFIED)

Classification: UNCLASSIFIED

Caveats: FOUO

Erich, Jim,

Checking on the status of our RTCs. If they are ok, then we can start on finalizing the report and get this one in the finish column.

Thanks in advance,
JJM

-----Original Message-----

From: McKenna, James J CIV (US)
Sent: Thursday, August 15, 2013 3:14 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler, Jim
Cc: beth lohman (elohman@deq.virginia.gov); Stewart, Jay (US SSA); Alberts, Matt (US SSA); MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US); Bressette, James W CIV USARMY MEDCOM PHC (US); Leahy, Timothy
Subject: FW: ARSAR RTCs (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Erich, Jim C., all,

Attached are the final RTCs for the ARSAR. The pdf file is the Oregon DEQ guidance for calculating the size of a population area and it can be forwarded along with the RTC file. Let me know if you have any questions.

Thank you for your support of the Radford AAP Installation Restoration Program.

JJM

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Classification: UNCLASSIFIED
Caveats: FOUO

Classification: UNCLASSIFIED
Caveats: FOUO

Leahy, Timothy

From: McKenna, James J CIV (US) [james.j.mckenna16.civ@mail.mil]
Sent: Thursday, August 15, 2013 3:41 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler, Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA);
Alberts, Matt (US SSA); MaryAnn Bogucki - Radford
(maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Mendoza,
Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC
USARMY JMC (US); Bressette, James W CIV USARMY MEDCOM PHC
(US); Leahy, Timothy
Subject: FW: ARSAR RTCs (UNCLASSIFIED)
Attachments: image001.gif; ARSAR_Apr13_Draft_RTCs_rev2.docx;
GuidanceEcologicalRisk (Levels I, II, III, IV).pdf

Classification: UNCLASSIFIED

Caveats: FOUO

Erich, Jim C., all,

Attached are the final RTCs for the ARSAR. The pdf file is the Oregon DEQ guidance for calculating the size of a population area and it can be forwarded along with the RTC file. Let me know if you have any questions.

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JJM

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Classification: UNCLASSIFIED

Caveats: FOUO

**Response to Comments from
Erich Weissbart (EPA) & Jim Cutler (VDEQ)
Army Reserve Small Arms Range RFI/IM Completion Report**

Comment. For the hillside area, the Army now recommends no further action with land use controls. This is the minimum acceptable action for an area with identified unacceptable risks to residential receptors. I still believe that the extent of lead contamination in the hillside area has not been established due to the limited number of confirmation samples obtained. This may not require any action for the present, but should be noted for any future revisions to land use controls that will be put in place. Furthermore, it is the unacceptable risks due to lead associated with potential residential use of the hillside area which necessitates future land use controls on the hillside area. The Army does not draw this 'conclusion' in the revised report.

Response. The conclusions of the HHRA in the Executive Summary, Section 6.6, and Section 8.2 state that concentrations of lead at the SE Hillside are above the health protective criteria for lead for the residential receptors. No changes are necessary for these sections. However, the text in Section 8.5 will be revised to clarify that lead exceeds health protective levels for residential use. Although residential development of this site would be highly unlikely, the text will further state that the results of the lead evaluation will be used to document the need for land use controls.

Comment. In addition, the proposed remedy for the hillside area (land use controls) ignores the unacceptable risks identified for terrestrial wildlife, including food chain impacts and an expected reduction in food supply. This is unacceptable with regard to ecological risks.

Response. Given the relatively small size of the site (1.1 acres), it is unlikely populations of wildlife such as American robins, short-tailed shrews, and/or meadow voles would be adversely impacted by concentrations of some metals in soil, such as lead. While a few individuals may suffer deleterious effects based on modeled exposure, these are conservative modeled estimations, not results of ecological field studies. Also, no threatened or endangered species are known to occur at the site; therefore, losses of individuals that are common species of wildlife are not an overriding concern. Potential reductions in food supply (due to modeled earthworm and plant toxicity) are not an overriding concern to area wildlife, as they would be expected to forage in non-impacted area proximate to the site where soil invertebrates and plants are expected to be abundant.

Another line of evidence to support these conclusions comes from Oregon DEQ *Final Guidance for Ecological Risk Assessment: Levels I, II, III, IV* (Oregon DEQ Waste Management and Clean-up Division, 1998, updated 12/2001) that discusses an approach they recommend to estimate the size of a population area, for evaluating potential population-level impacts (see the discussion that starts on PDF page 65 of this attached document). This guidance gives a relatively simple approach for estimating the “size” of a wildlife population (basically: $100 \times \text{Home Range}/\pi$). Our shrew receptor has a HR of about 1 acre, so the population size for this species would be about 32 acres, and for the vole (with a HR of about 0.09 acres), population size for this species would be about

2.9 acres. Our robin has a HR of 1.2 acres, so population size would be about 38 acres. Given that ARSAR Hillside site is only 1.1 acres, this suggests that impacted area would likely not adversely impact local populations.

Note that the vole is much less impacted than either the shrew or the robin, per our SLERA, so even though about 38% of the Site is within the vole's population area (1.1/2.9), this receptor had a much lower HQ. Shrews and robins should not be adversely impacted at the local population level.

In addition, the location of the hillside is behind the berm and across the stream from an access point for equipment required for soil removal. Access to this area would require removal of portions of the berm, clearing the trees on the near side of the stream and clearing portions of the hillside itself. These actions would degrade the quality of the stream through the removal of the trees stabilizing the banks and providing shade. Excavation of the hillside to remove lead-containing soil would de-stabilize the soil above that point, creating an ongoing erosion issue. These actions would collectively lead to a greater loss of habitat and potential receptors populations than taking no action on the hillside.

Finally, other sites at Radford have used similar justification that the small size of the site does not warrant clean-up to ecological risk levels. Specifically, the RAL for lead at the Northern Burning Ground was 3000 mg/kg and the site is approximately 2 acres in size. The summed EEQs for SWMU 41A, SWMU 50 and SWMU 59 were similar in magnitude to those at the ARSAR, and no clean-up for ecological concerns was approved based, in part, on the lack of RTE species, the uncertainties in toxicity values and the small size of the site.

The SWMU 31 RFI Addendum (Arcadis, 2009) includes the following language to justify no further action for ecological receptors:

"However, it is important to realize that the size or space of an impacted area is directly related to the potential for ecological exposure if ecological habitat is present. Spatial scale can be useful as a screening criterion if used in conjunction with other considerations, such as the valued ecological resources that may be present, current and future land use, the likelihood for COPEC migration from the site, and the proximity to a valued or sensitive ecological habitat. Spatial scale screening criteria are used widely in ERA guidance.

Although no information on spatial scale screening could be found in the Virginia DEQ guidance, several states' guidance address the importance of spatial scale in ecological assessments, as does the ASTM Standard Guide for Risk-Based Corrective Action for Protection of Ecological Resources, E 2205-02 (ASTM [American Society for Testing and Materials], 2002). The following spatial scale screening criteria are used by the following states: 1 to 2 acres for Minnesota (the smaller scale for bioaccumulative compounds); 1 acre for Texas, Louisiana, and Mississippi; 2 acres for Pennsylvania; and 2 acres or 1,000 square feet of sediments for Massachusetts (MPCA, 1998; TCEQ, 2001; MDEQ, 1997; LDEQ, 2003; PADEP, 1998; MADEP, 1996). This spatial scale criterion has often been referred to as de minimis because it is not expected to cause adverse impacts to the population, community, or ecosystem, providing certain conditions are met (Suter, 1995; Henning and Shear, 1998). These conditions include similar but unimpacted habitat be available adjacent to the impacted area, that sensitive habitat not be present within ¼ mile if the COPECs will migrate off site, and COPEC fate and transport must be unlikely to

increase the spatial extent to greater than the current spatial extent. Based on available information, which is discussed below, it is believed that these other conditions are met for SWMU-31."

Comment. Issues identified with revised report:

1. The list of appendices in the front of the report lists 3 sections in Appendix E, and should be revised to reflect the 6 sections that now appear in Appendix E.

Response: The list of appendices will be revised to include all sections of Appendix E.

2. Table E-2.39 concludes at the bottom of page 1 that a blood lead exceedance probability of 12.5% "meets the CDC goal of no more than a 5% probability of children exceeding a blood lead level of 10 ug/dl." Clearly, the 12.5% value exceeds the 5% CDC standard. This table must be corrected.

Response: The table will be corrected to indicate that the blood lead level associated with the SE Hillside exceeds the CDC goal. This revision will match the text in Section 6.4.1, which correctly indicates that the results of the IEUBK model for lead concentrations at the SE Hillside fail (i.e., exceed the CDC goal).

3. Tables E.2-17 through E.2-36 have irregular entries in some columns: for example, "Groundwater at the ARSAR is accounted for in the Firing Point/Berm Area HHRA" and "Sediment from Strouble's creek located at the ARSAR is accounted for in the Firing Point/Berm Area HHRA". These phrases appear in various locations on the tables noted above, and must be corrected in the final report.

Response: The tables will be corrected so that these irregular entries (i.e., phrases) will not appear on the tables in the final report.

Comment. Issues with EPA comments:

EPA Comments nos. 9 and 13: The facility did not group samples into 3 distinct exposure areas in accordance with EPA comments. Instead, the Army combined data from the firing point/ berm into one exposure area, and hillside samples into another exposure area. This is despite acknowledging in the Feb 2012 draft report that this will skew the area average for the firing point/berm area in a downward direction. The lack of significant contamination in the firing point/berm area may render the point moot, however.

Response: Comment noted. Note, however, that the area average calculations were removed from the report due to the grouping of samples into two areas, as agreed upon in the comment and response process.

EPA Comment no. 8: The facility response to EPA's comment indicated that the exposure frequency for the excavation worker would be changed to 250 days/year across the site, reflecting EPA guidance. However in the April 2013 report revision, a sentence was added to section 6.2.1 stating that a construction period of 125 days/year would be assumed for the

hillside area, which deviated from the facility's response to EPA's comment. Review of revised table E.2-6 for the hillside area reveals a construction period of 250 days/year. However, the estimated risks listed on tables E.2-21 and E.2-22 were calculated using the 125 day/year exposure frequency. While a construction period of 125 days/year may be acceptable for the hillside area (may not impact the final disposition of the hillside area), both the facility's response to comments and the various sections/tables of the report should consistently list the same value.

Response: Table E.2-6 will be corrected to reflect that a construction period of 125 days/year was used in the risk/hazard calculations for the construction scenario. This value is consistent with the facility's second response to EPA Comment 8 (Responses to Comments dated February 2012), which stated "If EPA is willing to split the site into two regions as described in General Response, the exposure frequency of 250 days/year will be used for the larger area (6.4 acres) and 125 days/year will be used for the smaller area (1.3 acres) to maintain consistency for the smaller area."

Comment 13: The requested change regarding the updated CDC blood lead level for children was made in section 6.3.2; however, the outdated 'blood lead level of concern,' 10 ug/dl, still appears in section 6.4.1, and must be corrected.

Response: The text in Section 6.4.1 will be revised to match the language in Section 6.3.2. Therefore, the last sentence of the second paragraph in Section 6.4.1 will be replaced with the following text:

"Percentages below 5 percent are considered to be protective of human health. As noted in Section 6.3.2, the CDCP recently agreed to use a child blood lead level of 5 µg/dL to identify children who are living or staying for long periods in environments that expose them to lead hazards (DoD, 2012)."

The VDEQ has reviewed the Army Reserve Small Arms Range RFI/IM Report and offers the following comments:

Comment 1. Pages ES-7 and 8-9. Regarding the conclusions for the Firing Point/Berm Area "unrestricted use" implies that there are no unacceptable risks not "very limited risks". For the SE Hillside Area the conclusions should be based on risk conclusions not "difficult to access and not suitable for development".

Response. The text in the executive summary will be revised to state that there are no unacceptable risks in the Firing Pint/Berm area. The conclusions of the HHRA in the Executive Summary, Section 6.6, and Section 8.2 state that concentrations of lead at the SE Hillside are above the health protective criteria for lead for the residential receptors. This will be used to justify the conclusions that land use controls recommended for the SE Hillside area.

Comment 2. Throughout the report SLERA conclusions note concerns related to wildlife chain impacts. More discussion is required on what additional evaluation would be necessary to address these concerns.

Response. Additional text will be added to the executive summary and conclusion sections of the report to justify the Institutional Controls remedy for the site, specifically the SE hillside area: *“Given the relatively small size of the site (1.1 acres), it is unlikely populations of wildlife such as American robins, short-tailed shrews, and/or meadow voles would be adversely impacted by concentrations of some metals in soil, such as lead. While a few individuals may suffer deleterious effects based on modeled exposure, these are conservative modeled estimations, not results of ecological field studies. Also, no threatened or endangered species are known to occur at the site; therefore, losses of individuals that are common species of wildlife are not an overriding concern. Potential reductions in food supply (due to modeled earthworm and plant toxicity) are not an overriding concern to area wildlife, as they would be expected to forage in non-impacted area proximate to the site where soil invertebrates and plants are expected to be abundant.*

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Leahy, Timothy

From: McKenna, James J CIV (US) [james.j.mckenna16.civ@mail.mil]
Sent: Wednesday, August 14, 2013 4:45 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler, Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA);
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(maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Mendoza,
Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC
USARMY JMC (US); Bressette, James W CIV USARMY MEDCOM PHC
(US); Leahy, Timothy
Subject: FW: Teleconference meeting notes (UNCLASSIFIED)
Attachments: image001.gif; Teleconference Meeting Note 8-14-2013s.docx

Classification: UNCLASSIFIED
Caveats: FOUO

All,

Tim just sent me his notes on our conference call today which I have reviewed. I'm providing them for your review, record and/or comment. They appear to describe the salient points of our call today, although I would take note that the delivery dates mentioned for reports, etc are subject to change and should be viewed as goals.

Thank you again for your support of the Radford AAP Installation Restoration Program.
JJM

-----Original Message-----

From: Leahy, Timothy [<mailto:Timothy.Leahy@CBIFederalServices.com>]
Sent: Wednesday, August 14, 2013 4:31 PM
To: McKenna, James J CIV (US)
Subject: Teleconference meeting notes

Hi Jim,

Here are my notes from the call.

Tim

Description: Description: Description: Description: Description:
[cid: 1 0AD725A00AD721CC001388C386257B11](#)

Timothy Leahy, PMP

Project Manager

Project Management

Federal Services

Tel. +1 410 273 7228

Cell +1 410 322 6430

Fax +1 410 273 7103

timothy.leahy@CBIFederalServices.com

CB&I

4696 Millennium Drive, Suite 320

Belcamp, MD 21017

U.S.A

www.CBI.com <<mailto:timothy.leahy@shawgrp.com>>

Please note new email address effective May 17, 2013.

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Classification: UNCLASSIFIED

Caveats: FOUO

Teleconference Meeting Notes

Date: Wednesday August 14, 2013

Subject: SWMU 54 Yr 1 MNA Report comments and Responses;
ARSAR RFI/IM Completion Report Comments and Responses

Attendees:

Rich Mendoza (USAEC)	Matt Alberts (BAE)
Tom Meyer (USACE)	MaryAnn Bogucki (BAE)
Jim McKenna (Radford AAP)	Cindy Hassan (CB&I)
Jim Bressette (USAIPH)	Mark Weisberg (CB&I)
Jim Cutler (VDEQ)	Tim Leahy (CB&I)
Erich Weissbart (USEPA)	Jeff Hillebrand (CB&I)
Betty Ann Quinn (USEPA)	

Notes: **SWMU 54 Yr 1 Comments and Responses Discussion**

Everyone agreed with the main points of the comments and responses as follows:

- 1) Additional analysis of MNA parameters and demonstration that MNA is actually occurring will be added to the year 2 report.
- 2) Wells where all constituents have been below RGs for 2 years will be dropped from the sampling program, per the exit strategy in the workplan.
- 3) Additional MNA parameters specific to explosives degradation (MNx, TNx and DNx) will be added to the sampling program.
- 4) The Year 1 report will be considered final and the changes will be made to the Year 2 report. The Year 2 report will be submitted to the Army at the end of August for review and to the regulators by the end of September for regulatory review.

ARSAR RFI/IM Completion Report Comments and Responses Discussion

Discussed the EPA and VDEQ comments and the draft responses. Most discussion centered on the ecological risk. Additional information will be added to the RTCs to support institutional controls for the hillside area based on decisions at other Radford sites and on an expanded discussion of the home ranges of potentially affected ecological receptors. Betty Ann Quinn stated that she would discuss the RTC with the EPA ecological risk assessor.

SWMU 48/49 Groundwater sampling results

Groundwater wells have been installed and sampled. The results are back and have been validated. Another conference call will be scheduled to discuss the results and path forward for the site in the near future – possibly to coincide with an additional discussion on the ARSAR once the regulators have reviewed the responses to comments on that site.

Leahy, Timothy

From: Weissbart, Erich [Weissbart.Erich@epa.gov]
Sent: Tuesday, July 30, 2013 10:41 AM
To: McKenna, James J CIV (US)
Cc: Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US)
Subject: RE: Radford AAP ARSAR RFI/IM (UNCLASSIFIED)

I know of the differences in lead; it is just a reference and a starting point for conversation.

Erich Weissbart, P.G.
Land and Chemicals Division (3LC20)
USEPA Region III
1650 Arch Street
Philadelphia, PA 19103
(215) 814-3284
weissbart.erich@epa.gov

-----Original Message-----

From: McKenna, James J CIV (US) [<mailto:james.j.mckenna16.civ@mail.mil>]
Sent: Tuesday, July 30, 2013 10:15 AM
To: Weissbart, Erich
Cc: Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US)
Subject: RE: Radford AAP ARSAR RFI/IM (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Erich,

I was on leave last week and I'm getting through the emails. I'll pass this along to the team. I think we can discuss both SWMU 54 and the ARSAR.

One thing I would point out from a quick review of the attached paper, is that the ARSAR was a small arms training range for rifles and pistols wouldn't have lead shot that is associated with a shotgun range.

Thanks,
JJM

-----Original Message-----

From: Weissbart, Erich [<mailto:Weissbart.Erich@epa.gov>]
Sent: Thursday, July 25, 2013 11:39 AM
To: McKenna, James J CIV (US)
Cc: Mendoza, Richard R Jr CIV (US)
Subject: FW: Radford AAP ARSAR RFI/IM

Gentlemen,

Below are the comments generated by VADEQ on the Small Arms Range. I have previously forwarded Betty Ann's comments on the Small Arms Range. Yesterday we (EPA and VDEQ) had a

call regarding the RFI report for the Small Arms Range. I conclude that Betty Ann's comments were not significant in general but the biggest issue is how we deal with the hillside area going forward regarding the lead. Jim Cutler has experience with another Army site, Fort Eustis, that has a lead shot problem and provided me with the attached paper. I would like to include a few minutes in our call in August for the Small Arms Range. I'm assuming you can easily address Betty Ann's comments and if you can't address them be prepared to discuss them with her then but primarily I want to resolve the problem of the Eco Risk Exceedance for the hillside area. So for our call on August 14, at 2:00 pm I expect we'll discuss MNA and our comments for SWMU 54 followed by a discussion of the Small Arms Range. Let me know if you disagree or if what I propose is a problem.

Erich Weissbart, P.G.

Land and Chemicals Division (3LC20)

USEPA Region III

1650 Arch Street

Philadelphia, PA 19103

(215) 814-3284

weissbart.erich@epa.gov

From: Cutler, Jim (DEQ) [<mailto:James.Cutler@deq.virginia.gov>]
Sent: Thursday, July 25, 2013 11:18 AM
To: Weissbart, Erich
Subject: Radford AAP ARSAR RFI/IM

Erich,

The VDEQ has reviewed the Army Reserve Small Arms Range RFI/IM Report and offers the following comments:

Pages ES-7 and 8-9. Regarding the conclusions for the Firing Point/Berm Area "unrestricted use" implies that there are no unacceptable risks not "very limited risks". For the SE Hillside Area the conclusions should be based on risk conclusions not "difficult to access and not suitable for development".

Throughout the report SLERA conclusions note concerns related to wildlife chain impacts. More discussion is required on what additional evaluation would be necessary to address these concerns.

Please contact me if you have any question regarding these comments.

Thanks,

Jim

James L. Cutler Jr.

Federal Facilities Project Manager

Office of Remediation Programs

Virginia Dept. of Environmental Quality

804-698-4498

Classification: UNCLASSIFIED

Caveats: FOUO

Leahy, Timothy

From: Weissbart, Erich [Weissbart.Erich@epa.gov]
Sent: Thursday, July 25, 2013 11:39 AM
To: McKenna, James J CIV (US)
Cc: Mendoza, Richard R Jr CIV (US)
Subject: FW: Radford AAP ARSAR RFI/IM
Attachments: lead and birds.pdf

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James L. Cutler Jr.

Federal Facilities Project Manager
Office of Remediation Programs
Virginia Dept. of Environmental Quality
804-698-4498

Short Communication

LEAD PELLET RETENTION TIME AND ASSOCIATED TOXICITY IN NORTHERN BOBWHITE QUAIL (*COLINUS VIRGINIANUS*)RICHARD KERR,[†] STEVEN HOLLADAY,[†] TIMOTHY JARRETT,[†] BARBARA SELCER,[†] BLAIR MELDRUM,[‡] SUSAN WILLIAMS,[§] LAWRENCE TANNENBAUM,^{||} JEREMY HOLLADAY,[†] JAMIE WILLIAMS,[†] and ROBERT GOGAL^{*†}[†]Department of Anatomy and Radiology, College of Veterinary Medicine, University of Georgia, Athens, Georgia 30602, USA[‡]Virginia Maryland Regional College of Veterinary Medicine at Virginia Tech, Blacksburg, Virginia, USA[§]Department of Population Health, College of Veterinary Medicine, University of Georgia, Athens, Georgia, USA^{||}U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen, Maryland

(Submitted 22 June 2010; Returned for Revision 20 July 2010; Accepted 23 August 2010)

Abstract—Birds are exposed to Pb by oral ingestion of spent Pb shot as grit. A paucity of data exists for retention and clearance of these particles in the bird gastrointestinal tract. In the current study, northern bobwhite quail (*Colinus virginianus*) were orally gavaged with 1, 5, or 10 Pb shot pellets, of 2-mm diameter, and radiographically followed over time. Blood Pb levels and other measures of toxicity were collected, to correlate with pellet retention. Quail dosed with either 5 or 10 pellets exhibited morbidity between weeks 1 and 2 and were removed from further study. Most of the Pb pellets were absorbed or excreted within 14 d of gavage, independent of dose. Pellet size in the ventriculus decreased over time in radiographs, suggesting dissolution caused by the acidic pH. Birds dosed with one pellet showed mean blood Pb levels that exceeded 1,300 µg/dl at week 1, further supporting dissolution in the gastrointestinal tract. Limited signs of toxicity were seen in the one-pellet birds; however, plasma δ-aminolevulinic acid dehydratase (d-ALAD) activity was persistently depressed, suggesting possible impaired hematological function. Environ. Toxicol. Chem. 2010;29:2869–2874. © 2010 SETAC

Keywords—Lead Avian Ventriculus Retention d-ALAD

INTRODUCTION

Federal, state, and private shooting ranges and open-range hunting and military training sites contain spent lead (Pb) shot that may be harmful to wildlife health [1,2]. An estimated 80,000 tons of Pb were released annually by recreational shooting alone in the United States during the 1990s [3]. Sampling of migratory and nonmigratory avian species near shooting ranges showed that birds ingest metal fragments as grit particles or possibly mistake them for food [4,5].

Mateo et al. [6] similarly found ingested Pb shot in 32% of white-headed ducks (*Oxyura leucocephala*) sampled from a wetlands area used for waterfowl hunting. Furthermore, Kendall and Scanlon [7,8] documented lead in the tissues and blood in mourning doves and rock doves in Virginia. In a controlled acute lead toxicity study in mourning doves, Schulz et al. [9] dosed 157 birds with 2 to 24 Pb pellets and showed a high survival correlation with fewer pellets administered but did not address the effects of one Pb pellet. Currently, no clear consensus exists on the effects of an acute exposure to one Pb pellet in birds.

No data are currently available for retention and gastrointestinal tract clearance of single and multiple metal no. 9 Pb shot pellets in bobwhite quail within the same study. These pellets are markedly heavier than mineral grit of comparable size. Similarly, in vivo data are not available in quail for absorption of Pb “grit” from the ventriculus, although a recent in vitro simulated ventriculus-intestine model showed dissolved Pb levels that were higher in the presence of siliceous grit as compared with calcareous grit [10]. In the current study, north-

ern bobwhite quail (*Colinus virginianus*) were orally gavaged with single or multiple Pb shot pellets and evaluated over multiple postgavage time points for pellet retention, blood Pb levels, and associated signs of toxicity.

MATERIALS AND METHODS

Birds

Forty-eight male and female 16-week-old Northern Bobwhite quail (six birds/sex/treatment) were acquired from M&M Quail Farms and maintained in individual quail cages fitted with an automatic watering system. Birds were acclimated for two weeks on a wild-bird seed-based diet (Pennington Pride, white millet, milo, wheat, sunflower seed, calcium carbonate, vitamin A supplement, vitamin D3 supplement, potassium iodide, vegetable oil) with fortified grit (Purgarin, a high-calcium product that contains phosphorus, magnesium, potassium, and sulfur sources). Housing was at 23 ± 5°C, humidity of 45 ± 10%, and 14:10-h light:dark cycle. All procedures were approved by the University of Georgia's Institutional Animal Care and Use Committee, and experiments were conducted in compliance with Good Laboratory Practice standard operating procedures.

Lead Pellets

Number 9 lead shot pellets (spherical, 2 mm, 45–50 mg) were provided by the U.S. Army Center for Health Promotion and Preventive Medicine and were from soil samples acquired at Fort Eustis, Virginia, USA. Pellets were washed in 70% ethanol (Sigma) and then distilled water to remove soil contaminants.

Exposure Regimen

Birds were randomly grouped by treatment ($n \geq 4$ /sex). Males and females were studied separately, because differences

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(rgogal@uga.edu).

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(wileyonlinelibrary.com).

in response by sex have previously been observed [11]. On d 1, birds were orally gavaged into the crop with 0, 1, 5, or 10 Pb pellets in 2 ml physiologic saline, using rubber tubing and a 3-ml dosing syringe. On d 2 and weekly thereafter, the Pb pellet content of the gastrointestinal tract was radiographically determined.

Blood collection

On days 0, 7, 14, 21, and 28, blood was collected aseptically from the jugular vein of each bird, using a 25-gauge needle and 1-ml syringe. After collection, an 18-gauge needle was attached to the syringe, and the blood was transferred into a 4-ml depressurized, heparinized Vacutainer tube and mixed by gentle inversion. Blood physiologic parameters including total red blood cell number, packed cell volume, mean corpuscular volume, and total protein were performed by protocols as described by Gogal et al. [12].

Pellet and blood Pb analysis

Ten pellets were arbitrarily selected from the stock and submitted to the Diagnostic Toxicology Laboratory at Virginia Tech, Blacksburg, Virginia, for Pb content analysis. Heparinized whole blood samples (0.5 ml/bird) were frozen at -80°C and shipped on dry ice, along with the Pb pellets, also for Pb analysis. The method described by Meldrum and Ko [13] was used. The spiked source was acquired from Wisconsin State Laboratory of Hygiene and tested with each run. The source recoveries were within $\pm 10\%$ of the specified range, with the lower detection limit for this assay at 25 ppm.

Delta aminolevulinic-acid dehydratase assay

Delta aminolevulinic-acid dehydratase (d-ALAD) activity is inhibited by Pb exposure in birds [14]. The d-ALAD activity was determined by using the European standardized method [15], and results were expressed as nanomoles of aminolevulinic-acid per min per ml red blood cells.

Histopathology

Birds were killed by using CO_2 gas and necropsied at the termination of the study or when displaying signs of morbidity or excessive weight loss. Representative samples of kidney, liver, spleen, sciatic nerve, and reproductive organs were collected and routinely processed, embedded in paraffin, and stained with hematoxylin and eosin.

Statistics

Analysis of variance was conducted at each time point to test for differences among dose groups. Dunnett's post hoc tests were then used to compare each group with the controls. Pearson's correlation was used to quantify the relationship between dose levels and blood Pb concentrations. For all analyses, significance was determined at $\alpha = 0.05$.

RESULTS

Feed consumption and body weight

Birds gavaged with 5 or 10 pellets consumed less feed, became moribund (inactive and recumbent), and lost significant body ($>10\%$ body weight) weight by two weeks postexposure (data not shown), and they were therefore killed using CO_2 gas. Body weight in females dosed with one Pb pellet was unchanged at weeks 1 to 4. Body weight in males dosed with 1 Pb pellet was unchanged at weeks 1, 2, and 4 and was

marginally decreased (by approximately 4%) at week 3 (data not shown).

Pb pellet retention and radiographs

Most Pb pellets remained in the crop on day 2 (Fig. 1). By week 1, total pellet retention had declined to 21% of the original, and all retained Pb pellets were in the ventriculus. By week 2, retained pellets were again located in the ventriculus and had declined to 7% of original (radiographs not shown). Size of retained pellets appeared visually smaller by week 3. For example, one male bird had a single Pb pellet in its crop at week 1, which had moved to the ventriculus by weeks 2 and 3. The radiographs of this pellet were measured by using eFilm software (Sound-EklinTM) and calibrated against the averaged mid-diaphyseal diameter of the right and left femurs (averaged to account for differences in bird positioning, thickness, and potential resultant magnification). A 9.2-pixel decrease in measured diameter of the Pb pellet occurred from d 7 to d 14, which equated to a 40% reduction in pellet size, whereas there was only a 3.7% difference in comparative averaged femoral diaphysis on these same images (Fig. 2).

Pellet and blood Pb analysis

The 10 pellets submitted for Pb analysis were all greater than 90% Pb (data not shown). Blood Pb levels showed a significant correlation with the number of gavaged pellets for weeks 1 and 2 (Pearson's coefficient $r = 0.64$, $p \leq 0.01$; $r = 0.50$, $p \leq 0.01$, respectively). For birds dosed with one pellet, blood Pb concentrations were greater than 3 log-fold higher than control at week 1, and then declined over weeks 2 to 4 as pellets were eliminated (Table 1).

Delta aminolevulinic-acid dehydratase activity

The d-ALAD activity was markedly decreased by oral exposure to Pb, in an effect that persisted after Pb pellets had been eliminated (Fig. 3).

Blood parameters, cytology, and histopathology

Birds dosed with one Pb pellet were not different from controls in circulating red blood cell numbers, packed cell volume, mean corpuscular volume, or total blood protein level. No differences in the morphology or percentages of leukocytes, or in histology of all tissues evaluated, were caused by one Pb pellet (data not shown). Throughout all the data sets analyzed, no differences based on sex were seen across treatment groups.

DISCUSSION

Birds consume grit particles to aid in mechanical digestion of food. The ventriculus (gizzard) of graniform birds may contain as many as 200 such grit particles of greater than 0.75 mm [16]. A survey of partridges (*Alectoris rufa*) occupying a driven shooting estate, with average soil burdens of 73,600 Pb shot units/ha, showed Pb shot ingestion in 7.8% of the birds, and a positive correlation between shot ingestion and large seed particles in the diet [17]. Very limited data are available, however, for mineral grit retention time or turnover in these or other birds, and no data are available for retention time or turnover of the common no. 9 shot [10], including multiple pellet ingestion. This represents a critical gap of information, in that ingestion of elemental Pb foreign bodies in mammals is thought to have a low risk of clinically significant Pb absorption unless gastrointestinal pathology or prolonged transit time are

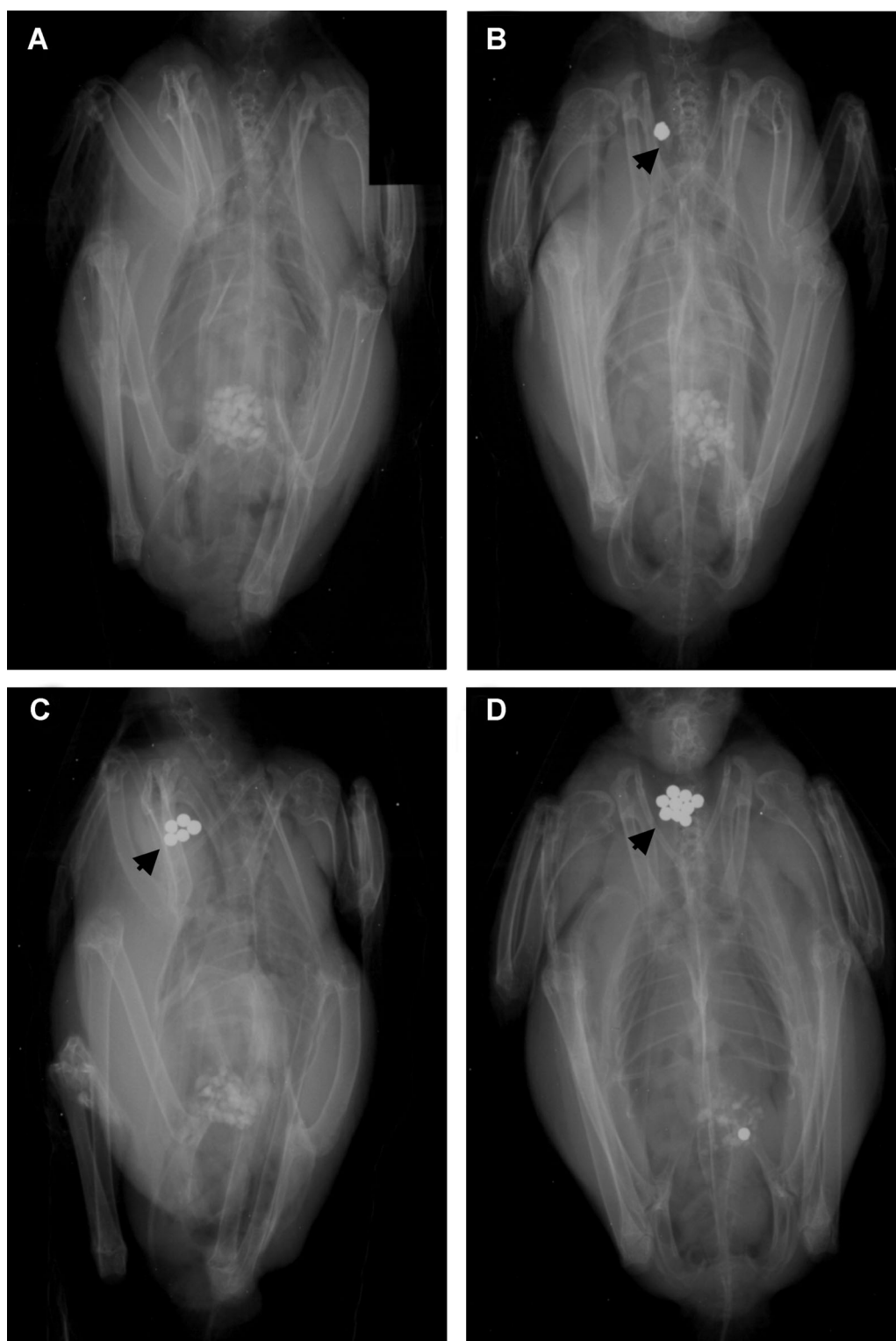


Fig. 1. Day 1 representative D-V radiographs of 16-week-old quail dosed with 0 (A), 1 (B), 5 (C), and 10 (D) Pb pellets (indicated by arrows).

present [18]. In the avian ventriculus, prolonged transit time of Pb shot seems likely to occur.

Yamamoto et al. [19] orally dosed Japanese quail with a single no. 4 lead shot pellet (245 ± 13 mg/pellet) and sampled these birds every two weeks for six weeks [19]. Similar to the current study, the authors reported no weight loss or mortality with single pellet dosing, and retention time varied significantly among the birds lasting as long as 32 d.

A single no. 4 Pb shot is approximately five times the weight of a single no. 9 lead shot. In the current study, quail went off feed within 24 h of oral gavage with five or ten no. 9 Pb shot pellets, and showed appreciable weight loss within the first week. Surface area of a no. 9 Pb shot pellet (diameter 2 mm), calculated as $4\pi r^2$, is 12.6 mm^2 , whereas surface area of a no. 4 Pb shot (diameter 3.3 mm) is 28.3 mm^2 . Five no. 9 Pb shot pellets therefore would have a total surface area of 63 mm^2 ,

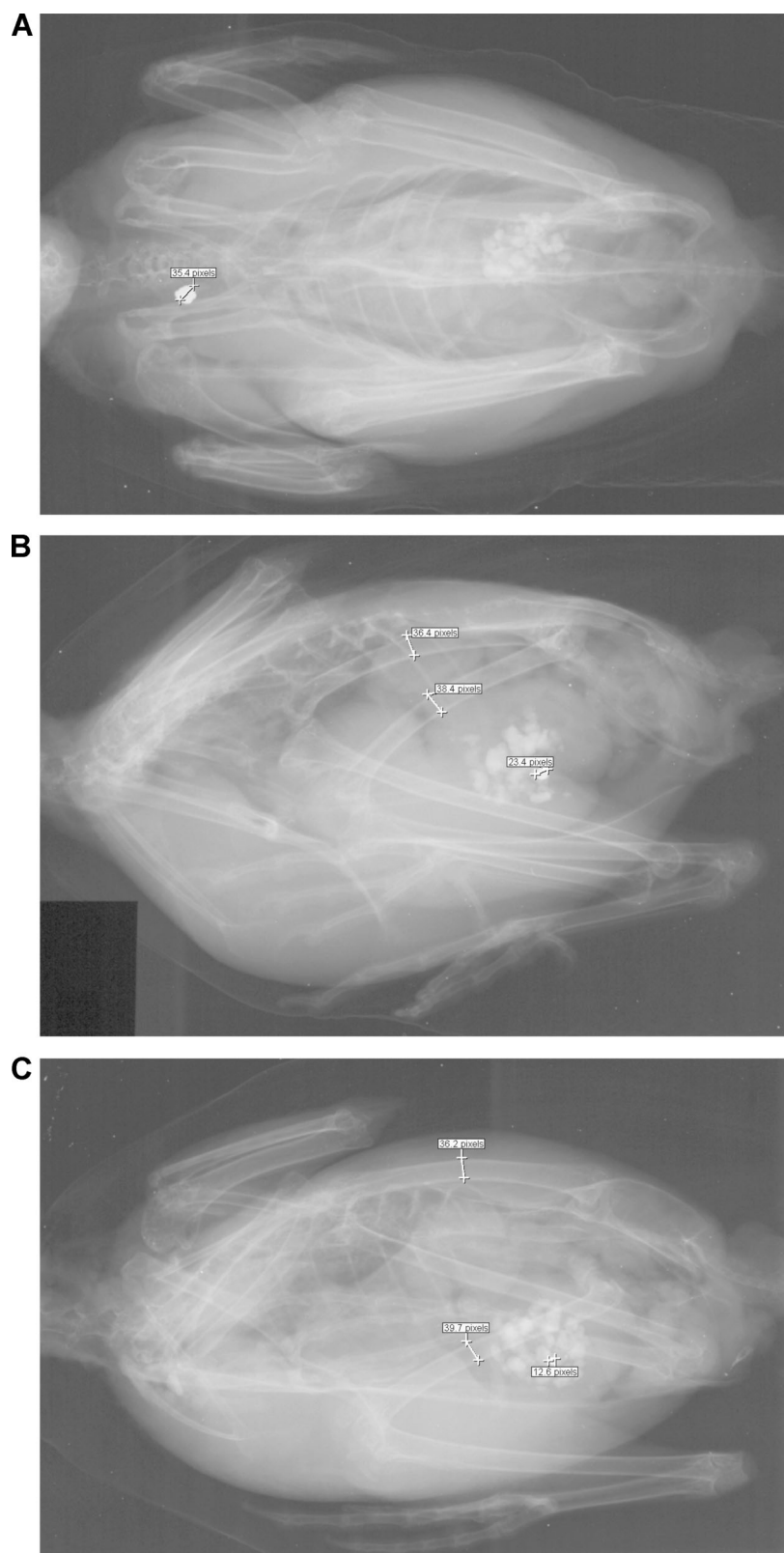


Fig. 2. Representative radiographs taken weekly of 16-week-old male quail dosed with one Pb pellet on day 1 (A), day 7 (B), and day 14 (C). Radiographs of the pellet were measured using eFilm software (Sound-EklinTM). For days 7 and 14, the radiographic densities (i.e., pixels) were calibrated against the averaged mid-diaphyseal diameter of the right and left femurs for comparison. The radio-dense material surrounding the pellet in the ventriculus is grit.

or more than 2.2-fold higher than a single no. 4 shot pellet, which would result in increased Pb absorption and may explain the higher toxicity seen in the current quail as compared with those studied by Yamamoto et al. In support of this idea, Yamamoto et al. observed blood Pb levels ranging from 6.20

to 6.96 $\mu\text{g/g}$ blood [19], equating to 620 to 696 $\mu\text{g/dL}$, or approximately half the blood Pb levels detected in the current quail dosed with five no. 9 pellets.

A possible difference between the current study and the Yamamoto et al. [19] study was type of diet and grit employed.

Table 1. Peripheral blood lead concentration in bobwhite quail^a

		Saline	1 Pellet	5 Pellet	10 Pellet
Blood lead level ($\mu\text{g}/\text{dl}$)		Mean $\pm$ SEM	Mean $\pm$ SEM	Mean $\pm$ SEM	Mean $\pm$ SEM
Baseline	Male	1.25 $\pm$ 0.72	1.25 $\pm$ 0.56	1.25 $\pm$ 0.63	1.25 $\pm$ 0.56
	Female	1.25 $\pm$ 0.63	1.25 $\pm$ 0.63	1.25 $\pm$ 0.63	1.25 $\pm$ 0.63
Week 1	Male	1.25 $\pm$ 0.00	1,347 $\pm$ 587	3,884 $\pm$ 1,173	4,131 $\pm$ 1,332*
	Female	1.25 $\pm$ 0.00	1,720 $\pm$ 49*	2,157 $\pm$ 292*	—
Week 2	Male	1.25 $\pm$ 0.00	918 $\pm$ 561	—	—
	Female	1.25 $\pm$ 0.00	342 $\pm$ 192	—	—
Week 3	Male	1.25 $\pm$ 0.00	300 $\pm$ 168	—	—
	Female	1.25 $\pm$ 0.00	149 $\pm$ 95	—	—
Week 4	Male	1.25 $\pm$ 0.00	90 $\pm$ 28*	—	—
	Female	1.25 $\pm$ 0.00	51 $\pm$ 23	—	—

^a $n \geq 4$ birds/treatment (* $\alpha = 0.05$, Dunnett's test).

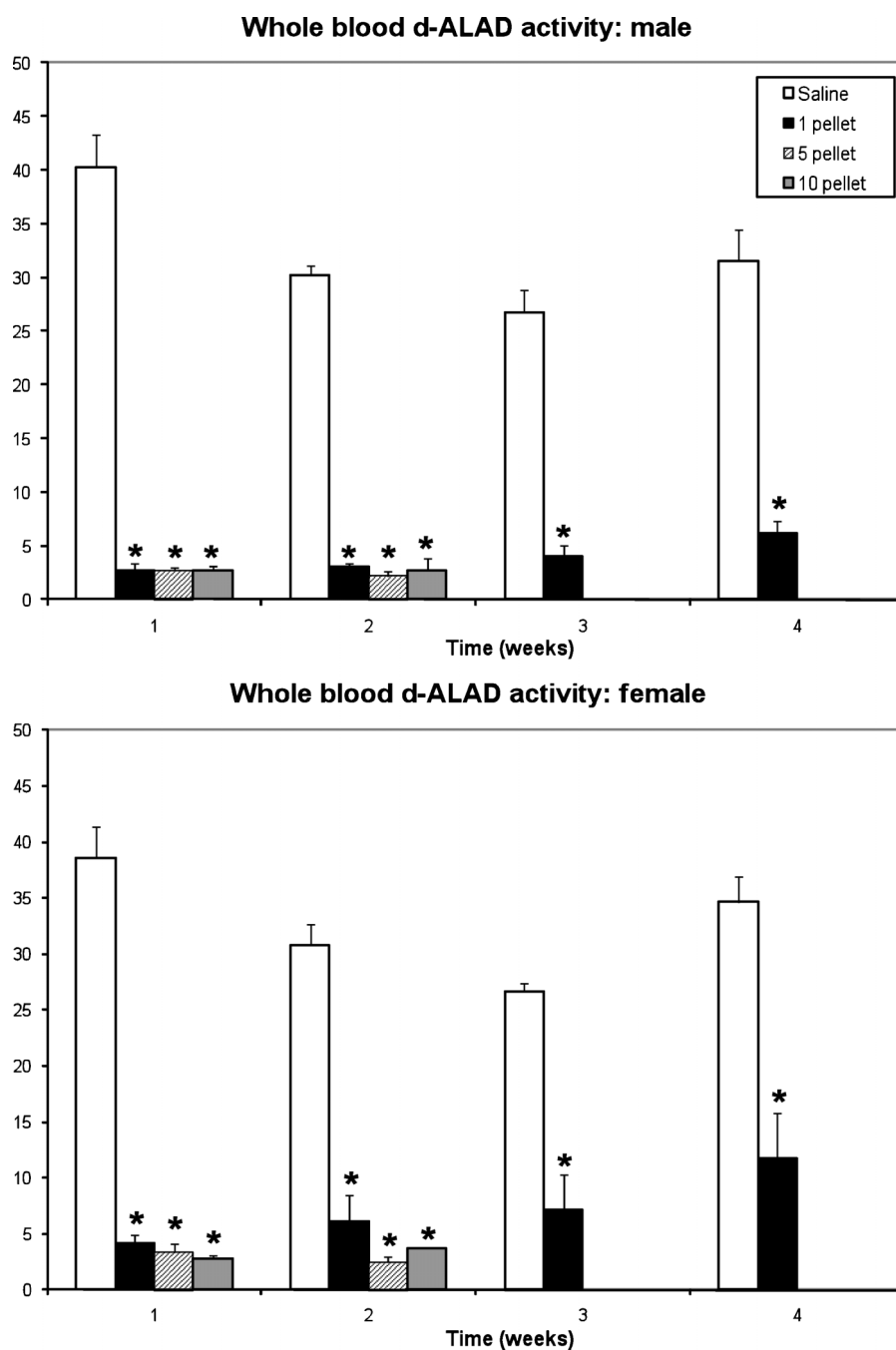


Fig. 3. Fifty-microliter aliquots of whole blood were assayed for d-ALAD activity for each bird based on treatment and sex at weekly intervals. Values are reported as mean millimoles aminolevulinic-acid/h/ml $\pm$ standard error of the mean (* $p \leq 0.05$, Dunnett's test).

This remains uncertain, because Yamamoto et al. did not identify feed type or grit used in the Japanese quail. A granular diet, which would have greatly altered ventricular function compared with a seed-based diet, thus could have affected the rate of Pb retention and absorption [20]. In addition, others have shown with both in vivo and in vitro avian models that the composition of the grit (i.e., calcium vs silica) affects Pb absorption across the gut [9,20,21]. For example, dissolved Pb levels were consistently higher in siliceous grit than with calcareous grit [10]. Furthermore, Trost [20], working in captive mallard ducks, reported that grit consumption was affected by diet, sex, season, and particle size and mineral composition. These are important dietary characteristics that could explain some of the differences in the results obtained between the two studies and are worth exploring in future studies.

By one week postgavage, the bobwhite quail retained 21% of no. 9 Pb shot, and all these particles were located in the ventriculus. The pH of the ventriculus is variable in birds depending on diet and species, but it is acidic, typically in the range of 4.4 to 3.6 [22]. This acidity, combined with grinding activity and ventriculus residence time of up to a week or more, would be predicted to mobilize Pb. This is supported by the current observation of a 40% reduction in pellet size in a bird that retained its ventricular pellet for greater than 14 d, relative to averaged diameter of the mid-diaphyses of the femurs. The high blood Pb levels in the quail of this study clearly verified that lead in the gastrointestinal tract was mobilized and systemically available, with associated morbidity and mortality at 5- and 10-pellet doses. Blood Pb levels quickly fell after one week, in agreement with radiographic clearance of the shot. One-pellet birds did not show overt signs of toxicity; however, plasma d-ALAD activity, a marker of Pb exposure, was persistently depressed, again similar to the findings of Yamamoto et al. [19]. This suggests possible impaired hematologic function, the persistence of which may correlate with mobilization of absorbed Pb from bone, serum proteins, and other compartments. Interestingly, no significant differences were seen across sex and treatment. These observations might have changed had the current study been of longer duration. Additional studies are necessary to determine whether function of reproductive, neurological, or other systems may be adversely affected by ingestion of one Pb shot particle.

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Leahy, Timothy

From: McKenna, James J CIV (US) [james.j.mckenna16.civ@mail.mil]
Sent: Thursday, July 18, 2013 11:09 AM
To: Bressette, James W Mr CIV US USA MEDCOM PHC
Cc: Alberts, Matt (US SSA); MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Leahy, Timothy; Richard Mendoza
Subject: FW: risk Assessor comment at small arms range (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Jim B., all,

FYI, heads up. Wanted to keep you in the loop. Partial set of EPA comments.

Thanks,
JJM

-----Original Message-----

From: Mendoza, Richard R Jr CIV (US)
Sent: Thursday, July 18, 2013 9:11 AM
To: McKenna, James J CIV (US); 'tom.meyer@usace.army.mil'; 'Timothy.Leahy@CBIFederalServices.com'
Subject: Fw: risk Assessor comment at small arms range

Risk assessor comments on the small arms range. This is more than a few additional comments.

----- Original Message -----

From: Weissbart, Erich [mailto:Weissbart.Erich@epa.gov]
Sent: Thursday, July 18, 2013 12:54 PM Coordinated Universal Time
To: Mendoza, Richard R Jr CIV (US)
Subject: RE: SWMU 54 MNA Sampling Year 1 Report (UNCLASSIFIED)

Rich,
I don't normally like to forward comments like this since DEQ hasn't sent me anything but if it will help.

I have reviewed the revised Small Arms Range report. The Army included in the latest revision most of the changes that were agreed upon. I have the following comments.

For the hillside area, the Army now recommends no further action with land use controls. This is the minimum acceptable action for an area with identified unacceptable risks to residential receptors. I still believe that the extent of lead contamination in the hillside area has not been established due to the limited number of confirmation samples obtained. This may not require any action for the present, but should be noted for any future revisions to land use controls that will be put in place. Furthermore, it is the unacceptable risks due to lead associated with potential residential use of the hillside area which necessitates future land use controls on the hillside area. The Army does not draw this 'conclusion' in the revised report. In addition, the proposed remedy for the hillside area (land use controls) ignores the unacceptable risks identified for terrestrial wildlife, including food

chain impacts and an expected reduction in food supply. This is unacceptable with regard to ecological risks.

Issues identified with revised report:

1. The list of appendices in the front of the report lists 3 sections in Appendix E, and should be revised to reflect the 6 sections that now appear in Appendix E.
2. Table E-2.39 concludes at the bottom of page 1 that a blood lead exceedance probability of 12.5% "meets the CDC goal of no more than a 5% probability of children exceeding a blood lead level of 10 ug/dl." Clearly, the 12.5% value exceeds the 5% CDC standard. This table must be corrected.
3. Tables E.2-17 through E.2-36 have irregular entries in some columns: for example, "Groundwater at the ARSAR is accounted for in the Firing Point/Berm Area HHRA" and "Sediment from Strouble's creek located at the ARSAR is accounted for in the Firing Point/Berm Area HHRA". These phrases appear in various locations on the tables noted above, and must be corrected in the final report.

Issues with EPA comments:

EPA Comments nos. 9 and 13: The facility did not group samples into 3 distinct exposure areas in accordance with EPA comments. Instead, the Army combined data from the firing point/ berm into one exposure area, and hillside samples into another exposure area. This is despite acknowledging in the Feb 2012 draft report that this will skew the area average for the firing point/berm area in a downward direction. The lack of significant contamination in the firing point/berm area may render the point moot, however.

EPA Comment no. 8: The facility response to EPA's comment indicated that the exposure frequency for the excavation worker would be changed to 250 days/year across the site, reflecting EPA guidance. However in the April 2013 report revision, a sentence was added to section 6.2.1 stating that a construction period of 125 days/year would be assumed for the hillside area, which deviated from the facility's response to EPA's comment. Review of revised table E.2-6 for the hillside area reveals a construction period of 250 days/year. However, the estimated risks listed on tables E.2-21 and E.2-22 were calculated using the 125 day/year exposure frequency. While a construction period of 125 days/year may be acceptable for the hillside area (may not impact the final disposition of the hillside area), both the facility's response to comments and the various sections/tables of the report should consistently list the same value.

Comment 13: The requested change regarding the updated CDC blood lead level for children was made in section 6.3.2; however, the outdated 'blood lead level of concern,' 10 ug/dl, still appears in section 6.4.1, and must be corrected.

Erich Weissbart, P.G.
Land and Chemicals Division (3LC20)
USEPA Region III
1650 Arch Street
Philadelphia, PA 19103
(215) 814-3284
weissbart.erich@epa.gov

-----Original Message-----

From: Mendoza, Richard R Jr CIV (US) [mailto:richard.r.mendoza.civ@mail.mil]
Sent: Thursday, July 18, 2013 8:09 AM

To: Weissbart, Erich; McKenna, James J CIV (US); 'James.Cutler@deq.virginia.gov'
Cc: Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US);
'matt.alberts@baesystems.com'; 'maryann.bogucki@baesystems.com'; 'Timothy.Leahy@cbi.com';
'Tom.Meyer@usace.army.mil'
Subject: Re: SWMU 54 MNA Sampling Year 1 Report (UNCLASSIFIED)

Erich. Thanks. Can you get us Betty Ann's comments? Based on the comments We may need to have a call and include her.

----- Original Message -----

From: Weissbart, Erich [mailto:Weissbart.Erich@epa.gov]
Sent: Thursday, July 18, 2013 10:45 AM Coordinated Universal Time
To: McKenna, James J CIV (US); Cutler,Jim <James.Cutler@deq.virginia.gov>
Cc: Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US); Alberts, Matt (US SSA) <matt.alberts@baesystems.com>; MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com) <maryann.bogucki@baesystems.com>; Leahy, Timothy <Timothy.Leahy@cbi.com>; Meyer, Tom NAB02 <Tom.Meyer@usace.army.mil>; Mendoza, Richard R Jr CIV (US)
Subject: RE: SWMU 54 MNA Sampling Year 1 Report (UNCLASSIFIED)

I am available August 14. Regarding the Small Arms Range; unfortunately I have a few comments from Betty Ann and am still waiting on DEQ to complete their review.

Erich Weissbart, P.G.
Land and Chemicals Division (3LC20)
USEPA Region III
1650 Arch Street
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-----Original Message-----

From: McKenna, James J CIV (US) [mailto:james.j.mckenna16.civ@mail.mil]
Sent: Wednesday, July 17, 2013 3:44 PM
To: Weissbart, Erich; Cutler,Jim
Cc: Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US); Alberts, Matt (US SSA); MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Leahy, Timothy; Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US)
Subject: RE: SWMU 54 MNA Sampling Year 1 Report (UNCLASSIFIED)
Importance: High

Classification: UNCLASSIFIED
Caveats: FOUO

Erich, Jim C.

Good news. I just got off a conference call with the Army team.

Are you both available for a conference call on August 14 or August 15, 2013 at 200PM EST to discuss our draft responses to EPA and VADEQ comments on the subject report? In anticipation that you can, we blocked out these dates/times. I'm trying to plan this conference call now before I go on leave this week and won't return to the office until 07/29/2013. Please reply to all and Tim can coordinate the call in information in my absence.

FYI. Our path forward is for the Army team to receive the draft responses on 07/29 from Tim Leahy. We'll review, comment, revise and send them to you on or before 08/05/2013 then hold the conference call on 08/14 or 08/15 at 200pm EST depending on your availability. Hopefully one of these two dates/times will work for you.

Thank you for your support of the Radford AAP Installation Restoration Program,

JJM

PS What the status of the Army Reserve Small Arms Range RFI Report? We thought we had revised the report satisfactorily based on our January 2013 meeting and are anticipating approval. Thanks,JJM

-----Original Message-----

From: McKenna, James J CIV (US)

Sent: Thursday, July 11, 2013 10:01 AM

To: 'Weissbart, Erich'

Cc: Cutler,Jim; Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US)

Subject: RE: SWMU 54 MNA Sampling Year 1 Report (UNCLASSIFIED)

Classification: UNCLASSIFIED

Caveats: FOUO

Erich,

Thanks for comments and thoughts. I'll forward them separately to the Army team to develop response. I do remember your 02/23/2011 email, it took me some time to find it. I attach it when I forward this email to the team.

Thanks,

JJM

-----Original Message-----

From: Weissbart, Erich [mailto:Weissbart.Erich@epa.gov]

Sent: Wednesday, July 10, 2013 9:43 AM

To: McKenna, James J CIV (US)

Cc: Cutler,Jim

Subject: SWMU 54 MNA Sampling Year 1 Report

Jim,

EPA and VADEQ have reviewed the subject document and submit the following comments:

There was very little MNA evaluation contained in the document. The statement, "Based on data obtained in the first year of sampling and the overall site-wide decreasing concentrations of contaminants of concern.....it appears that the selected remedial action (MNA) is currently viable." The report should have included an evaluation of the performance of MNA to date and does not. I refer you to my email of Feb. 23, 2011 wherein I commented on the lack of substance in the workplan of an actual MNA demonstration.

* The water quality parameters do not appear to support conditions necessary for biodegradation of the COCs;

- * The text in section 5.7 should be expanded to discuss the present potential for MNA and how the indicator parameters compare to the MNA screening tables;
- * The conclusions should focus on implications, if any, for future monitoring;
- * Additional MNA criteria should be considered for future rounds to better evaluate MNA for selected wells.

The reason this unit was removed from a remedy decision in 2011 was because of the lack of a true MNA evaluation pursuant to EPA guidance. That still applies. As of now Radford is monitoring SWMU 54 per an approved workplan, however the monitoring is not leading towards an MNA remedy. Based on generally declining concentrations and low overall concentrations for COC's it's possible a groundwater remedy will not be necessary but then there are the 4th quarter results where the most elevated concentrations of COCs were reported from 54MW12, a downgradient well.

I'll provide you with a couple of my thoughts: Radford can revise this report to reflect the agencies comments; Radford can tweak the monitoring based on agency comments, literature research related to MNA of the specific explosive constituents and report with an evaluation after another year; continue down the current path and hope the COCs are below RGs for two consecutive years in all site wells.

I welcome Radford's response and if necessary we can have a call that includes VADEQ.

Erich Weissbart, P.G.

Land and Chemicals Division (3LC20)

USEPA Region III

1650 Arch Street

Philadelphia, PA 19103

(215) 814-3284

weissbart.erich@epa.gov

Classification: UNCLASSIFIED

Caveats: FOUO

Classification: UNCLASSIFIED

Caveats: FOUO

Classification: UNCLASSIFIED

Caveats: FOUO

ORDNANCE SYSTEMS INC.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24143
Telephone (540) 639-7631
Fax (540) 639-8588

May 20, 2013

Mr. Erich Weissbart
RCRA General Operations Branch, Mail Code: 3WC23
Waste and Chemicals Management Division
U. S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Mr. James L. Cutler, Jr.
Virginia Department of Environmental Quality
629 East Main Street
Richmond, VA 23219

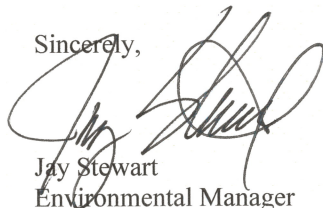
Subject: With Certification, Army Reserve Small Arms Range (ARSAR) RCRA Facility Investigation/Interim Measures
Completion Report, Draft Document, April 2013
EPA ID# VA1210020730

Dear Mr. Weissbart and Mr. Cutler:

Enclosed is the certification for the subject documents that were sent to you on May 15, 2013. Also enclosed is the May 15, 2013 transmittal email.

Please coordinate with and provide any questions or comments to myself at 540 639 7785 or Mr. Jim McKenna, ACO Staff at 540 731 5782.

Sincerely,



Jay Stewart
Environmental Manager
BAE Systems, Ordnance Systems Inc.

cc: E. A. Lohman
Virginia Department of Environmental Quality
Blue Ridge Regional Office
3019 Peters Creek Road
Roanoke, VA 24019

Rich Mendoza
US Army Environmental Center
2450 Connell Rd., Bldg. 2264, 1st Fl, Rm126
Attn: Richard Mendoza
San Antonio, TX 78234-7664

Tom Meyer
Corps of Engineers, Baltimore District
ATTN: CENAB-EN-HM
10 South Howard Street
Baltimore, MD 21201

bc: BAE Administrative File
J. McKenna, ACO Staff
Rob Davie-ACO Staff
Environmental File

Coordination:


J. McKenna

Concerning the following:

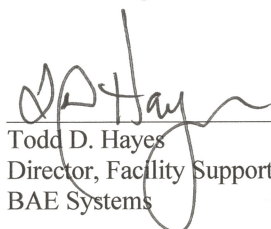
Radford Army Ammunition Plant
Army Reserve Small Arms Range (ARSAR)
RCRA Facility Investigation/
Interim Measures Completion Report
Draft Document, April 2013

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

SIGNATURE:
PRINTED NAME:
TITLE :

 22 May 2013
Wm Byron Penland
Lieutenant Colonel, US Army
Commanding

SIGNATURE:
PRINTED NAME:
TITLE:

 21 May 2013
Todd D. Hayes
Director, Facility Support Services
BAE Systems

Alberts, Matt (US SSA)

From: McKenna, James J CIV (US) <james.j.mckenna16.civ@mail.mil>
Sent: Wednesday, May 15, 2013 1:38 PM
To: Cutler, Jim; Weissbart.Erich@epamail.epa.gov
Cc: Alberts, Matt (US SSA); beth lohman (ealohman@deq.virginia.gov); Bogucki, MaryAnn (US SSA); Mendoza, Richard R Jr CIV (US); Meyer, Tom NAB02; Stewart, Jay (US SSA); Timothy.Leahy@shawgrp.com; Davie, Robert N.
Subject: Draft ARSAR RFI/IM Report Transmittal Email (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Erich, Jim C, All:

Note the contractor will ship the subject document with a copy of this email to the POCs and tracking numbers below. Certification will follow by separate letter. This document was revised per our 25 Jan 2013 meeting at Radford AAP.

Erich Weissbart	3 Paper copy/3 CD	1Z63V8840198872511
Jim Cutler	1 Paper copy/1 CD	1Z63V8840198476520
Tom Meyer	1 Paper copy/1 CD	1Z63V8840195150083
Richard Mendoza	1 Paper copy/1 CD	1Z63V8840195614108
E.A. Lohman	1 CD	1Z63V8840199722136
Jay Stewart	1 Paper Copy/1 CD	1Z63V8840195265343
Jim Bressette	1 CD	1Z63V8840197722158
Jim McKenna	Replacement pages/CD	1Z63V8840199752470

Thank you for your support of the Radford Army Ammunition Plant Installation Restoration Program.

Jim McKenna

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Classification: UNCLASSIFIED
Caveats: FOUO

Classification: UNCLASSIFIED
Caveats: FOUO

Leahy, Timothy

From: Weissbart.Erich@epamail.epa.gov
Sent: Wednesday, January 30, 2013 11:06 AM
To: McKenna, James J CIV (US)
Cc: Jim Cutler; Alberts, Matt (US SSA); Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Leahy, Timothy; Meyer, Tom NAB02; Maiden, Vince (DEQ)
Subject: Re: FW: EPA/VDEQ meeting - Jan 25, 2013 (UNCLASSIFIED)

To All:

Please accept this email as conditional approval of the SWMU48/49 November 30, 2012 response to comments and ARSAR December 13, 2012 response to comments. In conjunction with the January 25, 2013 site meeting and the email summary and pdf attachment submitted January 29, 2013, EPA and VADEQ have no further comment on proposed work and pending reports for either unit. Therefore this email constitutes an unconditional approval of proposed scopes of work and responses to comments for both units (ARSAR and SWMUs 48/49). It is our understanding that with this email approval, work will proceed towards additional monitoring well installation at SWMUs 48/49, a monitoring event will take place subsequent to the well installation, and a meeting proposed to discuss the results and the path forward for SWMUs 48/49. Additionally we expect that the previous draft submittals related to Interim Measures and Risk Assessment will be revised as proposed. If there are any questions please contact me.

Erich Weissbart P.G.
Land and Chemicals Division (3LC20)
US EPA Region III
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-3284
e-mail: weissbart.erich@epa.gov

-----"McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil> wrote: -----

To: "Meyer, Tom NAB02" <Tom.Meyer@usace.army.mil>, "Mendoza, Richard R Jr CIV (US)" <richard.r.mendoza.civ@mail.mil>, "Alberts, Matt (US SSA)" <matt.alberts@baesystems.com>, Erich Weissbart/R3/USEPA/US@EPA, "Cutler,Jim" <James.Cutler@deq.virginia.gov>, "Maiden, Vince (DEQ)" <Vincent.Maiden@deq.virginia.gov>
From: "McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil>
Date: 01/29/2013 02:44PM
Cc: "Davie, Robert N III CIV (US)" <robert.n.davie4.civ@mail.mil>, "Timothy.Leahy@shawgrp.com" <Timothy.Leahy@shawgrp.com>
Subject: FW: EPA/VDEQ meeting - Jan 25, 2013 (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

All,

See Tim's notes below and attached figure to document our path forward for SWMUs 48/49 and the ARSAR. Only thing I can add is that we were going to have data review meeting or conference call after we get the gw data back from SWMU 48/49 effort.

Thanks,
JJM

-----Original Message-----

From: Leahy, Timothy [<mailto:Timothy.Leahy@shawgrp.com>]
Sent: Tuesday, January 29, 2013 2:20 PM
To: McKenna, James J CIV (US)
Subject: EPA/VDEQ meeting - Jan 25, 2013

Here are my notes from the field trip last week. I think it was very helpful to meet face-to-face and get out to see the actual sites. Let me know if you have any changes or if you want to forward them to the rest of the group.

Thanks,

Tim

Path forward for SWMU 48&49

We will do what was in the response to comments with a few exceptions based on our meeting at RFAAP on Friday, Jan 25, 2013. The changes made to the RTCs are captured below:

-Install 4 new wells at locations shown on attached figure (rather than 2 as proposed in the RTCs).

-Collect one round of samples (instead of 2 rounds) from the newly installed wells and existing wells (circled on the attached figure) Note the wells circled on the figure are a smaller subset than what is in the RTCs:

48MW06

48MW1

49MW01

50MW02

48MW02

48MW3

13MW2

13MW3

13MW4

13MW5

Also, we will resample the existing wells where dioxins were elevated and ensure that no entrained sediment is present.

Path forward for ARSAR:

We will revise the report based on the RTCs and will also add additional geologic information that supports the elevated arsenic being the result of the "unique geologic setting" of the ARSAR at Radford. Here's the information that I presented in the van about the geology of that particular area:

The geologic map describes the unit (D0) on the hillside behind the ARSAR as:

Devonian, Silurian, and Ordovician, undivided: Includes partial sections of the Millboro Shale, undivided Silurian units, and Martinsburg Formation. These rocks are exposed in two windows of the Pulaski thrust sheet: one is north of the City of Radford and the other is just to the southeast of the Radford Army Ammunition Plant. These rocks are highly deformed allochthonous tectonic horses that are complexly folded, faulted, and internally fractured.

The Millboro Shale is described as:

Millboro Shale: Dark-gray to black, thinly bedded, sparsely fossiliferous, fissile mudstone and black shale. Contains abundant concretions and disseminated sulfides as well as a few thin beds of carbonate. Thickness ranges from about 1,000 to 1,300 feet (305 to 400 m)

and the Martinsburg formation is described as:

Martinsburg Formation: Upper portion consists of interbedded 0.5- to 1.0-foot (15 to 30 cm) thick beds of massive, fine-grained, medium-gray sandstone with fossil debris and medium-gray well-laminated calcareous mudstone. This grades down section into dominantly medium- to dark-gray, coarse-grained, bioclastic limestone interbedded with medium-gray, well laminated calcareous mudstone. The thickness is estimated to be about 1,100 feet (335 m). The use of Martinsburg Formation in this area follows past usage by Butts (1933, 1940) and Cooper (1961).

Soils developed from the Millboro Shale have higher amounts of of arsenopyrite (a sulfide mineral), which will have its own As/Fe ratio that differs from the soils in the range floor, along with naturally higher As concentrations.

Timothy Leahy, PMP

Project Manager

Shaw's Environmental and Infrastructure Group

4696 Millennium Drive, Suite 320

Belcamp, MD 21017

410-273-7228 (Direct)

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www.shawgrp.com <<http://www.shawgrp.com/>>

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Classification: UNCLASSIFIED

Caveats: FOUO

[attachment "FieldTripfigure.pdf" removed by Erich Weissbart/R3/USEPA/US]

Leahy, Timothy

From: Weissbart.Erich@epamail.epa.gov
Sent: Tuesday, January 15, 2013 9:50 AM
To: McKenna, James J CIV (US)
Cc: Cutler,Jim; Bressette, James W CIV USARMY MEDCOM PHC (US); Stewart, Jay (US SSA); Jeremy Flint (jeremy.flint@atk.com); MaryAnn Bogucki (maryann.bogucki@baesystems.com); Alberts, Matt (US SSA); Mendoza, Richard R Jr CIV (US); Davie, Robert N III CIV (US); Ryan, Susan M CIV USARMY IMCOM AEC (US); Leahy, Timothy; Meyer, Tom NAB02
Subject: RE: ARSAR RTCs (UNCLASSIFIED)

Jim,
EPA/VADEQ accepts the proposal to split the site into two parts and redo the risk assessment for each (firing range floor and berm and the southeast hillside). EPA/VADEQ accepts the proposal to redo the eco risk assessment for the hillside area. EPA/VADEQ would both like reprints of the journal article describing the geochemical method explaining the elevated arsenic.

Erich Weissbart P.G.
Land and Chemicals Division (3LC20)
US EPA Region III
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-3284
e-mail: weissbart.erich@epa.gov

From: "McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil>
To: Erich Weissbart/R3/USEPA/US@EPA, "Cutler,Jim" <James.Cutler@deq.virginia.gov>
Cc: "Davie, Robert N III CIV (US)" <robert.n.davie4.civ@mail.mil>, "Stewart, Jay (US SSA)" <jay.stewart@baesystems.com>, "Alberts, Matt (US SSA)" <matt.alberts@baesystems.com>, "MaryAnn Bogucki (maryann.bogucki@baesystems.com)" <maryann.bogucki@baesystems.com>, "Meyer, Tom NAB02" <Tom.Meyer@usace.army.mil>, "Mendoza, Richard R Jr CIV (US)" <richard.r.mendoza.civ@mail.mil>, "Ryan, Susan M CIV USARMY IMCOM AEC (US)" <susan.m.ryan.civ@mail.mil>, "Bressette, James W CIV USARMY MEDCOM PHC (US)" <james.w.bressette@us.army.mil>, "Timothy.Leahy@shawgrp.com" <Timothy.Leahy@shawgrp.com>, "Jeremy Flint (jeremy.flint@atk.com)" <jeremy.flint@atk.com>
Date: 12/13/2012 09:36 AM
Subject: RE: ARSAR RTCs (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Erich and Jim

Please see attached files for our responses to EPA and VDEQ comments on the ARSAR report. After the holiday break we can schedule a conference call to discuss these comments as well as the comments on the SWMU 48/49 RFI/CMS report. Again I'd like to offer a site visit at RFAAP in conjunction with this discussion.

Thanks in advance,
JJM

-----Original Message-----

From: Weissbart.Erich@epamail.epa.gov [<mailto:Weissbart.Erich@epamail.epa.gov>]

Sent: Wednesday, November 21, 2012 8:07 AM
To: McKenna, James J CIV (US)
Subject: Re: ARSAR RTCs (UNCLASSIFIED)

Jim,
Below are Mr. Cutler's (VADEQ) comments in response to the Word documents forwarded to EPA and VADEQ responding to our comments on the ARSAR. Attached you will find EPA's comments. After distributing to your team, let's figure out the best way to resolve continuing issues.

Erich

VDEQ does not concur with the latest responses which refer to the following comments:

General Comment #2.

The structure of the report places the risk assessment before the description of soil removal. Again I'm assuming the risk assessment was applied to site conditions after removal. Typically a risk assessment would point towards removal as a remediation option. Approaches such as the iterative truncation method are presented prior to removal and approved if applicable to site conditions (which it is not -see other regulator comments). The two after-the-fact assessments remain confusing and contradictory as presented.

General Comment #3.

My original comment to the work plan noted that "potential 'remediation areas' other than the berm were not discussed". The RTC indicated that "excavation and sampling within the additional 'remediation areas' has also been furthered discussed" in the revised work plan. The revised work plan was changed to present berm excavation and other area excavation in separate paragraphs; the other areas including the "cliff behind the berm". " 1-ft lifts will be removed until XRF concentrations are below the RG...soil removal will continue until RG levels are achieved...All stakeholders will be notified of the changes and modifications needed..."(page 2-6).

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While the hillside may contain a particular type of soil I'm not sure that it's been demonstrated why it would contain elevated arsenic compared to the rest of RAAP.

Specific Comment #14 and#15.

The fact remains that the selection of the exposure area is the important factor when discussing risk at the site. Many different sample groupings have been used throughout the report. The most conservative assessment would be to focus on the apparent source areas.

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area. Note that VDEQ required removal of soils contiguous to the source area. The hillside appears to be a separate source area and should be treated as such.

Erich Weissbart P.G.
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1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-3284
e-mail: weissbart.erich@epa.gov

-----"McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil> wrote: -----
To: Erich Weissbart/R3/USEPA/US@EPA, "Cutler, Jim" <James.Cutler@deq.virginia.gov>
From: "McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil>
Date: 09/26/2012 03:55PM
Cc: "Meyer, Tom NAB02" <Tom.Meyer@usace.army.mil>, "Mendoza, Richard R Jr CIV (US)" <richard.r.mendoza.civ@mail.mil>, "Bob Winstead (bob.winstead@baesystems.com)" <bob.winstead@baesystems.com>, "Alberts, Matt (US SSA)" <matt.alberts@baesystems.com>, "Ryan, Susan M CIV USARMY IMCOM AEC (US)" <susan.m.ryan.civ@mail.mil>, "Bressette, James W CIV (US)" <james.w.bressette@us.army.mil>, "Timothy Leahy@shawgrp.com" <Timothy.Leahy@shawgrp.com>, "Parks, Jeffrey N" <Jeffrey.Parks@shawgrp.com>, "Davie, Robert N III CIV (US)" <robert.n.davie4.civ@mail.mil>, "Jeremy Flint (jeremy.flint@atk.com)" <jeremy.flint@atk.com>, "Stewart, Jay (US SSA)" <jay.stewart@baesystems.com>
Subject: ARSAR RTCs (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

All,

Checking my files, it appears this email was not sent on August 7, 2012 as I intended so I am resending it. Still want to schedule a conference call to discuss in about two weeks, say Wednesday October 10. Note on Sep 17, BAE has brought on board Jay Stewart as their Environmental Manager so I'm ccing him on this email.

If in fact this email was sent on August 7, let's schedule a conference call sometime next week.

I apologize for any confusion.
Thanks,
JJM

Erich, Jim, All,

Attached are the subject RTCs. Maybe we could schedule a conference call to discuss them on or about 08/22/2012.

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[attachment "VDEQ_ARSAR_ RTCs_7-25-2012_complete jjm.docx" removed by Erich Weissbart/R3/USEPA/US]
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[attachment "RFAAP_ARSAR_RTC_Figures.pdf" deleted by Erich Weissbart/R3/USEPA/US]
[attachment "VDEQ_ARSAR_ RTCs_2nd set of comments 12-11-12.pdf" deleted by Erich Weissbart/R3/USEPA/US] [attachment "EPA_ARSAR_ RTCs_2nd set of comments 12-11-12.pdf" deleted by Erich Weissbart/R3/USEPA/US]

Leahy, Timothy

From: McKenna, James J CIV (US) [james.j.mckenna16.civ@mail.mil]
Sent: Thursday, December 13, 2012 9:36 AM
To: Weissbart.Erich@epamail.epa.gov; Cutler, Jim
Cc: Davie, Robert N III CIV (US); Stewart, Jay (US SSA); Alberts, Matt (US SSA); MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Ryan, Susan M CIV USARMY IMCOM AEC (US); Bressette, James W Mr CIV US USA MEDCOM PHC; Leahy, Timothy; Jeremy Flint (jeremy.flint@atk.com)
Subject: RE: ARSAR RTCs (UNCLASSIFIED)
Attachments: RFAAP_ARSAR_RTC_Figures.pdf; VDEQ_ARSAR_RTCs_2nd set of comments 12-11-12.pdf; EPA_ARSAR_RTCs_2nd set of comments 12-11-12.pdf

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Erich and Jim

Please see attached files for our responses to EPA and VDEQ comments on the ARSAR report. After the holiday break we can schedule a conference call to discuss these comments as well as the comments on the SWMU 48/49 RFI/CMS report. Again I'd like to offer a site visit at RFAAP in conjunction with this discussion.

Thanks in advance,
JJM

-----Original Message-----

From: Weissbart.Erich@epamail.epa.gov [mailto:Weissbart.Erich@epamail.epa.gov]
Sent: Wednesday, November 21, 2012 8:07 AM
To: McKenna, James J CIV (US)
Subject: Re: ARSAR RTCs (UNCLASSIFIED)

Jim,
Below are Mr. Cutler's (VADEQ) comments in response to the Word documents forwarded to EPA and VADEQ responding to our comments on the ARSAR. Attached you will find EPA's comments. After distributing to your team, let's figure out the best way to resolve continuing issues.

Erich

VDEQ does not concur with the latest responses which refer to the following comments:

General Comment #2.

The structure of the report places the risk assessment before the description of soil removal. Again I'm assuming the risk assessment was applied to site conditions after removal. Typically a risk assessment would point towards removal as a remediation option. Approaches such as the iterative truncation method are presented prior to removal and approved if applicable to site conditions (which it is not -see other regulator comments). The two after-the-fact assessments remain confusing and contradictory as presented.

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Cc: "Meyer, Tom NAB02" <Tom.Meyer@usace.army.mil>, "Mendoza, Richard R Jr CIV (US)" <richard.r.mendoza.civ@mail.mil>, "Bob Winstead (bob.winstead@baesystems.com)" <bob.winstead@baesystems.com>, "Alberts, Matt (US SSA)" <matt.alberts@baesystems.com>, "Ryan,

Susan M CIV USARMY IMCOM AEC (US)" <susan.m.ryan.civ@mail.mil>, "Bressette, James W CIV (US)" <james.w.bressette@us.army.mil>, "Timothy.Leahy@shawgrp.com" <Timothy.Leahy@shawgrp.com>, "Parks, Jeffrey N" <Jeffrey.Parks@shawgrp.com>, "Davie, Robert N III CIV (US)" <robert.n.davie4.civ@mail.mil>, "Jeremy Flint (jeremy.flint@atk.com)" <jeremy.flint@atk.com>, "Stewart, Jay (US SSA)" <jay.stewart@baesystems.com>
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[attachment "VDEQ_ARSAR_ RTCs_7-25-2012_complete jjm.docx" removed by Erich Weissbart/R3/USEPA/US] [attachment "EPA_ARSAR_ RTCs_7-25-2012_complete jjm.docx" removed by Erich Weissbart/R3/USEPA/US]

Classification: UNCLASSIFIED

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Responses to the Second Set of EPA comments on the
Draft Army Reserve Small Arms Range RFI/ Interim Measures Completion Report
February 2012

General Response

Note that the entire set of original comments and responses are provided below for clarity and completeness. Follow up (2nd round) regulatory comments and responses are shown below in blue.

In order to move this site forward, the Army suggests breaking the site into two regions, separated by Stroubles Creek. The majority of the comments deal with the area on the southeast side of the Creek where elevated lead and arsenic are present. No contamination was found on the firing range floor, and the top foot of soil was removed from the berm during the Interim Measures Removal Action, addressing the principal threat to human health and the environment at the site. The risk assessments will also be split into two sections based on the stream as a dividing line. The report will be re-organized so that the IM is described before the risk assessments as a “previous investigation” to follow the actual sequence of events (instead of trying to stick to the same organization as other reports where the IM was done after the initial RFI assessment). The larger area (firing points and berm) will likely be recommended for No Further Action and Unrestricted re-use. The Southeast Hillside area will be reevaluated separately through a new Human Health Risk Assessment and a new Screening Level Ecological Risk Assessment that uses the data set from the hillside. Separating out the two areas of the site will lead to different recommendations for future use in the two areas. The proposed division of the site is shown on attached **Figure 1**.

1. Executive summary: EPA disagrees with grouping of sample data as described in the report. See additional comments below.

RESPONSE: Comment noted. Specific responses are provided below next to the additional comments.

2. Executive summary: EPA disagrees with a no further action determination for this area based on demonstrated risks to ecologic receptors, and hot spots of lead contamination as well as arsenic concentrations exceeding background levels in hillside samples. EPA also disagrees with the characterization of “very limited risk” to hypothetical future residential receptors. The workplan makes clear that the remedial goal for lead for this site is the residential standard of 400 mg/kg. This site is not suitable for unrestricted use.

RESPONSE: Interim Measures for the site were intended for the berm, where contamination was identified prior to the RFI/IM investigation. See Section 1.0 of the workplan: “Specifically, this Work Plan addresses the complete characterization of site media and removal of soil in the target berm with concentrations of antimony and lead to below the residential remedial goal (r-RG) in order to facilitate clean closeout in accordance with Part II(D)(11-21) IM of the RFAAP Corrective Action Permit (USEPA, 2000a).”

The RFI portion was intended to characterize the remaining portions (the firing areas, the stream and the hillside behind the berm) of the site.

With regard to the HHRA, it is acknowledged that there are exceedences of lead and arsenic on the hillside. Given the topography of this hillside, however, the exposure parameters applied in the overall HHRA (i.e., combined data) were particularly conservative for this area. It is unlikely that residential receptors, especially young children, would cross Strouble's Creek and traverse the steep, wooded hillside on a daily basis. Although the concentrations of lead and arsenic in the hillside samples are greater than those of the firing range floor and berm, the exposure frequency and exposure duration are expected to be much less than that assumed for the residential scenario. With respect to lead, 3 of 12 sample locations exceeded the residential soil level of 400 mg/kg. The potential for routine contact by the same receptor at these 3 locations is extremely low. Although 10 of 12 sample locations exceeded the background value for arsenic, subsequent geochemical evaluation demonstrated that arsenic was naturally-occurring. A discussion of the differences between actual exposures to the firing range/berm area and the hillside will be added to the uncertainty section (Section 6.5.3).

SLERA lead hazards were only elevated as 6 for the American robin and 8 for the shrew, using LOAEL-based TRVs and the adjusted interspecies TRV extrapolation uncertainty factor of 1. As these two species have home ranges of 1.2 acres and 1 acre, respectively, they might just forage within each one of the three sub-sites, and not range over the entire 7.6 acre ARSAR Site. However, neither of these two species is state- or federally-threatened or endangered, and the assessment endpoint used in the SLERA is the protection of wildlife populations, not individuals. Therefore, the potential loss of a few individual wildlife species would not be expected to significantly reduce local populations of wildlife.

2nd set of Comments

EPA maintains that the hillside area is not suitable for an unrestricted use designation. Unrestricted use, i.e., residential, means that the area must be suitable for frequent, long term contact over a reasonable exposure area with no limitations whatsoever. This assumption for potential future use also assumes the Army no longer controls the property, and cannot prevent access from any direction. It is clear that the southeast hillside, with its areas of significant lead and arsenic contamination does not meet this criterion.

The statement that the possibility of repeated contact with the three elevated lead concentration locations in confirmation samples is remote is not supportable. The three confirmation samples are located within approximately 125 ft of each other, a reasonable size for a residential lot. XRF results reveal a pattern of significantly elevated lead concentrations (ranging from 1153 mg/kg to 3837 mg/kg) in samples that are directly adjacent to one another, along the NW boundary of the grid area investigated for the RFI. These sample locations could also in theory all be located on a single residential lot. In addition, given the observed pattern of lead contamination in XRF results, it is reasonable to assume that additional fixed laboratory samples along the NW boundary would reveal significantly elevated lead concentrations, thereby reinforcing the hypothesis that substantial lead contamination exists on the hillside.

With regard to the SLERA, note that robins and shrews are very sensitive to soil contamination due to their limited home range and their invertebrate diet.

Furthermore, the concentration term for lead used data obtained over the entire 7.6 acre site. It is not unreasonable that, as suggested by the Army, that robins and shrews would range over a sub-site such as the hillside area with its significantly higher lead concentrations. Additional action based on the conclusions of the SLERA cannot be ruled out.

2nd Response

The Army suggests breaking the site into two distinct areas, separated by Stroubles Creek. The area where the firing points were located and the berm itself would likely be designated as an unrestricted re-use area and Land Use Controls would be established over the hillside located SE of Stroubles Creek to maintain its current use as an industrial area. As noted in the original response, the area is difficult to access and not suitable for future development due to the steep, rocky nature of the hillside (**Figure 2** shows the topographic contours of the hillside).

3. Sample identifiers for 4 berm samples are inconsistent throughout the report. Berm samples are identified as ARSBC11 through ARSBC14 in report text (sections 3.1.1.1 and 4.1.1) and some tables (table nos. 4-2, 4-3, 4-17, 6-1, and 7-4); however, other tables (nos. 3-1 and 4-1) and figures (3-1, 4-1, and 4-2) designate these samples as ARSBSC11 through ARSBSC14. Confirm that despite the different identifiers, these samples represent a single soil sample analysis. All inconsistent sample identifiers should be corrected.

RESPONSE: The discrepancy in the sample IDs will be corrected.

4. Section 4.1.3: Confirmation (fixed laboratory) samples from the southeast hillside revealed significantly elevated lead concentrations (average 378 mg/kg, max 2500 mg/kg). In addition, XRF results for lead for the 33 hillside samples revealed significantly higher average (629 mg/kg) and hot spot (3837 mg/kg) lead concentrations than were reported in the confirmation samples. It appears that the limited number of confirmation samples obtained from the hillside is not indicative of the true extent of lead contamination, and that lead contamination extends farther than anticipated. In section 2.2.3, Delineation and Excavation (p. 2-6) of the ARSAR workplan, it is stated that all detections of lead exceeding the residential remedial goal of 400 mg/kg will be removed until lead remedial goals are achieved. Moreover, stakeholder notification that lead contamination extended farther than anticipated (also noted in section 2.2.3) should have been initiated. The presence of significant lead concentrations in the hillside area may indicate the need for additional remedial activities in this location

RESPONSE: As noted above, the IM portion was intended for the berm, where elevated lead was identified during the SI. Section 1.0, last paragraph states: *“Specifically, this Work Plan addresses the complete characterization of site media and removal of soil in the target berm with concentrations of antimony and lead to below the residential remedial goal (r-RG) in order to facilitate clean closeout in accordance with Part II(D)(11-21) IM of the RFAAP Corrective Action Permit (USEPA, 2000a).”* Stakeholder Notification was not initiated because the Southeast Hillside was investigated for the RFI portion and was not part of the IM.

2nd set of Comments

As noted in EPA's response to comment 2, it is likely that the limited number of fixed laboratory (confirmation) samples obtained along the NW boundary of the hillside area is not an accurate representation of the extent of elevated lead in soil for the hillside area. In addition, a combined lab and XRF lead exposure point concentration will be added to the risk assessments, for informational purposes.

2nd Response

It is acknowledged that the lead is not bound completely by the confirmation samples, however; the combined data set of XRF and laboratory based samples do provide constraints on the limits of lead on the hillside area, and the correlation coefficient between laboratory and XRF data for lead was 0.96, demonstrating that the XRF data for lead, while not acceptable for use in the risk assessment, is usable for constraining the lateral extent of lead on the hillside. An additional figure will be added to the revised report that shows the combined dataset from the XRF and laboratory samples so that the extent of lead is more apparent.

5. Figure 4-5 and Table 4-8: The ARSAR workplan indicated in Section 3.3.1 that arsenic XRF samples would be collected, stepping outwards along gridlines, until sample concentrations are below the established background value of 15.8 mg/kg. This does not appear to have happened. All XRF samples from the hillside area revealed arsenic results that exceeded the background concentration. In addition, 11 out of 12 confirmation samples revealed arsenic concentrations exceeding background. Stakeholder notification of the larger area of soil contamination should have been initiated. Additional sampling in the hillside area for arsenic may be required

RESPONSE: Samplers could not safely climb further up the hill to collect an additional row of XRF samples. The consistently high levels of arsenic on the hillside suggested a non-anthropogenic source for the arsenic, which lead to the geochemical analysis presented in Section 4.7.3. This geochemical analysis differs from the facility-wide background study in several important ways. First, the facility wide background study looked at samples from different soil types, rather than a specific type of soil over a specific bedrock unit. Second, the Background study was a statistical approach and did not attempt to identify sources. The geochemical analysis uses the natural relationships between specific metals and substitutions in minerals to identify whether the concentrations are elevated due to natural weathering processes or due to an anthropogenic source that would not necessarily be present at the same ratios. Results of the geochemical evaluation determined that arsenic is naturally occurring.

2nd Set of Comments

It is not definitively established that the elevated arsenic concentrations in the hillside area are naturally occurring.

2nd Response

The geochemical method described in the report and in the response above has been published in peer-reviewed scientific journals and has been accepted by the

scientific community as an acceptable method of determining whether metals in soils are naturally occurring or from anthropogenic sources. We could provide reprints of the articles if the reviewers are not familiar with the methodology.

It should be also noted that the furthest row of samples is upgradient/uphill from the elevated lead and thus out of what would be expected for the ARSAR footprint, strongly suggesting that the ARSAR is not the source of the arsenic, as it would be unlikely to migrate uphill.

6. Section 4.7.3: Background concentrations for the Radford AAP have been established, and it is clear that the arsenic concentrations measured on the southeast hillside exceed these background concentrations.

RESPONSE: See response to Comment 5 for the rationale for completing a geochemical analysis of the metals on the southeast hillside.

2nd Set of Comments

EPA maintains that the arsenic concentrations reported on the southeast hillside exceed the Radford AAP background concentrations.

2nd Response

The Army agrees with the statement, which is why additional analysis was performed and included in Section 4.7.3 of the report. Because there have been no other documented historic uses of this area besides the firing range and the use of the hillside as a backstop for firing does not explain the elevated arsenic, the next logical step was to assess whether it could be due to natural causes. The geochemical method described in the report and in the response above has been published in peer-reviewed scientific journals and has been accepted by the scientific community as an acceptable method of determining whether metals in soils are naturally occurring or from anthropogenic sources. We could provide reprints of the articles if the reviewers are not familiar with the methodology.

A portion of the geologic map of the area (USGS Radford North Quadrangle) has also been attached to these Responses to Comments (**Figure 3**) that shows the Radford Area. As can be seen from the map, the Devonian “DO” unit outcrops at the top of the slope and is the only outcrop of this formation at Radford. The ARSAR is a unique geologic setting at Radford and explains why the concentrations of metals in this area may be different than the rest of the installation.

Note the entire geologic map is available at the following link:

<http://www.dmme.virginia.gov/DMR3/newpubs.shtml#openfilereports>

7. Table nos. 4-1, 4-4, and 4-7: A sample specific detection limit should be provided for each result that is below the limit of detection.

RESPONSE: Sample specific detection limits will be provided on the XRF results tables.

8. Section 6.2.1: Per the EPA Supplemental Soil Screening Level Guidance, Exhibit 5-1, the exposure frequency for a construction worker should be 250 days.

RESPONSE: Although the exposure frequency (EF) of 125 days/year for the construction scenario was justified for HHRA at other sites (e.g., SWMU 43, SWMU 41A, 41B) and approved by EPA, it is acknowledged that these sites were smaller in size than the ARSAR. In response to the comment, the EF will be changed to 250 days/year to account for a larger site (approximately 7.6 acres).

2nd Set of Comments

It is noted that risks must be recalculated using the higher exposure frequency and conclusions must be restated where appropriate.

2nd Response

Agreed. If EPA is willing to split the site into two regions as described above in the General Response, then the exposure frequency of 250 days/yr will be used for the larger area (6.4 acres) and 125 days/yr will be used for the smaller area of (1.3 acres) to maintain consistency for the smaller area.

9. Table 6-1: Soil samples from the berm, the firing range floor, and the southeast hillside were combined to develop a single chemical concentration input for the risk assessment. This is a non-conservative approach due to the large area (7.6 acres) encompassed by the firing range and the fact that a receptor would not be expected to move randomly across the entire ARSAR site. In addition, the spacing between samples in the different areas varies widely; for example, berm samples are spaced approximately 20 feet apart, while some hillside samples are greater than 100 feet apart, and one or more firing range floor samples used in the risk assessment are greater than 150 feet apart. The inclusion of the closely-spaced berm samples in the larger dataset serves to skew the entire dataset in the direction of the berm results (which represent a post-excavation, “clean” soil). The approach even contradicts methodology presented in Section 8.6 where segregation of firing range floor samples from the remainder of soil samples is described, “to prevent the downward skewing of the area-average.” The exposure areas must be evaluated separately: firing range floor, berm, and southeast hillside, and risks must be recalculated.

RESPONSE: This comment does not appear to be consistent with other Risk Assessments done at Radford. The HHRA presented in section 6 and the SLERA presented in Section 7 follow the same methodology as other risk assessments done for Radford. Sites have been split up where there are noncontiguous units, (e.g. SWMU 41A&B), but they have not split in the manner suggested in this comment. Furthermore, given the terrain and access to the site, the firing area and berm are accessible and could potentially be developed in the future, while the southeast hillside is very steep and can only be accessed by people wading through the stream and then climbing the hill. A fence at the top precludes access from the other side.

The Area Average/Iterative Truncation presented in Section 8 was intended to be extremely conservative in its approach, which is why only the area from the berm back to the hillside was considered.

2nd Set of Comments

EPA disagrees, and maintains that an exposure area of 7.6 acres is inconsistent with EPA risk assessment policy. The consolidation of sample groupings that are unevenly spaced (20 ft apart vs. 100 ft apart vs. 150 ft apart) is also not defensible. EPA guidance notes that reasonable exposure areas for residential receptors should be no larger than ¼ to ½ acre. This suggests that 15 to 30 individual exposure areas may be appropriate for the risk assessment.

2nd Response

It should be noted that the samples from the firing range itself, which makes up the largest portion of the site were biased to the areas most likely to contain contamination (ie. the actual firing points) based on historical evidence, making it a very conservative estimate of the risk in that area. In addition, the one calculation that is dependent upon the size of the site involves the particulate emission factor (PEF). When we run the residential scenario, we are assuming that all contamination at the site is within the 0.5 acre area. We base the PEFs for the residential scenario on 0.5 acres. Also, see the General Response above about splitting the site into two areas separated by the stream.

10. Section 6.2.1: The terms ‘excavation’ worker and ‘construction’ worker both appear in this section. If these receptors represent the same population, a single term should be used. Note also that the exposure frequency for construction/excavation workers as listed in Exhibit 5-1 of EPA 2002 is 250 days, not 125 days. This modification must be made (including tables in Appendix E) and risks recalculated (see additional comment with regard to lead contamination below). This comment has also been made by EPA during reviews of prior Radford reports

RESPONSE: The terms “excavation worker” and “construction worker” represent the same population. The text and tables will be revised and the term “excavation worker” will be used for this receptor throughout the report.

As discussed in the response to Comment 8, the EF will be changed to 250 days/year to account for a larger site (approximately 7.6 acres).

2nd Set of Comments

EPA reiterates that an exposure area of 7.6 acres is not acceptable.

2nd Response

See response to second comment #9 above.

11. Section 6.2.3: Language addressing the unique handling of lead exposure point concentrations should be included in this section for clarity (despite the inclusion of the later section on lead); and footnotes describing lead exposure concentrations on tables (E.1-10) where UCLs are listed would also be helpful.

RESPONSE: The following paragraph will be inserted after the second paragraph of Section 6.2.3: “It is noted that the EPC for lead was based on the arithmetic mean concentration rather than the 95% UCL. Because the lead models are probabilistic models, several of the USEPA default parameters are based on central tendency (i.e., average) values. As discussed in Section 6.3.2, the arithmetic mean for surface soil served as the input values for the Adult Lead Model (ALM) and the Integrated Exposure Uptake Biokinetic Model (IEUBK).” A footnote will also be added to Table E.1-10.

12. Section 6.3.2 and Table E.1-47b: The cited EPA reference, “Frequently Asked Questions Regarding the Adult Lead Methodology” (2011), provides no recommendation for a construction worker exposure frequency of 125 days, although it is acknowledged that a central tendency exposure input for this variable is appropriate in lead biokinetic exposure models (unlike the upper bound inputs required for risk evaluation of other contaminants). Furthermore, the cited reference does state that use of a shorter term exposure frequency in the ALM requires averaging over the shorter time interval, i.e., 6 months. Table E.1-47b shows an averaging time of 365 days (12 months), and must be corrected if the shorter term exposure frequency is used.

RESPONSE: The reference, “Frequently Asked Questions Regarding the Adult Lead Methodology” (2011), was primarily cited as the source of the ingestion rate for contact-intense exposures to soil (100 mg/day). Because the exposure frequency will be revised to the construction scenario default value of 250 days/year, it will not be necessary to revise the averaging time.

13. Section 6.4 and 6.4.1: As noted earlier, soil sample results must be evaluated for each of three exposure areas: firing range floor, berm, and southeast hillside. Risks must be recalculated in accordance with comments in this memo. Assuming the default drinking water lead concentration to be 15 ug/l is overly conservative. It is sufficient to use the IEUBK default for unknown lead concentrations in drinking water, 4 ug/l. The statement regarding the Centers for Disease Control and Prevention (CDCP) concern threshold for lead of 10 g/dl [sic] must be revised. CDCP recently agreed to use a child blood lead level of 5 ug/dl “to identify children living or staying for long periods in environments that expose them to lead hazards.” This blood lead level will supplant the 10 ug/dl “level of concern” cited by CDCP in the past. In Section 6.4.1 an incorrect unit for the blood lead level of concern (g/dl) is used. The correct unit is ug/dl.

The final statement in this section, that ‘surface soil at the ARSAR passes the lead exposure assessment for all receptors in this HHRA’ will need to be revised pending revisions to the RFI/IM report required in this memo.

RESPONSE: Please see the response to Comments 2 and 4 regarding the exposure areas.

Because future conditions are unknown, the drinking water action level (15 µg/L) was conservatively assumed in the IEUBK model. Because the use of the default value would not change the overall conclusions of the HHRA, the IEUBK model will remain as originally presented.

The sentence regarding the CDCP concern threshold for lead (10 µg/dl) will be revised to read: “It is noted that the Centers for Disease Control and Prevention (CDCP) recently agreed to use a child blood lead level of 5 µg/dl to identify children living or staying for long periods in environments that expose them to lead hazards. USEPA is currently evaluating the potential implications of the revised blood lead level.” This information will also be repeated as an uncertainty in Section 6.5.4.

The symbol (µ) was inadvertently omitted from the unit for lead in Section 6.4.1. The unit will be corrected.

Please see Comments 2 and 4 regarding the requested revisions to the exposure areas. Although the Adult Lead Model for the excavation worker will be revised using an EF of 250 days/year, it will not be necessary to revise the models for the site worker or residents.

[2nd Set of Comments](#)

[See EPA responses to comment nos. 2, 4, 9, and 10.](#)

[2nd Response](#)

[See General response and responses to comments 2, 4 and 9 above.](#)

14. Table 6-3: References that site concentrations of lead in surface soil are below the ‘health protective criterion for lead’ should be removed pending revisions required in this memo. Note that the southeast hillside reveals fixed laboratory lead results with an arithmetic mean lead concentration of 478 mg/kg as well as at least two hotspots of lead contamination. Both the average and hotspot concentrations of lead exceed the current residential remedial goal of 400 mg/kg. Revision to this table is necessary

RESPONSE: See response to Comment 9 above.

[2nd Set of Comments](#)

[See EPA responses to comment nos. 2, 4, 9, and 10.](#)

[2nd Response](#)

[See General response and responses to comments 2, 4 and 9 above.](#)

15. Section 6.5.1: As noted in comment no. 4, it appears that hillside confirmation samples do not adequately represent the extent of contamination in the hillside area.

RESPONSE: See Response to Comment 4 above.

[2nd Set of Comments](#)

[See EPA response to comment no. 2.](#)

[2nd Response](#)

[See General Response above.](#)

16. Section 6.6: This section will need to be rewritten to conform with new risk estimates

RESPONSE: See response to Comment 9 above.

2nd Set of Comments

See prior EPA responses.

2nd Response

See General Response above.

17. Section 8.6: The workplan included no language or description of the area-average approach for determining attainment of cleanup goals. In addition, as noted previously, exposure areas must be evaluated separately and cannot be combined. EPA guidance on the area-average approach notes that individual exposure units be evaluated, and that residential exposure units are ‘typically less than 1 acre in size.’ Moreover, the cited EPA guidances include methods for addressing hotspot contamination such as was encountered in the hillside area. The iterative truncation method used may not be protective when, as is the case here, the highest sample concentrations (i.e., confirmation fixed lab samples from the hillside) do not represent the highest concentrations at the site (i.e., the hillside XRF results).

RESPONSE: As noted previously, the work-plan was intended to address lead in the berm, not in the hillside. The iterative truncation method was added to the report after the investigation of the hillside detected elevated levels. The method was modified slightly to account for the relative accessibility of the areas of the site - the hillside is essentially inaccessible, and the berm is easily accessible from the fields. The iterative truncation method was run using the combined data sets including the laboratory and XRF data, as well as each data set individually to ensure that the highest concentrations in the samples represented the highest concentration onsite.

2nd set of Comments

EPA maintains that the iterative truncation method did not receive prior review or approval for its use. Moreover, requirements for the iterative truncation method described in EPA guidance including evaluation of individual exposure areas and consideration of hot spots were not incorporated into the cleanup goal determination. EPA continues to question the validity of remedial goals proposed for the small arms range.

2nd Response

See General response above. Once the site is split into two sub-sites, the EPA guidance will be addressed. The remedial goal for lead was based on the EPA’s Interim Lead Clean-up Goal (400 mg/kg), rather than a calculated value.

18. Table E.1-19 and E.1-20: Inputs for the construction worker PEF need to be revised in accordance with the revised exposure frequency requested in this memo. The limited amount of vehicle travel assumed in this algorithm is considered representative of current conditions, and would not necessarily apply to a future case where construction is actively occurring?

RESPONSE: Because future construction plans vary by site and are often unknown at the time the HHRA is prepared, there is no default value in the *Supplemental*

Guidance for Developing Soil Screening Levels for Superfund Sites (SSG; USEPA, 2002) for the number of construction vehicles to be used during construction. It was assumed in this HHRA that two 2-ton cars and one 10-ton truck would be used during the duration of the project, which is similar to the parameters applied in HHRA for other sites at RFAAP. It is acknowledged that these previous sites (e.g., SWMU 43, SWMU 41A, 41B) comprised a smaller area. As discussed in the response to Comment 8, the EF will be revised to 250 days/year. The numbers and types of vehicles will be based on the assumptions used in the example calculation in Section 5.3.2 of the SSG (i.e., twenty 2-ton cars and ten 20-ton trucks).

19. Table E.1-15 and 1-17: Note that the proper exposure duration value for cancer endpoints is 30 years, not 24 years. The correct exposure duration for non-cancer endpoints is 24 years for adults and 6 years for children. The averaging times for non-cancer endpoints must be revised also. Risks must be recalculated.

RESPONSE: For cancer endpoints, the incremental lifetime cancer risk calculations for residents were calculated by combining the cancer risks for the adult (exposure duration = 24 years) and child (exposure duration = 6 years) for a total exposure duration of 30 years. For noncancer endpoints, noncancer hazards were calculated individually for the adult (exposure duration = 30 years) and the child (exposure duration = 6 years). The assumptions for these calculations are consistent with those used at other RFAAP sites. The procedure for these calculations will be clarified in Section 6.4 and footnotes will be added to Tables E.1-15 and 1-17.

20. Table E.1-19, 1-20, and 1-21: Explain why values for A, B, and C on Table E.1-19 are default values, whereas in algorithms on Tables E.1-20 and E.1-21 site-specific values are used for A, B, and C

RESPONSE: According to the SSG (USEPA, 2002), Section 5.3.2 and Equation 5.6, the Q/C term for dust generated by unpaved road traffic (Q/C_{sr}) was derived using EPA's ISC3 dispersion model for a hypothetical site under a wide range of meteorological conditions. Unlike the Q/C values for the other scenarios, the Q/C_{sr} term for the excavation scenario's simple site-specific approach can be modified only to reflect different site sizes; it cannot be modified for climatic zone. Therefore, the default values for variables A, B, and C assumed in the SSG were used to calculate Q/C_{sr} for this HHRA. A footnote will be added to Table E.1-19 to clarify this point.



LEGEND

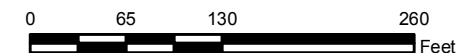
-  Water Feature
-  Surface Water Flow Direction
-  Dirt Road
-  Paved Road
-  Fence Line
-  MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Outermost MRS boundary was obtained from Final Site Screening Process Report (URS, 2009).



Scale:



U.S. Army Corps of Engineers



Shaw Environmental, Inc.

FIGURE 1
Army Reserve Small Arms Range
Site Map
Radford Army Ammunition Plant,
Radford, VA



LEGEND

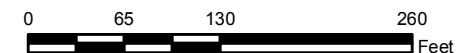
- 2 ft Contour Line
- 10 ft Contour Line
- Water Feature
- Surface Water Flow Direction
- - - Dirt Road
- Paved Road
- x — Fence Line
- MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Outermost MRS boundary was obtained from Final Site Screening Process Report (URS, 2009).



Scale:

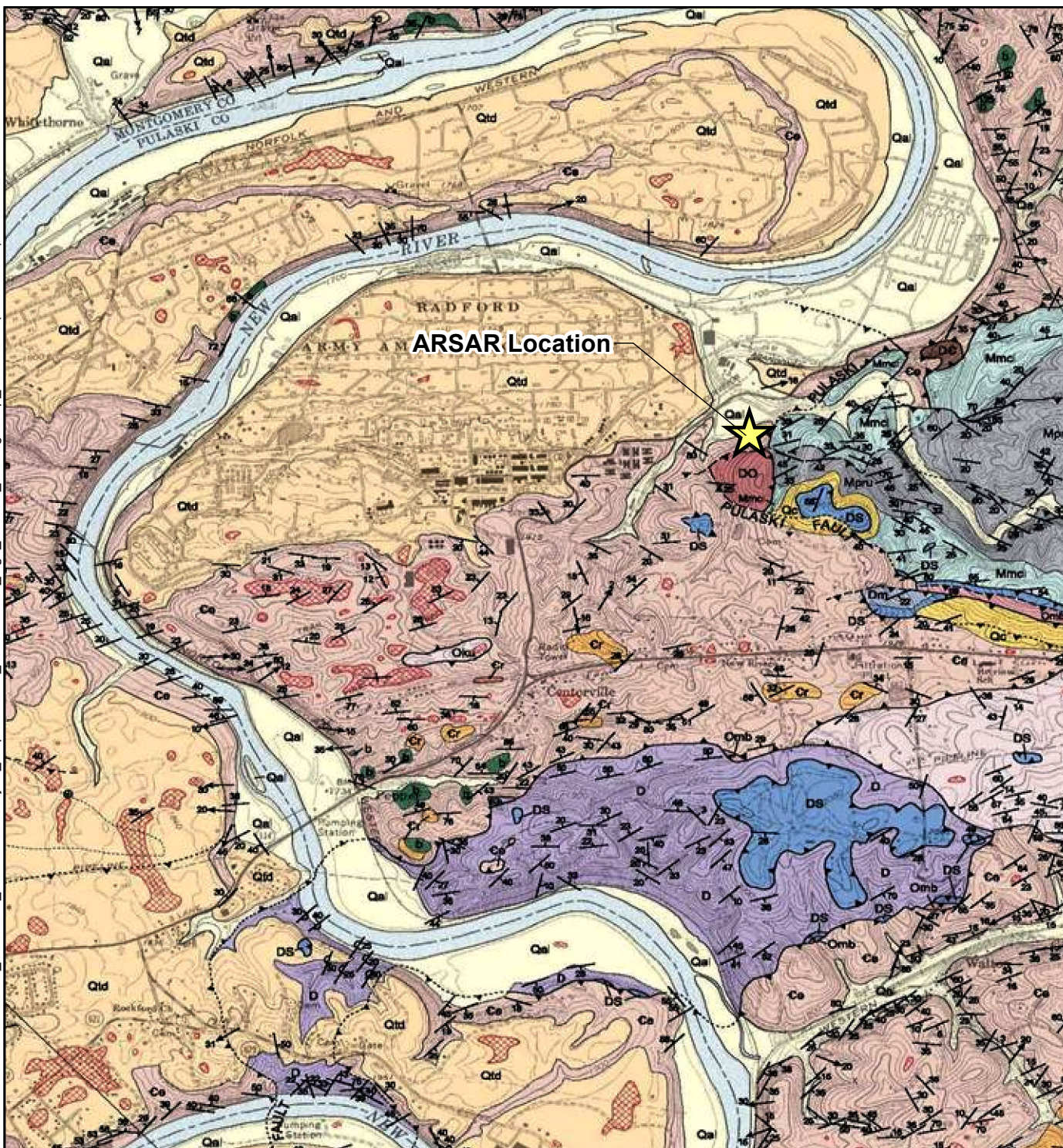


U.S. Army Corps of Engineers



Shaw Environmental, Inc.

FIGURE 2
Army Reserve Small Arms Range
Topography Map
Radford Army Ammunition Plant,
Radford, VA



Notes:

- 1) Geologic map source: Geologic Map of the Radford North Quadrangle, Virginia, 2009.
- 2) Map is not to scale (graphic depiction use only).



U.S. Army Corps of Engineers

 Shaw Environmental, Inc.

FIGURE 3
Army Reserve Small Arms Range
2009 Geologic Map
 Radford Army Ammunition Plant,
 Radford, VA

Responses to the Second Set of VDEQ comments on the
Draft Army Reserve Small Arms Range RFI/ Interim Measures Completion Report
February 2012

General Response

Note that the entire set of original comments and responses are provided below for clarity and completeness. Follow up (2nd round) regulatory comments and responses are shown below in blue.

In order to move this site forward, the Army suggests breaking the site into two regions, separated by Stroubles Creek. The majority of the comments deal with the area on the southeast side of the Creek where elevated lead and arsenic are present. No contamination was found on the firing range floor, and the top foot of soil was removed from the berm during the Interim Measures Removal Action, addressing the principal threat to human health and the environment at the site. The risk assessments will also be split into two sections based on the stream as a dividing line. The report will be re-organized so that the IM is described before the risk assessments as a “previous investigation” to follow the actual sequence of events (instead of trying to stick to the same organization as other reports where the IM was done after the initial RFI assessment). The larger area (firing points and berm) will likely be recommended for No Further Action and Unrestricted re-use. The Southeast Hillside area will be reevaluated separately through a new Human Health Risk Assessment and a new Screening Level Ecological Risk Assessment that uses the data set from the hillside. Separating out the two areas of the site will lead to different recommendations for future use in the two areas. The proposed division of the site is shown on attached **Figure 1**.

GENERAL COMMENTS

1. The arrangement of the report with the IM “activities” discussed in a separate section made the report very difficult to follow. Sampling activities were discussed in both the field investigation and IM section making it difficult to interpret the sequence of events. The use of different descriptors (pre-confirmation, post- excavation, etc.) for the same sample sets made it difficult to determine exactly when the samples were collected. I suggest that the actual excavation and removal be discussed separately; the sampling and delineation activities integrated into sections 3 and 4.

RESPONSE: The report will be re-structured to follow the sequence of field events. As suggested, the IM will be described separately from the sampling. Also, a single descriptor will be used for each sample set.

2. Two contradictory risk assessments of site conditions after soil removal (Section 6 and 8) are presented in the report and need to be resolved.

RESPONSE: Section 6 presents the HHRA in the same format as other EPA/VDEQ approved RFIs at Radford Army Ammunition Plant. Section 8 is not intended to be a separate risk assessment; rather, it is an analysis of a single analyte (lead) that was found at unexpectedly high concentrations in southeast hillside. The main source of lead onsite (the berm) was excavated and removed, but the hillside concentrations remained.

Because the HHRA showed that the average site lead concentration in surface soil was below the health protective criterion for lead, a more conservative approach was followed to show that concentrations were acceptable. Although the area average approach was slightly modified to account for accessibility of different areas of the site, the iterative truncation does show that the lead concentrations are acceptable, even in the smaller subset of samples that make up the “downrange” or target area of the range.

2nd Set of Comments

The structure of the report places the risk assessment before the description of soil removal. Again I’m assuming the risk assessment was applied to site conditions after removal. Typically a risk assessment would point towards removal as a remediation option. Approaches such as the iterative truncation method are presented prior to removal and approved if applicable to site conditions (which it is not -see other regulator comments). The two after-the-fact assessments remain confusing and contradictory as presented.

2nd Set of Responses

The intent of removing the berm was to streamline the process and remove the known source of lead contamination at the site in a timely fashion. The layout of the report was left the same as other reports where the process was not streamlined. As noted in response to other comments, the report will be re-structured and the site will be re-grouped to separate out the hillside from the berm and firing points.

3. The remedial approach (excavation of soils above the RG of 400) in the work plan was not followed.

RESPONSE: The work plan was intended to cover IMs for the berm, where contamination had been previously identified, and an RFI for the remainder of the site. See Section 1 - Introduction (Last paragraph) *“Specifically, this Work Plan addresses the complete characterization of site media and removal of soil in the target berm with concentrations of antimony and lead to below the residential remedial goal (r-RG) in order to facilitate clean closeout in accordance with Part II(D)(11-21) IM of the RFAAP Corrective Action Permit (USEPA, 2000a).”*

2nd Set of Comments

My original comment to the work plan noted that “potential ‘remediation areas’ other than the berm were not discussed”. The RTC indicated that “excavation and sampling within the additional ‘remediation areas’ has also been furthered discussed” in the revised work plan. The revised work plan was changed to present berm excavation and other area excavation in separate paragraphs; the other areas including the “cliff behind the berm”. “ 1-ft lifts will be removed until XRF concentrations are below the RG...soil removal will continue until RG levels are achieved...All stakeholders will be notified of the changes and modifications needed...”(page 2-6).

2nd Set of Responses

Comment noted. The complete quote on page 2-6 is:

*“If lead concentrations are greater than the RG **below the surface samples**, [emphasis added] 1-ft lifts will be removed until the remediation area contain XRF concentrations below the RG.”*

Due to the steep, rocky nature of the hillside (**Figure 2** shows the contours for the hillside), samples could not be collected below the surface soil samples. In addition, the dangers to site personnel, the likelihood of contaminating the stream and the inaccessibility of the hillside to heavy equipment due to the berm, the stream, and the steep, wooded hillside itself precluded excavation of the cliff. The Army suggests moving forward with the regrouping and re-organization described in the General Response above.

SPECIFIC COMMENTS

1. Page ES-1 (Target Berm). I am assuming that the first sentence refers to “this” RFI/IM.

RESPONSE: That is correct. The text will be updated to replace “an RFI” with “this RFI”.

2. Page ES-1 (Firing Range Floor and.....). It seems redundant and confusing to the reader to state that sampling was performed for this RFI. It suggests a different 2011 RFI exists (this report is dated 2012) as this shorthand is often used to designate the final report.

RESPONSE: The section will be re-written as follows:

“The soil at the ARSAR firing range floor and potential firing points was not sampled during previous investigations. Analytical data was collected in 2011 to support this RFI/IM. Based on the results of this data, there are no constituents of concern for the firing range floor.”

3. ES-4. The ecological risk discussion concludes that food chain impacts are a concern for lead. This does not appear to be addressed in this report.

RESPONSE: SLERA lead hazards were only elevated as 6 for the American robin and 8 for the shrew, using LOAEL-based TRVs and the adjusted interspecies TRV extrapolation uncertainty factor of 1. As these two species have home ranges of 1.2 acres and 1 acre, respectively, they might just forage within each one of the three subsites, and not range over the entire 7.6 acre ARSAR Site. However, neither of these two species is state- or federally-threatened or endangered, and the assessment endpoint used in the SLERA is the protection of wildlife populations, not individuals. Therefore, the potential loss of a few individual wildlife species would not be expected to significantly reduce local populations of wildlife.

4. ES-4. The IM conclusions should be integrated with the berm discussion above.

RESPONSE: Agreed. Once the report is re-organized per General Comment #1, the Executive summary will be re-organized to follow the new organization of the report.

5. Page 2-5 (Section 2.7.2). The building area debris is not depicted on Figure 2-3.

RESPONSE: The building debris area will be added to Figure 2-3 at the eastern end of berm where samples SS-14 and SS-15 are located.

6. Page 3-1 (Section 3.1.1). Indicate that the XRF was performed after the excavation as part of the IM.

RESPONSE: The first sentence of the section will be revised to: “ *XRF surveys were completed at the site in three areas for different reasons:*

- 1) *Confirm lead had been removed from the berm to below 400 mg/kg following the IM excavation;*
- 2) *Assess the firing range floor for the presence or absence of lead; and,*
- 3) *Delineate arsenic and lead concentrations in the southeast hillside behind the berm.”*

7. Page 3-5 (Section 3.1.1.1). Surface soils or 1-2 feet?

RESPONSE: These samples currently represent surface soil. The table will be corrected to reflect that they were 1-2 ft bgs prior to the IM (the original table came from the work plan) - but that now they are surface soil.

8. Page 4-1 (Section 4.1.1). The 2nd sentence implies that surface samples were collected and not used. The labeling in the text is a little different ARSCSB01 (Sect. 3) vs. ARSBSC01(Sect.4). It is my understanding that the only IM soil sampling was collected after one foot of soil was removed.

RESPONSE: The sample labels will be corrected. The correct ID should be ARS (Army Reserve Small) B (Berm) SC (Soil Confirmation). The sentence will be re-written to make it clearer that surface soil samples were not collected until after 1 foot of soil was removed from the berm.

9. Page 4-1 (Section 4.1.1). IM is Section 8 not 6. I strongly suggest that the berm excavation be discussed before or within Section 3.

RESPONSE: As noted above in Response to General Comment 1, the report will be re-structured to more closely follow the sequence of field activities.

10. Page 4-1 (Section 4.1.1). No samples above SLs were indicated on Figure 4-2

RESPONSE: The sentence will be re-written: “*As indicated on **Figure 4-2**, no analytes were detected above screening levels in the berm soil. Detected results are presented in **Table 4-2** and summarized in **Table 4-3**.”*

11. Page 4-46 (Section 4.7.1). By “elevated levels” do you mean above 400 ppm?

RESPONSE: Yes. However, to avoid further confusion, the section will be re-written to: *“The combined data set indicates that metals (primarily lead and antimony) were the constituents of concern at the ARSAR target berm. Through the IM discussed in Section 8.0, the source material of the constituents of concern has been removed. Confirmation samples collected after removal of the berm surface indicated that the IM was successful in removing soil with concentrations of lead greater than 400 mg/kg. Post excavation samples showed no constituents with concentrations greater than screening levels.”*

12. Page 4-49 (Section 4.7.3). The font/spacing changes in the middle of the page. Also, this appears to present an argument for a re-evaluation of background.

RESPONSE: The font/spacing will be corrected. This section looks specifically at the geochemistry of certain metals and their affinities to substitute in minerals for each other. Instead of re-evaluating background, this analysis takes a more-site specific approach to assess whether the ratio of metals present in each sample is similar and suggests a natural origin rather than an anthropogenic source. Peer-reviewed, scientific journal articles can be provided to document the validity of this type of analysis, if requested.

2nd Set of Comments

While the hillside may contain a particular type of soil I’m not sure that it’s been demonstrated why it would contain elevated arsenic compared to the rest of RAAP.

2nd Set of Responses

The geochemical analysis does not attempt to address why the hillside area has a higher naturally occurring level of arsenic. It is only looking at whether the arsenic is present at ratios that are indicative of a naturally occurring source rather than an anthropogenic source.

Because there have been no other documented historic uses of this area besides the firing range and the use of the hillside as a backstop for firing does not explain the elevated arsenic, the next logical step was to assess whether it could be due to natural causes. The geochemical method described in the report and in the response above has been published in peer-reviewed scientific journals and has been accepted by the scientific community as an acceptable method of determining whether metals in soils are naturally occurring or from anthropogenic sources. We could provide reprints of the articles if the reviewers are not familiar with the methodology.

A portion geologic map of the area (USGS Radford North Quadrangle) has also been attached to these Responses to Comments (**Figure 3**) that shows the Radford Area. As can be seen from the map, the Devonian “DO” unit outcrops at the top of the slope and is the only outcrop of this formation at Radford. The ARSAR is a unique geologic setting at Radford and explains why the concentrations of metals in this area may be different than the rest of the installation.

Note the entire geologic map is available at the following link:

<http://www.dmme.virginia.gov/DMR3/newpubs.shtml#openfilereports>

13. Page 6-1 (Section 6.6.1). If this table represents post removal conditions then the risk assessment should be discussed in the context of the IM.

RESPONSE: The risk assessments were both completed with post-IM samples. As noted earlier, the organization of the report will be re-structured based on these comments, and will be clearer that the IM was done prior to the risk assessments.

14. Page 6-13 (Section 6.4.1). How do these models account for hotspots? The mean of 189 is significantly different than the EPC of 553 found in Table E.1-10 and other concentrations discussed in the IM section.

RESPONSE: Because the Adult Lead Model (ALM) and the Integrated Exposure Uptake Biokinetic Model (IEUBK) are probabilistic models, several of the USEPA default parameters in the models are based on central tendency (i.e., average) values. Therefore, the arithmetic mean concentration for lead (189 mg/kg) is used rather than the 95% upper confidence limit (553 mg/kg). This point will be clarified in Section 6.4.1 and a footnote will also be added to Table E.1-10.

The lead models are not designed to identify or account for hot spots. It is acknowledged that there are exceedences of lead on the hillside. Given the topography of this hillside, however, the exposure parameters applied in the overall HHRA (i.e., combined data) were particularly conservative for this area. It is unlikely that residential receptors, especially young children, would cross Strouble's Creek and traverse the steep, wooded hillside on a daily basis. The exposure frequency and exposure duration for the hillside would be expected to be much less than that assumed for the residential scenario. It is noted that 3 of 12 sample locations exceeded the residential soil level of 400 mg/kg. The potential for routine contact by the same receptor at these 3 locations is extremely low. A discussion of the differences between actual exposures to the firing range/berm area and the hillside will be added to the uncertainty section (Section 6.5.3).

2nd Set of Comments

Specific Comment #14 and #15.

The fact remains that the selection of the exposure area is the important factor when discussing risk at the site. Many different sample groupings have been used throughout the report. The most conservative assessment would be to focus on the apparent source areas.

2nd Response

See the General Response about re-grouping the site based on the stream as a dividing line. It should also be noted that a combined lab and XRF lead exposure

point concentration will be added to the risk assessments, for informational purposes. This approach will thus present a more robust lead EPC for the separate hillside subsite, as the EPC will be based on more sample results compared with just lab results alone. The correlation coefficient between laboratory and XRF data for lead was 0.96, demonstrating that the XRF data for lead, while not acceptable for use in the risk assessment, is usable for constraining the lateral extent of lead on the hillside.

15. Page 6-13 (Section 6.4.1). It is stated that the surface soil passes for all receptors. How does this compare with the reasoning in the IM section concerning “diluting” the sample set with floor samples?

RESPONSE: The HHRA presented in Section 6 follows the same format and methodology as other RFIs completed and approved at Radford AAP. The iterative truncation/area average method presented in Section 8 is intended to supplement the risk assessment by demonstrating that the soil is acceptable under even more conservative assumptions (such as limiting the area to the target areas) than those made in the HHRA.

16. Page 7-60 (Section 7.11). The findings of the SLERA regarding food chain impacts do not appear to be addressed in the report.

RESPONSE: Additional text will be added to the Report to discuss potential food chain impacts. Also, see response to USEPA Comment No. 2.

17. Page 8-1 (Section 8.0). This section is very confusing as a stand alone section at this point in the report. I would insert this discussion before section 3 and focus on the berm excavation only. The other field activities are discussed in the following sections (3 and 4).

RESPONSE: As noted above in previous comment responses, the report will be re-organized following these suggestions.

18. Page 8-1 (Section 8.1). It states that the site specific corrective measures objective is to be protective of industrial workers however the RG indicated is residential.

RESPONSE: The typographical error will be corrected so that the sentence in Section 8.1 reads “*The site-specific corrective measures objective for the ARSAR was to reduce contaminant concentrations in soil to levels that are protective of residents at the site*”.

19. Page 8-2 (Section 8.3). This section is confusing as a separate section. Would the following sections be subsections?

RESPONSE: The entire IM portion will be re-written and moved forward in the report so that the report follows the actual sequence of events in the field.

20. Page 8-5 (Section 8.5). Most of the text in the first paragraph is not part of the excavation activities and is a duplication of info. presented in section 4.1.2.

RESPONSE: See response to comment 19 above.

21. Page 8-6 (Section 8.5). The last paragraph discusses “pre-confirmation sampling” as if it took place before the excavation began. Is the pre-confirmation sampling the same as the XRF screening discussed above?

RESPONSE: Yes. As noted above, the section will be re-written and moved forward in the report.

22. Page 8-6 (Section 8.6). It states that “post excavation samples” were collected. Are they additional samples to the pre-confirmation samples or do they represent lab confirmation of XRF? They use of pre- and post- is confusing if the samples were collected at the same time.

RESPONSE: Agreed. The “pre-” and “post-” terminology will be dropped. It was an attempt to differentiate the data sets from pre- and post IM for the purposes of the iterative truncation, but it seems to end up making the sequence of events more confusing.

23. Page 8-7 (Section 8.6). The discussion regarding “confirmation” sampling is confusing. Are lab samples confirming XRF results or removal assumptions? What is XRF confirming?

RESPONSE: See Response Above. The XRF samples on the berm were confirming that the RGs have been met. The laboratory samples from the berm, hillside and firing floor were confirming the results of the XRF, (and are the final “confirmation samples” for the berm since the XRF data is considered screening level data.

24. Page 8-7 (Section 8.6). The “area average” approach was not discussed in the work plan. The work plan stated that the berm excavation would continue until confirmation samples were below the RG (400 mg/kg). Other areas including the hillside where 400 was exceeded would be excavated in a similar manner.

RESPONSE: Elevated lead levels were not expected on the hillside and the IMs were only intended for the berm, where excavation did continue until the RGs were met. The hillside was characterized and the results are reported in the RFI. Based on the iterative truncation/area average analysis, leaving the lead in place will still be protective of residential receptors.

2nd set of Comments

The fact that the RFI and IM reasoning and conclusions are mixed throughout this report creates much confusion. Given the after-the-fact use of iterative truncation would removal of some of the hillside samples made the berm okay?

2nd Set of Responses

Breaking the site into two areas would resolve this issue and allow the focus of the revised report to be the hillside area, as that seems to be the concern at the site. See the General Response about breaking the site up into two areas based on the stream as a dividing line.

25. Page 8-7 (Section 8.6). The sediment results did not appear to represent any significant lead contamination.

RESPONSE: Agreed. The fact that the stream does not appear to be impacted by activities at the site, and the fact that elevated constituents on the hillside are not migrating offsite; are two of the reasons, along with limited risks to human and ecological receptors, and no groundwater contamination, that No Further Action was recommended for the site.

26. Page 8-7 (Section 8.6). Two 2009 samples (SS14 and 15) were collected from the building debris area which doesn't appear on the figures as part of the berm. It is not clear if this area was actually removed as part of the berm. If this is the case then the new "berm average" would be higher (717 vs. 547) and the revised list would include six samples and eight "averages. The new pre-remediation average would be 492. Similarly increasing the number of post remediation confirmation samples (assuming the samples were collected from adjacent areas and had similar low concentrations) would result in a lower post remediation average. It appears that the data can be skewed depending on how many samples are taken or replaced.

RESPONSE: As noted above in other comment responses, the standard grouping was done in Section 6 (Human Health Risk Assessment). The grouping done in Section 8 was done to show even a smaller subset of the data, just the southeast end of the site, is still protective of human health.

2nd Set of Comments

The response did not address my hypothetical question. Am I correct? I'm not a statistician but it appears that the data can be skewed depending how many samples are taken or replaced.

2nd Set of Responses

Yes, you are hypothetically correct.

- 27 Page 8-9 (Section 8.6). There appears to be many ways of grouping this data. If only hillside XRF samples are used then the mean is 625. If hillside lab samples (2009 and 2011) are considered then the average is 438. The bottom line is that levels found in the 2011 investigation of the hillside represent potentially more significant contamination than was removed from the berm. The area above 400 on the hillside is equivalent to the entire areal extent of the berm. No delineation with depth was performed on the hillside.

RESPONSE: We agree that there are many different ways of grouping the data, all of which are more conservative than the standard, default grouping by site that has been done throughout Radford AAP. Lead was delineated laterally across the hillside

as well as up and down the hillside. Depth is limited due to the shallow bedrock encountered on the steep, rocky hillside.

It is unlikely that the hillside represents significantly more contamination than was removed. The SI (URS, 2009) detected lead levels above background; however all concentrations were below the residential criteria of 400 mg/kg and bullet fragments were not found on the hillside, while the berm samples did contain bullet fragments and elevated levels of lead up to 1600 mg/kg. Additional berm samples were not collected until after the completion of the IM at the berm, while extensive additional sampling was completed on the hillside. (Note that the SSP Report discusses collecting samples on the hillside “between rock outcrops”).

Finally, other sites at Radford have followed a similar, iterative-truncation/area average method and for example at the Northern Burning Ground determined that a remedial action level for lead at 3,000 mg/kg would attain an average lead concentration of 400mg/kg and achieve residential use. Note this is higher than highest concentration detected at the ARSAR.

2nd Set of Comments

The method used at NBG was valid to the extent that it applied to outliers from a source area. Note that VDEQ required removal of soils contiguous to the source area. The hillside appears to be a separate source area and should be treated as such.

2nd Set of Responses

Comment noted. See The General Response above about breaking the site into two distinct areas, based on the stream as a dividing line.

Leahy, Timothy

From: Weissbart.Erich@epamail.epa.gov
Sent: Wednesday, November 21, 2012 8:07 AM
To: McKenna, James J CIV (US)
Subject: Re: ARSAR RTCs (UNCLASSIFIED)
Attachments: Radford small arms range response to comments 11-2012-baq.docx

Jim,
Below are Mr. Cutler's (VADEQ) comments in response to the Word documents forwarded to EPA and VADEQ responding to our comments on the ARSAR. Attached you will find EPA's comments. After distributing to your team, let's figure out the best way to resolve continuing issues.

Erich

VDEQ does not concur with the latest responses which refer to the following comments:

General Comment #2.

The structure of the report places the risk assessment before the description of soil removal. Again I'm assuming the risk assessment was applied to site conditions after removal. Typically a risk assessment would point towards removal as a remediation option. Approaches such as the iterative truncation method are presented prior to removal and approved if applicable to site conditions (which it is not -see other regulator comments). The two after-the-fact assessments remain confusing and contradictory as presented.

General Comment #3.

My original comment to the work plan noted that "potential 'remediation areas' other than the berm were not discussed". The RTC indicated that "excavation and sampling within the additional 'remediation areas' has also been furthered discussed" in the revised work plan. The revised work plan was changed to present berm excavation and other area excavation in separate paragraphs; the other areas including the "cliff behind the berm". " 1-ft lifts will be removed until XRF concentrations are below the RG....soil removal will continue until RG levels are achieved...All stakeholders will be notified of the changes and modifications needed..."(page 2-6).

Specific Comment #12.

While the hillside may contain a particular type of soil I'm not sure that it's been demonstrated why it would contain elevated arsenic compared to the rest of RAAP.

Specific Comment #14 and#15.

The fact remains that the selection of the exposure area is the important factor when discussing risk at the site. Many different sample groupings have been used throughout the report. The most conservative assessment would be to focus on the apparent source areas.

Specific Comment #24.

The fact that the RFI and IM reasoning and conclusions are mixed throughout this report creates much confusion. Given the after-the-fact use of iterative truncation would removal of some of the hillside samples made the berm okay?

Specific Comment #26.

The response did not address my hypothetical question. Am I correct? I'm not a statistician but it appears that the data can be skewed depending how many samples are taken or replaced.

Specific Comment #27.

The method used at NBG was valid to the extent that it applied to outliers from a source area. Note that VDEQ required removal of soils contiguous to the source area. The hillside appears to be a separate source area and should be treated as such.

Erich Weissbart P.G.
Land and Chemicals Division (3LC20)
US EPA Region III
1650 Arch Street
Philadelphia, PA 19103
Phone: 215-814-3284
e-mail: weissbart.erich@epa.gov

-----"McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil> wrote: -----

To: Erich Weissbart/R3/USEPA/US@EPA, "Cutler,Jim" <James.Cutler@deg.virginia.gov>

From: "McKenna, James J CIV (US)" <james.j.mckenna16.civ@mail.mil>

Date: 09/26/2012 03:55PM

Cc: "Meyer, Tom NAB02" <Tom.Meyer@usace.army.mil>, "Mendoza, Richard R Jr CIV (US)"

<richard.r.mendoza.civ@mail.mil>, "Bob Winstead (bob.winstead@baesystems.com)"

<bob.winstead@baesystems.com>, "Alberts, Matt (US SSA)" <matt.alberts@baesystems.com>, "Ryan,

Susan M CIV USARMY IMCOM AEC (US)" <susan.m.ryan.civ@mail.mil>, "Bressette, James W CIV (US)"

<james.w.bressette@us.army.mil>, "Timothy.Leahy@shawgrp.com" <Timothy.Leahy@shawgrp.com>, "

"Parks, Jeffrey N" <Jeffrey.Parks@shawgrp.com>, "Davie, Robert N III CIV (US)"

<robert.n.davie4.civ@mail.mil>, "Jeremy Flint (jeremy.flint@atk.com)" <jeremy.flint@atk.com>, "

"Stewart, Jay (US SSA)" <jay.stewart@baesystems.com>

Subject: ARSAR RTCs (UNCLASSIFIED)

Classification: UNCLASSIFIED

Caveats: FOUO

All,

Checking my files, it appears this email was not sent on August 7, 2012 as I intended so I am resending it. Still want to schedule a conference call to discuss in about two weeks, say Wednesday October 10. Note on Sep 17, BAE has brought on board Jay Stewart as their Environmental Manager so I'm ccing him on this email.

If in fact this email was sent on August 7, let's schedule a conference call sometime next week.

I apologize for any confusion.

Thanks,
JJM

Erich, Jim, All,

Attached are the subject RTCs. Maybe we could schedule a conference call to discuss them on or about 08/22/2012.

Thanks,
JJM

Classification: UNCLASSIFIED
Caveats: FOUO

[attachment "VDEQ_ARSAR_ RTCs_7-25-2012_complete jjm.docx" removed by Erich Weissbart/R3/USEPA/US]

[attachment "EPA_ARSAR_ RTCs_7-25-2012_complete jjm.docx" removed by Erich Weissbart/R3/USEPA/US]

To: Erich Weissbart, Project Manager

From: Betty Ann Quinn, Toxicologist

Date: 11/08/2012

RE: Review of Radford responses to EPA comments

After review of responses to EPA comments on the Draft Army Reserve Small Arms Range RCRA RFI/IM Completion Report, the following issues remain.

Comment 2: EPA maintains that the hillside area is not suitable for an unrestricted use designation. Unrestricted use, i.e., residential, means that the area must be suitable for frequent, long term contact over a reasonable exposure area with no limitations whatsoever. This assumption for potential future use also assumes the Army no longer controls the property, and cannot prevent access from any direction. It is clear that the southeast hillside, with its areas of significant lead and arsenic contamination does not meet this criterion.

The statement that the possibility of repeated contact with the three elevated lead concentration locations in confirmation samples is remote is not supportable. The three confirmation samples are located within approximately 125 ft of each other, a reasonable size for a residential lot. XRF results reveal a pattern of significantly elevated lead concentrations (ranging from 1153 mg/kg to 3837 mg/kg) in samples that are directly adjacent to one another, along the NW boundary of the grid area investigated for the RFI. These sample locations could also in theory all be located on a single residential lot. In addition, given the observed pattern of lead contamination in XRF results, it is reasonable to assume that additional fixed laboratory samples along the NW boundary would reveal significantly elevated lead concentrations, thereby reinforcing the hypothesis that substantial lead contamination exists on the hillside.

With regard to the SLERA, note that robins and shrews are very sensitive to soil contamination due to their limited home range and their invertebrate diet. Furthermore, the concentration term for lead used data obtained over the entire 7.6 acre site. It is not unreasonable that, as suggested by the Army, that robins and shrews would range over a sub-site such as the hillside area with its significantly higher lead concentrations. Additional action based on the conclusions of the SLERA cannot be ruled out.

Comment 4: As noted in EPA's response to comment 2, it is likely that the limited number of fixed laboratory (confirmation) samples obtained along the NW boundary of the hillside area is not an accurate representation of the extent of elevated lead in soil for the hillside area.

Comment 5: It is not definitively established that the elevated arsenic concentrations in the hillside area are naturally occurring.

Comment 6: EPA maintains that the arsenic concentrations reported on the southeast hillside exceed the Radford AAP background concentrations.

Comment 8: It is noted that risks must be recalculated using the higher exposure frequency and conclusions must be restated where appropriate.

Comment 9: EPA disagrees, and maintains that an exposure area of 7.6 acres is inconsistent with EPA risk assessment policy. The consolidation of sample groupings that are unevenly spaced (20 ft apart vs. 100 ft apart vs. 150 ft apart) is also not defensible. EPA guidance notes that reasonable exposure areas for residential receptors should be no larger than $\frac{1}{4}$ to $\frac{1}{2}$ acre. This suggests that 15 to 30 individual exposure areas may be appropriate for the risk assessment.

Comment 10: EPA reiterates that an exposure area of 7.6 acres is not acceptable.

Comment 13: See EPA responses to comment nos. 2, 4, 9, and 10.

Comment 14: See EPA responses to comment nos. 2, 4, 9, and 10.

Comment 15: See EPA response to comment no. 2.

Comment 16: See prior EPA responses.

Comment 17: EPA maintains that the iterative truncation method did not receive prior review or approval for its use. Moreover, requirements for the iterative truncation method described in EPA guidance including evaluation of individual exposure areas and consideration of hot spots were not incorporated into the cleanup goal determination. EPA continues to question the validity of remedial goals proposed for the small arms range.

Leahy, Timothy

From: McKenna, James J CIV (US) [james.j.mckenna16.civ@mail.mil]
Sent: Wednesday, September 26, 2012 3:55 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler, Jim
Cc: Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Bob Winstead (bob.winstead@baesystems.com); Alberts, Matt (US SSA); Ryan, Susan M CIV USARMY IMCOM AEC (US); Bressette, James W Mr CIV US USA MEDCOM PHC; Leahy, Timothy; Parks, Jeffrey N; Davie, Robert N III CIV (US); Jeremy Flint (jeremy.flint@atk.com); Stewart, Jay (US SSA)
Subject: ARSAR RTCs (UNCLASSIFIED)
Attachments: VDEQ_ARSAR_RTCs_7-25-2012_complete jjm.docx; EPA_ARSAR_RTCs_7-25-2012_complete jjm.docx

Classification: UNCLASSIFIED
Caveats: FOUO

All,

Checking my files, it appears this email was not sent on August 7, 2012 as I intended so I am resending it. Still want to schedule a conference call to discuss in about two weeks, say Wednesday October 10. Note on Sep 17, BAE has brought on board Jay Stewart as their Environmental Manager so I'm ccing him on this email.

If in fact this email was sent on August 7, let's schedule a conference call sometime next week.

I apologize for any confusion.
Thanks,
JJM

Erich, Jim, All,

Attached are the subject RTCs. Maybe we could schedule a conference call to discuss them on or about 08/22/2012.

Thanks,
JJM

Classification: UNCLASSIFIED
Caveats: FOUO

Presented below are EPA comments on the *Draft Army Reserve Small Arms Range (ARSAR) RCRA Facility Investigation (RFI)/Interim Measures Completion Report*, Radford Army Ammunition Plant (RFAAP), Virginia, dated February 2012.

1. Executive summary: EPA disagrees with grouping of sample data as described in the report. See additional comments below.

RESPONSE: Comment noted. Specific responses are provided below next to the additional comments.

2. Executive summary: EPA disagrees with a no further action determination for this area based on demonstrated risks to ecologic receptors, and hot spots of lead contamination as well as arsenic concentrations exceeding background levels in hillside samples. EPA also disagrees with the characterization of “very limited risk” to hypothetical future residential receptors. The workplan makes clear that the remedial goal for lead for this site is the residential standard of 400 mg/kg. This site is not suitable for unrestricted use.

RESPONSE: Interim Measures for the site were intended for the berm, where contamination was identified prior to the RFI/IM investigation. See Section 1.0 of the workplan: “Specifically, this Work Plan addresses the complete characterization of site media and removal of soil in the target berm with concentrations of antimony and lead to below the residential remedial goal (r-RG) in order to facilitate clean closeout in accordance with Part II(D)(11-21) IM of the RFAAP Corrective Action Permit (USEPA, 2000a).”

The RFI portion was intended to characterize the remaining portions (the firing areas, the stream and the hillside behind the berm) of the site.

With regard to the HHRA, it is acknowledged that there are exceedences of lead and arsenic on the hillside. Given the topography of this hillside, however, the exposure parameters applied in the overall HHRA (i.e., combined data) were particularly conservative for this area. It is unlikely that residential receptors, especially young children, would cross Strouble’s Creek and traverse the steep, wooded hillside on a daily basis. Although the concentrations of lead and arsenic in the hillside samples are greater than those of the firing range floor and berm, the exposure frequency and exposure duration are expected to be much less than that assumed for the residential scenario. With respect to lead, 3 of 12 sample locations exceeded the residential soil level of 400 mg/kg. The potential for routine contact by the same receptor at these 3 locations is extremely low. Although 10 of 12 sample locations exceeded the background value for arsenic, subsequent geochemical evaluation demonstrated that arsenic was naturally-occurring. A discussion of the differences between actual exposures to the firing range/berm area and the hillside will be added to the uncertainty section (Section 6.5.3).

SLERA lead hazards were only elevated as 6 for the American robin and 8 for the shrew, using LOAEL-based TRVs and the adjusted interspecies TRV extrapolation uncertainty factor of 1. As these two species have home ranges of 1.2 acres and 1 acre, respectively, they might just forage within each one of the three sub-sites, and not range over the entire 7.6 acre ARSAR Site. However, neither of these two species is state- or federally-threatened or endangered, and the assessment endpoint

used in the SLERA is the protection of wildlife populations, not individuals. Therefore, the potential loss of a few individual wildlife species would not be expected to significantly reduce local populations of wildlife.

3. Sample identifiers for 4 berm samples are inconsistent throughout the report. Berm samples are identified as ARSBC11 through ARSBC14 in report text (sections 3.1.1.1 and 4.1.1) and some tables (table nos. 4-2, 4-3, 4-17, 6-1, and 7-4); however, other tables (nos. 3-1 and 4-1) and figures (3-1, 4-1, and 4-2) designate these samples as ARSBSC11 through ARSBSC14. Confirm that despite the different identifiers, these samples represent a single soil sample analysis. All inconsistent sample identifiers should be corrected.

RESPONSE: The discrepancy in the sample IDs will be corrected.

4. Section 4.1.3: Confirmation (fixed laboratory) samples from the southeast hillside revealed significantly elevated lead concentrations (average 378 mg/kg, max 2500 mg/kg). In addition, XRF results for lead for the 33 hillside samples revealed significantly higher average (629 mg/kg) and hot spot (3837 mg/kg) lead concentrations than were reported in the confirmation samples. It appears that the limited number of confirmation samples obtained from the hillside is not indicative of the true extent of lead contamination, and that lead contamination extends farther than anticipated. In section 2.2.3, Delineation and Excavation (p. 2-6) of the ARSAR workplan, it is stated that all detections of lead exceeding the residential remedial goal of 400 mg/kg will be removed until lead remedial goals are achieved. Moreover, stakeholder notification that lead contamination extended farther than anticipated (also noted in section 2.2.3) should have been initiated. The presence of significant lead concentrations in the hillside area may indicate the need for additional remedial activities in this location

RESPONSE: As noted above, the IM portion was intended for the berm, where elevated lead was identified during the SI. Section 1.0, last paragraph states: *“Specifically, this Work Plan addresses the complete characterization of site media and removal of soil in the target berm with concentrations of antimony and lead to below the residential remedial goal (r-RG) in order to facilitate clean closeout in accordance with Part II(D)(11-21) IM of the RFAAP Corrective Action Permit (USEPA, 2000a).”* Stakeholder Notification was not initiated because the Southeast Hillside was investigated for the RFI portion and was not part of the IM.

5. Figure 4-5 and Table 4-8: The ARSAR workplan indicated in Section 3.3.1 that arsenic XRF samples would be collected, stepping outwards along gridlines, until sample concentrations are below the established background value of 15.8 mg/kg. This does not appear to have happened. All XRF samples from the hillside area revealed arsenic results that exceeded the background concentration. In addition, 11 out of 12 confirmation samples revealed arsenic concentrations exceeding background. Stakeholder notification of the larger area of soil contamination should have been initiated. Additional sampling in the hillside area for arsenic may be required

RESPONSE: Samplers could not safely climb further up the hill to collect an additional row of XRF samples. The consistently high levels of arsenic on the hillside suggested a non-anthropogenic source for the arsenic, which lead to the geochemical analysis presented in Section 4.7.3. This geochemical analysis differs from the facility-wide background study in several important ways. First, the facility wide background study looked at samples from different soil types, rather than a

specific type of soil over a specific bedrock unit. Second, the Background study was a statistical approach and did not attempt to identify sources. The geochemical analysis uses the natural relationships between specific metals and substitutions in minerals to identify whether the concentrations are elevated due to natural weathering processes or due to an anthropogenic source that would not necessarily be present at the same ratios. Results of the geochemical evaluation determined that arsenic is naturally occurring.

6. Section 4.7.3: Background concentrations for the Radford AAP have been established, and it is clear that the arsenic concentrations measured on the southeast hillside exceed these background concentrations.

RESPONSE: See response to Comment 5 for the rationale for completing a geochemical analysis of the metals on the southeast hillside.

7. Table nos. 4-1, 4-4, and 4-7: A sample specific detection limit should be provided for each result that is below the limit of detection.

RESPONSE: Sample specific detection limits will be provided on the XRF results tables.

8. Section 6.2.1: Per the EPA Supplemental Soil Screening Level Guidance, Exhibit 5-1, the exposure frequency for a construction worker should be 250 days.

RESPONSE: Although the exposure frequency (EF) of 125 days/year for the construction scenario was justified for HHRA at other sites (e.g., SWMU 43, SWMU 41A, 41B) and approved by EPA, it is acknowledged that these sites were smaller in size than the ARSAR. In response to the comment, the EF will be changed to 250 days/year to account for a larger site (approximately 7.6 acres).

9. Table 6-1: Soil samples from the berm, the firing range floor, and the southeast hillside were combined to develop a single chemical concentration input for the risk assessment. This is a non-conservative approach due to the large area (7.6 acres) encompassed by the firing range and the fact that a receptor would not be expected to move randomly across the entire ARSAR site. In addition, the spacing between samples in the different areas varies widely; for example, berm samples are spaced approximately 20 feet apart, while some hillside samples are greater than 100 feet apart, and one or more firing range floor samples used in the risk assessment are greater than 150 feet apart. The inclusion of the closely-spaced berm samples in the larger dataset serves to skew the entire dataset in the direction of the berm results (which represent a post-excavation, “clean” soil). The approach even contradicts methodology presented in Section 8.6 where segregation of firing range floor samples from the remainder of soil samples is described, “to prevent the downward skewing of the area-average.” The exposure areas must be evaluated separately: firing range floor, berm, and southeast hillside, and risks must be recalculated.

RESPONSE: This comment does not appear to be consistent with other Risk Assessments done at Radford. The HHRA presented in section 6 and the SLERA presented in Section 7 follow the same methodology as other risk assessments done for Radford. Sites have been split up where there are noncontiguous units, (e.g. SWMU 41A&B), but they have not split in the manner suggested in this comment. Furthermore, given the terrain and access to the site, the firing area and berm are accessible and could potentially be developed in the future, while the southeast

hillside is very steep and can only be accessed by people wading through the stream and then climbing the hill. A fence at the top precludes access from the other side.

The Area Average/Iterative Truncation presented in Section 8 was intended to be extremely conservative in its approach, which is why only the area from the berm back to the hillside was considered.

10. Section 6.2.1: The terms ‘excavation’ worker and ‘construction’ worker both appear in this section. If these receptors represent the same population, a single term should be used. Note also that the exposure frequency for construction/excavation workers as listed in Exhibit 5-1 of EPA 2002 is 250 days, not 125 days. This modification must be made (including tables in Appendix E) and risks recalculated (see additional comment with regard to lead contamination below). This comment has also been made by EPA during reviews of prior Radford reports

RESPONSE: The terms “excavation worker” and “construction worker” represent the same population. The text and tables will be revised and the term “excavation worker” will be used for this receptor throughout the report.

As discussed in the response to Comment 8, the EF will be changed to 250 days/year to account for a larger site (approximately 7.6 acres).

11. Section 6.2.3: Language addressing the unique handling of lead exposure point concentrations should be included in this section for clarity (despite the inclusion of the later section on lead); and footnotes describing lead exposure concentrations on tables (E.1-10) where UCLs are listed would also be helpful.

RESPONSE: The following paragraph will be inserted after the second paragraph of Section 6.2.3: “It is noted that the EPC for lead was based on the arithmetic mean concentration rather than the 95% UCL. Because the lead models are probabilistic models, several of the USEPA default parameters are based on central tendency (i.e., average) values. As discussed in Section 6.3.2, the arithmetic mean for surface soil served as the input values for the Adult Lead Model (ALM) and the Integrated Exposure Uptake Biokinetic Model (IEUBK).” A footnote will also be added to Table E.1-10.

12. Section 6.3.2 and Table E.1-47b: The cited EPA reference, “Frequently Asked Questions Regarding the Adult Lead Methodology” (2011), provides no recommendation for a construction worker exposure frequency of 125 days, although it is acknowledged that a central tendency exposure input for this variable is appropriate in lead biokinetic exposure models (unlike the upper bound inputs required for risk evaluation of other contaminants). Furthermore, the cited reference does state that use of a shorter term exposure frequency in the ALM requires averaging over the shorter time interval, i.e., 6 months. Table E.1-47b shows an averaging time of 365 days (12 months), and must be corrected if the shorter term exposure frequency is used.

RESPONSE: The reference, “Frequently Asked Questions Regarding the Adult Lead Methodology” (2011), was primarily cited as the source of the ingestion rate for contact-intense exposures to soil (100 mg/day). Because the exposure frequency will

be revised to the construction scenario default value of 250 days/year, it will not be necessary to revise the averaging time.

13. Section 6.4 and 6.4.1: As noted earlier, soil sample results must be evaluated for each of three exposure areas: firing range floor, berm, and southeast hillside. Risks must be recalculated in accordance with comments in this memo. Assuming the default drinking water lead concentration to be 15 ug/l is overly conservative. It is sufficient to use the IEUBK default for unknown lead concentrations in drinking water, 4 ug/l. The statement regarding the Centers for Disease Control and Prevention (CDCP) concern threshold for lead of 10 g/dl [sic] must be revised. CDCP recently agreed to use a child blood lead level of 5 ug/dl “to identify children living or staying for long periods in environments that expose them to lead hazards.” This blood lead level will supplant the 10 ug/dl “level of concern” cited by CDCP in the past. In Section 6.4.1 an incorrect unit for the blood lead level of concern (g/dl) is used. The correct unit is ug/dl.

The final statement in this section, that ‘surface soil at the ARSAR passes the lead exposure assessment for all receptors in this HHRA’ will need to be revised pending revisions to the RFI/IM report required in this memo.

RESPONSE: Please see the response to Comments 2 and 4 regarding the exposure areas.

Because future conditions are unknown, the drinking water action level (15 µg/L) was conservatively assumed in the IEUBK model. Because the use of the default value would not change the overall conclusions of the HHRA, the IEUBK model will remain as originally presented.

The sentence regarding the CDCP concern threshold for lead (10 µg/dl) will be revised to read: “It is noted that the Centers for Disease Control and Prevention (CDCP) recently agreed to use a child blood lead level of 5 µg/dl to identify children living or staying for long periods in environments that expose them to lead hazards. USEPA is currently evaluating the potential implications of the revised blood lead level.” This information will also be repeated as an uncertainty in Section 6.5.4.

The symbol (µ) was inadvertently omitted from the unit for lead in Section 6.4.1. The unit will be corrected.

Please see Comments 2 and 4 regarding the requested revisions to the exposure areas. Although the Adult Lead Model for the excavation worker will be revised using an EF of 250 days/year, it will not be necessary to revise the models for the site worker or residents.

14. Table 6-3: References that site concentrations of lead in surface soil are below the ‘health protective criterion for lead’ should be removed pending revisions required in this memo. Note that the southeast hillside reveals fixed laboratory lead results with an arithmetic mean lead concentration of 478 mg/kg as well as at least two hotspots of lead contamination. Both the average and hotspot concentrations of lead exceed the current residential remedial goal of 400 mg/kg. Revision to this table is necessary

RESPONSE: See response to Comment 9 above.

15. Section 6.5.1: As noted in comment no. 4, it appears that hillside confirmation samples do not adequately represent the extent of contamination in the hillside area.

RESPONSE: See Response to Comment 4 above.

16. Section 6.6: This section will need to be rewritten to conform with new risk estimates

RESPONSE: See response to Comment 9 above.

17. Section 8.6: The workplan included no language or description of the area-average approach for determining attainment of cleanup goals. In addition, as noted previously, exposure areas must be evaluated separately and cannot be combined. EPA guidance on the area-average approach notes that individual exposure units be evaluated, and that residential exposure units are ‘typically less than 1 acre in size.’ Moreover, the cited EPA guidances include methods for addressing hotspot contamination such as was encountered in the hillside area. The iterative truncation method used may not be protective when, as is the case here, the highest sample concentrations (i.e., confirmation fixed lab samples from the hillside) do not represent the highest concentrations at the site (i.e., the hillside XRF results).

RESPONSE: As noted previously, the work-plan was intended to address lead in the berm, not in the hillside. The iterative truncation method was added to the report after the investigation of the hillside detected elevated levels. The method was modified slightly to account for the relative accessibility of the areas of the site - the hillside is essentially inaccessible, and the berm is easily accessible from the fields. The iterative truncation method was run using the combined data sets including the laboratory and XRF data, as well as each data set individually to ensure that the highest concentrations in the samples represented the highest concentration onsite.

18. Table E.1-19 and E.1-20: Inputs for the construction worker PEF need to be revised in accordance with the revised exposure frequency requested in this memo. The limited amount of vehicle travel assumed in this algorithm is considered representative of current conditions, and would not necessarily apply to a future case where construction is actively occurring?

RESPONSE: Because future construction plans vary by site and are often unknown at the time the HHRA is prepared, there is no default value in the *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (SSG; USEPA, 2002) for the number of construction vehicles to be used during construction. It was assumed in this HHRA that two 2-ton cars and one 10-ton truck would be used during the duration of the project, which is similar to the parameters applied in HHRAs for other sites at RFAAP. It is acknowledged that these previous sites (e.g., SWMU 43, SWMU 41A, 41B) comprised a smaller area. As discussed in the response to Comment 8, the EF will be revised to 250 days/year. The numbers and types of vehicles will be based on the assumptions used in the example calculation in Section 5.3.2 of the SSG (i.e., twenty 2-ton cars and ten 20-ton trucks).

19. Table E.1-15 and 1-17: Note that the proper exposure duration value for cancer endpoints is 30 years, not 24 years. The correct exposure duration for non-cancer endpoints is 24 years for adults and 6 years for children. The averaging times for non-cancer endpoints must be revised also. Risks must be recalculated.

RESPONSE: For cancer endpoints, the incremental lifetime cancer risk calculations for residents were calculated by combining the cancer risks for the adult (exposure duration = 24 years) and child (exposure duration = 6 years) for a total exposure

duration of 30 years. For noncancer endpoints, noncancer hazards were calculated individually for the adult (exposure duration = 30 years) and the child (exposure duration = 6 years). The assumptions for these calculations are consistent with those used at other RFAAP sites. The procedure for these calculations will be clarified in Section 6.4 and footnotes will be added to Tables E.1-15 and 1-17.

20. Table E.1-19, 1-20, and 1-21: Explain why values for A, B, and C on Table E.1-19 are default values, whereas in algorithms on Tables E.1-20 and E.1-21 site-specific values are used for A, B, and C

RESPONSE: According to the SSG (USEPA, 2002), Section 5.3.2 and Equation 5.6, the Q/C term for dust generated by unpaved road traffic (Q/C_{sr}) was derived using EPA's ISC3 dispersion model for a hypothetical site under a wide range of meteorological conditions. Unlike the Q/C values for the other scenarios, the Q/C_{sr} term for the excavation scenario's simple site-specific approach can be modified only to reflect different site sizes; it cannot be modified for climatic zone. Therefore, the default values for variables A, B, and C assumed in the SSG were used to calculate Q/C_{sr} for this HHRA. A footnote will be added to Table E.1-19 to clarify this point.

Responses to VDEQ comments on the
Draft Army Reserve Small Arms Range RFI/ Interim Measures Completion Report
February 2012

GENERAL COMMENTS

1. The arrangement of the report with the IM “activities” discussed in a separate section made the report very difficult to follow. Sampling activities were discussed in both the field investigation and IM section making it difficult to interpret the sequence of events. The use of different descriptors (pre-confirmation, post- excavation, etc.) for the same sample sets made it difficult to determine exactly when the samples were collected. I suggest that the actual excavation and removal be discussed separately; the sampling and delineation activities integrated into sections 3 and 4.

RESPONSE: The report will be re-structured to follow the sequence of field events. As suggested, the IM will be described separately from the sampling. Also, a single descriptor will be used for each sample set.

2. Two contradictory risk assessments of site conditions after soil removal (Section 6 and 8) are presented in the report and need to be resolved.

RESPONSE: Section 6 presents the HHRA in the same format as other EPA/VDEQ approved RFIs at Radford Army Ammunition Plant. Section 8 is not intended to be a separate risk assessment; rather, it is an analysis of a single analyte (lead) that was found at unexpectedly high concentrations in southeast hillside. The main source of lead onsite (the berm) was excavated and removed, but the hillside concentrations remained. Because the HHRA showed that the average site lead concentration in surface soil was below the health protective criterion for lead, a more conservative approach was followed to show that concentrations were acceptable. Although the area average approach was slightly modified to account for accessibility of different areas of the site, the iterative truncation does show that the lead concentrations are acceptable, even in the smaller subset of samples that make up the “downrange” or target area of the range.

3. The remedial approach (excavation of soils above the RG of 400) in the work plan was not followed.

RESPONSE: The work plan was intended to cover IMs for the berm, where contamination had been previously identified, and an RFI for the remainder of the site. See Section 1 - Introduction (Last paragraph) “*Specifically, this Work Plan addresses the complete characterization of site media and removal of soil in the target berm with concentrations of antimony and lead to below the residential remedial goal (r-RG) in order to facilitate clean closeout in accordance with Part II(D)(11-21) IM of the RFAAP Corrective Action Permit (USEPA, 2000a).*”

SPECIFIC COMMENTS

1. Page ES-1 (Target Berm). I am assuming that the first sentence refers to “this” RFI/IM.

RESPONSE: That is correct. The text will be updated to replace “an RFI” with “this RFI”.

2. Page ES-1 (Firing Range Floor and.....). It seems redundant and confusing to the reader to state that sampling was performed for this RFI. It suggests a different 2011 RFI exists (this report is dated 2012) as this shorthand is often used to designate the final report.

RESPONSE: The section will be re-written as follows:

“The soil at the ARSAR firing range floor and potential firing points was not sampled during previous investigations. Analytical data was collected in 2011 to support this RFI/IM. Based on the results of this data, there are no constituents of concern for the firing range floor.”

3. ES-4. The ecological risk discussion concludes that food chain impacts are a concern for lead. This does not appear to be addressed in this report.

RESPONSE: SLERA lead hazards were only elevated as 6 for the American robin and 8 for the shrew, using LOAEL-based TRVs and the adjusted interspecies TRV extrapolation uncertainty factor of 1. As these two species have home ranges of 1.2 acres and 1 acre, respectively, they might just forage within each one of the three subsites, and not range over the entire 7.6 acre ARSAR Site. However, neither of these two species is state- or federally-threatened or endangered, and the assessment endpoint used in the SLERA is the protection of wildlife populations, not individuals. Therefore, the potential loss of a few individual wildlife species would not be expected to significantly reduce local populations of wildlife.

4. ES-4. The IM conclusions should be integrated with the berm discussion above.

RESPONSE: Agreed. Once the report is re-organized per General Comment #1, the Executive summary will be re-organized to follow the new organization of the report.

5. Page 2-5 (Section 2.7.2). The building area debris is not depicted on Figure 2-3.

RESPONSE: The building debris area will be added to Figure 2-3 at the eastern end of berm where samples SS-14 and SS-15 are located.

6. Page 3-1 (Section 3.1.1). Indicate that the XRF was performed after the excavation as part of the IM.

RESPONSE: The first sentence of the section will be revised to: “XRF surveys were completed at the site in three areas for different reasons:

- 1) Confirm lead had been removed from the berm to below 400 mg/kg following the IM excavation;
- 2) Assess the firing range floor for the presence or absence of lead; and,
- 3) Delineate arsenic and lead concentrations in the southeast hillside behind the berm.”

7. Page 3-5 (Section 3.1.1.1). Surface soils or 1-2 feet?

RESPONSE: These samples currently represent surface soil. The table will be corrected to reflect that they were 1-2 ft bgs prior to the IM (the original table came from the work plan) - but that now they are surface soil.

8. Page 4-1 (Section 4.1.1). The 2nd sentence implies that surface samples were collected and not used. The labeling in the text is a little different ARSCSB01 (Sect. 3) vs. ARSBSC01(Sect.4). It is my understanding that the only IM soil sampling was collected after one foot of soil was removed.

RESPONSE: The sample labels will be corrected. The correct ID should be ARS (Army Reserve Small) B (Berm) SC (Soil Confirmation). The sentence will be re-written to make it clearer that surface soil samples were not collected until after 1 foot of soil was removed from the berm.

9. Page 4-1 (Section 4.1.1). IM is Section 8 not 6. I strongly suggest that the berm excavation be discussed before or within Section 3.

RESPONSE: As noted above in Response to General Comment 1, the report will be re-structured to more closely follow the sequence of field activities.

10. Page 4-1 (Section 4.1.1). No samples above SLs were indicated on Figure 4-2

RESPONSE: The sentence will be re-written: “As indicated on **Figure 4-2**, no analytes were detected above screening levels in the berm soil. Detected results are presented in **Table 4-2** and summarized in **Table 4-3**.”

11. Page 4-46 (Section 4.7.1). By “elevated levels” do you mean above 400 ppm?

RESPONSE: Yes. However, to avoid further confusion, the section will be re-written to: “*The combined data set indicates that metals (primarily lead and antimony) were the constituents of concern at the ARSAR target berm. Through the IM discussed in Section 8.0, the source material of the constituents of concern has been removed. Confirmation samples collected after removal of the berm surface indicated that the IM was successful in removing soil with concentrations of lead greater than 400 mg/kg. Post excavation samples showed no constituents with concentrations greater than screening levels.*”

12. Page 4-49 (Section 4.7.3). The font/spacing changes in the middle of the page. Also, this appears to present an argument for a re-evaluation of background.

RESPONSE: The font/spacing will be corrected. This section looks specifically at the geochemistry of certain metals and their affinities to substitute in minerals for each other. Instead of re-evaluating background, this analysis takes a more-site specific approach to assess whether the ratio of metals present in each sample is similar and suggests a natural origin rather than an anthropogenic source. Peer-

reviewed, scientific journal articles can be provided to document the validity of this type of analysis, if requested.

13. Page 6-1 (Section 6.6.1). If this table represents post removal conditions then the risk assessment should be discussed in the context of the IM.

RESPONSE: The risk assessments were both completed with post-IM samples. As noted earlier, the organization of the report will be re-structured based on these comments, and will be clearer that the IM was done prior to the risk assessments.

14. Page 6-13 (Section 6.4.1). How do these models account for hotspots? The mean of 189 is significantly different than the EPC of 553 found in Table E.1-10 and other concentrations discussed in the IM section.

RESPONSE: Because the Adult Lead Model (ALM) and the Integrated Exposure Uptake Biokinetic Model (IEUBK) are probabilistic models, several of the USEPA default parameters in the models are based on central tendency (i.e., average) values. Therefore, the arithmetic mean concentration for lead (189 mg/kg) is used rather than the 95% upper confidence limit (553 mg/kg). This point will be clarified in Section 6.4.1 and a footnote will also be added to Table E.1-10.

The lead models are not designed to identify or account for hot spots. It is acknowledged that there are exceedences of lead on the hillside. Given the topography of this hillside, however, the exposure parameters applied in the overall HHRA (i.e., combined data) were particularly conservative for this area. It is unlikely that residential receptors, especially young children, would cross Strouble's Creek and traverse the steep, wooded hillside on a daily basis. The exposure frequency and exposure duration for the hillside would be expected to be much less than that assumed for the residential scenario. It is noted that 3 of 12 sample locations exceeded the residential soil level of 400 mg/kg. The potential for routine contact by the same receptor at these 3 locations is extremely low. A discussion of the differences between actual exposures to the firing range/berm area and the hillside will be added to the uncertainty section (Section 6.5.3).

15. Page 6-13 (Section 6.4.1). It is stated that the surface soil passes for all receptors. How does this compare with the reasoning in the IM section concerning "diluting" the sample set with floor samples?

RESPONSE: The HHRA presented in Section 6 follows the same format and methodology as other RFIs completed and approved at Radford AAP. The iterative truncation/area average method presented in Section 8 is intended to supplement the risk assessment by demonstrating that the soil is acceptable under even more conservative assumptions (such as limiting the area to the target areas) than those made in the HHRA.

16. Page 7-60 (Section 7.11). The findings of the SLERA regarding food chain impacts do not appear to be addressed in the report.

RESPONSE: Additional text will be added to the Report to discuss potential food chain impacts. Also, see response to USEPA Comment No. 2.

17. Page 8-1 (Section 8.0). This section is very confusing as a stand alone section at this point in the report. I would insert this discussion before section 3 and focus on the berm excavation only. The other field activities are discussed in the following sections (3 and 4).

RESPONSE: As noted above in previous comment responses, the report will be re-organized following these suggestions.

18. Page 8-1 (Section 8.1). It states that the site specific corrective measures objective is to be protective of industrial workers however the RG indicated is residential.

RESPONSE: The typographical error will be corrected so that the sentence in Section 8.1 reads *“The site-specific corrective measures objective for the ARSAR was to reduce contaminant concentrations in soil to levels that are protective of residents at the site”*.

19. Page 8-2 (Section 8.3). This section is confusing as a separate section. Would the following sections be subsections?

RESPONSE: The entire IM portion will be re-written and moved forward in the report so that the report follows the actual sequence of events in the field.

20. Page 8-5 (Section 8.5). Most of the text in the first paragraph is not part of the excavation activities and is a duplication of info. presented in section 4.1.2.

RESPONSE: See response to comment 19 above.

21. Page 8-6 (Section 8.5). The last paragraph discusses “pre-confirmation sampling” as if it took place before the excavation began. Is the pre-confirmation sampling the same as the XRF screening discussed above?

RESPONSE: Yes. As noted above, the section will be re-written and moved forward in the report.

22. Page 8-6 (Section 8.6). It states that “post excavation samples” were collected. Are they additional samples to the pre-confirmation samples or do they represent lab confirmation of XRF? They use of pre- and post- is confusing if the samples were collected at the same time.

RESPONSE: Agreed. The “pre-” and “post-” terminology will be dropped. It was an attempt to differentiate the data sets from pre- and post IM for the purposes of the iterative truncation, but it seems to end up making the sequence of events more confusing.

23. Page 8-7 (Section 8.6). The discussion regarding “confirmation” sampling is confusing. Are lab samples confirming XRF results or removal assumptions? What is XRF confirming?

RESPONSE: See Response Above. The XRF samples on the berm were confirming that the RGs have been met. The laboratory samples from the berm, hillside and firing floor were confirming the results of the XRF, (and are the final “confirmation samples” for the berm since the XRF data is considered screening level data.

24. Page 8-7 (Section 8.6). The “area average” approach was not discussed in the work plan. The work plan stated that the berm excavation would continue until confirmation samples were below the RG (400 mg/kg). Other areas including the hillside where 400 was exceeded would be excavated in a similar manner.

RESPONSE: Elevated lead levels were not expected on the hillside and the IMs were only intended for the berm, where excavation did continue until the RGs were met. The hillside was characterized and the results are reported in the RFI. Based on the iterative truncation/area average analysis, leaving the lead in place will still be protective of residential receptors.

25. Page 8-7 (Section 8.6). The sediment results did not appear to represent any significant lead contamination.

RESPONSE: Agreed. The fact that the stream does not appear to be impacted by activities at the site, and the fact that elevated constituents on the hillside are not migrating offsite; are two of the reasons, along with limited risks to human and ecological receptors, and no groundwater contamination, that No Further Action was recommended for the site.

26. Page 8-7 (Section 8.6). Two 2009 samples (SS14 and 15) were collected from the building debris area which doesn’t appear on the figures as part of the berm. It is not clear if this area was actually removed as part of the berm. If this is the case then the new “berm average” would be higher (717 vs. 547) and the revised list would include six samples and eight “averages. The new pre-remediation average would be 492. Similarly increasing the number of post remediation confirmation samples (assuming the samples were collected from adjacent areas and had similar low concentrations) would result in a lower post remediation average. It appears that the data can be skewed depending on how many samples are taken or replaced.

RESPONSE: As noted above in other comment responses, the standard grouping was done in Section 6 (Human Health Risk Assessment). The grouping done in Section 8 was done to show even a smaller subset of the data, just the southeast end of the site, is still protective of human health.

- 27 Page 8-9 (Section 8.6). There appears to be many ways of grouping this data. If only hillside XRF samples are used then the mean is 625. If hillside lab samples (2009 and 2011) are considered then the average is 438. The bottom line is that levels found in the

2011 investigation of the hillside represent potentially more significant contamination than was removed from the berm. The area above 400 on the hillside is equivalent to the entire areal extent of the berm. No delineation with depth was performed on the hillside.

RESPONSE: We agree that there are many different ways of grouping the data, all of which are more conservative than the standard, default grouping by site that has been done throughout Radford AAP. Lead was delineated laterally across the hillside as well as up and down the hillside. Depth is limited due to the shallow bedrock encountered on the steep, rocky hillside.

It is unlikely that the hillside represents significantly more contamination than was removed. The SI (URS, 2009) detected lead levels above background; however all concentrations were below the residential criteria of 400 mg/kg and bullet fragments were not found on the hillside, while the berm samples did contain bullet fragments and elevated levels of lead up to 1600 mg/kg. Additional berm samples were not collected until after the completion of the IM at the berm, while extensive additional sampling was completed on the hillside. (Note that the SSP Report discusses collecting samples on the hillside “between rock outcrops”).

Finally, other sites at Radford have followed a similar, iterative-truncation/area average method and for example at the Northern Burning Ground determined that a remedial action level for lead at 3,000 mg/kg would attain an average lead concentration of 400mg/kg and achieve residential use. Note this is higher than highest concentration detected at the ARSAR.

Leahy, Timothy

From: Erich Weissbart [Weissbart.Erich@epamail.epa.gov]
Sent: Monday, July 09, 2012 3:01 PM
To: McKenna.Beverly@epamail.epa.gov;
James__J__CIV__@mintra03.pyd.epa.gov; "
<james.j.mckenna16.civ@mail.mil/@epamail.epa.gov
(US)"@mintra03.pyd.epa.gov
Subject: Radford Small Arms Range
Attachments: DEQ Small Arms Range comments.docx; radford small arms firing range
rfi-im review (1).docx

Jim,
EPA and DEQ have reviewed the Small Arms Range RFI/IM Completion Report and provide the following comments (attached). In summary, we believe there are arsenic and lead soil exceedances. Statistics were inappropriately applied to minimize average lead concentrations of the southeast hillside. An elaborate alternate source for soil arsenic was provided but still doesn't change the fact that samples exceeded the long-standing site-wide arsenic background concentration. In conclusion we do not concur with no further action based on presented results. See the two attached memos for specific comments.

Erich Weissbart P.G.
Land and Chemicals Division (3LC20)
US EPA Region III
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**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029**

SUBJECT: Army Reserve Small Arms Range **DATE:** June 11, 2012
RFI/Interim Measures Completion Report,
Radford Army Ammunition Plant
FROM: Betty Ann Quinn, Toxicologist
TO: Erich Weissbart, Project Manager

1. Executive summary: EPA disagrees with grouping of sample data as described in the report. See additional comments below.
2. Executive summary: EPA disagrees with a no further action determination for this area based on demonstrated risks to ecologic receptors, and hot spots of lead contamination as well as arsenic concentrations exceeding background levels in hillside samples. EPA also disagrees with the characterization of “very limited risk” to hypothetical future residential receptors. The workplan makes clear that the remedial goal for lead for this site is the residential standard of 400 mg/kg. This site is not suitable for unrestricted use.
3. Sample identifiers for 4 berm samples are inconsistent throughout the report. Berm samples are identified as ARSBC11 through ARSBC14 in report text (sections 3.1.1.1 and 4.1.1) and some tables (table nos. 4-2, 4-3, 4-17, 6-1, and 7-4); however, other tables (nos. 3-1 and 4-1) and figures (3-1, 4-1, and 4-2) designate these samples as ARSBSC11 through ARSBSC14. Confirm that despite the different identifiers, these samples represent a single soil sample analysis. All inconsistent sample identifiers should be corrected.
4. Section 4.1.3: Confirmation (fixed laboratory) samples from the southeast hillside revealed significantly elevated lead concentrations (average 378 mg/kg, max 2500 mg/kg). In addition, XRF results for lead for the 33 hillside samples revealed significantly higher average (629 mg/kg) and hot spot (3837 mg/kg) lead concentrations than were reported in the confirmation samples. It appears that the limited number of confirmation samples obtained from the hillside is not indicative of the true extent of lead contamination, and that lead contamination extends farther than anticipated. In section 2.2.3, Delineation and Excavation (p. 2-6) of the ARSAR workplan, it is stated that all detections of lead exceeding the residential remedial goal of 400 mg/kg will be removed until lead remedial goals are achieved. Moreover, stakeholder notification that lead contamination extended farther than anticipated (also noted in section 2.2.3) should have been initiated. The presence of significant lead concentrations in the hillside area may indicate the need for additional remedial activities in this location.
5. Figure 4-5 and Table 4-8: The ARSAR workplan indicated in Section 3.3.1 that arsenic XRF samples would be collected, stepping outwards along gridlines, until sample concentrations are below the established background value of 15.8 mg/kg. This does not



appear to have happened. All XRF samples from the hillside area revealed arsenic results that exceeded the background concentration. In addition, 11 out of 12 confirmation samples revealed arsenic concentrations exceeding background. Stakeholder notification of the larger area of soil contamination should have been initiated. Additional sampling in the hillside area for arsenic may be required.

6. Section 4.7.3: Background concentrations for the Radford AAP have been established, and it is clear that the arsenic concentrations measured on the southeast hillside exceed these background concentrations.
7. Table nos. 4-1, 4-4, and 4-7: A sample specific detection limit should be provided for each result that is below the limit of detection.
8. Section 6.2.1: Per the EPA Supplemental Soil Screening Level Guidance, Exhibit 5-1, the exposure frequency for a construction worker should be 250 days.
9. Table 6-1: Soil samples from the berm, the firing range floor, and the southeast hillside were combined to develop a single chemical concentration input for the risk assessment. This is a nonconservative approach due to the large area (7.6 acres) encompassed by the firing range and the fact that a receptor would not be expected to move randomly across the entire ARSAR site. In addition, the spacing between samples in the different areas varies widely; for example, berm samples are spaced approximately 20 feet apart, while some hillside samples are greater than 100 feet apart, and one or more firing range floor samples used in the risk assessment are greater than 150 feet apart. The inclusion of the closely-spaced berm samples in the larger dataset serves to skew the entire dataset in the direction of the berm results (which represent a post-excavation, “clean” soil). The approach even contradicts methodology presented in Section 8.6 where segregation of firing range floor samples from the remainder of soil samples is described, “to prevent the downward skewing of the area-average.” The exposure areas must be evaluated separately: firing range floor, berm, and southeast hillside, and risks must be recalculated.
10. Section 6.2.1: The terms ‘excavation’ worker and ‘construction’ worker both appear in this section. If these receptors represent the same population, a single term should be used. Note also that the exposure frequency for construction/excavation workers as listed in Exhibit 5-1 of EPA 2002 is 250 days, not 125 days. This modification must be made (including tables in Appendix E) and risks recalculated (see additional comment with regard to lead contamination below). This comment has also been made by EPA during reviews of prior Radford reports.
11. Section 6.2.3: Language addressing the unique handling of lead exposure point concentrations should be included in this section for clarity (despite the inclusion of the later section on lead); and footnotes describing lead exposure concentrations on tables (E.1-10) where UCLs are listed would also be helpful.
12. Section 6.3.2 and Table E.1-47b: The cited EPA reference, “Frequently Asked Questions Regarding the Adult Lead Methodology” (2011), provides no recommendation for a construction worker exposure frequency of 125 days, although it is acknowledged that a central tendency exposure input for this variable is appropriate in lead biokinetic



exposure models (unlike the upper bound inputs required for risk evaluation of other contaminants). Furthermore, the cited reference does state that use of a shorter term exposure frequency in the ALM requires averaging over the shorter time interval, i.e., 6 months. Table E.1-47b shows an averaging time of 365 days (12 months), and must be corrected if the shorter term exposure frequency is used.

13. Section 6.4 and 6.4.1: As noted earlier, soil sample results must be evaluated for each of three exposure areas: firing range floor, berm, and southeast hillside. Risks must be recalculated in accordance with comments in this memo. Assuming the default drinking water lead concentration to be 15 ug/l is overly conservative. It is sufficient to use the IEUBK default for unknown lead concentrations in drinking water, 4 ug/l.

The statement regarding the Centers for Disease Control and Prevention (CDCP) concern threshold for lead of 10 g/dl [sic] must be revised. CDCP recently agreed to use a child blood lead level of 5 ug/dl “to identify children living or staying for long periods in environments that expose them to lead hazards.” This blood lead level will supplant the 10 ug/dl “level of concern” cited by CDCP in the past.

In Section 6.4.1 an incorrect unit for the blood lead level of concern (g/dl) is used. The correct unit is ug/dl.

The final statement in this section, that ‘surface soil at the ARSAR passes the lead exposure assessment for all receptors in this HHRA’ will need to be revised pending revisions to the RFI/IM report required in this memo.

14. Table 6-3: References that site concentrations of lead in surface soil are below the ‘health protective criterion for lead’ should be removed pending revisions required in this memo. Note that the southeast hillside reveals fixed laboratory lead results with an arithmetic mean lead concentration of 478 mg/kg as well as at least two hotspots of lead contamination. Both the average and hotspot concentrations of lead exceed the current residential remedial goal of 400 mg/kg. Revision to this table is necessary.
15. Section 6.5.1: As noted in comment no. 4, it appears that hillside confirmation samples do not adequately represent the extent of contamination in the hillside area.
16. Section 6.6: This section will need to be rewritten to conform with new risk estimates.
17. Section 8.6: The workplan included no language or description of the area-average approach for determining attainment of cleanup goals. In addition, as noted previously, exposure areas must be evaluated separately and cannot be combined. EPA guidance on the area-average approach notes that individual exposure units be evaluated, and that residential exposure units are ‘typically less than 1 acre in size.’ Moreover, the cited EPA guidances include methods for addressing hotspot contamination such as was encountered in the hillside area. The iterative truncation method used may not be protective when, as is the case here, the highest sample concentrations (i.e., confirmation fixed lab samples from the hillside) do not represent the highest concentrations at the site (i.e., the hillside XRF results).



18. Table E.1-19 and E.1-20: Inputs for the construction worker PEF need to be revised in accordance with the revised exposure frequency requested in this memo. The limited amount of vehicle travel assumed in this algorithm is considered representative of current conditions, and would not necessarily apply to a future case where construction is actively occurring.
19. Table E.1-15 and 1-17: Note that the proper exposure duration value for cancer endpoints is 30 years, not 24 years. The correct exposure duration for non-cancer endpoints is 24 years for adults and 6 years for children. The averaging times for non-cancer endpoints must be revised also. Risks must be recalculated.
20. Table E.1-19, 1-20, and 1-21: Explain why values for A, B, and C on Table E.1-19 are default values, whereas in algorithms on Tables E.1-20 and E.1-21 site-specific values are used for A, B, and C.



RFI/IM Completion Report
Army Reserve Small Arms Range

General Comments:

1. The arrangement of the report with the IM “activities” discussed in a separate section made the report very difficult to follow. Sampling activities were discussed in both the field investigation and IM section making it difficult to interpret the sequence of events. The use of different descriptors (pre-confirmation, post- excavation, etc.) for the same sample sets made it difficult to determine exactly when the samples were collected. I suggest that the actual excavation and removal be discussed separately; the sampling and delineation activities integrated into sections 3 and 4.
2. Two contradictory risk assessments of site conditions after soil removal (Section 6 and 8) are presented in the report and need to be resolved.
3. The remedial approach (excavation of soils above the RG of 400) in the work plan was not followed.

Specific Comments:

1. Page ES-1 (Target Berm). I am assuming that the first sentence refers to “this” RFI/IM.
2. Page ES-1 (Firing Range Floor and.....). It seems redundant and confusing to the reader to state that sampling was performed for this RFI. It suggests a different 2011 RFI exists (this report is dated 2012) as this shorthand is often used to designate the final report.
3. ES-4. The ecological risk discussion concludes that food chain impacts are a concern for lead. This does not appear to be addressed in this report.
4. ES-4. The IM conclusions should be integrated with the berm discussion above.
5. Page 2-5 (Section 2.7.2). The building area debris is not depicted on Figure 2-3.
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7. Page 3-5 (Section 3.1.1.1). Surface soils or 1-2 feet?
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12. Page 4-49 (Section 4.7.3). The font/spacing changes in the middle of the page. Also, this appears to present an argument for a re-evaluation of background.
13. Page 6-1 (Section 6.6.1). If this table represents post removal conditions then the risk assessment should be discussed in the context of the IM.
14. Page 6-13 (Section 6.4.1). How do these models account for hotspots? The mean of 189 is significantly different than the EPC of 553 found in Table E.1-10 and other concentrations discussed in the IM section.
15. Page 6-13 (Section 6.4.1). It is stated that the surface soil passes for all receptors. How does this compare with the reasoning in the IM section concerning “diluting” the sample set with floor samples?
16. Page 7-60 (Section 7.11). The findings of the SLERA regarding food chain impacts do not appear to be addressed in the report.
17. Page 8-1 (Section 8.0). This section is very confusing as a stand alone section at this point in the report. I would insert this discussion before section 3 and focus on the berm excavation only. The other field activities are discussed in the following sections (3 and 4).
18. Page 8-1 (Section 8.1). It states that the site specific corrective measures objective is to be protective of industrial workers however the RG indicated is residential.
19. Page 8-2 (Section 8.3). This section is confusing as a separate section. Would the following sections be subsections?
20. Page 8-5 (Section 8.5). Most of the text in the first paragraph is not part of the excavation activities and is a duplication of info. presented in section 4.1.2.
21. Page 8-6 (Section 8.5). The last paragraph discusses “pre-confirmation sampling” as if it took place before the excavation began. Is the pre-confirmation sampling the same as the XRF screening discussed above?
22. Page 8-6 (Section 8.6). It states that “post excavation samples” were collected. Are they additional samples to the pre-confirmation samples or do they represent lab confirmation of XRF? They use of pre- and post- is confusing if the samples were collected at the same time.
23. Page 8-7 (Section 8.6). The discussion regarding “confirmation” sampling is confusing. Are lab samples confirming XRF results or removal assumptions? What is XRF confirming?

24. Page 8-7 (Section 8.6). The “area average” approach was not discussed in the work plan. The work plan stated that the berm excavation would continue until confirmation samples were below the RG (400 mg/kg). Other areas including the hillside where 400 was exceeded would be excavated in a similar manner.
25. Page 8-7 (Section 8.6). The sediment results did not appear to represent any significant lead contamination.
26. Page 8-7 (Section 8.6). Two 2009 samples (SS14 and 15) were collected from the building debris area which doesn’t appear on the figures as part of the berm. It is not clear if this area was actually removed as part of the berm. If this is the case then the new “berm average” would be higher (717 vs. 547) and the revised list would include six samples and eight “averages. The new pre-remediation average would be 492. Similarly increasing the number of post remediation confirmation samples (assuming the samples were collected from adjacent areas and had similar low concentrations) would result in a lower post remediation average. It appears that the data can be skewed depending on how many samples are taken or replaced.
27. Page 8-9 (Section 8.6). There appears to be many ways of grouping this data. If only hillside XRF samples are used then the mean is 625. If hillside lab samples (2009 and 2011) are considered then the average is 438. The bottom line is that levels found in the 2011 investigation of the hillside represent potentially more significant contamination than was removed from the berm. The area above 400 on the hillside is equivalent to the entire areal extent of the berm. No delineation with depth was performed on the hillside.



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February 23, 2012

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Subject: With Certification, Army Reserve Small Arms Range (ARSAR), RCRA Facility Investigation/Interim
Measures Completion Report, Draft February 2012
EPA ID# VA1 210020730

Dear Mr. Weissbart and Mr. Cutler:

Enclosed is the certification for the subject document that was sent to you on February 22, 2012. Also enclosed is the February 22, 2012 transmittal email.

Please coordinate with and provide any questions or comments to myself at (540) 639-8658, Jeremy Flint, ATK staff (540) 639-7668 or Jim McKenna, ACO Staff (540) 731-5782.

Sincerely,

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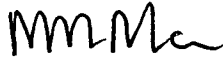
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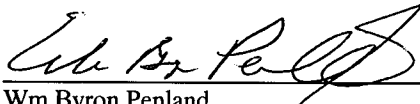

M. A. Miano

Concerning the following:

Radford Army Ammunition Plant
Army Reserve Small Arms Range (ARSAR)
RCRA Facility Investigation/Interim Measures Completion Report
Draft
February 2012

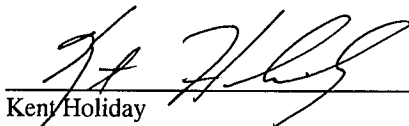
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Subject: Draft ARSAR RFI/IM Completion Report Transmittal email (UNCLASSIFIED)
Importance: High

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Note the contractor will ship the subject document with a copy of this email to the POCs and tracking numbers below. Here are the UPS tracking numbers for the Draft Army Reserve Small Arms Range (RFAAP-001-R-01) RFI/IM Completion Report.

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Thank you for your support of the Radford Army Ammunition Plant Installation Restoration Program.

Jim McKenna

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LIST OF APPENDICES

The Appendices are included on a CD located at the back of this report.

Appendix A Quality Assurance/Quality Control

Appendix A-1 Laboratory Analytical Services

Appendix A-2 QA Analysis

Appendix A-3 Data Validation and Form 1s

Appendix B Photo Log

Appendix C RFI/IM Data

Appendix C-1 Laboratory Analytical Data

Appendix C-2 XRF Data

Appendix C-3 Chain of Custody

Appendix D GPS Sample Locations

Appendix E HHRA Tables and Statistical Comparison Results

Appendix E-1 RAGS Part D Tables – Firing Point/Berm Area

Appendix E-2 RAGS Part D Tables – Southeast Hillside Area

Appendix E-3 Exposure Point Concentrations – ProUCL 4.1 Output – Firing Point/Berm Area

Appendix E-4 Exposure Point Concentrations – ProUCL 4.1 Output – Southeast Hillside Area

Appendix E-5 Background Comparisons – ProUCL 4.1 Output – Firing Point/Berm Area

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Appendix F SLERA Site Reconnaissance Photographs and Risk Characterization Tables

Appendix F-1 SLERA Site Reconnaissance Photographs

Appendix F-2 SLERA Risk Characterization Tables

Appendix G Interim Measures Records

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Appendix G-2 Site Safety Reports and Equipment Inspection

Appendix G-3 Non-Hazardous Waste Profile and Manifests

Appendix G-4 Shipping Log

Appendix H Oregon DEQ Final Guidance for Ecological Risk Assessment

LIST OF ACRONYMS AND ABBREVIATIONS

µg/dL.....	micrograms per deciliter	GSD.....	Geometric Standard Deviation
µg/L.....	micrograms per liter	HEAST.....	Health Effects Assessment Summary Tables
ADAF.....	Age-Dependent Adjustment Factor	HHRA	Human Health Risk Assessment
ALM.....	Adult Lead Model	HI	Hazard Index
ARCS	Assessment and Remediation of Contaminated Sediments	HQ.....	Hazard Quotient
ARSAR	Army Reserve Small Arms Range	HR	Home Range
ATK	Alliant TechSystems, Inc.	HRR	Historical Records Review
ATSDR	Agency for Toxic Substances Disease Registry	IC.....	Institutional Control
AUF.....	Area Use Factor	IEUBK	Integrated Exposure Uptake Biokinetic
BAF.....	Bioaccumulation Factor	IM.....	Interim Measures
BCF	Bioconcentration Factor	IMWP.....	Interim Measures Work Plan
BG SB	Background Subsurface Soil	IRIS	Integrated Risk Information System
BG SS.....	Background Surface Soil	i-SL	Industrial Screening Level
bgs.....	below ground surface	LOAEL	Lowest-Observed-Adverse-Effect Level
BLM.....	Biotic Ligand Model	MC	Munitions Constituents
BTAG.....	Biological Technical Assistance Group	MCL.....	Maximum Contaminant Level
CCME	Canadian Council of Ministers of the Environment	MDC	Maximum Detected Concentration
CDCP	Center for Disease Control and Prevention	MDL.....	Method Detection Limit
COPC	Chemical of Potential Concern	MEC.....	Munitions and Explosives of Concern
COPEC.....	Chemical of Potential Ecological Concern	mg/kg	milligrams per kilogram
CSF	Cancer Slope Factor	mg/L	milligrams per liter
CY.....	cubic yards	MMA.....	Main Manufacturing Area
DEQ	Department of Environmental Quality	MMRP.....	Military Munitions Response Program
DoD.....	Department of Defense	MRL	Minimum Risk Level
DQO.....	Data Quality Objective	MRS	Munitions Response Site
EcoSSL	Ecological Soil Screening Level	msl.....	mean sea level
EEQ.....	Ecological Effects Quotient	MWP	Master Work Plan
EPC	Exposure Point Concentration	NHANES	National Health and Nutrition Examination Survey
ERAGS.....	Ecological Risk Assessment Guidance for Superfund	NOAEL	No-Observed-Adverse-Effect Level
ft.....	foot or feet	NRWQC.....	National Recommended Water Quality Criteria

ORNL.....	Oak Ridge National Laboratory	SLERA.....	Screening Level Ecological Risk Assessment
OSWER.....	Office of Solid Waste and Emergency Response	SSL.....	Soil Screening Level
PAH.....	Polynuclear Aromatic Hydrocarbon	SSP.....	Site Screening Process
PCB.....	Polychlorinated Biphenyl	SVOC.....	Semivolatile Organic Compound
PPRTV.....	Provisional Peer Reviewed Toxicity Value	TAL.....	Target Analyte List
PRG.....	Preliminary Remedial Goal	TCL.....	Target Compound List
QA.....	Quality Assurance	TCLP.....	Toxicity Characteristic Leaching Procedure
QC.....	Quality Control	TCLPRL.....	TCLP Regulatory Limit
RCRA.....	Resource Conservation and Recovery Act	TOC.....	Total Organic Carbon
RDA.....	Recommended Daily Allowance	TRV.....	Toxicity Reference Value
RFAAP.....	Radford Army Ammunition Plant	tw-SL.....	Tap Water Screening Level
RfD.....	Reference Dose	UCL.....	Upper Confidence Limit
RFI.....	RCRA Facility Investigation	UF.....	Uncertainty Factor
RG.....	Remedial Goal	USACE.....	U.S. Army Corps of Engineers
r-RG.....	Residential Remedial Goal	USEPA.....	U.S. Environmental Protection Agency
r-SL.....	Residential Screening Level	VDEQ.....	Virginia Department of Environmental Quality
Shaw.....	Shaw Environmental, Inc.	VOC.....	Volatile Organic Compound
SL.....	Screening Level	XRF.....	X-ray Fluorescence

EXECUTIVE SUMMARY

Shaw Environmental, Inc. (Shaw), a CB&I company, has been contracted by the U.S. Army Corps of Engineers (USACE) to perform Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and Interim Measures (IM) activities at the Army Reserve Small Arms Range (ARSAR), at Radford Army Ammunition Plant (RFAAP), Radford, VA. This site was investigated under the Military Munitions Response Program (MMRP) for potential release of Munitions Constituents (MC), including lead. Munitions and Explosives of Concern (MEC) were eliminated as concerns at this site based on the previous investigations. This work was performed under Contract Number W912QR-04-D-0027, Delivery Order DA04. Specific elements of the project included: development of a work plan; collection of environmental samples to support the RFI and assess the extent of contamination; the excavation and disposal of contaminated soil from the berm; restoration of the site; and, development of a final report.

The objectives of the field investigation at the ARSAR were designed to:

- Address data gaps in soil, sediment, surface water, and groundwater to complete an RFI, including human health and ecological risk assessments.
- Obtain current data that can be compared to existing data.
- Remove the lead contaminated soil in the firing range target berm.

Work was performed in accordance with the approved *Final RFI/Interim Measures Work Plan (IMWP) for the ARSAR* (Shaw, 2011), the *Radford Army Ammunition Plant, Radford, Virginia, Final Master Work Plan (MWP)* (URS, 2003), and the *U.S. Environmental Protection Agency (USEPA) Permit for Corrective Action and Waste Minimization* (USEPA, 2000).

Nature and Extent Conclusions

Target Berm

The soil at the ARSAR target berm was investigated during the 2009 Site Screening Process (SSP) and then again in 2011 in support of this RFI/IM. The 2009 SSP data set indicated that lead and antimony were the constituents of concern in the target berm. The IM was performed to address these constituents detected at elevated concentrations in the berm soil. Following the removal of the top 1-2 feet (ft) of soil from the firing range berm, surface soil samples were collected from 0-0.5 ft below ground surface (bgs) and screened for lead and antimony using an X-ray Fluorescence (XRF). All samples screened by XRF for lead and antimony were also sent to an off-site lab and tested for target analyte list (TAL) metals. In addition to TAL metals, 50 percent of the collected samples were also analyzed for target compound list (TCL) volatile organic compounds (VOCs), TCL semivolatile organic compounds (SVOCs), polynuclear aromatic hydrocarbons (PAHs), TCL pesticides/polychlorinated biphenyls (PCBs), herbicides, and explosives. Analytical results from the laboratory confirmation samples demonstrated that: 1) the IM successfully addressed the elevated concentrations of lead and antimony in the berm; 2) no analytes were detected above screening levels (SLs) in the berm soil; and, 3) no further action is recommended for the target berm.

Firing Range Floor and Potential Firing Point Area

The soil at the ARSAR firing range floor and potential firing points was not sampled during previous investigations. Analytical data was collected in 2011 to support this RFI/IM. Ninety-

three surface soil samples were collected from 0-0.5 ft bgs for XRF lead screening from the firing range floor and potential firing points to determine the extent and depth of potential soil contamination and determine if remediation was warranted for the firing range floor. XRF screening indicated that lead concentrations in the firing range floor were below the 400 milligrams per kilogram (mg/kg) remedial goal (RG) designated for the site. Laboratory confirmation samples from nine XRF screening samples analyzed for TAL metals, TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives, verified that: 1) XRF screening results for lead were all below the residential remedial goal (r-RG); 2) although three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene], one PCB (PCB-1254), and two metals (arsenic and iron) were detected at concentrations above soil SLs, these detections were isolated and not considered to be related to past site use; and, 3) no further action is recommended for the firing range floor and potential firing points.

Southeast Hillside

The soil at the southeast hillside was investigated during the 2009 SSP and then again in 2011 in support of the 2011 RFI. A total of 33 surface soil samples were collected from 0-0.5 ft bgs in a grid pattern for XRF screening to delineate the elevated arsenic concentrations detected during the SSP and assess lead concentrations. Twelve samples were sent to an off-site laboratory to confirm the XRF screening results, to assess the extent of elevated arsenic and determine whether there was a correlation between elevated lead and elevated arsenic, and characterize the soil at five locations for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives.

The XRF and laboratory confirmation data indicates that arsenic was detected at levels above the accepted background concentration and soil SLs over much of the southeast hillside, including areas where lead concentrations were minimal. As samples were collected in the 6- to 8-inch soil layer directly overlying the bedrock, elevated arsenic concentrations appear to be naturally occurring. The Southeast Hillside Area is situated in a tectonic fault window of an undifferentiated Devonian, Silurian, and Ordovician unit, a unique geologic setting at RFAAP. This tectonic window exposes the Martinsburg Formation and the Millboro Shale. Soils developed from these units contain higher amounts of arsenopyrite (a sulfide mineral). Elevated concentrations in soil along the hillside are attributed to the higher amounts of arsenopyrite naturally occurring in these soils (Schultz and Bartholomew, 2009). Based on the lack of detections in surface water and concentrations well below SLs in sediment in Stroubles Creek samples, elevated concentrations of arsenic detected in the southeast hillside do not appear to be mobile or migrating from the hillside.

The XRF and laboratory confirmation data indicates that elevated concentrations of lead were predominantly encountered in a focused area approximately 10 ft above Stroubles Creek. Although no bullet fragments were discovered along the hillside during sampling activities, the distribution of lead at this height and area along the hillside indicates that errant shots from the firing range most likely flew just over the top of the target berm and lodged into the surface of the hillside. Similar to arsenic, the lack of lead detections in surface water and concentrations well below SLs in sediment in Stroubles Creek samples, elevated concentrations of lead detected in the southeast hillside do not appear to be mobile or migrating from the hillside.

Building Debris Area

The debris located at the east end of the target berm was investigated in 2010 during the initial site reconnaissance. Prior to removal activities, the soil beneath the building debris area was investigated during the 2011 sampling event to determine if the building debris had negatively impacted the underlying soil. Data from the samples indicated that there were no Toxicity Characteristic Leaching Procedure (TCLP) metal exceedances below the building debris area. Chrysotile was encountered within the sample at a level of 1.3 percent and was determined to be not friable. A total of 5.21 tons of building debris was removed and disposed of as nonhazardous waste at an off-site landfill.

Surface Water and Sediment

Five surface water and sediment sample pairs (one upgradient, two behind the berm, and two downgradient) were collected from Stroubles Creek to assess whether previous activities at the ARSAR have impacted the stream and whether constituents were being transported off site by the stream.

Data from the surface water samples indicated that although three VOCs (acetone, chloromethane, and toluene), one SVOC (di-n-butylphthalate), one pesticide (methoxychlor), and perchlorate were detected in the samples, detected concentrations were well below applicable SLs and are not a concern in surface water at the site. PCBs, explosives, and herbicides were not detected in any of the samples and, therefore, are not a concern in surface water at the site. Three metals (aluminum, iron, and manganese) were detected at concentrations exceeding applicable SLs. Aluminum, iron, and manganese are ubiquitous in surface water samples collected throughout RFAAP. In addition, the main constituents of concern (antimony, arsenic, and lead) in soil at the site were not detected in any surface water samples collected at the site.

Data from the sediment samples indicated that three VOCs (acetone, benzene, and toluene), 14 SVOCs/PAHs, six pesticides (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, endrin, heptachlor, and methoxychlor), and 22 metals were detected in sediment samples at concentrations below applicable SLs and, therefore, are not a concern in sediment at the site. Three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene] were the only analytes detected in sediment samples above applicable SLs. In most cases, detected concentrations of benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene were marginally greater than their respective residential screening levels (r-SLs) and all were well below industrial screening levels (i-SLs). The presence of these PAHs is not considered to be related to past site use, rather, their presence is attributable to the deteriorating asphalt roads and parking lots immediately adjacent to the site.

Groundwater

Two direct-push downgradient groundwater samples were collected from temporary wells installed in the southwestern portion of the site. Groundwater sample data indicated that five VOCs (acetone, chloroform, chloromethane, ethylbenzene, and toluene), five SVOCs/PAHs [benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, di-n-butylphthalate, and naphthalene], nine total metals, and nine dissolved metals were detected in groundwater samples at concentrations below applicable SLs and, therefore, are not a concern in groundwater at the site. Pesticides, PCBs, explosives, and herbicides were not detected in any of the samples and,

therefore, are not a concern in groundwater at the site. Analytes detected at concentrations exceeding groundwater SLs included three PAHs [bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene], one total metal (antimony), and perchlorate. These isolated exceedances at concentrations marginally exceeding groundwater SLs are not a concern in groundwater at the site. None of the analytes exceeding groundwater SLs are related to past site use. In addition, these samples were collected from direct-push temporary wells without a sand-pack, which increases the amount of sediment in the sample. It is likely that the elevated concentrations are due to sediment entrained in the samples or potential drag down from the surface during boring advancement.

Human Health Risk Assessment (HHRA) Conclusions

An HHRA was performed to evaluate the potential human health effects associated with previous activities at the ARSAR. Receptors evaluated for both areas included current/future maintenance worker, future industrial worker, future excavation worker, future adult resident, future child resident, and lifetime resident.

Firing Point/Berm Area Summary

As presented in *Section 6.4* for the Firing Point/Berm Area, the total cancer risk for current/future maintenance worker exposures to surface soil (1E-06) was equal to the lower limit of the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total hazard index (HI) for surface soil was less than 1. The total cancer risk for exposures to sediment (1E-06) was equal to the lower limit of the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No chemicals of potential concern (COPCs) were identified in surface water or groundwater.

For future industrial worker exposures to surface soil, the total cancer risk for exposures to surface soil (5E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (4E-06) was within the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the future excavation worker, the total cancer risk for exposures to surface soil (3E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to cobalt. Based on the background comparison, cobalt was found to be background-related. The total HI for surface soil (16) was above 1 due to aluminum, cobalt, and manganese. Based on background comparisons, however, these COPCs were found to be background-related. The total cancer risk for exposures to sediment (5E-07) was below the acceptable risk range. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the future hypothetical lifetime resident, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic and benzo(a)pyrene. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (2E-06) was within the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the hypothetical child resident, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic and benzo(a)pyrene. The total HI for surface soil (HI = 4) is above an acceptable HI of 1 primarily due to iron and thallium with individual HIs that were each equal to 1. The margin of exposure evaluation for iron

indicated that concentrations of iron were within the allowable range. While the HI for thallium did not exceed 1, it was equal to 1 and contributed to the exceedance of the target organ HI for skin. The results from ProUCL concluded that thallium was above background; however, it is noted that the mean, median, and maximum concentrations of thallium for the site data set were all below the corresponding statistics for the background data set. The total cancer risk for exposures to sediment (1E-06) was equal to the lower limit of the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

Southeast Hillside Area Summary

As presented in *Section 6.4* for the Southeast Hillside Area, the total cancer risk for current/future maintenance worker exposures to surface soil (4E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For future industrial worker exposures to surface soil, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For the future excavation worker, the total cancer risk for exposures to surface soil (1E-06) was equal to the lower limit of the acceptable risk range of 1E-06 to 1E-04. The total HI for surface soil was equal to 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For the future hypothetical lifetime resident, the total cancer risk for exposures to surface soil (9E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are above the health protective criterion for lead.

For the hypothetical child resident, the total cancer risk for exposures to surface soil (6E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil (HI = 5) is above an acceptable HI of 1 due to arsenic and thallium. Although ProUCL concluded that thallium was above background, it is noted that the mean, median, and maximum concentrations of thallium for the site data set were all below the corresponding statistics for the background data set. Site concentrations of lead in surface soil are above the health protective criterion for lead.

Screening Level Ecological Risk Assessment (SLERA) Conclusions

Firing Point/Berm Area. The data, results, and conclusions of the SLERA evaluated risks to ecological populations inhabiting terrestrial and aquatic habitats at the Firing Point/Berm Area. Conclusions are derived from the risk assessment and are based on the responses to the assessment hypotheses and assessment endpoints.

The food chain assessment suggests potential adverse impacts to terrestrial wildlife, especially shrews, robins, and voles for modeled contact with cadmium, chromium, copper, lead, nickel, selenium, and zinc in surface soil. However, the use of alternative uncertainty factors (UFs) [e.g., alternative UFs for toxicity reference value (TRV) species extrapolation] would reduce the estimated lowest-observed-adverse-effect level (LOAEL)-based ecological effects quotients

(EEQs) to 1 (when rounded to one significant figure) or less than one for all receptors at the Firing Point/Berm Area.

The direct contact assessment results suggest a potential reduction in wildlife food supply (i.e., plants, soil invertebrates, surface water biota, and sediment biota) due to manganese in surface soil; copper, iron, and benzo(b)fluoranthene in sediment; and aluminum and barium in surface water. However, manganese in surface soil is background related and is not considered further. Although some aluminum concentrations in surface water exceed the promulgated chronic criterion for the protection of aquatic life, aluminum toxicity is expected to be minimal due to the expected presence of moderately hard water at the site and associated reduced bioavailability.

Southeast Hillside Area

The data, results, and conclusions of the SLERA evaluated risks to ecological populations inhabiting terrestrial and aquatic habitats at the Southeast Hillside Area. Conclusions are derived from the risk assessment and are based on the responses to the assessment hypotheses and assessment endpoints. The assessment results for food chain exposure are summarized in **Table 7-23**, and direct contact exposure results for terrestrial invertebrates, which may serve as a food source for wildlife, are summarized in **Table 7-24** and discussed in *Section 7.3.7*.

The food chain assessment suggests potential adverse impacts to terrestrial wildlife, especially shrews, robins, and voles for modeled contact with the hazard driver (lead) in surface soil. Based on the Tier 2 LOAEL-based approach, lead for the short-tailed shrew, American robin, and meadow vole had estimated EEQs greater than 1 when rounded to one significant figure even when alternative UFs were used in the SLERA EEQ calculations. These findings suggest that wildlife food chain impacts related to lead are a potential concern for surface soil at the Southeast Hillside Area. However, given the relatively small size of the site (1.1 acres), it is unlikely populations of wildlife such as American robins, short-tailed shrews, and/or meadow voles would be adversely impacted by concentrations of some metals in soil, such as lead. While a few individuals may suffer deleterious effects based on modeled exposure, these are conservative modeled estimations, not results of ecological field studies. Also, no threatened or endangered species are known to occur at the site; therefore, losses of individuals that are common species of wildlife are not an overriding concern. Potential reductions in food supply (due to modeled earthworm and plant toxicity) are not an overriding concern to area wildlife, as they would be expected to forage in non-impacted area proximate to the site where soil invertebrates and plants are expected to be abundant.

Another line of evidence to support these conclusions comes from Oregon Department of Environmental Quality (DEQ) Final Guidance for Ecological Risk Assessment: Levels I, II, III, IV (Oregon DEQ Waste Management and Clean-up Division, 1998, updated 12/2001) that discusses an approach they recommend to estimate the size of a population area, for evaluating potential population-level impacts (see the discussion that starts on pdf page 65 of **Appendix H**). This guidance gives a relatively simple approach for estimating the “size” of a wildlife population (basically: $100 \times \text{Home Range} / \pi$). The shrew receptor has an HR of about 1 acre, so the population size for this species would be about 32 acres, and for the vole (with an HR of about 0.09 acres), population size for this species would be about 2.9 acres. The robin has an HR of 1.2 acres, so population size would be about 38 acres. Given that the Southeast Hillside Area is only 1.1 acres, this suggests that impacted area would likely not adversely impact local populations.

Note that the vole is much less impacted than either the shrew or the robin, so even though about 38 percent of the site is within the vole's population area (1.1/2.9), this receptor had a much lower HQ. Shrews and robins should not be adversely impacted at the local *population level*.

The direct contact assessment results suggest a potential reduction in wildlife food supply (i.e., plants and soil invertebrates) due to manganese and lead in surface soil. However, manganese in surface soil is background related (*Section 7.3.5*) and is not considered further. Potential reductions in food supply (due to modeled earthworm and plant toxicity from lead) are not an overriding concern to area wildlife, as they would be expected to forage in unimpacted area proximate to the site where soil invertebrates and plants are expected to be abundant.

Finally, the location of the hillside is behind the berm and across the stream from an access point for equipment required for soil removal. Access to this area would require removal of portions of the berm, clearing the trees on the near side of the stream and clearing portions of the hillside itself. These actions would degrade the quality of the stream through the removal of the trees stabilizing the banks and providing shade. Excavation of the hillside to remove lead-containing soil would de-stabilize the soil above that point, creating an ongoing erosion issue. These actions would collectively lead to a greater loss of habitat and potential receptors populations than taking no action on the hillside.

Interim Measures Conclusions

Interim Measures were performed in conjunction with the RFI investigation to address the elevated lead and antimony previously reported in surface soil of the berm. Prior to the commencement of excavation activities, trees growing on top and in the face of the berm were removed. After the trees were removed, three series of exploratory trenches were cut within the berm to determine how the berm was constructed. The exploratory trenches showed that the berm was constructed of a lean well graded, clayey material that was free of debris.

Following tree removal activities, several piles of debris, located behind and adjacent to the berm, were removed. The debris consisted of various types of wastes including concrete, brick, fence posts, wood, and wire. These items were removed with an excavator and stored in a central location until after completion of the target berm soil excavation and load out. The debris, totaling 5.21 tons, was loaded into a dump truck and hauled off-site to an approved local landfill.

A composite soil sample was collected from the berm to characterize the soil for proper disposal; composite soil results indicated that the berm soil was non-hazardous. Approximately 1-2 ft of soil was removed from the berm face and direct loaded into dump trucks for off-site disposal. During soil excavation activities, an XRF was used to measure real time lead and antimony concentrations in the excavated surface of the berm and guide the excavation. Soil was excavated from the berm face until XRF results demonstrated that lead and antimony concentrations were below the pre-established RGs. Once XRF screening results indicated that the RGs for lead and antimony had been achieved, samples from the XRF screening locations were sent to an off-site laboratory to confirm the XRF screening results. Laboratory confirmation samples indicated the XRF screening results and demonstrated that the RGs for lead and antimony had been achieved for the target berm. Upon completion of the berm excavation, it was determined that a total of 147 tons, or approximately 105 cubic yards (CY), of impacted soil was removed from the firing range berm.

Once it was determined that the RGs had been achieved, the berm excavation was graded for proper drainage and a seed mat was applied. A site inspection performed approximately 60 days following restoration activities confirmed that the site was properly restored.

Recommendations

Based on past use of the site and the previous investigation conducted at the site, lead and antimony were constituents identified as the main constituents of concern for the Firing Point/Berm Area of the ARSAR. Media samples collected during from the Firing Point/Berm Area during 2011 RFI/IM activities indicated that lead and antimony were not detected in soil, surface water, sediment, or groundwater at concentrations exceeding applicable SLs/RGs. Isolated occurrences of benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene, PCB-1254, perchlorate, and other naturally-occurring metals at concentrations marginally above SLs in media samples are not related to past site use and not considered to be a concern at the Firing Point/Berm Area. Therefore, No Further Action is recommended for the Firing Point/Berm Area of the ARSAR. The Firing Point/Berm Area of the ARSAR is suitable for unrestricted use because there are no unacceptable risks to site receptors.

Arsenic was reported at elevated levels in soil samples collected along the Southeast Hillside Area during the previous investigation and during the 2011 RFI. No source related to past site use has been identified for arsenic. Elevated concentrations of arsenic detected in the southeast hillside soil are considered to be naturally occurring. The geology of the Southeast Hillside Area is different than the geology in the rest of RFAAP, as documented on the Radford North geologic quadrangle map (Schultz and Bartholomew, 2009). A tectonic window exposes an undivided Devonian, Silurian, and Ordovician unit that only outcrop in one other location within the Radford North Quadrangle (not within RFAAP) (Schultz and Bartholomew, 2009). This unit consists, in part, of the Millsboro Shale and the Martinsburg Formation, both of which are rich in arsenopyrites, giving them their dark grey color. These arsenopyrites are the likely source of the elevated arsenic in the Southeast Hillside Area.

Concentrations of lead are above the health protective criterion for hypothetical future residents in surface soil at the Southeast Hillside Area. Although residential development of the Southeast Hillside Area is highly unlikely, the results of the lead evaluation indicate a need for future land use controls.

Institutional Controls (ICs) are being implemented at the site within the boundary of Southeast Hillside Area as shown on **Figure 2-2**. The objective of the ICs is to prevent any future residential use. In the event the property is transferred or leased, equivalent ICs will be put into terms and conditions of the deed or lease, which are no less restrictive than the IC objectives described above. Furthermore, the transferee or lessee will be responsible for ensuring IC compliance by any future users. However, the Army acknowledges the responsibility for all original liability under the Comprehensive Environmental Response, Compensation, and Liability Act and its right and responsibility to enforce ICs unless otherwise transferred to the new property recipient.

1.0 INTRODUCTION

Shaw Environmental, Inc. (Shaw), a CB&I company, has been contracted by the U.S. Army Corps of Engineers (USACE) to perform Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and Interim Measures (IM) activities at the Army Reserve Small Arms Range (ARSAR), at Radford Army Ammunition Plant (RFAAP), Radford, VA. This site was investigated under the Military Munitions Response Program (MMRP) for potential release of Munitions Constituents (MC), including lead. Munitions and Explosives of Concern (MEC) were eliminated as concerns at this site based on the previous investigations. This work was performed under Contract Number W912QR-04-D-0027, Delivery Order DA04. Specific elements of the project included: development of a work plan; site preparation; delineation sampling of the area to determine the extent of contamination; the excavation and disposal of contaminated soil; confirmation sampling; restoration of the site; and, development of a final report.

Three previous investigations have been conducted at the ARSAR and are discussed in the following section of this report. A data review, including the development of a conceptual site model and data gap analysis, was performed during the development of the *RFI/Interim Measures Work Plan (IMWP) for the ARSAR* (Shaw, 2011). Review of the ARSAR data indicated that additional samples needed to be collected in order to characterize the current state of potentially impacted media, representing a data gap. Once the data needs were identified, sampling strategies were developed to complete the characterization of the ARSAR.

The objectives of the field investigation at the ARSAR were designed to:

- Address data gaps in soil, sediment, surface water, and groundwater.
- Obtain current data that can be compared to existing data.
- Remove the source of lead contamination in the firing range berm.

Work was performed in accordance with the approved *Final RFI/IMWP for the ARSAR* (Shaw, 2011), the *Radford Army Ammunition Plant, Radford, Virginia, Final Master Work Plan (MWP)* (URS, 2003), and the *U.S. Environmental Protection Agency (USEPA) Permit for Corrective Action and Waste Minimization* (USEPA, 2000).

2.0 SITE BACKGROUND

2.1 Site Description

The ARSAR is a munitions response site (MRS) being investigated under the MMRP. The ARSAR is an approximately 7.6-acre area located along the southeastern boundary of the Main Manufacturing Area (MMA) (**Figure 2-1**). Most of the site is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. As illustrated on **Figure 2-2**, the site is divided into two areas consisting of the Firing Point/Berm Area and the Southeast Hillside Area. A target berm, which is approximately 8 feet (ft) high and 270 ft long, is located along the southeastern portion of the Firing Point Area was remediated in 2011. The Southeast Hillside Area is a steep, rocky hillside thought to have been used as a backstop prior to the construction of the target berm. A fence is located at the top of the southeast hillside, which precludes access to the site.

The site is located within a nearly level alluvial plain at an elevation of approximately 1,715 ft mean sea level (msl) (**Figure 2-2**). The area across Stroubles Creek (Southeast Hillside Area), to the south, slopes steeply upward to an elevation greater than 1,950 ft msl.

2.2 Site History and Operations

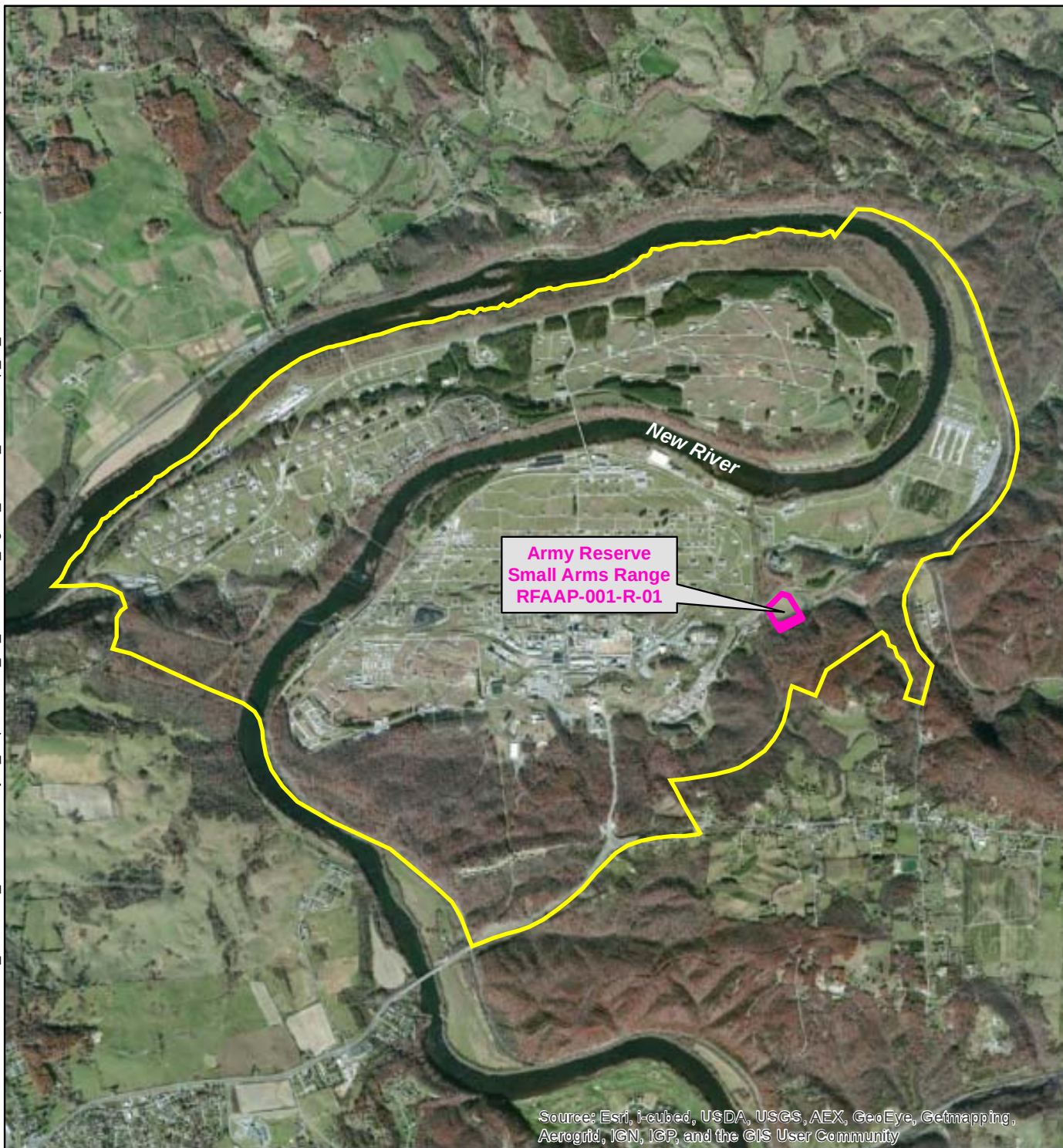
According to URS (2008), the ARSAR was a .30 caliber small arms firing range used by both the National Guard and the Army Reserve from approximately 1941 to 1968. The closed range consisted of an approximately 10-ft-high berm and four potential firing areas (see **Figure 2-2**). Currently, public access to RFAAP is controlled and includes the former range site although public access may have been possible in the past. The former range is now a grass field surrounded by a fence that is occasionally used as a helicopter landing pad and as a baseball field.

The ARSAR was added to RFAAP's RCRA Corrective Action Permit on July 15, 2005.

2.3 Site Soil

The Firing Point/Berm Area is underlain by Weaver soil, which consists of moderately well drained and deep soil located in nearly level areas within flood plains. The soil has a low to moderate permeability, low to moderate organic content, and it is neutral to moderately alkaline. The Weaver Soil has a high available water capacity and surface runoff is generally slow. A typical profile of undisturbed soil consists of a 10-inch-thick surface layer of dark brown silt loam underlain by a 39-inch-thick subsoil of silt loam of variable color. The substratum is dark grey alluvial material consisting of gravel sandy clay loam below approximately 49 inches. Depth to bedrock is greater than 40 inches (URS, 2003) (SCS, 1985).

Soil overlying the bedrock of the Southeast Hillside Area is comprised of the Berks-Weikert Complex, which consists of well-drained soil on moderately steep to steep side slopes. Soil of the Berks-Weikert Complex are extremely to strongly acidic. Permeability ranges from moderate to moderately rapid with high to rapid surface water runoff. The Berks-Weikert Complex typically consists of a surface layer of shaley silt loam underlain by a subsoil of shaley silt loam. Shale bedrock is typically present from 20 to 40 inches (URS, 2003) (SCS 1985).



Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

LEGEND

-  MRS Boundary
-  Installation Boundary



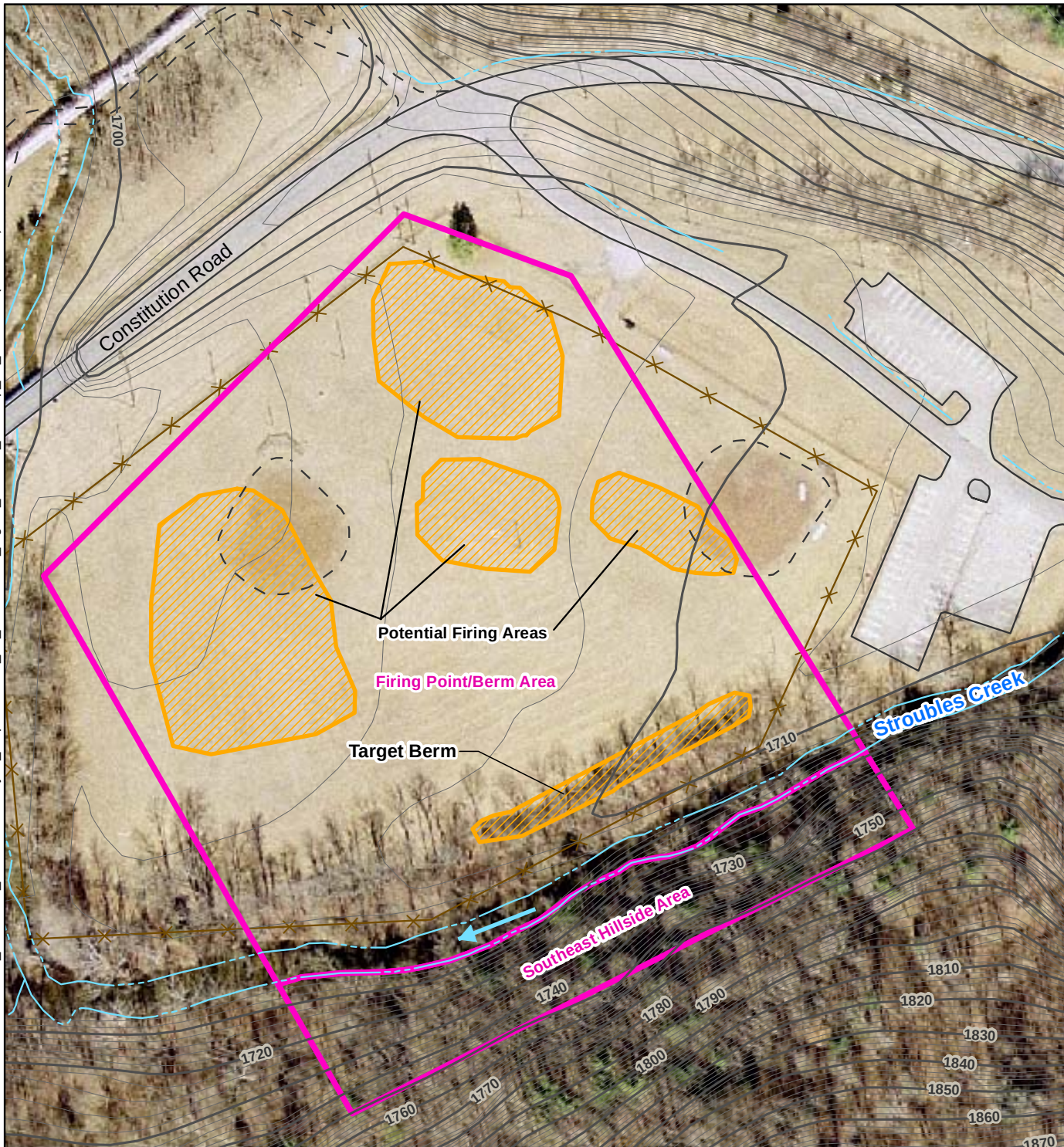
Scale:
0 1,600 3,200 6,400 Feet



U.S. Army Corps of Engineers

Shaw Environmental, Inc.
(A CB&I Company)

FIGURE 2-1
Army Reserve Small Arms Range
Site Location Map
Radford Army Ammunition Plant,
Radford, VA



LEGEND

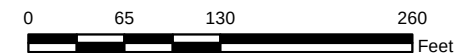
- 2 ft Contour Line
- 10 ft Contour Line
- Water Feature
- Surface Water Flow Direction
- - - Dirt Road
- Paved Road
- x — Fence Line
- MRS Boundary
- ▨ Historic Feature

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).



Scale:



U.S. Army Corps of Engineers

Shaw Environmental, Inc.
(A CB&I Company)

FIGURE 2-2
Army Reserve Small Arms Range
Site Map
 Radford Army Ammunition Plant,
 Radford, VA

2.4 Site Geology

RFAAP is located in the New River Valley, which crosses the Valley and Ridge Province approximately perpendicular to the regional strike of the bedrock, and cuts Cambrian and Ordovician limestone or dolostone. Deep clay-rich residuum is prevalent in areas underlain by carbonate rocks. The valley floor is covered by river flood plain and terrace deposits; karst topography is prevalent.

2.5 ARSAR Geology

Site geology was characterized during the 2011 investigation during the advancement of direct-push borings for the collection of groundwater samples. These borings encountered silt and lean clay with refusal on limestone bedrock at depth ranging from 12-15 ft below ground surface (bgs).

The lithology below the Firing Point/Berm Area is typically alluvium, consisting of unconsolidated alluvial deposits within the flood plain of Stroubles Creek. Carbonate bedrock of the Cambrian Elbrook formation underlies these alluvial deposits. This formation consists of thick stylolitic, dark gray, fine-grained dolomitic limestone and massive bedded thick, thrombolytic dolomite (URS, 2003).

The geologic map of the Radford North Quadrangle, Virginia indicates that the Southeast Hillside Area is underlain by the “DO” geologic unit. The DO unit consists of an undivided Devonian, Silurian, and Ordovician unit and includes partial sections of the Millboro Shale, undivided Silurian units, and Martinsburg Formation. These rocks are exposed in two windows of the Pulaski thrust sheet: one is north of the City of Radford and the other is just to the southeast of the RFAAP (Southeast Hillside Area). These rocks are highly deformed allochthonous tectonic horses that are complexly folded, faulted, and internally fractured (Schultz and Bartholomew, 2009).

The Millboro Shale is described as dark-gray to black, thinly bedded, sparsely fossiliferous, fissile mudstone and black shale. The Millboro Shale contains abundant concretions and disseminated sulfides as well as a few thin beds of carbonate. The thickness ranges from about 1,000 to 1,300 ft.

2.6 Site Hydrology

There are no monitoring wells at the site and no site-specific groundwater investigations were conducted prior to the direct-push borings advanced in 2011. The groundwater table was present below the ARSAR during the 2011 investigation at depths ranging from 5.4 to 6.5 ft bgs. Groundwater was not encountered prior to bedrock refusal in the northern portion of the site. Groundwater is expected to flow south through the unconsolidated sediments and discharge in Stroubles Creek.

Stroubles Creek is a perennial stream that flows through the southern portion of the ARSAR and then turns northward towards the New River where it discharges approximately 3,000 ft north of the site. The site has no other surface water bodies.

It is assumed that overland storm water flow is directed toward Stroubles Creek. In the area of the target berm, runoff from the north side of the berm would flow away from Stroubles Creek for a short distance north, and infiltrate into the grassy field. Due to its location on a flood plain, areas adjacent to Stroubles Creek may experience inundation during periods of high flow and

flooding and would likely preclude any type of residential re-development from occurring within this area.

2.7 Previous Investigations

There have been three previous investigations at the ARSAR: a Historical Records Review (HRR) by URS in 2008, a Site Screening Process (SSP), performed by URS in 2009, and IM performed by Shaw in 2011. These investigations are discussed in the following subsections.

2.7.1 Historical Records Review, URS (2008)

The HRR Report was completed in 2008 to support the SSP (URS, 2008). The HRR utilized historical records, interviewed on-site personnel, aerial photography, existing site maps, and environmental restoration documents to provide information used to identify, verify, and establish physical limits and potential for MEC and MC at the ARSAR. The HRR also concluded that MEC is not a concern at this site. The HRR, however, did indicate that MC in the form of lead in the target berm and potential explosives residues at the firing points was likely at the ARSAR.

The Final HRR Report was submitted in January 2008 to USACE, Baltimore District, the U.S. Army Environmental Command, RFAAP, USEPA, and the Virginia Department of Environmental Quality (VDEQ).

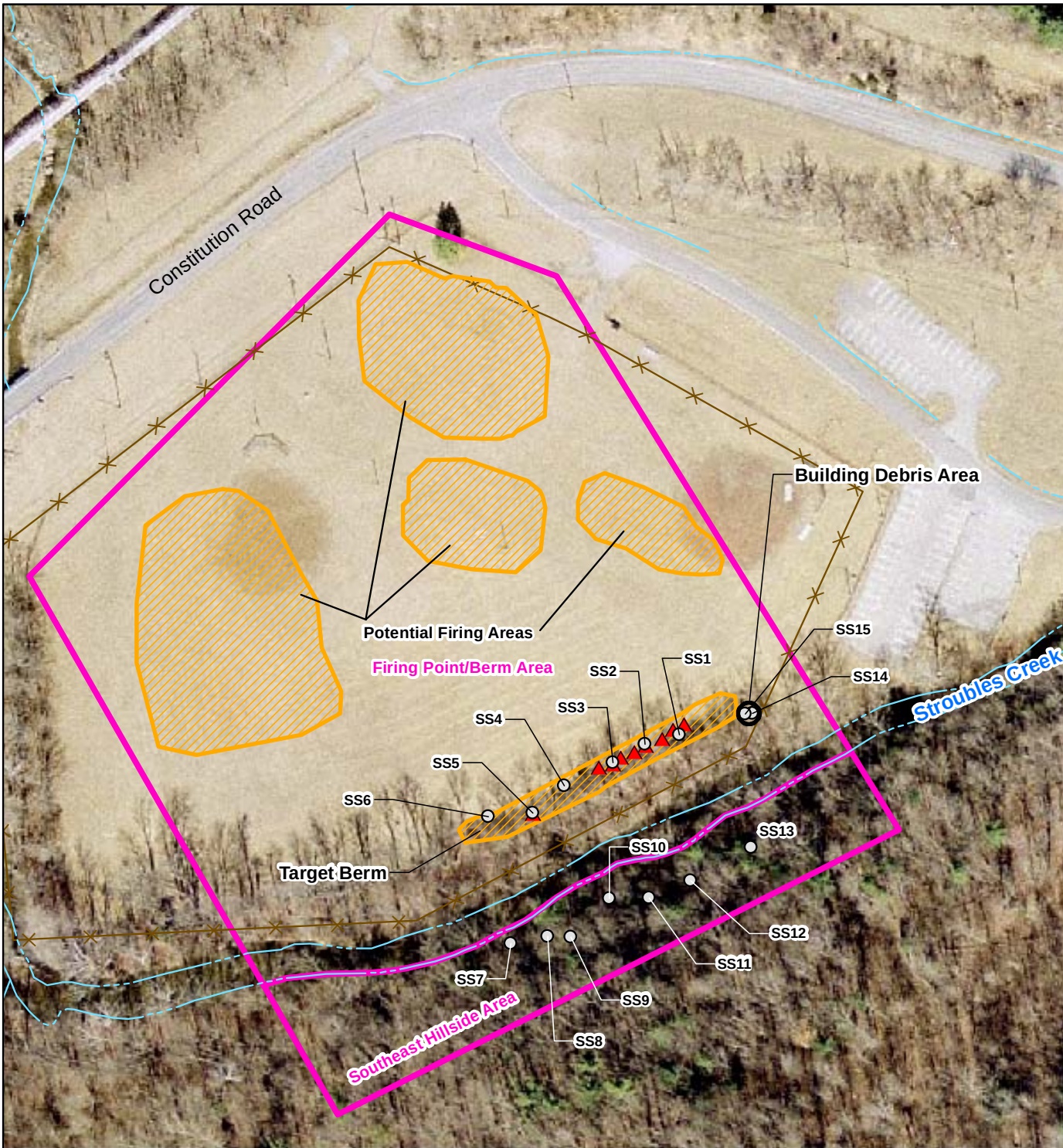
2.7.2 Site Screening Process, URS (2009)

An SSP was performed by URS in October 2008 to assess the presence or absence of MEC and MC that may remain from activities conducted by the Department of Defense (DoD) during the operation of the ARSAR. MEC was not expected at the ARSAR because of its use as only a small arms and pistol firing range. As such, the field sampling activities were developed to investigate MC at the site.

Sampling was conducted using a visual inspection of the target berm and southeast hillside, followed by a sweep for potential bullet fragments using a metal detector. Locations where target responses occurred were limited to the berm. Additionally, a shovel was used to dig into the surface soil at the target response locations to investigate whether bullet fragments were present at these locations. Fragments were identified at several locations within the berm at depths of approximately 2 to 4 inches. There were no recordable metal detector responses for the Southeast Hillside Area, indicating that bullets or bullet fragments are not present in the southeast hillside.

Composite soil samples were collected from a depth of 0 to 6 inches within the target berm, southeast hillside, and building debris area. Soil samples were analyzed for arsenic, chromium, and lead. Soil sample locations are shown on **Figure 2-3** and results are presented in **Table 2-1**.

Sample results indicated that elevated antimony and lead concentrations were detected in the target berm. Elevated arsenic levels were detected within the Southeast Hillside Area, though no source was identified. Based on the results of the SSP evaluation, further action for MC was recommended at the ARSAR. No further action was recommended for MEC at the site.



LEGEND

- Previous Soil Sample Location
- ▲ Fragment Location
- Water Feature
- Fence Line
- Historic Feature
- MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Historic features, MRS boundary, fragment and previous soil sample locations were obtained from Final Site Screening Process Report (URS, 2009).



Scale:
0 65 130 260 Feet



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FIGURE 2-3
Army Reserve Small Arms Range
Site Screening Process Sample Locations
Radford Army Ammunition Plant,
Radford, VA

Table 2-1
Army Reserve Small Arms Range - Detected Soil Results, 2009 SSP

Sample ID Sample Date Sample Depth (ft bgs)	ARSARSS1 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	DUP-1 (ARSARSS1) 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS2 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS3 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL
	Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r			
Constituent																				
Metals (mg/kg)																				
Antimony	7	J,L,m	B,D,E	1.11	11.1	8.98	J,L,m	B,D,E	1.1	11	19.4	L,m	B,D,E	1.18	11.8	24.4	L,m	B,D,E	1.15	11.5
Arsenic	4.22		B,C,D,E	0.443	1.11	3.9		B,C,D,E	0.442	1.1	5.45		B,C,D,E	0.471	1.18	6.01		B,C,D,E	0.462	1.15
Chromium ⁽¹⁾	NT					NT					NT					NT				
Lead	319		A,E	0.221	1.11	407		A,B,E	0.221	1.1	1,600		A,B,C,E	0.236	1.18	1,630		A,B,C,E	0.231	1.15
Sample ID Sample Date Sample Depth (ft bgs)	ARSARSS4 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS5 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS6 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS7 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL
	Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r			
Constituent																				
Metals (mg/kg)																				
Antimony	4.47	J,L,m	B,D,E	1.12	11.2	<11.3	U,UL,m		1.13	11.3	3.1	J,L,m	B,D,E	1.14	11.4	1.32	J,L,m	D,E	1.22	12.2
Arsenic	4.56		B,C,D,E	0.447	1.12	4.56		B,C,D,E	0.454	1.13	4.03		B,C,D,E	0.456	1.14	9.59		B,C,D,E	0.488	1.22
Chromium ⁽¹⁾	NT					NT					NT					NT				
Lead	400		A,B,E	0.223	1.12	27.1		A,E	0.227	1.13	328		A,E	0.228	1.14	225		A,E	0.244	1.22
Sample ID Sample Date Sample Depth (ft bgs)	ARSARSS8 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS9 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS10 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS11 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL
	Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r			
Constituent																				
Metals (mg/kg)																				
Antimony	<13.3	U,UL,m		1.33	13.3	<13.2	U,UL,m		1.32	13.2	<14.1	U,UL,m		1.41	14.1	<14.5	U,UL,m		1.45	14.5
Arsenic	8.44		B,C,D,E,	0.533	1.33	30.4		A,B,C,D,E	0.53	1.32	25.1		A,B,C,D,E	0.564	1.41	32.6		A,B,C,D,E	0.58	1.45
Chromium ⁽¹⁾	NT					NT					NT					NT				
Lead	88.6		A,E	0.266	1.33	95.1		A,E	0.265	1.32	174		A,E	0.282	1.41	104		A,E	0.29	1.45
Sample ID Sample Date Sample Depth (ft bgs)	ARSARSS12 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS13 10/8/2008 0-0.5		Criteria Exceeded?	MDL	RL	ARSARSS14 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL	DUP-2 (ARSARSS14) 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL
	Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r			
Constituent																				
Metals (mg/kg)																				
Antimony	1.32	J,L,m	D,E	1.3	13	<13	U,UL,m		1.3	13	NT					NT				
Arsenic	49.2		A,B,C,D,E	0.519	1.3	37		A,B,C,D,E	0.521	1.3	7.04		B,C,D,E	0.504	1.26	4.65		B,C,D,E	0.504	1.26
Chromium ⁽¹⁾	NT					NT					18			0.252	1.26	17.7			0.252	1.26
Lead	138		A,E	0.26	1.3	51.5		A,E	0.26	1.3	55.6		A,E	0.252	1.26	51.6		A,E	0.252	1.26

Sample ID Sample Date Sample Depth (ft bgs)	ARSARSS15 10/7/2008 0-0.5		Criteria Exceeded?	MDL	RL
	Result	LQ, VQ, r			
Constituent					
Metals (mg/kg)					
Antimony	NT				
Arsenic	5.95		B,C,D,E	0.453	1.13
Chromium ⁽¹⁾	13			0.227	1.13
Lead	16.6		E	0.227	1.13

Notes:
CAS = Chemical Abstracts Service
ft bgs = feet below ground surface
mg/kg = milligram per kilogram
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

NT = Not Tested
- = No Value Available
Screening Levels = USEPA Regional Screening Table (September 2008)
SSL = Site Screening Level 12 September 2008
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA SSL Table (September 2008)
MCL = Maximum Contaminant Level
(1) = Chromium III Groundwater SSL used
(A) = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT, 2001)

SCREENING CRITERIA:

			A	B	C	D	E
			Facility-Wide Background Point Estimate ^(A)	Adjusted Soil Screening Levels (Residential)	Adjusted Soil Screening Levels (Industrial)	Protection of Groundwater Risk-based SSL	Protection of Groundwater MCL-based SSL
Constituent	CAS #	C/N					
Metals (mg/kg)							
Antimony	7440-36-0	N	-	3.1	41	0.66	0.27
Arsenic	7440-38-2	C	15.8	0.39	1.6	0.0013	0.29
Chromium ⁽¹⁾	7440-47-3	C	65.3	280	1,400	9.90E+07	-
Lead	7439-92-1	N	26.8	400	800	-	14

Note that all detections are bolded.

Laboratory Qualifiers

J Estimated value
U The compound was analyzed for but not detected. The reporting limit will be adjusted to reflect any dilution, and for soil, the percent moisture.

Validation Qualifiers

L Analyte present. Reported value may be biased low. Actual value is expected to be higher.
UL Not detected, quantitation limit is probably higher.

Reason Codes

m MS/MSD recovery failure

2.7.3 Interim Measures, Shaw (2011)

2.7.3.1 Project Objectives

Based on the *ARSAR RFI/IMWP* (Shaw, 2011), a combined RFI and IM was performed at the ARSAR. The RFI investigation was conducted to:

- Collect sufficient samples in order to characterize the site.
- Address data gaps in both soil and groundwater.
- Obtain current data that can be compared to existing data.

The IM were conducted to:

- Mitigate the threat of a contaminant release, migration, and/or exposure to the public and the environment.
- Facilitate clean closeout in accordance with Part II (D) (11-21) IM of the *RFAAP Corrective Action Permit* (USEPA, 2000a). The IM include:
 1. **Site Preparation.** Prior to commencement of work, a utility survey was performed and dig permits were obtained. In addition, erosion/sediment control measures were implemented.
 2. **Soil Delineation Sampling and Excavation.** Delineation of soil containing arsenic, antimony, and lead above the residential remedial goal (r-RG).
 3. **Soil Excavation.** Excavation of the delineated area such that the remaining soil is below the r-RGs for antimony and lead.
 4. **Waste Characterization & Off-site Disposal.** Samples were collected to assess appropriate disposal options prior to soil excavation. Sample results determined the appropriate off-site disposal method.
 5. **Site Restoration.** Following the removal of soil, the site was restored and all equipment demobilized.

IM were completed within the target berm at the ARSAR to remove the antimony and lead source area, previously established by the SSP, on site. The objective of the IM action was to reduce concentrations of antimony and lead in the berm below the r-RGs of 3.1 and 400 milligrams per kilogram (mg/kg), respectively. It is also to facilitate clean closeout in accordance with Part II (D) (11-21) IM of the *RFAAP Corrective Action Permit* (USEPA, 2000a).

The site-specific corrective measures objective for the ARSAR was to reduce contaminant concentrations in soil to levels that are protective of residents at the site. The extent of lead was expected to be the greatest of the chemicals of potential concern (COPCs). Lead was used as a tracer compound and samples were screened for lead during excavation activities in the target berm.

As mentioned above, preliminary remedial goals (PRGs) were obtained from USEPA Office of Solid Waste and Emergency Response (OSWER) Directives (USEPA, 1999, 2004b), if available. Regional SLs published by USEPA in May 2010 were used as conservative PRGs for lead and antimony (USEPA, 2010d). The published values were then compared with the background values (95 percent upper tolerance limit) and the maximum of the two values was

selected as the remedial goal (RG) for the analyte. The future land use identified for the ARSAR study area is industrial. However, for comparison purposes in the approved *ARSAR RFI Work Plan* (Shaw, 2011), RGs for both residential and industrial exposure scenarios were developed. RGs for the ARSAR are shown in **Table 2-2**.

Table 2-2
Remedial Goals Developed for the ARSAR

COC	Industrial SL (mg/kg)	Residential SL (mg/kg)
Lead	800	400
Antimony	410	3.1

2.7.3.2 Mobilization

Prior to intrusive activity at the site, a utility survey to identify underground service lines within or near the excavation area was performed and all lines were identified by Alliant TechSystems, Inc. (ATK). An Area Access Permit and a Hot Work Permit were issued by the ATK Safety Department for the duration of the project. Copies of the permits are presented in **Appendix G-2**. A job safety analysis was completed by the site safety officer, was reviewed with the crew, and all potential hazards were identified prior to commencement of work activities. Daily tailgate safety meetings were held and daily work plans discussed with the crew every morning before work began. Copies of the completed health and safety forms are presented in **Appendix G-2**.

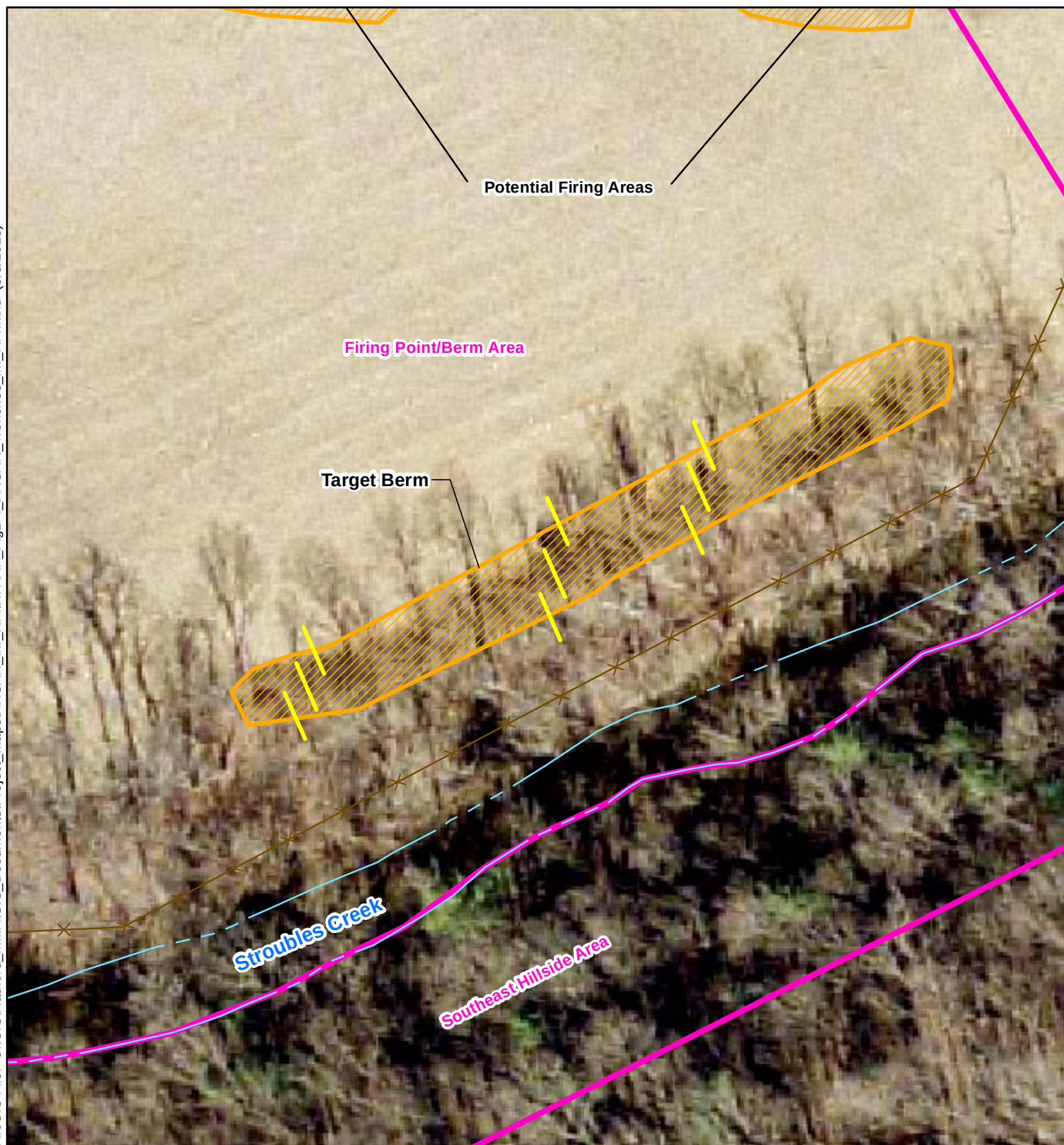
Prior to excavation, Shaw cut down and chipped approximately 20 trees that were growing within the berm area. Approximately 19.99 tons of wood chips were shipped off site prior to the investigation of the target berm.

In addition to the tree removal activities, several piles of debris, located behind and adjacent to the berm, were removed. The debris consisted of various types of wastes including concrete, brick, fence posts, wood, and wire. These items were removed with an excavator and stored in a central location until after completion of the target berm soil excavation and load out (see *Section 2.7.3.4*). The debris, totaling 5.21 tons, was loaded into a dump truck and hauled to New River Resource Authority (NRRA) landfill located at 7100 Cloyds Mountain Road in Dublin, Virginia.

2.7.3.3 Pre-Excavation Sampling

Berm Characterization. Prior to the commencement of removal activities, three series of exploratory trenches were cut within the berm. Each series of trenches involved a 4-ft-wide by 3-ft-deep excavation on the face of the berm, top of the berm, and behind the berm (**Figure 2-4**). Based on visual observations obtained during the excavation process, the berm consisted of Lean CLAY fill, largely absent of building debris or rubble.

One composite sample (ARDM01) was collected from three locations 0-2 ft bgs within the target berm to characterize the soil for disposal. The sample was analyzed for Toxicity Characteristic Leaching Procedure (TCLP) metals, and TCLP reactivity, ignitability, and corrosivity as pH. The results from the composite sample are presented in **Table 2-3**.



LEGEND

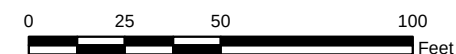
-  Fence Line
-  Water Feature
-  4" Wide Exploratory Trench
-  Historic Feature
-  MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Historic features, MRS boundary, fragment and previous soil sample locations were obtained from Final Site Screening Process Report (URS, 2009).



Scale:



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FIGURE 2-4
Army Reserve Small Arms Range
Exploratory Trenches
 Radford Army Ammunition Plant,
 Radford, VA

Table 2-3
Target Berm Waste Characterization Sample Results

Analyte	Sample ID	ARDM01		ARDM01 Rerun	
	Matrix	Soil		Soil	
	Sample Date	04/06/2011		04/06/2011	
	TCLP RL	Result	Lab Q	Result	Lab Q
Explosives (mg/kg)					
Nitrobenzene	na	0.25	U	NT	
2-Amino-4,6-dinitrotoluene	na	0.25	U	NT	
2,6-Dinitrotoluene	na	0.25	U	NT	
3-Nitrotoluene	na	0.25	U	NT	
4-Amino-2,6-dinitrotoluene	na	0.25	U	NT	
4-Nitrotoluene	na	0.40	U	NT	
2,4-Dinitrotoluene	na	0.50	U	NT	
1,3-Dinitrobenzene	na	0.40	U	NT	
3,5-Dinitroaniline	na	0.40	U	NT	
2-Nitrotoluene	na	0.50	U	NT	
Tetryl	na	0.40	U	NT	
2,4,6-Trinitrotoluene	na	0.40	U	NT	
HMX	na	0.40	U	NT	
1,3,5-Trinitrobenzene	na	0.50	U	NT	
RDX	na	0.50	U	NT	
Nitroglycerin	na	2.0	U	NT	
PETN	na	2.0	U	NT	
TCLP Metals (mg/L)					
TCLP Silver	5.0	0.00070	U	NT	
TCLP Arsenic	5.0	0.0040	U	NT	
TCLP Cadmium	1.0	0.00031	JB	NT	
TCLP Chromium	5.0	0.00091	J	NT	
TCLP Selenium	1.0	0.011	J	NT	
TCLP Barium	100	0.35	B	NT	
TCLP Lead	5.0	5.3*	M	1.6	
TCLP Mercury	0.2	0.000030	U	NT	
TCLP SVOCs (mg/L)					
TCLP Nitrobenzene	2.0	0.010	U	NT	
TCLP Hexachlorobutadiene	0.5	0.010	U	NT	
TCLP 1,4-Dichlorobenzene	7500	0.010	U	NT	
TCLP 2,4-Dinitrotoluene	0.13	0.030	U	NT	
TCLP Hexachloroethane	3.0	0.010	U	NT	
TCLP Hexachlorobenzene	0.13	0.010	U	NT	
TCLP Pyridine	5.0	0.030	U	NT	
TCLP 2-Methylphenol	200	0.060	U	NT	
TCLP 2,4,6-Trichlorophenol	2.0	0.060	U	NT	
TCLP Pentachlorophenol	100	0.060	U	NT	
TCLP 2,4,5-Trichlorophenol	400	0.060	U	NT	
TCLP 4-Methylphenol	200	0.11	U	NT	

*Sample was rerun for lead due to matrix spike recovery failure on initial run.

**Table 2-3
Target Berm Waste Characterization Sample Results (Continued)**

Analyte	Sample ID Matrix Sample Date	ARDM01 Soil 04/06/2011		ARDM01 Rerun Soil 04/06/2011	
	TCLP RL	Result	Lab Q	Result	Lab Q
TCLP Characteristics					
Ignitability (Flashpoint)	140 (°F) <2 or >12	>140 (°F)		NT	
Corrosivity as pH	(Units)	5.93		NT	
Sulfide Reactivity	500 (mg/kg)	120		NT	
Cyanide Reactivity	250 (mg/kg)	25		NT	

J = (organics) Value <MRL and >MDL and is considered estimated.

B = Blank contamination. Value detected in sample and associated blank.

U = Analyte not detected.

M = Matrix spike and/or Matrix Spike Duplicate recovery outside acceptance limits.

NT = Not tested.

As shown in **Table 2-3**, sample results indicated that the concentration of leachable lead initially was 5.3 milligrams per liter (mg/L), which is greater than the TCLP Regulatory Limit (TCLPRL) of 5 mg/L. The laboratory indicated an “M” qualifier indicating the matrix spike and/or matrix spike duplicate recovery was outside acceptance limits. As such, the sample was reanalyzed for TCLP lead. The resulting lead concentration from the sample reanalysis was 1.6 mg/L. All other sample concentrations were below the waste characterization SLs, where applicable; as such, the soil removed from the ARSAR target berm was shipped as non-hazardous. The waste disposal profile is presented in **Appendix G-3**.

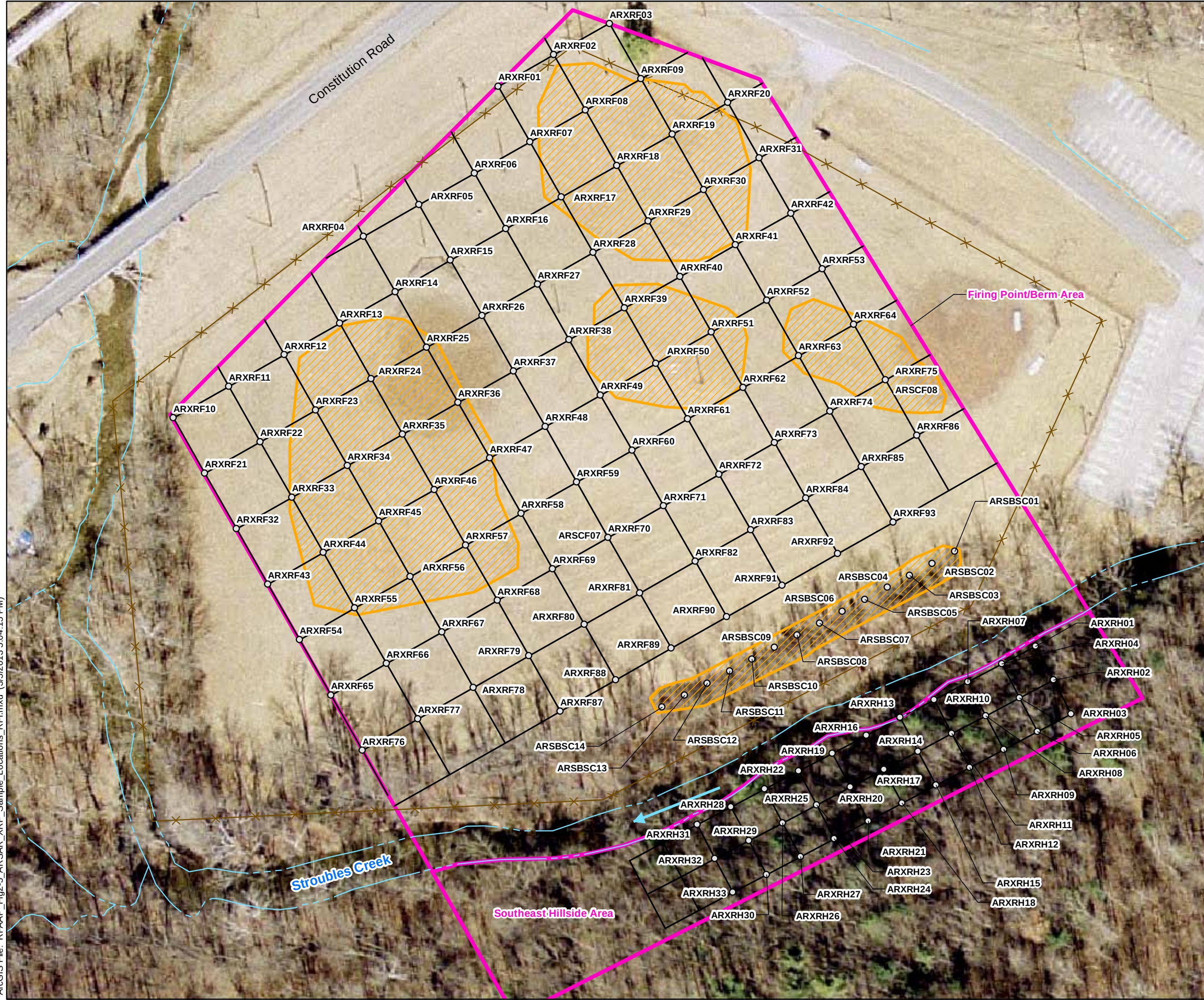
Firing Range Floor X-ray Fluorescence (XRF) Screening. Ninety-three surface soil samples were collected from 0-0.5 ft bgs for XRF lead screening from the firing range floor and potential firing points to determine the extent and depth of potential soil contamination and determine if remediation was warranted for the firing range floor (**Figure 2-5**). XRF screening indicated that lead concentrations in the firing range floor were below the 400 mg/kg RG designated for the site. Laboratory confirmation samples verified the XRF screening results for lead, indicating that site RGs had been met for the firing range floor. Based on the firing range floor XRF and laboratory samples, no excavation was warranted to achieve the firing range floor RGs. Detailed information regarding the XRF screening of the firing range floor and results are provided in *Section 3.1.1*.

2.7.3.4 Excavation Activities

Upon receipt of the waste characterization results waste disposal profiles were completed and approved. The berm excavation began in the western portion of the berm and progressed eastward. Soil was removed every 20 ft across the face of the berm in an alternating top, middle, and bottom pattern to expose the soil 1-2 ft below the berm surface.

Excavation and the loading of dump trailers were performed using a 20-Ton tracked excavator (trackhoe) and a front-end loader. No stockpiling of material was performed during the project; any excavated soil was directly loaded into dump trailers and shipped out the same day they were

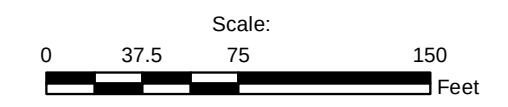
ArcGIS File: RFAAP_Fig2-5_ARSAR_XRF_Sample_Locations_RFI.mxd (3/5/2013 5:04:15 PM)



LEGEND

- Soil XRF Sample Location
- Water Feature
- Surface Water Flow Direction
- ✕ Fence Line
- XRF Sample Grid
- ▨ Historic Feature
- ▭ MRS Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).



U.S. Army Corps of Engineers

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FIGURE 2-5
Army Reserve Small Arms Range
Soil XRF Sample Locations
Radford Army Ammunition Plant,
Radford, VA

excavated. Photos depicting different aspects of the project are presented in **Appendix B** and Daily Quality Control Reports are presented in **Appendix G-1**. The non-hazardous waste disposal manifests are presented in **Appendix G-3**. The truck log for the shipments of non-hazardous waste is presented in **Appendix G-4**.

Based on preliminary calculations regarding the area and depth of berm excavation, it was estimated that 87 cubic yards (CY), or 121 tons, of contaminated soil would be removed to meet RGs. Upon completion of the project, it was determined that a total of 147 tons, or approximately 105 CY, of contaminated soil was removed from the firing range berm.

2.7.3.5 Post-Excavation Sampling

XRF Screening. Fourteen soil samples were collected and screened for lead and antimony concentrations using an XRF (**Figure 2-5**). Results from the XRF screening and laboratory confirmation samples indicated that RGs were achieved for lead and antimony concentrations in the target berm. Detailed information regarding the XRF screening of the firing range floor and results are provided in *Section 3.1.1*.

Laboratory Confirmation Analysis. Fourteen soil confirmation samples were collected from XRF screening locations in the target berm to confirm XRF results and verify that soil concentrations were below the established RGs. Confirmation samples were shipped to an off-site laboratory and analyzed for target analyte list (TAL) metals. In addition to TAL metals, 50 percent of the collected samples were also analyzed for target compound list (TCL) volatile organic compounds (VOCs), TCL semivolatile organic compounds (SVOCs), polynuclear aromatic hydrocarbons (PAHs), TCL pesticides/polychlorinated biphenyls (PCBs), herbicides, and explosives to fill data gaps identified after the SSP investigation. Additional information regarding the collection of the target berm soil confirmation samples are provided in *Section 3.1.2*.

2.7.3.6 Site Restoration and Demobilization

This stage of the project commenced after the completion of the excavation and the receipt of all analytical samples collected to confirm that the remaining soil concentrations were below their associated RGs. This task included the final grading and seeding of the excavated areas of the berm and disturbed areas resulting from the debris removal.

Final Grading and Debris Removal. Final grading was performed to smooth out the surface of the berm excavation so that precipitation would properly drain away from the berm surface. Following the final grading, construction debris material that was located behind the berm was removed for shipping to an off-site disposal facility, as per the Army's request.

Seeding. After the final grading and debris removal was complete, Shaw laid and secured seeding mat across the face and top of the target berm and the areas which were disturbed during site activities. Seeding mat application is a process in which grass seed, fertilizer, and mulch are applied in a roll seed mat which is typically fastened onto the ground surface with stakes. The seeding at the ARSAR project site was performed June 1 through June 3, 2011.

Post-Completion Inspection. An inspection was completed on August 13, 2011, approximately 60 days after completion of the site restoration activities. The purpose of the inspection was to ensure that grass was growing and that the excavated areas were not eroding. Observations from the inspection indicated that the site had been successfully restored.

3.0 FIELD INVESTIGATION PROGRAM

An additional field sampling event was conducted for the ARSAR by Shaw in 2011 based on the EPA/VDEQ-approved *RFI/IMWP for the ARSAR* (Shaw, 2011). The investigation was performed in order to obtain current analytical data for the site to complete its characterization and to perform an IM removal action for the berm, where lead fragments were observed during the SSP. As part of the investigation, soil, sediment, and surface water samples were collected at the ARSAR to refine the delineation of elevated constituents detected in previous investigations, as well as to define concentrations of untested analyte classes. Groundwater samples were also collected to determine whether the groundwater table was impacted by prior site activities. Samples and chemical analyses performed in support of the investigation are presented in **Table 3-1**. Sample locations are displayed on **Figure 3-1**. Results from the investigation are discussed in *Section 4.0*.

3.1 Soil Sampling

Complete characterization of the site soil for lead, TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives was a data gap identified after the 2009 SSP. A sampling plan involving investigation through on-site XRF surveys combined with fixed-laboratory confirmation sampling was formed to address the data gap.

3.1.1 XRF Survey

XRF surveys were completed at the site in three areas for different reasons: 1) confirm lead had been removed from the berm to below 400 mg/kg following the IM excavation; 2) assess the firing range floor for the presence or absence of lead; and, 3) delineate arsenic and lead concentrations in the southeast hillside behind the berm. Soil samples were screened for lead, antimony, and arsenic using dispersive XRF technology with an Innov-X Alpha Series model XRF analyzer following USEPA Method SW-846 6200. XRF analysis provides a field screening method for analysis of these metals in soil. The XRF detected lead concentrations in soil down to 10 mg/kg at the ARSAR. The XRF can detect arsenic down to 10 mg/kg; however, the presence of lead can cause interference and result in the detection of elevated levels of arsenic. As indicated in the Innov-X Systems manual, typically, the arsenic detection limit increases by a factor of 2 for a ten-fold increase of lead. The effect on precision of the arsenic measurement will follow a similar trend.

As shown on **Figure 3-1**, samples were collected along a grid pattern over the range floor, target berm, and southeast hillside. All surface soil samples for XRF screening were collected from under the vegetative mat using disposable sampling trowels. The samples were then prepared for analysis by removing the larger-grained and gravelly particles as well as any vegetative material and homogenized in plastic zip-lock bags. The surface soil samples were analyzed by the XRF instrument for three separate read periods of at least 30 seconds.

Sample results for the XRF confirmation samples and associated laboratory confirmation sample results are presented in *Section 4.0*. XRF sample logs are presented in **Appendix C-2**.

Table 3-1. Sampling Program for the ARSAR RFI/IM

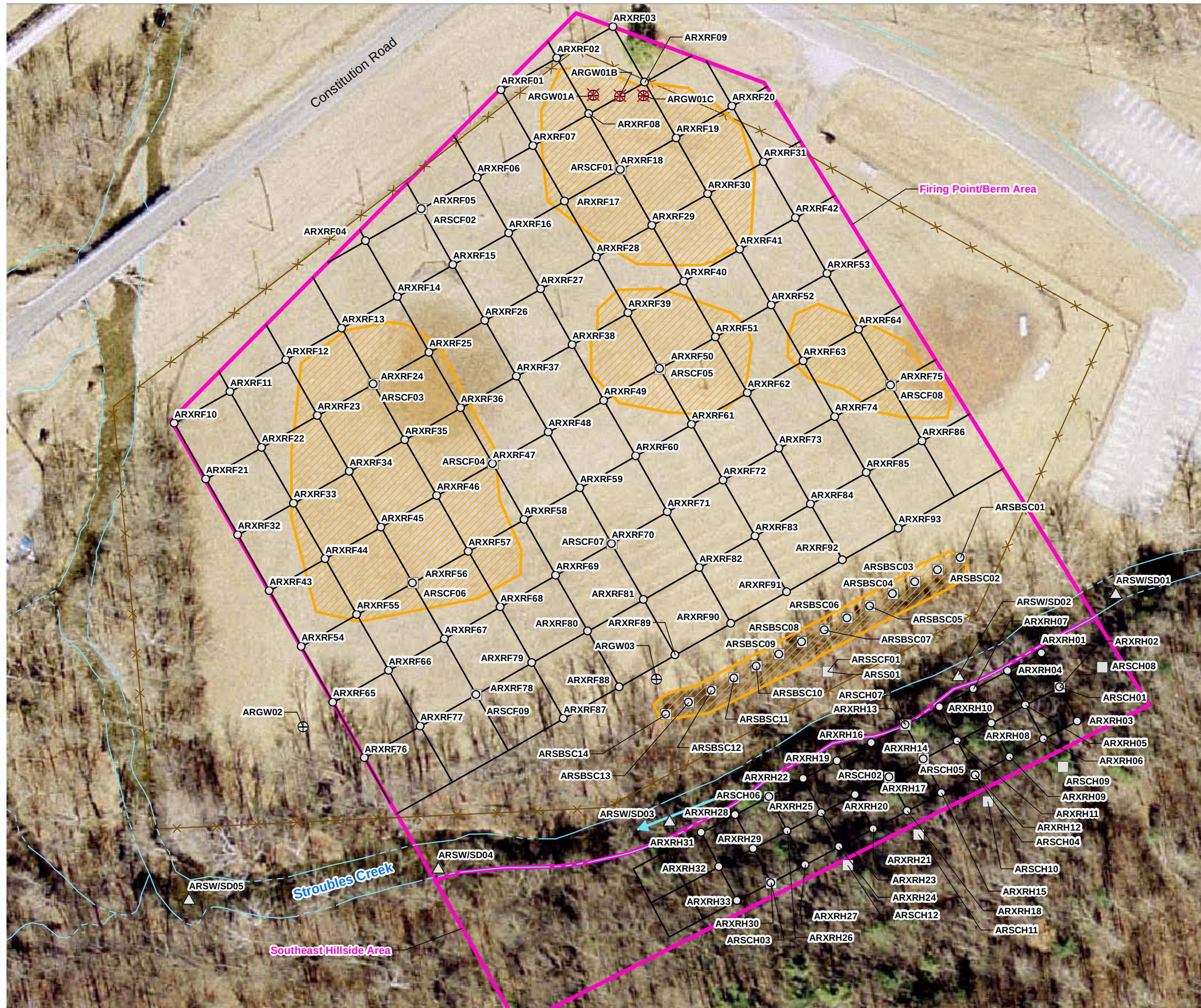
Media	Sampling ID	Depth	Location	Analytes
Soil	ARSBSC01 through ARSBSC14	0-0.5 ft bgs (following soil excavation)	One berm sample approximately every 20 ft	XRF Lead and Antimony. TAL Metals. 50% for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives
	ARXRF01 through ARXRF93	0-0.5 ft bgs	Potential firing areas and range floor	XRF Lead. A sufficient number of samples were collected and screened to define the extent of lead in the potential firing areas and range floor soil.
	ARSCF01 through ARSCF09	0-0.5 ft bgs	Random grid samples within potential firing areas and range floor	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals
	ARXRH01 through ARXR33	0-0.5 ft bgs	Southeast hillside	XRF Arsenic and Lead. A sufficient number of samples were collected and screened to assess arsenic in soil along the southeast hillside.
	ARSCH01 through ARSCH03 ARSCH09 ARSCH11	0-0.5 ft bgs	Southeast hillside	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals
	ARSCH04 through ARSCH08 ARSCH10 ARSCH12	0-0.5 ft bgs	Southeast hillside	TAL metals
	ARSSCF01	0-0.5 ft bgs	Building debris area	TCLP metals, asbestos
Groundwater	ARGW02	7.5-8	Downgradient well	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals (total and dissolved), and perchlorate
	ARGW03	10-10.5	Downgradient well	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals (total and dissolved), and perchlorate
Surface Water	ARSW01	na	Upgradient of MRS boundary in Stroubles Creek	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals, and perchlorate
	ARSW02	na	Behind berm in Stroubles Creek	TAL metals, explosives, perchlorate
	ARSW03	na	Behind berm in Stroubles Creek	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals, and perchlorate
	ARSW04	na	Downgradient Stroubles Creek	TAL metals, explosives, and perchlorate
	ARSW05	na	Downgradient Stroubles Creek	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals, and perchlorate

Table 3-1. Sampling Program for the ARSAR RFI/IM (Continued)

Media	Sampling ID	Depth	Location	Analytes
Sediment	ARSD01	na	Upgradient of MRS boundary in Stroubles Creek	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals
	ARSD02	na	Behind berm in Stroubles Creek	TAL metals and explosives
	ARSD03	na	Behind berm in Stroubles Creek	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals
	ARSD04	na	Downgradient Stroubles Creek	TAL metals and explosives
	ARSD05	na	Downgradient Stroubles Creek	TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals

Notes:

- 1) Refer to Appendix A-1, Table A-1 for the preparation and analytical methodologies used.
- 2) MS/MSD and rinse blank samples were collected at a frequency of 5% of the total environmental sample volume (not applicable for waste/borrow, asbestos, or XRF analysis).
- 3) Blind duplicate samples were collected at a frequency of 10% of the total environmental sample volume (not applicable for waste/borrow, asbestos, or XRF analysis).
- 4) Soil samples ARSBSC01 through ARSBSC14 were collected from the berm soil surface following the removal of the top 1-2 ft of soil during the IM; these samples now represent surface soil.



LEGEND

- Soil XRF Sample Location
- Soil Lab Confirmation Sample Location
- ⊗ Soil XRF & Lab Confirmation Sample Location
- △ Surface Water/Sediment Sample Location
- ⊕ Direct Push Groundwater Sample Location
- ⊗ Direct Push Groundwater Sample Location (Not Sampled; Failed to Encounter Groundwater)
- Water Feature
- Surface Water Flow Direction
- Fence Line
- XRF Sample Grid
- Historic Feature
- MRS Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).



Scale:
0 37.5 75 150
Feet



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FIGURE 3-1
Army Reserve Small Arms Range
Sample Locations
Radford Army Ammunition Plant,
Radford, VA

3.1.2 Firing Range Berm Sampling

As presented in **Table 3-1**, 14 surface soil samples (ARSBSC01 through ARSBSC14) were collected for XRF lead and antimony analysis. Following XRF screening, soil samples ARSBSC01 through ARSBSC14 were shipped to an off-site laboratory and analyzed for TAL metals to confirm the XRF results. In addition to TAL metals, 50 percent of the collected samples were also analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives and to fill data gaps identified following the SSP. Sample locations are displayed on **Figure 3-1**. XRF field screening and confirmation sampling results are presented in *Section 4.0*.

3.1.3 Firing Range Floor and Potential Firing Point Sampling

As presented in **Table 3-1**, 93 XRF samples (ARXRF01 through ARXRF93) were collected and screened for lead. Nine confirmation samples (ARSCF01 through ARSCF09) were collected and analyzed by an off-site laboratory for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals to serve as confirmation samples and to fulfill the identified data gaps. These samples were collected from randomly picked XRF screening grid cells in accordance with the systematic grid sampling strategy as defined in Standard Operating Procedure 30.7 of the MWP (URS, 2003). The sample locations are depicted on **Figure 3-1**. XRF field screening results and confirmation sampling results are presented in *Section 4.0*.

3.1.4 Southeast Hillside Sampling

Thirty-three soil samples (ARXRH01 through ARXRH33) were collected and screened for XRF arsenic and lead, as presented in **Table 3-1**. Seven confirmation soil samples (ARSCH01 through ARSCH07) were randomly picked from XRF screening locations in accordance with the systematic grid sampling strategy defined in Standard Operating Procedure 30.7 of the MWP (URS, 2003) and sent to an off-site laboratory to serve as confirmation samples for the XRF and to fulfill the data gaps associated with the Southeast Hillside Area. Three of the seven samples (ARSCH01, ARSCH02, and ARSCH03) were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals. Soil samples ARSCH04 through ARSCH07 were analyzed for TAL metals only.

Five additional soil samples (ARSCH08 through ARSCH12) were collected outside the established grid to assess the extent of elevated arsenic and determine whether there was a correlation between elevated lead and elevated arsenic concentrations in soil, which would indicate that the arsenic is the result of the sites past use. Samples ARSCH08 through ARSCH12 were all analyzed for TAL metals. Soil samples ARSCH09 and ARSCH11 were also analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives. Sample locations are shown on **Figure 3-1**. XRF field screening results and confirmation sampling results are presented in *Section 4.0*.

3.1.5 Debris Sampling

One debris sample (ARSS01) was collected during the initial site reconnaissance in 2010 from a green piece of conductive flooring material that was attached to a piece of concrete within the building debris area. In 2011, one soil sample (ARSSCF01) was collected prior construction debris removal activities from the soil directly beneath conductive flooring material and concrete within the building debris area. These samples were analyzed for TCLP metals and asbestos.

The green material found on the concrete debris comprised a small percentage of the total debris (<5 percent). The locations of the samples are illustrated on **Figure 3-1**. Sample results are discussed in *Section 4.0*.

3.2 Surface Water and Sediment Sampling

As shown in **Table 3-1** and **Figure 3-1**, five surface water and sediment pairs (ARSW/SD01 through ARSW/SD05) were collected from collocated locations in Stroubles Creek. These samples were collected to assess the fate and transport of the ARSAR constituents and evaluate whether these constituents are impacting Stroubles Creek.

Surface water samples ARSW01, ARSW03, and ARSW05 were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals, and perchlorate. Surface water samples ARSW02 and ARSW04 were analyzed for TAL metals, explosives, and perchlorate. Sample results are discussed in *Section 4.0*.

Sediment samples ARSD01, ARSD03, and ARSD05 were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals. Sediment samples ARSD02 and ARSD04 were analyzed for TAL metals and explosives. Sample results are discussed in *Section 4.0*.

3.3 Groundwater Sampling

Groundwater had not previously been sampled at the ARSAR. Three direct-push samples (ARGW01 through ARGW03) were proposed in the *RFI/IMWP for the ARSAR* (Shaw, 2011). Due to safety concerns involving overhead power lines directly above the location originally proposed for ARGW01 in Shaw (2011), the sample location was relocated inside the ARSAR fence. During the advancement of the boring for ARGW01, bedrock refusal was encountered in three offset locations (**Figure 3-1**) prior to reaching the groundwater table. As a result, groundwater sample ARGW01 was not collected. Two direct-push groundwater samples (ARGW02 and ARGW03) were collected from the locations depicted on **Figure 3-1**. Groundwater samples were collected and analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides, PCBs, herbicides, TAL metals, and perchlorate. Sample results are discussed in *Section 4.0*.

3.4 Global Positioning System Activities

Sample location coordinates for the target berm, range floor, southeast hillside, sediment/surface water, and groundwater samples were obtained using a Trimble Geo XH Global Positioning System. The Geo HX system was used to obtain real-time position information with sub-meter accuracy. Horizontal positioning information was recorded in the U.S. State Plane [Virginia (South)] Coordinate System (measured in U.S. survey feet) using the North American Datum of 1983.

3.5 Quality Assurance

The accuracy and integrity of the 2011 RFI and IM laboratory data was ensured through the implementation of internal quality control (QC) measures in accordance with Radford's MWP (URS, 2003) and the *RFI/IMWP for the ARSAR* (Shaw, 2011), as approved by USEPA Region III and the VDEQ. Quality assurance (QA) and QC activities, including field QC, laboratory QC, data management, and data validation were integrated into the investigation program to meet data quality objectives (DQOs) established for the RFI and IM. The data were evaluated

for each of the DQO indicators in **Appendix A-2** and found to meet the pre-established goals. Qualified data did not impact the data quality of the RFI and IM. Complete details of the RFI QA/QC analysis and activities are presented in **Appendix A-2**. Chemical data validation reports and Form 1 data are provided in **Appendix A-3**.

3.5.1 Modifications to the Sampling Plan

In some cases, modifications to the Work Plan were necessary to adjust for field conditions as they occurred during field sampling. Adjustments to the *RFI/IMWP for the ARSAR* (Shaw, 2011) were necessary during sampling activities at the ARSAR. These adjustments included the following:

- Thirteen soil samples were proposed to be collected for chemical analysis along the target berm. As part of the berm investigation, one additional sample was collected for XRF screening and laboratory confirmation analysis for a total of 14 samples.
- Ninety XRF samples were proposed to be collected within the firing range floor grid. An additional three samples were collected and screened for XRF analysis for a total of 93 samples.
- Thirty soil samples were proposed to be collected for XRF screening within the Southeast Hillside Area. Three additional samples were collected for XRF screening for a total of 33 samples.
- Three soil samples were proposed to confirm XRF screening results within the Southeast Hillside Area. An additional four samples were collected for a total of seven confirmation samples.
- Five additional soil samples were collected outside of the established grid along the Southeast Hillside Area. These samples were collected to assess the extent of elevated arsenic and determine whether there was a correlation between elevated lead and elevated arsenic, which would indicate that the arsenic is the result of the sites past use.
- Three direct-push groundwater samples were proposed to be collected at the ARSAR. The water table was not encountered in proposed location ARGW01 or any of the three offset locations prior to reaching refusal on weathered bedrock. Therefore, only two direct-push groundwater samples were collected at the site.

4.0 NATURE AND EXTENT OF CONTAMINATION

The following sections provide a discussion of the site conditions and the nature and extent of chemicals found in soil, sediment, surface water, and groundwater within the ARSAR site. The distribution and concentrations of the chemicals and parameter groups (i.e., VOCs, SVOCs, etc.) are evaluated for source locations, migration pathways, hotspots, and potential disposition areas. The laboratory analytical data is presented in **Appendix C-1**. Completed chain-of-custody forms for the shipments of samples to the laboratory are presented in **Appendix C-3**.

Soil/Sediment Screening. Chemical results from soil and sediment samples are compared to adjusted USEPA Regional industrial screening levels (i-SLs) and residential screening levels (r-SLs) (USEPA, 2012b), as well as facility-wide background inorganic concentrations (IT, 2001), and other regulatory criteria. I-SLs and r-SLs were adjusted downward to a hazard index (HI) of 0.1 for non-carcinogenic compounds to ensure that chemicals with additive effects are not prematurely eliminated during screening.

Current screening levels (SLs) (November, 2012) and background 95 percent upper tolerance limits are presented for comparison in the soil and sediment result tables. Analytical results for inorganics in soil are indicated on the tables and figures as constituents of concern when they were above both the background value and a screening value. Eliminating analytes as constituents of concern when they are above an SL but below their background value allows site-specific constituents to be more clearly indicated on the tables and figures. Soil and sediment results from the 2011 RFI are presented in the following sections.

Surface Water/Groundwater Screening. Surface water and groundwater sampling results are compared to the 2012 Edition of the Drinking Water Standards and Health Advisories [i.e., maximum contaminant levels (MCLs) and secondary MCLs] (USEPA, 2012a) and adjusted tap water screening levels (tw-SLs) (USEPA, 2012b). Consistent with soil screening, tw-SLs were adjusted downward to an HI of 0.1 for non-carcinogenic compounds to ensure that chemicals with additive effects are not prematurely eliminated during screening. Groundwater results from the 2011 RFI are presented in the following sections.

4.1 Soil

4.1.1 Firing Range Berm Analytical Results

XRF Results. An IM was performed for the berm as a presumptive remedy to eliminate the major source of contamination at the site and streamline the RFI process (refer to *Section 2.7.3*). Following the removal of the top 1-2 ft of soil from the firing range berm, 14 surface soil samples (ARSBSC01 through ARSBSC14) were collected from 0-0.5 ft bgs and screened for lead and antimony using an XRF. Lead results obtained during the XRF screening are presented in **Table 4-1** and illustrated on **Figure 4-1**. As shown in **Table 4-1** and illustrated on **Figure 4-1**, XRF lead screening results indicated that concentrations of lead were below the r-RG of 400 mg/kg within the target berm following the removal of the top 1-2 ft of soil from the top and face of the berm. As also shown on **Table 4-1**, antimony was not detected in any of the 14 samples collected.

Laboratory Results. All 14 samples screened by XRF for lead and antimony were also sent to an off-site lab and tested for TAL metals. In addition to TAL metals, 50 percent of the collected samples were also analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs,

Table 4-1
Target Berm Soil Sample Results

Location	Depth (ft bgs)*	XRF Concentration		Lab Concentration	
		Lead (mg/kg)	Antimony (mg/kg)	Lead (mg/kg)	Antimony (mg/kg)
ARSBSC01	0-0.5	16.77	<100.29	11.3	1.4
ARSBSC02	0-0.5	16.16	<99.52	9.8	0.39
ARSBSC03	0-0.5	22.88	<140.97	25.2	0.55
ARSBSC04	0-0.5	20.22	<99.69	12.6	0.13
ARSBSC05	0-0.5	20.37	<103.84	14.7	0.24
ARSBSC06	0-0.5	237.18	<102.86	259	1
ARSBSC07	0-0.5	41.69	<102.42	18.1	0.2
ARSBSC08	0-0.5	206.19	<110.40	207	0.19
ARSBSC09	0-0.5	16.08	<101.43	24.6	0.18
ARSBSC10	0-0.5	14.15	<101.40	12.6	0.22
ARSBSC11	0-0.5	23.32	<99.01	18	0.12
ARSBSC12	0-0.5	18.57	<101.71	11.5	<0.098
ARSBSC13	0-0.5	13.64	<102.38	11.7	<0.097
ARSBSC14	0-0.5	18.73	<99.42	79	0.12

* Samples were collected from the berm soil surface following the removal of the top 1-2 ft of soil during the IM.

herbicides, and explosives. As indicated on **Table 4-2** and **Figure 4-2**, no analytes were detected above SLs in the berm soil. Detected results are presented in **Table 4-2** and summarized in **Table 4-3**.

TAL Metals. Twenty-three TAL metals were detected in the confirmation samples collected at the target berm. Three metals [copper (one sample), lead (three samples), and mercury (one sample)] were detected at concentrations exceeding RFAAP background SLs. None of the detected metals were present at concentrations exceeding r-SLs or i-SLs. Lead and antimony concentrations were below the established residential RGs in all 14 samples, confirming the XRF results.

VOCs. One VOC (benzene) was detected in the samples. Benzene was only detected in one single sample (ARSBSC01) at a concentration well below its r-SL and i-SL.

SVOCs/PAHs. Four SVOCs/PAHs [benzo(b)fluoranthene, chrysene, fluoranthene, and phenanthrene] were detected in the berm samples; however, none of the detected SVOCs exceeded the i-SL or r-SL.

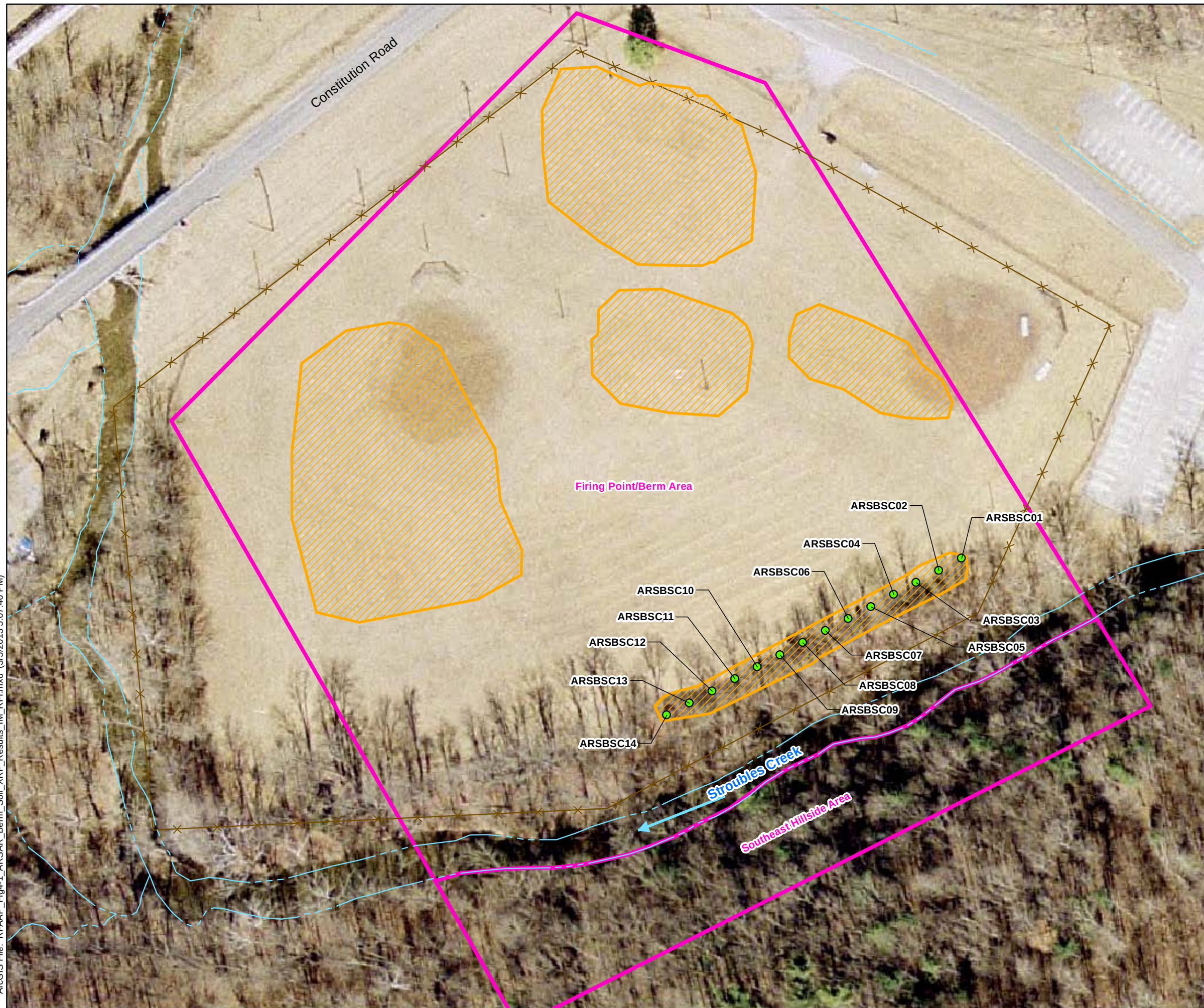
Pesticides. Three pesticides (4,4'-DDT, endrin, and methoxychlor) were each detected in one different berm sample. Detected concentrations did not exceed their respective r-SLs or i-SLs.

PCBs. PCBs were not detected in the target berm samples.

Explosives. Explosives were not detected in the target berm samples.

Herbicides. Herbicides were not detected in the target berm samples.

ArcGIS File: RFAAP_Fig4-1_ARSAR_Berm_Soil_XRF_Results_IM_RFI.mxd (3/5/2013 5:07:46 PM)



LEGEND

XRF Sample Location Lead Results

- < 400 mkg/kg
- > 400 mkg/kg
- Water Feature
- ➔ Surface Water Flow Direction
- x— Fence Line
- Historic Feature
- MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
- 3) Soil results are from 2011.



Scale:
0 37.5 75 150
Feet



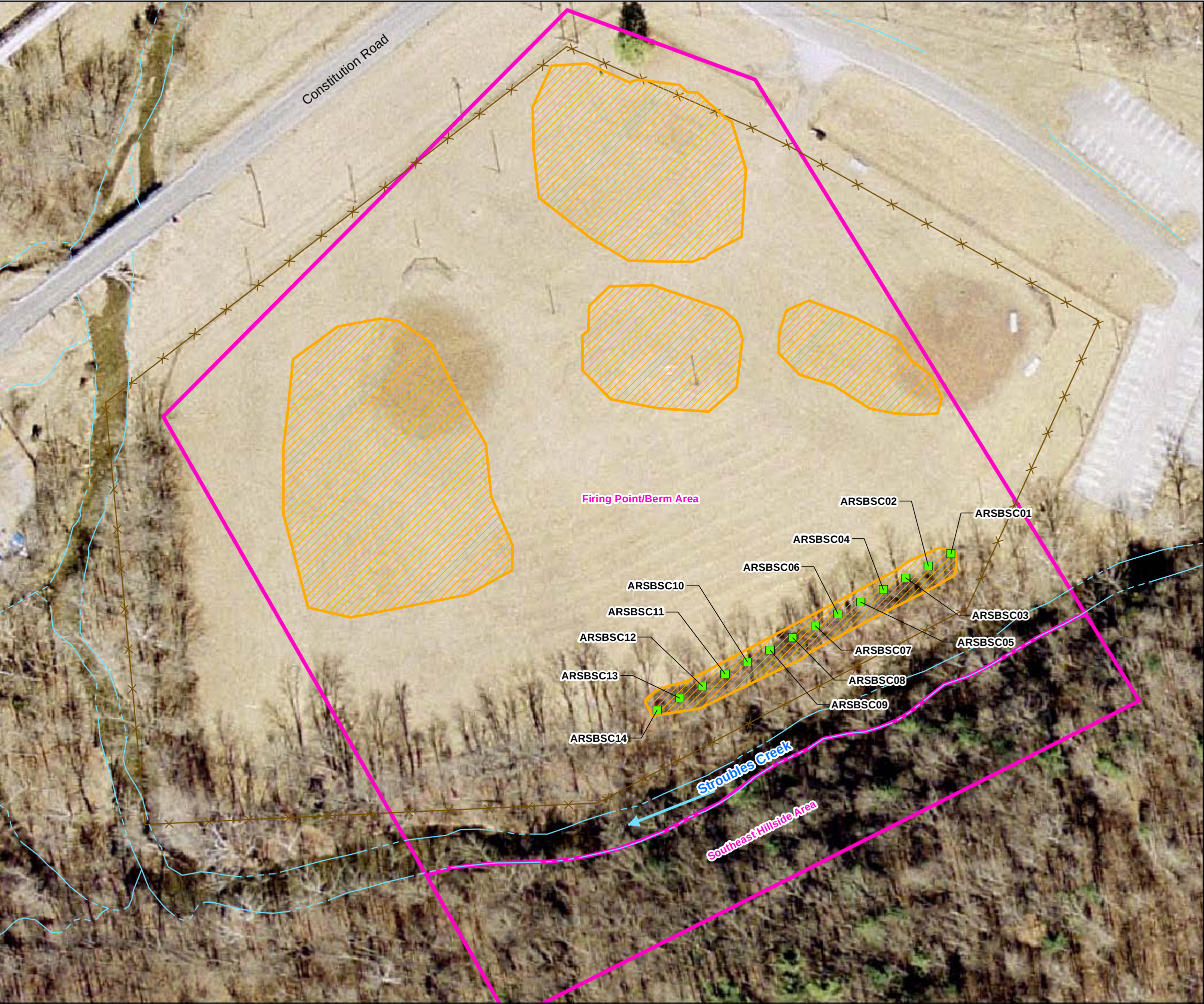
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FIGURE 4-1

Army Reserve Small Arms Range
Berm - Soil XRF Screening Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: RFAAP_Fig4-2_ARSA_Berm_Soil_Lab_Results_IM_RFI.mxd (3/5/2013 5:08:48 PM)



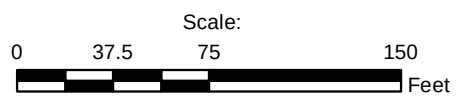
LEGEND

Lab Confirmation Location Results

- Soil Sample Location Result $\leq$ r-SL
- Soil Sample Location Result $\geq$ r-SL, but $\leq$ i-SL
- Soil Sample Location Result $\geq$ i-SL
- Water Feature
- Surface Water Flow Direction
- Fence Line
- Historic Feature
- MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
- 3) Soil results are from 2011.
- 4) Soil SLs were obtained from the USEPA Mid-Atlantic Region Regional Screening Level Summary Table, November 2012.



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FIGURE 4-2

Army Reserve Small Arms Range
Berm - Soil Lab Confirmation Results

Radford Army Ammunition Plant,
Radford, VA

Table 4-2
Analytes Detected in Laboratory Confirmation Berm Samples
Page 1 of 2

Analyte	Sample ID Sample Date Sample Depth			ARSBSC01 5/11/11 1-2					ARSBSC02 5/11/11 1-2					ARSBSC03 5/11/11 1-2					ARSBSC04 5/11/11 1-2					ARSBSC05 5/11/11 1-2					ARSBSC06 5/11/11 1-2					ARSBSC07 5/11/11 1-2				
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL					
VOCs (ug/kg)																																						
Benzene	5600	1100	na	13	J	J	5.8	58	NT					49	U		4.9	49	NT					63	U		6.3	63	NT					47	U		4.7	47
SVOCs/PAH (ug/kg)																																						
Benzo(b)fluoranthene	2100	150	na	1.1	J	J	0.51	3.8	NT					3.5	U		0.47	3.5	NT					3.7	U		0.49	3.7	NT					3.7	U		0.49	3.7
Chrysene	210000	15000	na	3.8	U		0.44	3.8	NT					3.5	U		0.41	3.5	NT					3.7	U		0.43	3.7	NT					2.2	J	J	0.43	3.7
Fluoranthene	2200000	230000	na	0.89	J	J	0.46	3.8	NT					3.5	U		0.42	3.5	NT					3.7	U		0.44	3.7	NT					3.7	U		0.44	3.7
Phenanthrene	1700000	170000	na	3.8	U		0.57	3.8	NT					3.5	U		0.52	3.5	NT					3.7	U		0.55	3.7	NT					3.7	U		0.55	3.7
Pesticides (ug/kg)																																						
4,4'-DDT	7000	1700	na	2	J	J	0.63	3	NT					2.8	U		0.58	2.8	NT					2.9	U		0.61	2.9	NT					3	U		0.62	3
Endrin	18000	1800	na	3	U		0.51	3	NT					2.8	U		0.47	2.8	NT					2.9	U		0.49	2.9	NT					3	U		0.5	3
Methoxychlor	310000	31000	na	3	U		0.88	3	NT					2.8	U		0.82	2.8	NT					2.9	U		0.86	2.9	NT					3	U		0.87	3
PCBs (mg/kg)																																						
None detected																																						
Explosives (mg/kg)																																						
None detected																																						
Herbicides (ug/kg)																																						
None detected																																						
Metals (mg/kg)																																						
Aluminum	99000	7700	40041	15400	M	J	0.051	0.3	13700		J	0.049	0.29	11100		J	0.047	0.28	8240		J	0.046	0.28	15700		J	0.049	0.3	12300		J	0.047	0.28	14000		J	0.049	0.3
Antimony	41	3.1	na	1.4	JV	L	0.51	3.4	0.39	J	L	0.097	0.66	0.55	J	L	0.094	0.64	0.13	J	L	0.092	0.62	0.24	J	L	0.099	0.67	1		L	0.095	0.64	0.2	J	L	0.099	0.67
Arsenic	1.6	0.39	15.8	2	M	L	0.16	1.1	2.2		L	0.16	1.1	2.3		L	0.15	1.1	2.9		L	0.15	1	2.8		L	0.16	1.1	3.3		L	0.15	1.1	2.3		L	0.16	1.1
Barium	19000	1500	209	74.3	B	J	0.051	0.3	38.2	B	J	0.009	0.058	58.5	B	J	0.009	0.056	44.2	B	J	0.009	0.055	37.9	B	J	0.009	0.059	42.1	B	J	0.009	0.057	38	B	J	0.009	0.059
Beryllium	200	16	1.02	0.011	JM	J	0.005	0.03	0.045			0.004	0.029	0.066			0.004	0.028	0.072			0.004	0.028	0.0049	U		0.004	0.03	0.068			0.004	0.028	0.08			0.004	0.03
Cadmium	80	7	0.69	0.0076	U	UL	0.007	0.053	0.0073	U	UL	0.007	0.051	0.0071	U	UL	0.007	0.049	0.036	J	L	0.006	0.049	0.0074	U	UL	0.007	0.052	0.019	J	L	0.007	0.05	0.0074	U	UL	0.007	0.052
Calcium	na	na	na	499		J	0.076	1.1	598		J	0.073	1.1	482		J	0.071	1.1	387		J	0.069	1	254		J	0.074	1.1	486		J	0.071	1.1	244		J	0.074	1.1
Chromium	150000	12000	65.3	26.3		K	0.024	0.32	46.1		K	0.023	0.3	26.5		K	0.022	0.29	18.5		K	0.022	0.29	40.6		K	0.023	0.31	32.3		K	0.023	0.3	25.4		K	0.023	0.31
Cobalt	30	2.3	72.3	4.5			0.095	0.62	3.4			0.018	0.12	5.8			0.018	0.12	7.5			0.017	0.11	5.6			0.018	0.12	15.5			0.018	0.12	5.5			0.019	0.12
Copper	4100	310	53.5	6.4		J	0.076	0.48	5.6		J	0.073	0.46	8		J	0.071	0.45	4.4		J	0.069	0.44	7.2		J	0.074	0.47	32.6		J	0.071	0.45	6.5		J	0.074	0.47
Iron	72000	5500	50962	47900		J	1.9	11	25100		J	0.36	2.2	21500		J	0.35	2.1	14400		J	0.35	2.1	28800		J	0.37	2.2	24300		J	0.36	2.1	25400		J	0.37	2.2
Lead	800	400	26.8	11.3	M	J	0.051	0.3	9.8		J	0.049	0.29	25.2		J	0.047	0.28	12.6		J	0.046	0.28	14.7		J	0.049	0.3	259		J	0.047	0.28	18.1		J	0.049	0.3
Magnesium	na	na	na	635		J	0.15	0.91	598		J	0.15	0.87	450		J	0.14	0.85	405		J	0.14	0.83	403		J	0.15	0.89	442		J	0.14	0.85	454		J	0.15	0.89
Manganese	2300	180	2543	386		K	0.1	0.76	229		K	0.019	0.15	435		K	0.019	0.14	621		K	0.018	0.14	490		K	0.02	0.15	694		K	0.019	0.14	202		K	0.02	0.15
Mercury	4.3	1.0	0.13	0.092	Y	J	0.002	0.01	0.13		J	0.002	0.01	0.058		J	0.002	0.009	0.091		J	0.002	0.009	0.068		J	0.002	0.01	0.087		J	0.002	0.009	0.12		J	0.002	0.01
Nickel	2000	150	62.8	3.7		J	0.023	0.15	3.2		J	0.022	0.15	3.2		J	0.021	0.14	2.9		J	0.021	0.14	4.2		J	0.022	0.15	3.3		J	0.021	0.14	4		J	0.022	0.15
Potassium	na	na	na	341		L	14	180	373		L	13	170	426		L	13	170	285		L	13	170	369		L	14	180	501		L	13	170	448		L	14	180
Selenium	510	39	na	0.83		L	0.088	0.53	0.52		L	0.085	0.51	0.61		L	0.082	0.49	0.62		L	0.081	0.49	0.67		L	0.086	0.52	0.83		L	0.083	0.5	0.62		L	0.086	0.52
Silver	510	39	na	0.021	U		0.021	0.28	0.021	U		0.021	0.27	0.02	U		0.02	0.26	0.02	U		0.02	0.25	0.021	U		0.021	0.27	0.02	U		0.02	0.26	0.021	U		0.021	0.27
Sodium	na	na	na	5.1	U		5.1	66	4.9	U		4.9	63	4.7	U		4.7	61	4.6	U		4.6	60	4.9	U		4.9	64	22.7	JB	J	4.7	62	4.9	U		4.9	64
Thallium	1	0.078	2.11	0.23	JB	B	0.051	0.71	0.28	JB	L	0.049	0.68	0.28	JB	L	0.047	0.66	0.48	JB	L	0.046	0.65	0.41	JB	L	0.049	0.69	0.52	J	L	0.047	0.66	0.24	JB	B	0.049	0.69
Vanadium	520	39	108	48.4		J	0.014	0.18	45.5		J	0.013	0.17	38.2		J	0.013	0.16	26.4		J	0.013	0.16	51.4		J	0.014	0.17	43.6		J	0.013	0.17	45.1		J	0.014	0.17
Zinc	31000	2300	202	15		J	0.051	0.61	12		J	0.049	0.58	11.8		J	0.047	0.56	10.3		J	0.046	0.55	15.2		J	0.049	0.59	17		J	0.047	0.57	16.2		J	0.049	0.59

**Refer to legend immediately following this table for a list of definitions and table notes.

Table 4-2
Analytes Detected in Laboratory Confirmation Berm Samples
Page 2 of 2

Analyte	Sample ID Sample Date Sample Depth			ARSBSC08 5/11/11 1-2					ARSBSC09 5/11/11 1-2					ARSBSC10 5/11/11 1-2					ARSBSC11 5/11/11 1-2					ARSBSC12 5/11/11 1-2					ARSBSC13 5/11/11 1-2					ARSBSC14 5/11/11 1-2				
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL					
VOCs (ug/kg)																																						
Benzene	5600	1100	na	NT					60	U		6	60	NT					51	U		5.1	51	NT					65	U		6.5	65	NT				
SVOCs/PAH (ug/kg)																																						
Benzo(b)fluoranthene	2100	150	na	NT					3.6	U		0.48	3.6	NT					3.8	U		0.5	3.8	NT					3.7	U		0.49	3.7	NT				
Chrysene	210000	15000	na	NT					2.3	J	J	0.42	3.6	NT					2.3	J	J	0.44	3.8	NT					3.7	U		0.43	3.7	NT				
Fluoranthene	2200000	230000	na	NT					3.6	U		0.43	3.6	NT					3.8	U		0.45	3.8	NT					3.7	U		0.44	3.7	NT				
Phenanthrene	1700000	170000	na	NT					3.6	U		0.54	3.6	NT					3.8	U		0.56	3.8	NT					1.3	J	J	0.55	3.7	NT				
Pesticides (ug/kg)																																						
4,4'-DDT	7000	1700	na	NT					2.9	U		0.6	2.9	NT					3	U		0.63	3	NT					2.9	U		0.61	2.9	NT				
Endrin	18000	1800	na	NT					12	P	J	0.48	2.9	NT					3	U		0.51	3	NT					2.9	U		0.48	2.9	NT				
Methoxychlor	310000	31000	na	NT					2.9	U		0.83	2.9	NT					3.5			0.88	3	NT					2.9	U		0.85	2.9	NT				
PCBs (mg/kg)																																						
None detected																																						
Explosives (mg/kg)																																						
None detected																																						
Herbicides (ug/kg)																																						
None detected																																						
Metals (mg/kg)																																						
Aluminum	99000	7700	40041	14400		J	0.047	0.28	16200		J	0.048	0.29	16100		J	0.048	0.29	16800		J	0.05	0.3	15300		J	0.049	0.29	17900	B	J	0.049	0.29	17000	B	J	0.049	0.29
Antimony	41	3.1	na	0.19	J	L	0.094	0.64	0.18	J	L	0.096	0.65	0.22	J	L	0.097	0.65	0.12	J	L	0.1	0.68	0.098	U	UL	0.098	0.66	0.097	U	UL	0.097	0.66	0.12	J	L	0.098	0.66
Arsenic	1.6	0.39	15.8	3.1		L	0.15	1.1	3.6		L	0.16	1.1	2.3		L	0.16	1.1	1.9		L	0.16	1.1	2		L	0.16	1.1	2.5		L	0.16	1.1	6.8		L	0.16	1.1
Barium	19000	1500	209	29.4	B	J	0.009	0.057	35.8		J	0.009	0.057	37.1		J	0.009	0.058	41.8		J	0.01	0.06	42.8		J	0.009	0.059	40.5		J	0.009	0.058	70.7		J	0.009	0.059
Beryllium	200	16	1.02	0.095			0.004	0.028	0.088		J	0.004	0.029	0.032			0.004	0.029	0.005	U		0.005	0.03	0.0072	J	J	0.004	0.029	0.0049	U		0.004	0.029	0.0049	U		0.004	0.029
Cadmium	80	7	0.69	0.0071	U	UL	0.007	0.05	0.0072	U	UL	0.007	0.05	0.0072	U	UL	0.007	0.051	0.0075	U	UL	0.007	0.053	0.0073	U	UL	0.007	0.051	0.0073	U	UL	0.007	0.051	0.051		L	0.007	0.051
Calcium	na	na	na	270		J	0.071	1.1	277		J	0.072	1.1	679		J	0.072	1.1	609		J	0.075	1.1	419		J	0.073	1.1	359		J	0.073	1.1	405		J	0.073	1.1
Chromium	150000	12000	65.3	30.1		K	0.022	0.3	28.2		J	0.023	0.3	25.3		K	0.023	0.3	28		K	0.024	0.31	22.9		K	0.023	0.31	26.7		K	0.023	0.3	39.6		K	0.023	0.3
Cobalt	30	2.3	72.3	3.5			0.018	0.12	10.4		R	0.018	0.12	4.3			0.018	0.12	3.8			0.019	0.12	3.6			0.018	0.12	4.3			0.018	0.12	19.3			0.018	0.12
Copper	4100	310	53.5	80.3		J	0.071	0.45	7		J	0.072	0.45	7.5		J	0.072	0.46	8		J	0.075	0.48	7.8		J	0.073	0.46	9.2		J	0.073	0.46	8.3		J	0.073	0.46
Iron	72000	5500	50962	27100		J	0.35	2.1	29200		J	0.36	2.2	26800		J	0.36	2.2	30000		J	0.38	2.3	27300		J	0.37	2.2	33800		J	1.8	11	38900		J	1.8	11
Lead	800	400	26.8	207		J	0.047	0.28	24.6		J	0.048	0.29	12.6		J	0.048	0.29	18		J	0.05	0.3	11.5		J	0.049	0.29	11.7		J	0.049	0.29	79		J	0.049	0.29
Magnesium	na	na	na	366		J	0.14	0.85	421		J	0.14	0.86	625		J	0.14	0.87	678		J	0.15	0.9	627		J	0.15	0.88	690		J	0.15	0.88	692		J	0.15	0.88
Manganese	2300	180	2543	202		K	0.019	0.14	896		R	0.019	0.14	228			0.019	0.14	215			0.02	0.15	221			0.02	0.15	206			0.019	0.15	1910			0.02	0.15
Mercury	4.3	1.0	0.13	0.11		J	0.002	0.009	0.12		J	0.002	0.009	0.11		J	0.002	0.01	0.088		J	0.002	0.01	0.07		J	0.002	0.01	0.071		J	0.002	0.01	0.07		J	0.002	0.01
Nickel	2000	150	62.8	3		J	0.021	0.14	3.5		J	0.022	0.14	3.7		J	0.022	0.14	4.9		J	0.023	0.15	4.9		J	0.022	0.15	6.1		J	0.022	0.15	5.3		J	0.022	0.15
Potassium	na	na	na	351		L	13	170	341		L	13	170	399		L	13	170	499		L	14	180	434		L	13	180	636		L	13	180	518		L	13	180
Selenium	510	39	na	0.54		L	0.083	0.5	1		J	0.084	0.5	0.52		L	0.085	0.51	0.42	J	L	0.088	0.53	0.33	J	L	0.086	0.51	0.17	UV	UL	0.17	1	1.5		L	0.17	1
Silver	510	39	na	0.02	U		0.02	0.26	0.02	U		0.02	0.26	0.021	U		0.021	0.27	0.021	U		0.021	0.28	0.021	U		0.021	0.27	0.021	U		0.021	0.27	0.035	J	J	0.021	0.27
Sodium	na	na	na	4.7	U		4.7	61	4.8	U		4.8	62	4.8	U		4.8	63	5	U		5	65	4.9	U		4.9	64	4.9	U		4.9	63	4.9	U		4.9	63
Thallium	1	0.078	2.11	0.23	JB	B	0.047	0.66	0.77		R	0.048	0.67	0.28	JB	L	0.048	0.68	0.23	JB	B	0.05	0.7	0.26	JB	B	0.049	0.68	0.26	JB	B	0.049	0.68	1.3		L	0.049	0.68
Vanadium	520	39	108	46.9		J	0.013	0.17	52.6		J	0.013	0.17	47.1		J	0.013	0.17	55.9		J	0.014	0.18	50.1		J	0.013	0.17	70		J	0.013	0.17	76.5		J	0.013	0.17
Zinc	31000	2300	202	20		J	0.047	0.57	12.5		J	0.048	0.57	13.7		J	0.048	0.58	20		J	0.05	0.6	19.2		J	0.049	0.59	26.1		J	0.049	0.58	21		J	0.049	0.59

**Refer to legend immediately following this table for a list of definitions and table notes.

Table 4-2
Legend

<u>12</u>	<u>J</u>	Bold, underlined font indicates a background exceedance.
12	12	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

SLs for non-Carcinogenic compounds have been recalculated to an HI of 0.1.

The pyrene SLs were used for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene.

Inorganic results below background UTLs are not indicated as exceedances on the table.

SL = Screening Level (Source: ORNL Regional Screening Table, November 2012).

Lead screening values from Technical Review Workgroup for Lead: Guidance Document (USEPA, 1999).

mg/kg = milligrams per kilogram (parts per million).

µg/kg = micrograms per kilogram (parts per billion).

NA = not applicable.

NT = analyte not tested.

Lab Q = Lab Data Qualifiers

B = (organics) Blank contamination. Value detected in sample and associated blank.

J = (organics) Value <MRL and >MDL and is considered estimated.

M = Matrix spike and/or matrix spike duplicate recovery outside acceptance limits.

P = Concentration of analyte differs more than 40% between primary and confirmation analysis

U = Analyte not-detected at the method reporting limit.

V = Raised Quantitation or Reporting Limit due to limited sample amount or dilution for matrix background interference.

Y = Replicate/Duplicate precision outside acceptance limits.

Val Q = Validation Data Qualifiers

B = blank contamination. Value detected in sample and associated blank.

J = estimated concentration.

K = estimated concentration bias high.

L = estimated concentration bias low.

R = The quality control associated with the analysis or analyte indicates severe uncertainty with the reported result. The analyte was analyzed for, but the presence or absence of the analyte has not been verified.

UL = estimated concentration non-detect bias low.

Table 4-3
Summary of Analytes Detected in Laboratory Confirmation Berm Samples

Analyte	i-SL	r-SL	Background	# of i-SL Exceedances	# of r-SL Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/kg)											
Benzene	5400	1100	na	0	0	na	1	7	13	13	ARSBSC01
SVOCs/PAH (ug/kg)											
Benzo(b)fluoranthene	2100	150	na	0	0	na	1	7	1.1	1.1	ARSBSC01
Chrysene	210000	15000	na	0	0	na	3	7	2.2	2.3	ARSBSC09
Fluoranthene	2200000	230000	na	0	0	na	1	7	0.89	0.89	ARSBSC01
Phenanthrene	1700000	170000	na	0	0	na	1	7	1.3	1.3	ARSBSC13
Pesticides (ug/kg)											
4,4'-DDT	7000	1700	na	0	0	na	1	7	2	2	ARSBSC01
Endrin	18000	1800	na	0	0	na	1	7	12	12	ARSBSC09
Methoxychlor	310000	31000	na	0	0	na	1	7	3.5	3.5	ARSBSC11
PCBs (mg/kg) None detected											
Explosives (mg/kg) None detected											
Herbicides (ug/kg) None detected											
Metals (mg/kg)											
Aluminum	99000	7700	40041	0	0	0	14	14	8240	17900	ARSBSC13
Antimony	41	3.1	na	0	0	na	12	14	0.12	1.4	ARSBSC01
Arsenic	1.6	0.39	15.8	0	0	0	14	14	1.9	6.8	ARSBSC14
Barium	19000	1500	209	0	0	0	14	14	29.4	74.3	ARSBSC01
Beryllium	200	16	1.02	0	0	0	10	14	0.0072	0.095	ARSBSC08
Cadmium	80	7	0.69	0	0	0	3	14	0.019	0.051	ARSBSC14
Calcium	na	na	na	na	na	na	14	14	244	679	ARSBSC10
Chromium	150000	12000	65.3	0	0	0	14	14	18.5	46.1	ARSBSC02
Cobalt	30	2.3	72.3	0	0	0	13	14	3.4	19.3	ARSBSC14
Copper	4100	310	53.5	0	0	1	14	14	4.4	80.3	ARSBSC08
Iron	72000	5500	50962	0	0	0	14	14	14400	47900	ARSBSC01
Lead	800	400	26.8	0	0	3	14	14	9.8	259	ARSBSC06
Magnesium	na	na	na	na	na	na	14	14	366	692	ARSBSC14
Manganese	2300	180	2543	0	0	0	13	14	202	1910	ARSBSC14
Mercury	4.3	1.0	0.13	0	0	1	14	14	0.058	0.13	ARSBSC02
Nickel	2000	150	62.8	0	0	0	14	14	2.9	6.1	ARSBSC13
Potassium	na	na	na	na	na	na	14	14	285	636	ARSBSC13
Selenium	510	39	na	0	0	na	13	14	0.33	1.5	ARSBSC14
Silver	510	39	na	0	0	na	1	14	0.035	0.035	ARSBSC14
Sodium	na	na	na	na	na	na	1	14	22.7	22.7	ARSBSC06
Thallium	1	0.078	2.11	0	0	0	13	14	0.23	1.3	ARSBSC14
Vanadium	520	39	108	0	0	0	14	14	26.4	76.5	ARSBSC14
Zinc	31000	2300	202	0	0	0	14	14	10.3	26.1	ARSBSC13

4.1.2 Firing Range Floor and Potential Firing Point Analytical Results

XRF Results. A total of 93 surface soil samples (ARXRF01 through ARXRF93) were collected from 0-0.5 ft bgs in a grid pattern for XRF screening over the approximately 5 acres northwest of the target berm (**Figure 4-3**). Samples were collected and screened to confirm that lead concentrations were below the r-SL of 400 mg/kg. Lead results obtained during the XRF screening, and associated confirmation sample results are presented in **Table 4-4**. As shown in **Table 4-4** and illustrated on **Figure 4-3**, XRF screening results indicate that no areas of elevated lead exist within the firing range floor and potential firing points.

Laboratory Results. A total of nine discrete soil samples (ARSCF01 through ARSCF09) were collected to confirm the XRF results and fill data gaps within the area. All confirmation samples were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals. Results detected in the confirmation samples are presented in **Table 4-5** and summarized in **Table 4-6**. **Figure 4-4** illustrates analytes detected above r-SLs and i-SLs.

TAL Metals. Twenty-two TAL metals were detected in samples collected from the firing range floor. Two metals (iron and arsenic) were detected at levels exceeding r-SLs. Arsenic exceeded the r-SL and i-SL at one location (ARSCF06). Iron exceeded the i-SL in four samples (ARSCF05, ARSCF06, ARSCF08, and ARSCF09) and the r-SL in seven samples (ARSCF02 and ARSCF04 through ARSCF09). It should be noted that the RFAAP background SL for iron is 50,962 parts per million, which is above the residential SL for iron. Lead concentrations were well below the r-SL, confirming the XRF results.

VOCs. Two VOCs (acetone and chloromethane) were detected in samples collected from the firing range floor. Acetone was detected at four sample locations and chloromethane at two. Concentrations of both detected VOCs were below their respective i-SLs and r-SLs.

SVOCs/PAHs. Eighteen SVOCs/PAHs were detected in soil samples collected from the firing range floor. Three PAHs [benzo(a)pyrene, benz(b)fluoranthene, and dibenz(a,h)anthracene] were detected at concentrations exceeding their respective r-SLs. These PAHs are likely associated with the old asphalt parking lot adjacent to the site and are not likely related to the site's former use as a firing range.

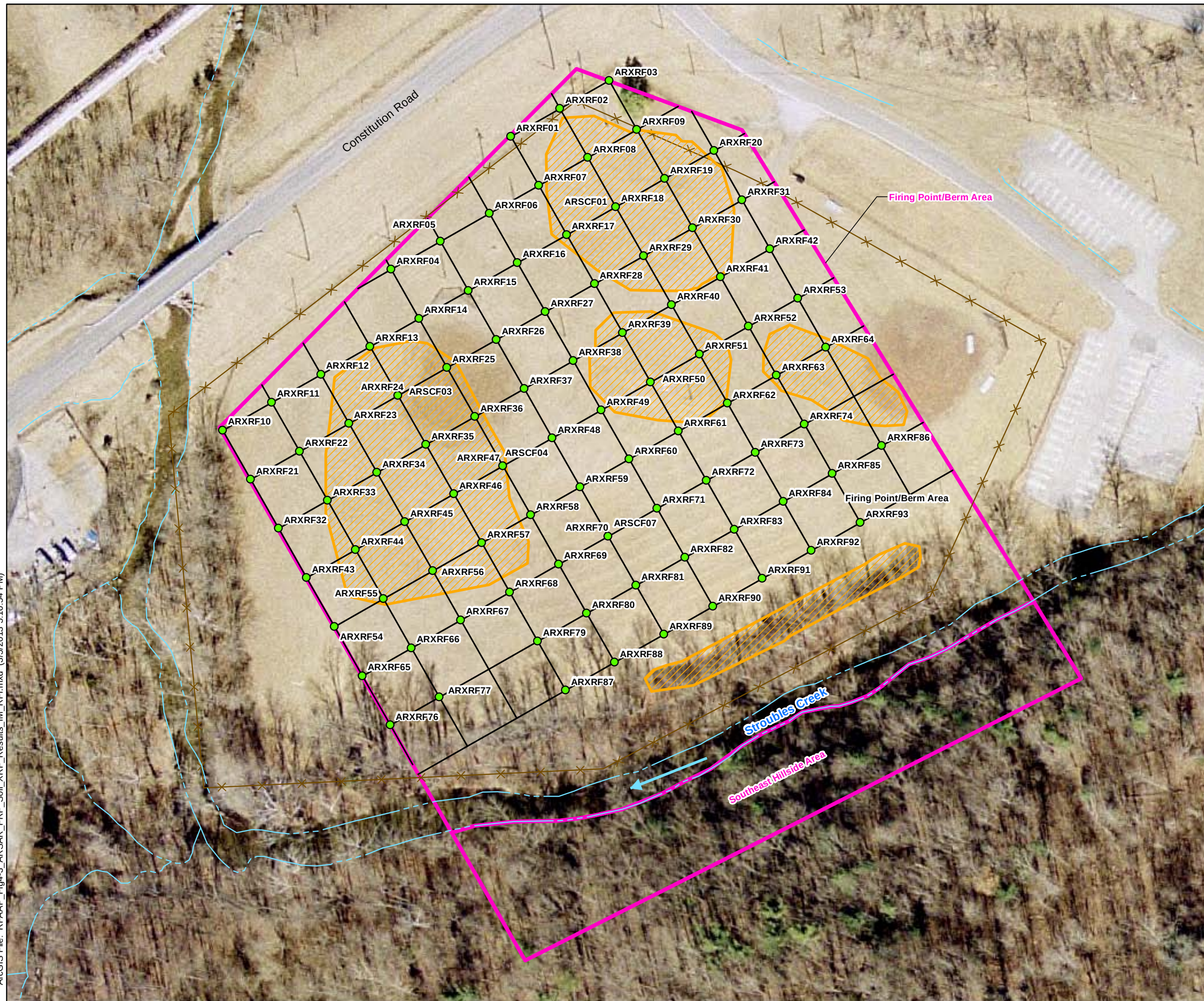
Pesticides. Eight pesticides were detected in samples collected from the firing range floor. None of the detected pesticides exceeded r-SLs or i-SLs.

PCBs. One PCB (PCB-1254) was detected in one of nine soil samples at a concentration (0.074 mg/kg) exceeding its r-SL (0.022 mg/kg), but below its i-SL (0.74 mg/kg).

Explosives. One explosive (2,6-DNT) was detected in one single sample (ARSCF01). The concentration of 2,6-DNT was well below its r-SL and i-SL in sample ARSCF01.

Herbicides. Herbicides were not detected in soil samples collected from the firing range floor.

ArcGIS File: RFAAP_Fig4-3_ARSAAR_FRE_Soil_XRF_Results_IM_RFI.mxd (3/5/2013 5:10:54 PM)

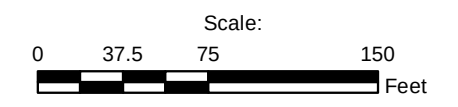


LEGEND

XRF Sample Location Lead Results

- < 400 mkg/kg
- > 400 mkg/kg
- Water Feature
- ➔ Surface Water Flow Direction
- ✕ Fence Line
- XRF Sample Grid
- Historic Feature
- MRS Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
3) Soil results are from 2011.



U.S. Army Corps of Engineers

Shaw Environmental, Inc.
(A CB&I Company)

FIGURE 4-3
Army Reserve Small Arms Range
Firing Range Floor - Soil XRF Screening Results
Radford Army Ammunition Plant,
Radford, VA

Table 4-4. Firing Range Floor XRF Screening Results

Location	Depth (ft bgs)	Pb (mg/kg)	As (mg/kg)	Lab Pb (mg/kg)	Lab As (mg/kg)
ARXRF01	0-0.5	23.93	<11.37	---	---
ARXRF02	0-0.5	33.35	<11.51	---	---
ARXRF03	0-0.5	20.7	17.53	---	---
ARXRF04	0-0.5	19.45	12.45	---	---
ARXRF05	0-0.5	41.59	<11.63	34.1	5.3
ARXRF06	0-0.5	22.02	13.17	---	---
ARXRF07	0-0.5	34.01	<11.81	---	---
ARXRF08	0-0.5	24.46	<10.35	---	---
ARXRF09	0-0.5	21.7	<10.19	---	---
ARXRF10	0-0.5	40.3	<12.62	---	---
ARXRF11	0-0.5	70.06	<15.79	---	---
ARXRF12	0-0.5	36.10	11.90	---	---
ARXRF13	0-0.5	18.51	11.95	---	---
ARXRF14	0-0.5	16.7	<10.09	---	---
ARXRF15	0-0.5	25.24	<10.79	---	---
ARXRF16	0-0.5	26.37	<10.84	---	---
ARXRF17	0-0.5	42.45	<12.61	---	---
ARXRF18	0-0.5	16.26	11.20	31	5.6
ARXRF19	0-0.5	18.99	<10.11	---	---
ARXRF20	0-0.5	18.87	<9.73	---	---
ARXRF21	0-0.5	73.34	12.07	---	---
ARXRF22	0-0.5	19.84	<9.51	---	---
ARXRF23	0-0.5	21.50	11.15	---	---
ARXRF24	0-0.5	26.10	15.34	22.8	4.8
ARXRF25	0-0.5	22.37	<11.42	---	---
ARXRF26	0-0.5	17.58	<9.87	---	---
ARXRF27	0-0.5	22.74	<10.96	---	---
ARXRF28	0-0.5	26.15	12.42	---	---
ARXRF29	0-0.5	23.48	<10.16	---	---
ARXRF30	0-0.5	15.31	10.33	---	---
ARXRF31	0-0.5	29.81	<11.33	---	---
ARXRF32	0-0.5	21.14	11.25	---	---
ARXRF33	0-0.5	27.40	<10.33	---	---
ARXRF34	0-0.5	18.72	<10.03	---	---
ARXRF35	0-0.5	23.69	<10.18	---	---
ARXRF36	0-0.5	12.85	<9.26	---	---
ARXRF37	0-0.5	18.8	<9.86	---	---
ARXRF38	0-0.5	16.36	<9.72	---	---

Table 4-4. Firing Range Floor XRF Screening Results (continued)

Location	Depth (ft bgs)	Pb (mg/kg)	As (mg/kg)	Lab Pb (mg/kg)	Lab As (mg/kg)
ARXRF39	0-0.5	18.51	<9.86	---	---
ARXRF40	0-0.5	25.24	<10.47	---	---
ARXRF41	0-0.5	20	10.85	---	---
ARXRF42	0-0.5	15.93	<9.30	---	---
ARXRF43	0-0.5	34.67	<10.83	---	---
ARXRF44	0-0.5	20.75	<10.05	---	---
ARXRF45	0-0.5	15.64	<10.52	---	---
ARXRF46	0-0.5	19.58	<10.40	---	---
ARXRF47	0-0.5	16.43	<9.29	22.5	6.6
ARXRF48	0-0.5	16.41	<10.04	---	---
ARXRF49	0-0.5	17.92	<9.07	---	---
ARXRF50	0-0.5	15.33	14.35	17.7	6.3
ARXRF51	0-0.5	17.80	<9.39	---	---
ARXRF52	0-0.5	19.05	<9.91	---	---
ARXRF53	0-0.5	19.21	<9.21	---	---
ARXRF54	0-0.5	20.71	<9.77	---	---
ARXRF55	0-0.5	27.28	<12.62	---	---
ARXRF56	0-0.5	16.15	12.43	17.8	19.1
ARXRF57	0-0.5	17.66	<9.81	---	---
ARXRF58	0-0.5	13.72	<9.53	---	---
ARXRF59	0-0.5	15.51	<9.00	---	---
ARXRF60	0-0.5	15.91	<9.36	---	---
ARXRF61	0-0.5	42.88	<11.81	---	---
ARXRF62	0-0.5	16.83	10.11	---	---
ARXRF63	0-0.5	15.78	11.24	---	---
ARXRF64	0-0.5	19.95	<10.69	---	---
ARXRF65	0-0.5	15.02	<8.26	---	---
ARXRF66	0-0.5	17	12.37	---	---
ARXRF67	0-0.5	14.63	<10.25	---	---
ARXRF68	0-0.5	13.95	<8.65	---	---
ARXRF69	0-0.5	15.78	<9.50	---	---
ARXRF70	0-0.5	19.54	9.66	16.6	5
ARXRF71	0-0.5	15.94	<9.61	---	---
ARXRF72	0-0.5	20.98	<9.78	---	---
ARXRF73	0-0.5	17.3	<8.82	---	---
ARXRF74	0-0.5	15.05	<9.31	---	---
ARXRF75	0-0.5	<13.95	<11.12	24.1	6

Table 4-4. Firing Range Floor XRF Screening Results (continued)

Location	Depth (ft bgs)	Pb (mg/kg)	As (mg/kg)	Lab Pb (mg/kg)	Lab As (mg/kg)
ARXRF76	0-0.5	18.37	<9.22	---	---
ARXRF77	0-0.5	17.72	11.34	---	---
ARXRF78	0-0.5	<11.98	11.44	14.4	7.4
ARXRF79	0-0.5	16.14	<9.33	---	---
ARXRF80	0-0.5	19.2	<10.17	---	---
ARXRF81	0-0.5	13.76	11.34	---	---
ARXRF82	0-0.5	15.28	<8.48	---	---
ARXRF83	0-0.5	14.70	<9.29	---	---
ARXRF84	0-0.5	17.85	<9.44	---	---
ARXRF85	0-0.5	16.05	<8.96	---	---
ARXRF86	0-0.5	14.67	<9.29	---	---
ARXRF87	0-0.5	15.37	<9.53	---	---
ARXRF88	0-0.5	25.90	<10.36	---	---
ARXRF89	0-0.5	18.54	<10.97	---	---
ARXRF90	0-0.5	332.68	<29.55	---	---
ARXRF91	0-0.5	24.55	11.25	---	---
ARXRF92	0-0.5	16.32	<9.01	---	---
ARXRF93	0-0.5	16.23	9.42	---	---

Table 4-5
Analytes Detected in Firing Range Floor Laboratory Samples
Page 1 of 2

Analyte	Sample ID			ARSCF01					ARSCF02					ARSCF03					ARSCF04					ARSCF05				
	Sample Date			5/5/11					5/5/11					5/5/11					5/5/11					5/5/11				
	Sample Depth			0.0-0.5					0.0-0.5					0.0-0.5					0.0-0.5					0.0-0.5				
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (ug/kg)																												
Acetone	63000000	6100000	na	1100	U		71	1100	80	JB	B	61	970	1100	U		68	1100	1100	U		72	1100	71	JB	B	56	880
Chloromethane	50000	12000	na	32	JB	B	28	110	97	U		24	97	110	U		27	110	30	JB	B	29	110	88	U		22	88
SVOCs/PAHs (ug/kg)																												
2-Methylnaphthalene	220000	23000	na	5.1		J	0.27	3.7	7.4			0.26	3.5	13			0.26	3.6	0.97	J	B	0.27	3.6	3.4	U	UL	0.25	3.4
Acenaphthene	3300000	340000	na	1.1	J	J	0.4	3.7	16			0.39	3.5	3.6	U		0.39	3.6	3.6	U		0.4	3.6	3.4	U	UL	0.38	3.4
Acenaphthylene	1700000	170000	na	0.73	J	J	0.29	3.7	1.1	J	J	0.28	3.5	3.6	U		0.29	3.6	3.6	U		0.29	3.6	3.4	U	UL	0.27	3.4
Anthracene	17000000	1700000	na	0.61	J	J	0.38	3.7	36			0.37	3.5	3.6	U		0.37	3.6	3.6	U		0.38	3.6	3.4	U	UL	0.35	3.4
Benz(a)anthracene	2100	150	na	3.8			0.39	3.7	140			0.38	3.5	1.8	J	J	0.38	3.6	3.6	U		0.39	3.6	3.4	U	UL	0.37	3.4
Benzo(a)pyrene	210	15	na	3.4	J	J	0.34	6.1	130			0.33	5.9	1.2	J	J	0.33	5.9	6.1	U		0.34	6.1	5.7	U	UL	0.32	5.7
Benzo(b)fluoranthene	2100	150	na	11		J	0.49	3.7	200			0.47	3.5	4.3			0.48	3.6	2.4	J	J	0.49	3.6	2.1	J	L	0.46	3.4
Benzo(g,h,i)perylene	1700000	170000	na	4.2		J	0.48	3.7	81			0.46	3.5	1.4	J	J	0.46	3.6	3.6	U		0.47	3.6	3.4	U	UL	0.45	3.4
Benzo(k)fluoranthene	21000	1500	na	2	J	J	0.45	3.7	65			0.44	3.5	3.6	U		0.44	3.6	3.6	U		0.45	3.6	3.4	U	UL	0.42	3.4
bis(2-Ethylhexyl)phthalate	120000	35000	na	490	U		110	490	470	U		100	470	480	U		100	480	490	U		110	490	460	U	UL	99	460
Chrysene	210000	15000	na	7		J	0.43	3.7	160			0.41	3.5	2.5	J	J	0.42	3.6	2.1	J	J	0.42	3.6	0.91	J	L	0.4	3.4
Dibenz(a,h)anthracene	210	15	na	1.2	J	J	0.43	3.7	21			0.41	3.5	0.71	J	J	0.42	3.6	3.6	U		0.42	3.6	3.4	U	UL	0.4	3.4
Fluoranthene	2200000	230000	na	7.7			0.44	3.7	270			0.42	3.5	2.4	J	J	0.43	3.6	1.7	J	J	0.44	3.6	4.6		L	0.41	3.4
Fluorene	2200000	230000	na	3.7	U		0.44	3.7	12			0.42	3.5	3.6	U		0.43	3.6	3.6	U		0.44	3.6	3.4	U	UL	0.41	3.4
Indeno(1,2,3-cd)pyrene	2100	150	na	5.4			0.44	3.7	93			0.42	3.5	2	J	J	0.43	3.6	1.6	J	J	0.44	3.6	3.4	U	UL	0.41	3.4
Naphthalene	18000	3600	na	4.8		J	0.33	3.7	8.6			0.32	3.5	10			0.32	3.6	3.6	U		0.33	3.6	3.4	U	UL	0.31	3.4
Phenanthrene	1700000	170000	na	11		J	0.55	3.7	140			0.53	3.5	6.3			0.53	3.6	5.5			0.55	3.6	3.3	J	L	0.51	3.4
Pyrene	1700000	170000	na	6.8			0.5	1.8	230			0.48	1.8	2.4			0.49	1.8	0.97	J	J	0.5	1.8	2.9		L	0.47	1.7
Pesticides (ug/kg)																												
4,4'-DDD	7200	2000	na	1.2	JP	J	0.36	2.9	2.8	U		0.36	2.8	2.8	U		0.35	2.8	2.9	U		0.36	2.9	2.8	U		0.34	2.8
4,4'-DDE	5100	1400	na	1.7	J	J	0.36	2.9	9.2			0.36	2.8	3.5	P	J	0.35	2.8	4.1	P	J	0.36	2.9	3.2	P	J	0.34	2.8
4,4'-DDT	7000	1700	na	3.4	P	J	0.6	2.9	6.4			0.59	2.8	2.7	J	J	0.59	2.8	2.5	J	J	0.6	2.9	2.8	U		0.57	2.8
alpha-Chlordane	na	na	na	7.3	P	J	0.36	2.9	2.8	U		0.36	2.8	2.8	U		0.35	2.8	2.9	U		0.36	2.9	2.8	U		0.34	2.8
delta-BHC	na	na	na	2.9	U		0.36	2.9	1.4	J	J	0.36	2.8	2.8	U		0.35	2.8	2.9	U		0.36	2.9	2.8	U		0.34	2.8
Dieldrin	110	30	na	2.9	U		0.36	2.9	2.1	JP	J	0.36	2.8	2.8	U		0.35	2.8	2.9	U		0.36	2.9	2.8	U		0.34	2.8
Heptachlor epoxide	190	53	na	2.9	U		0.6	2.9	2.4	JP	J	0.59	2.8	2.8	U		0.59	2.8	2.9	U		0.6	2.9	2.8	U		0.57	2.8
Methoxychlor	310000	31000	na	2.9	U		0.85	2.9	1.8	JP	J	0.83	2.8	1.2	J	J	0.82	2.8	1.4	J	J	0.84	2.9	1.1	JP	J	0.8	2.8
PCBs (mg/kg)																												
PCB-1254	0.74	0.022	na	0.12	U		0.028	0.12	0.047	J	J	0.027	0.12	0.12	U		0.027	0.12	0.12	U		0.028	0.12	0.11	U		0.026	0.11
Explosives (mg/kg)																												
2,6-Dinitrotoluene	62	6.1	na	0.13	J	J	0.07	0.5	0.5	U		0.07	0.5	0.5	U		0.07	0.5	0.5	U		0.07	0.5	0.5	U		0.07	0.5
Herbicides (ug/kg)																												
None detected																												
Metals (mg/kg)																												
Aluminum	99000	7700	40041	5810			0.049	0.29	5870			0.047	0.28	11300			0.047	0.28	6140			0.048	0.29	8730			0.046	0.27
Arsenic	1.6	0.39	15.8	5.6	M	K	0.79	5.5	5.3		K	0.77	5.3	4.8	JV	K	0.77	5.3	6.6		K	0.79	5.4	6.3		K	0.74	5.1
Barium	19000	1500	209	78.5	Y	J	0.009	0.058	73.5		J	0.009	0.057	51.4		J	0.009	0.057	90.7		J	0.009	0.058	92.2		J	0.009	0.055
Beryllium	200	16	1.02	0.71	M	K	0.024	0.15	0.79		K	0.024	0.14	0.16		K	0.024	0.14	1.2		K	0.024	0.15	1.4		K	0.023	0.14
Cadmium	80	7	0.69	0.01	J	J	0.007	0.051	0.098			0.007	0.05	0.0071	U		0.007	0.05	0.0073	U		0.007	0.051	0.082			0.006	0.048
Calcium	na	na	na	1320		J	0.073	1.1	82900		J	0.36	5.3	975		J	0.071	1.1	4720		J	0.073	1.1	1360		J	0.068	1
Chromium	150000	12000	65.3	10.4			0.023	0.3	9.9			0.023	0.3	25.7			0.022	0.3	12.1			0.023	0.3	14.8			0.022	0.29
Cobalt	30	2.3	72.3	28.1	Y,M	J	0.091	0.6	8.9		J	0.089	0.58	10.8		J	0.089	0.58	16.3		J	0.091	0.59	19		J	0.086	0.56
Copper	4100	310	53.5	15.5	M	K	0.36	2.3	28.9		K	0.36	2.3	6.1		K	0.35	2.2	18.6		K	0.36	2.3	29.7		K	0.34	2.2
Iron	72000	5500	50962	32400	M,Y	J	1.8	11	59600	J		1.8	11	45500		J	1.8	11	59700	J		1.8	11	90800	J		1.7	10
Lead	800	400	26.8	31	Y	J	0.24	1.5	34.1		J	0.24	1.4	22.8		J	0.24	1.4	22.5		J	0.24	1.5	17.7		J	0.23	1.4
Magnesium	na	na	na	1330	Y	J	0.15	0.88	39900		J	0.71	4.3	508		J	0.14	0.85	4230		J	0.15	0.87	3050		J	0.14	0.82
Manganese	2300	180	2543	648	Y	J	0.019	0.15	472		J	0.019	0.14	768		J	0.019	0.14	632		J	0.019	0.15	619		J	0.018	0.14
Mercury	4.3	1.0	0.13	0.025			0.002	0.01	0.02			0.002	0.009	0.094			0.002	0.009	0.022			0.002	0.01	0.0082	J	J	0.002	0.009
Nickel	2000	150	62.8	12.3		J	0.11	0.73	11.5		J	0.11	0.71	4.9		J	0.11	0.71	18.9		J	0.11	0.73	27		J	0.1	0.68
Potassium	na	na	na	584			13	180	563			13	170	399			13	170	517			13	170	665			13	160
Selenium	510	39	na	0.46	J	J	0.085	0.51	0.083	U	</																	

Table 4-5
Analytes Detected in Firing Range Floor Laboratory Samples
Page 2 of 2

Analyte	Sample ID Sample Date Sample Depth			ARSCF06 5/5/11 0.0-0.5					ARSCF07 5/5/11 0.0-0.5					ARSCF08 5/5/11 0.0-0.5					ARSCF09 5/5/11 0.0-0.5				
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (ug/kg)																							
Acetone	63000000	6100000	na	1100	U		67	1100	66	JB	B	65	1000	61	JB	B	60	950	880	U		55	880
Chloromethane	50000	12000	na	110	U		27	110	100	U		26	100	95	U		24	95	88	U		22	88
SVOCs/PAHs (ug/kg)																							
2-Methylnaphthalene	220000	23000	na	2.2	J	B	0.25	3.5	1.1	J	B	0.26	3.5	5.7			0.26	3.6	3.4	U		0.25	3.4
Acenaphthene	3300000	340000	na	3.5	U		0.38	3.5	3.5	U		0.39	3.5	3.6	U		0.39	3.6	3.4	U		0.38	3.4
Acenaphthylene	1700000	170000	na	3.5	U		0.28	3.5	3.5	U		0.28	3.5	3.6	U		0.28	3.6	3.4	U		0.27	3.4
Anthracene	17000000	1700000	na	3.5	U		0.36	3.5	3.5	U		0.37	3.5	1.4	J	J	0.37	3.6	3.4	U		0.35	3.4
Benz(a)anthracene	2100	150	na	1.8	J	J	0.37	3.5	3.5	U		0.38	3.5	6.9			0.38	3.6	3.4	U		0.37	3.4
Benzo(a)pyrene	210	15	na	0.92	J	J	0.32	5.8	5.9	U		0.33	5.9	6			0.33	5.9	5.7	U		0.32	5.7
Benzo(b)fluoranthene	2100	150	na	5.3			0.46	3.5	2.6	J	J	0.47	3.5	20			0.47	3.6	0.46	J	J	0.46	3.4
Benzo(g,h,i)perylene	1700000	170000	na	1.6	J	J	0.45	3.5	3.5	U		0.46	3.5	5.3			0.46	3.6	3.4	U		0.45	3.4
Benzo(k)fluoranthene	21000	1500	na	3.5	U		0.43	3.5	3.5	U		0.44	3.5	6			0.44	3.6	3.4	U		0.42	3.4
bis(2-Ethylhexyl)phthalate	120000	35000	na	460	U		100	460	110	J	J	100	470	170	J	J	100	470	460	U		99	460
Chrysene	210000	15000	na	4.3			0.4	3.5	1.9	J	J	0.41	3.5	12			0.42	3.6	3.4	U		0.4	3.4
Dibenz(a,h)anthracene	210	15	na	0.46	J	J	0.4	3.5	3.5	U		0.41	3.5	0.71	J	J	0.42	3.6	3.4	U		0.4	3.4
Fluoranthene	2200000	230000	na	3.9			0.41	3.5	1.6	J	J	0.42	3.5	9.1			0.43	3.6	3.4	U		0.41	3.4
Fluorene	2200000	230000	na	3.5	U		0.41	3.5	3.5	U		0.42	3.5	3.6	U		0.43	3.6	3.4	U		0.41	3.4
Indeno(1,2,3-cd)pyrene	2100	150	na	2.2	J	J	0.41	3.5	3.5	U		0.42	3.5	6.3			0.43	3.6	3.4	U		0.41	3.4
Naphthalene	18000	3600	na	3.7			0.31	3.5	2.7	J	J	0.32	3.5	5.7			0.32	3.6	0.8	J	J	0.31	3.4
Phenanthrene	1700000	170000	na	7.1			0.52	3.5	5.4			0.53	3.5	11			0.53	3.6	3.4	U		0.51	3.4
Pyrene	1700000	170000	na	3			0.47	1.7	1.1	J	J	0.48	1.8	8.3			0.49	1.8	1.7	U		0.47	1.7
Pesticides (ug/kg)																							
4,4'-DDD	7200	2000	na	2.8	U		0.35	2.8	2.8	U		0.36	2.8	2.8	U		0.36	2.8	2.8	U		0.34	2.8
4,4'-DDE	5100	1400	na	3.2	P	J	0.35	2.8	2.8	U		0.36	2.8	3.7	P	J	0.36	2.8	3.2	P	J	0.34	2.8
4,4'-DDT	7000	1700	na	2.8	U		0.58	2.8	2.8	U		0.59	2.8	2.4	J	J	0.59	2.8	1.9	J	J	0.57	2.8
alpha-Chlordane	na	na	na	0.92	JP	J	0.35	2.8	2.8	U		0.36	2.8	2.8	U		0.36	2.8	2.8	U		0.34	2.8
delta-BHC	na	na	na	2.8	U		0.35	2.8	2.8	U		0.36	2.8	2.8	U		0.36	2.8	2.8	U		0.34	2.8
Dieldrin	110	30	na	2.8	U		0.35	2.8	2.8	U		0.36	2.8	2.8	U		0.36	2.8	2.8	U		0.34	2.8
Heptachlor epoxide	190	53	na	2.8	U		0.58	2.8	2.8	U		0.59	2.8	2.8	U		0.59	2.8	2.8	U		0.57	2.8
Methoxychlor	310000	31000	na	2.8	U		0.81	2.8	1.5	JP	J	0.83	2.8	2	JP	J	0.83	2.8	1.3	J	J	0.8	2.8
PCBs (mg/kg)																							
PCB-1254	0.74	0.022	na	0.12	U		0.027	0.12	0.12	U		0.027	0.12	0.12	U		0.027	0.12	0.11	U		0.026	0.11
Explosives (mg/kg)																							
2,6-Dinitrotoluene	62	6.1	na	0.5	U		0.07	0.5	0.5	U		0.07	0.5	0.5	U		0.069	0.5	0.5	U		0.07	0.5
Herbicides (ug/kg)																							
None detected																							
Metals (mg/kg)																							
Aluminum	99000	7700	40041	7200			0.046	0.28	5990			0.047	0.28	7890			0.048	0.29	7680			0.046	0.28
Arsenic	1.6	0.39	15.8	19.1		K	0.75	5.2	5	J	K	0.77	5.3	6		K	0.77	5.4	7.4		K	0.75	5.2
Barium	19000	1500	209	115		J	0.009	0.055	86.9		J	0.009	0.057	89		J	0.009	0.057	124		J	0.009	0.055
Beryllium	200	16	1.02	1.4		K	0.023	0.14	1.3		K	0.024	0.14	1.1		K	0.024	0.14	1.2		K	0.023	0.14
Cadmium	80	7	0.69	0.064			0.006	0.048	0.0071	U		0.007	0.05	0.0071	U		0.007	0.05	0.016	J	J	0.006	0.048
Calcium	na	na	na	1170		J	0.069	1	673		J	0.071	1.1	2040		J	0.071	1.1	1360		J	0.069	1
Chromium	150000	12000	65.3	14.6			0.022	0.29	12.4			0.023	0.3	13.5			0.023	0.3	14			0.022	0.29
Cobalt	30	2.3	72.3	16.5		J	0.086	0.56	15.3		J	0.089	0.58	13.6		J	0.089	0.58	18.3		J	0.086	0.56
Copper	4100	310	53.5	30.4		K	0.34	2.2	16.5		K	0.36	2.3	18		K	0.36	2.3	24.2		K	0.35	2.2
Iron	72000	5500	50962	78100		J	1.7	10	66400		J	1.8	11	73700		J	1.8	11	77400		J	1.7	10
Lead	800	400	26.8	17.8		J	0.23	1.4	16.6		J	0.24	1.4	24.1		J	0.24	1.4	14.4		J	0.23	1.4
Magnesium	na	na	na	2360		J	0.14	0.83	1210		J	0.14	0.85	3040		J	0.14	0.86	3140		J	0.14	0.83
Manganese	2300	180	2543	758		J	0.018	0.14	688		J	0.019	0.14	649		J	0.019	0.14	711		J	0.018	0.14
Mercury	4.3	1.0	0.13	0.018			0.002	0.009	0.021			0.002	0.009	0.026			0.002	0.009	0.017			0.002	0.009
Nickel	2000	150	62.8	22.1		J	0.1	0.69	14.4		J	0.11	0.71	16.8		J	0.11	0.71	25		J	0.1	0.69
Potassium	na	na	na	580			13	170	415			13	170	577			13	170	495			13	170
Selenium	510	39	na	0.08	U		0.08	0.48	0.083	U		0.083	0.5	0.083	U		0.083	0.5	0.081	U		0.081	0.48
Silver	510	39	na	0.02	U		0.02	0.25	0.02	U		0.02	0.26	0.03	J	J	0.02	0.26	0.02	U		0.02	0.25
Sodium	na	na	na	6.2	J	J	4.6	60	4.7	U		4.7	62	7.6	J	J	4.8	62	6	J	J	4.6	60
Thallium	1	0.078	2.11	0.85		L	0.046	0.64	0.86		L	0.047	0.66	0.75		L	0.048	0.67	0.82		L	0.046	0.64
Vanadium	520	39	108	31.1		J	0.063	0.8	30.4		J	0.065	0.83	36.2		J	0.065	0.83	29.5		J	0.063	0.81
Zinc	31000	2300	202	50.8		J	0.23	2.8	37.5		J	0.24	2.8	51.8		J	0.24	2.9	50.9		J	0.23	2.8

**Refer to legend immediately following this table for a list of definitions and table notes.

Table 4-5
Legend

12	J	Shading and black font indicate an industrial SL exceedance.
12	J	Bold outline indicates a residential SL exceedance.
12	J	Bold, underlined font indicates a background exceedance.
12	12	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

SLs for non-Carcinogenic compounds have been recalculated to an HI of 0.1.

The pyrene SLs were used for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene.

Inorganic results below background UTLs are not indicated as exceedances on the table.

SL = Screening Level (Source: ORNL Regional Screening Table, November 2012).

BTAG sediment source: USEPA Region III BTAG Sediment Screening Benchmarks. December 2005.

BTAG soil source: USEPA Region III BTAG Soil Screening Values. 1995.

Lead screening values from Technical Review Workgroup for Lead: Guidance Document (USEPA, 1999).

mg/kg = milligrams per kilogram (parts per million).

µg/kg = micrograms per kilogram (parts per billion).

NA = not applicable.

Lab Q = Lab Data Qualifiers

B = (organics) Blank contamination. Value detected in sample and associated blank.

J = (organics) Value <MRL and >MDL and is considered estimated.

M = Matrix spike and/or matrix spike duplicate recovery outside acceptance limits.

P = Concentration of analyte differs more than 40% between primary and confirmation analysis.

U = Analyte not-detected at the method reporting limit.

Y = Replicate/Duplicate precision outside acceptance limits.

Val Q = Validation Data Qualifiers

B = blank contamination. Value detected in sample and associated blank.

J = estimated concentration.

K = estimated concentration bias high.

L = estimated concentration bias low.

UL = estimated concentration non-detect bias low.

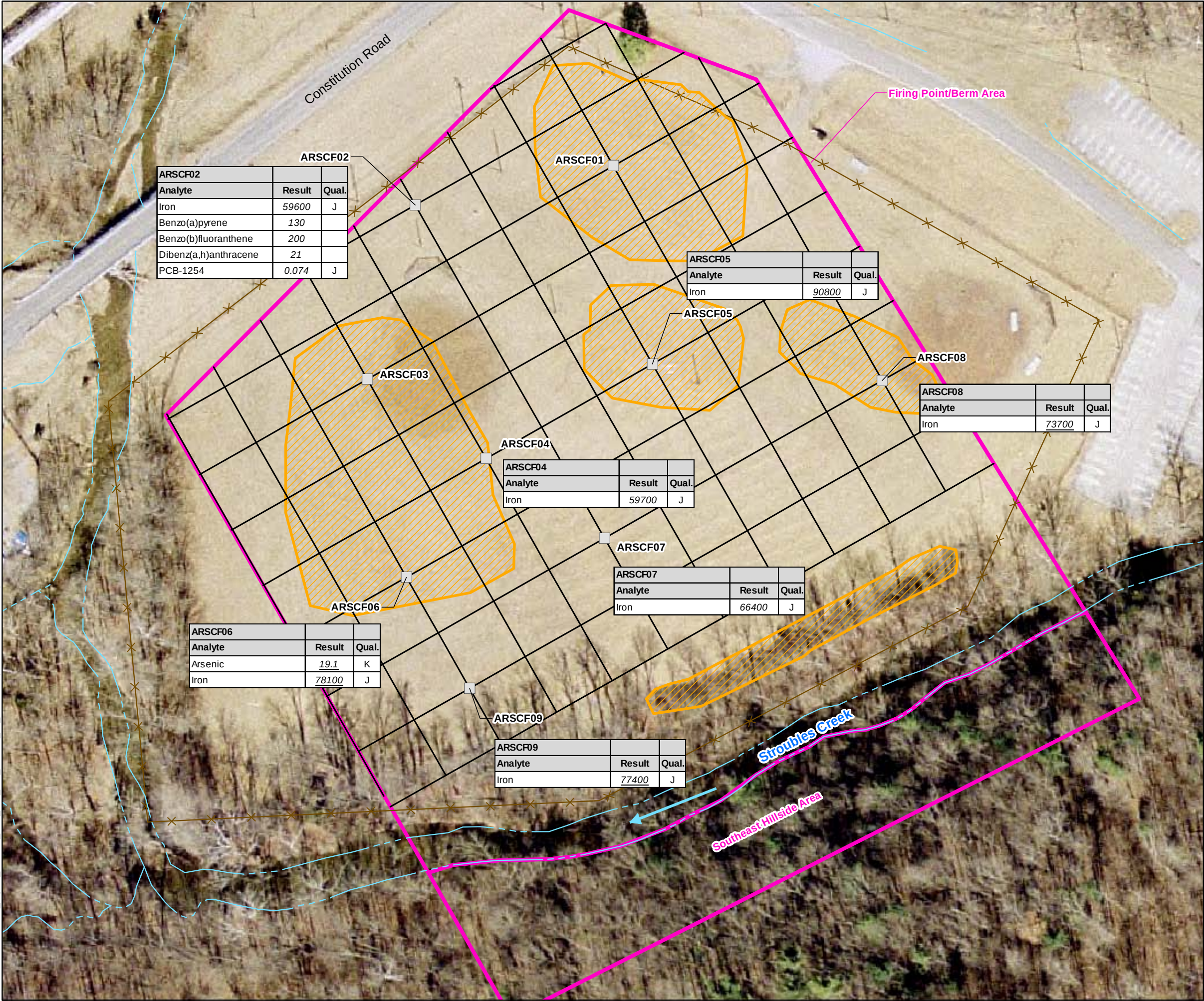
Table 4-6
Summary of Analytes Detected in Firing Range Floor Samples
Page 1 of 2

Analyte	i-SL	r-SL	Background	# of i-SL Exceedances	# of r-SL Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/kg)											
Acetone	63000000	6100000	na	0	0	na	4	9	61	80	ARSCF02
Chloromethane	50000	12000	na	0	0	na	2	9	30	32	ARSCF01
SVOCs/PAHs (ug/kg)											
2-Methylnaphthalene	220000	23000	na	0	0	na	7	9	0.97	13	ARSCF03
Acenaphthene	3300000	340000	na	0	0	na	2	9	1.1	16	ARSCF02
Acenaphthylene	1700000	170000	na	0	0	na	2	9	0.73	1.1	ARSCF02
Anthracene	17000000	1700000	na	0	0	na	3	9	0.61	36	ARSCF02
Benz(a)anthracene	2100	150	na	0	0	na	5	9	1.8	140	ARSCF02
Benzo(a)pyrene	210	15	na	0	1	na	5	9	0.92	130	ARSCF02
Benzo(b)fluoranthene	2100	150	na	0	1	na	9	9	0.46	200	ARSCF02
Benzo(g,h,i)perylene	1700000	170000	na	0	0	na	5	9	1.4	81	ARSCF02
Benzo(k)fluoranthene	21000	1500	na	0	0	na	3	9	2	65	ARSCF02
bis(2-Ethylhexyl)phthalate	120000	35000	na	0	0	na	2	9	110	170	ARSCF08
Chrysene	210000	15000	na	0	0	na	8	9	0.91	160	ARSCF02
Dibenz(a,h)anthracene	210	15	na	0	1	na	5	9	0.46	21	ARSCF02
Fluoranthene	2200000	230000	na	0	0	na	8	9	1.6	270	ARSCF02
Fluorene	2200000	230000	na	0	0	na	1	9	12	12	ARSCF02
Indeno(1,2,3-cd)pyrene	2100	150	na	0	0	na	6	9	1.6	93	ARSCF02
Naphthalene	18000	3600	na	0	0	na	7	9	0.8	10	ARSCF03
Phenanthrene	1700000	170000	na	0	0	na	8	9	3.3	140	ARSCF02
Pyrene	1700000	170000	na	0	0	na	8	9	0.97	230	ARSCF02
Pesticides (ug/kg)											
4,4'-DDD	7200	2000	na	0	0	na	1	9	1.2	1.2	ARSCF01
4,4'-DDE	5100	1400	na	0	0	na	8	9	1.7	9.2	ARSCF02
4,4'-DDT	7000	1700	na	0	0	na	6	9	1.9	6.4	ARSCF02
alpha-Chlordane	na	na	na	na	na	na	2	9	0.92	7.3	ARSCF01
delta-BHC	na	na	na	na	na	na	1	9	1.4	1.4	ARSCF02
Dieldrin	110	30	na	0	0	na	1	9	2.1	2.1	ARSCF02
Heptachlor epoxide	190	53	na	0	0	na	1	9	2.4	2.4	ARSCF02
Methoxychlor	310000	31000	na	0	0	na	7	9	1.1	2	ARSCF08
PCBs (mg/kg)											
PCB-1254	0.74	0.022	na	0	1	na	1	9	0.047	0.047	ARSCF02
Explosives (mg/kg)											
2,6-Dinitrotoluene	62	6.1	na	0	0	na	1	9	0.13	0.13	ARSCF01
Herbicides (ug/kg)											
Metals (mg/kg)											
Aluminum	99000	7700	40041	0	0	0	9	9	5810	11300	ARSCF03
Arsenic	1.6	0.39	15.8	1	1	1	9	9	4.8	19.1	ARSCF06
Barium	19000	1500	209	0	0	0	9	9	51.4	124	ARSCF09
Beryllium	200	16	1.02	0	0	6	9	9	0.16	1.4	ARSCF05
Cadmium	80	7	0.69	0	0	0	5	9	0.01	0.098	ARSCF02
Calcium	na	na	na	na	na	na	9	9	673	82900	ARSCF02
Chromium	150000	12000	65.3	0	0	0	9	9	9.9	25.7	ARSCF03
Cobalt	30	2.3	72.3	0	0	0	9	9	8.9	28.1	ARSCF01
Copper	4100	310	53.5	0	0	0	9	9	6.1	30.4	ARSCF06
Iron	72000	5500	50962	4	7	7	9	9	32400	90800	ARSCF05
Lead	800	400	26.8	0	0	2	9	9	14.4	34.1	ARSCF02
Magnesium	na	na	na	na	na	na	9	9	508	39900	ARSCF02

Table 4-6
Summary of Analytes Detected in Firing Range Floor Samples
Page 2 of 2

Analyte	i-SL	r-SL	Background	# of i-SL Exceedances	# of r-SL Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Manganese	2300	180	2543	0	0	0	9	9	472	768	ARSCF03
Mercury	4.3	1.0	0.13	0	0	0	9	9	0.0082	0.094	ARSCF03
Nickel	2000	150	62.8	0	0	0	9	9	4.9	27	ARSCF05
Potassium	na	na	na	na	na	na	9	9	399	665	ARSCF05
Selenium	510	39	na	0	0	na	2	9	0.24	0.46	ARSCF01
Silver	510	39	na	0	0	na	1	9	0.03	0.03	ARSCF08
Sodium	na	na	na	na	na	na	7	9	6	33.8	ARSCF02
Thallium	1	0.078	2.11	0	0	0	9	9	0.57	1	ARSCF03
Vanadium	520	39	108	0	0	0	9	9	25.9	62.9	ARSCF03
Zinc	31000	2300	202	0	0	0	9	9	22.5	64.5	ARSCF02

ArcGIS File: RFAAP_Fig4-4_ARSAAR_FRE_Soil_Lab_Results_IM_RFI.mxd (3/5/2013 5:13:00 PM)



LEGEND

- Soil Lab Confirmation Sample Location
- Water Feature
- Surface Water Flow Direction
- Fence Line
- XRF Sample Grid
- Historic Feature
- MRS Boundary

- Notes:
- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
 - 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
 - 3) Soil results are from 2011.
 - 4) Only result values above screening levels are reported.
 - 5) Metal and PCB results are in mg/kg, and SVOC results are in ug/kg.
 - 6) Soil SLs were obtained from the USEPA Mid-Atlantic Region Regional Screening Level Summary Table, November 2012.
 - 7) Italicized result value indicates an r-SL exceedance, and underlined result value indicates an i-SL exceedance.



Scale: 0 37.5 75 150 Feet



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FIGURE 4-4
Army Reserve Small Arms Range - Firing
Range Floor - Soil Lab Confirmation Results
Radford Army Ammunition Plant,
Radford, VA

4.1.3 Southeast Hillside Results

XRF Results. A total of 33 surface soil samples (ARXRH01 through ARXRH33) were collected from 0-0.5 ft bgs in a grid pattern for XRF screening along the Southeast Hillside Area (**Figure 4-5**) to delineate the elevated arsenic concentrations detected during the SSP and assess lead concentrations. The majority of the samples were collected from the 6-inch layer of soil directly overlying the dolomite/limestone bedrock. As shown on **Figure 4-5**, a 400-ft by 65-ft grid was superimposed over the site with grid line intersections at approximately 10-ft intervals. XRF samples were collected in the vicinity of previous sample locations along the hillside. Additional samples were collected stepping outward along grid lines. Arsenic and lead results from the XRF screening and their associated laboratory confirmation results are shown in **Table 4-7**. As shown in **Table 4-7**, XRF arsenic results were above the background SL of 15.8 mg/kg in the majority of screened samples. Elevated concentrations of lead were encountered in a focused area approximately 10 ft above Stroubles Creek (**Figure 4-5**), indicating that there may have been some shots that went over the target berm.

Laboratory Results. Seven samples (ARSCH01 through ARSCH07) were sent to an off-site laboratory to confirm the XRF screening results (**Figure 4-6**). Samples ARSCH01, ARSCH02, and ARSCH03 were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals. Samples (ARSCH04 through ARSCH07) were analyzed for TAL metals only. After reviewing the results from samples ARSCH04 through ARSCH07, five additional surface soil samples (ARSCH08 through ARSCH12) were collected from 0-0.5 ft bgs outside of the established XRF screening grid along the Southeast Hillside (**Figure 4-6**). These samples were collected to assess the extent of elevated arsenic and determine whether there was a correlation between elevated lead and elevated arsenic, which would indicate that the arsenic is the result of the sites past use. All five samples (ARSCH08 through ARSCH12) were analyzed for TAL metals. Soil samples ARSCH09 and ARSCH11 were also analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives. Results detected in the laboratory confirmation samples are presented in **Table 4-8** and summarized in **Table 4-9**. Analytes detected above the SLs in soil samples are illustrated on **Figure 4-6**.

TAL Metals. Twenty-three TAL metals were detected in the samples collected from the southeast hillside. Of these 23 metals, only arsenic and lead exceeded their respective i-SLs. Antimony and iron each exceeded their r-SLs at relatively low frequencies (1 of 12 samples for antimony and 3 of 12 samples for iron). Arsenic exceeded the i-SL in samples ARSCH01 through ARSCH05 and ARSCH08 through ARSCH12. Lead r-SL exceedances occurred in samples ARSCH02, ARSCH06, and ARSCH07. Lead exceeded the i-SL in two of the 12 samples, ARSCH06 and ARSCH07. The detected concentrations of arsenic all fell within a narrow range (15.4 mg/kg to 44.1 mg/kg).

VOCs. One VOC (acetone) was detected in three samples located along the southeast hillside at concentrations well below its i-SL and r-SL. Acetone is a common laboratory contaminant and was “B” flagged during data validation, indicating that its presence in the soil samples is likely attributable to laboratory contamination.

SVOCs/PAHs. Sixteen SVOCs/PAHs were detected in soil samples collected from the southeast hillside. None of the detected concentrations were above r-SLs or i-SLs.

ArcGIS File: RFAAP_Fig4-5_ARSA_Soil_XRF_Results_IM_RFI.mxd (3/5/2013 5:14:21 PM)



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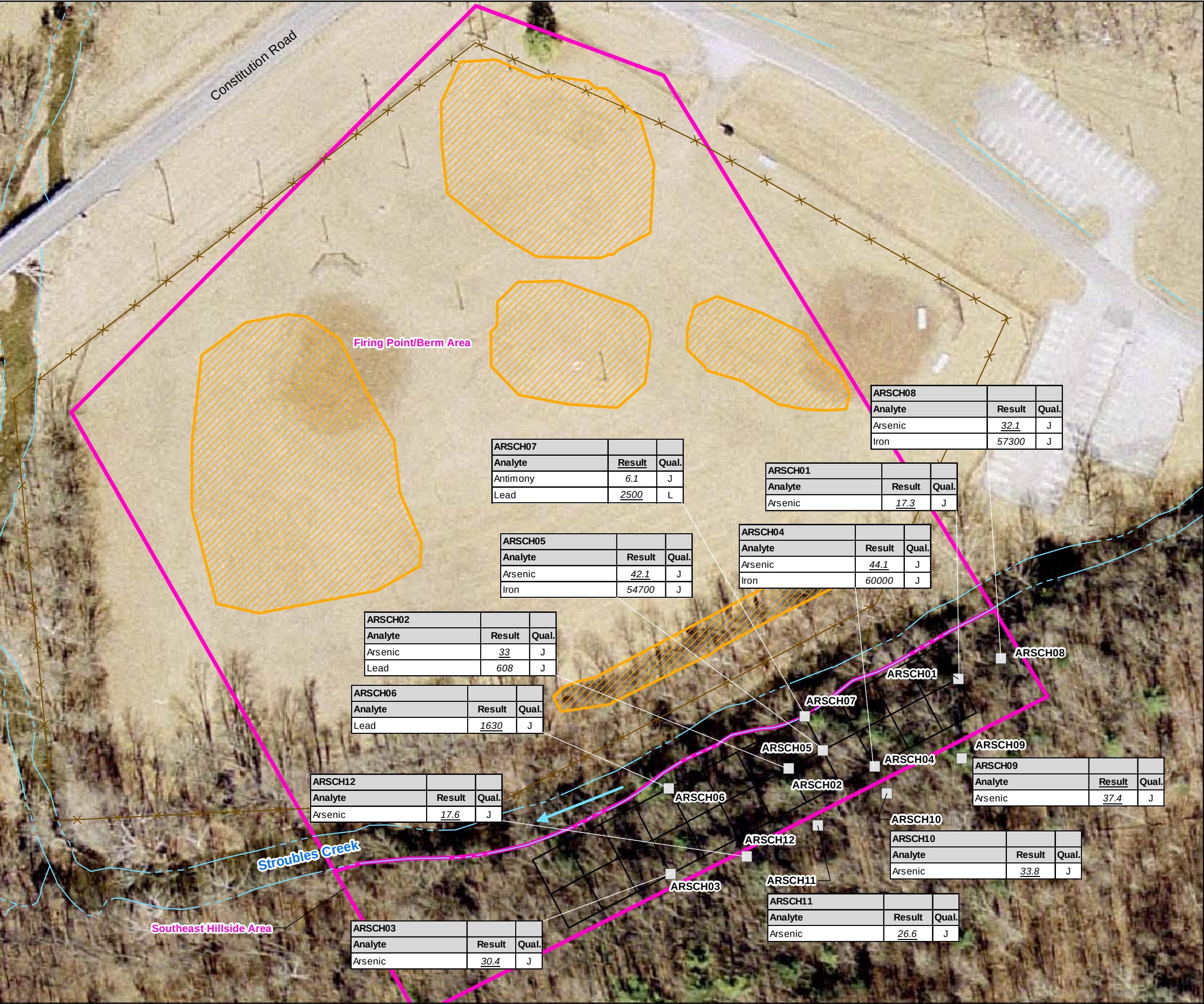
FIGURE 4-5
Army Reserve Small Arms Range
Southeast Hillside Area
Soil XRF Screening Results
Radford Army Ammunition Plant,
Radford, VA

Table 4-7. Southeast Hillside Arsenic and Lead Results

Location	Depth (ft bgs)	XRF Pb (mg/kg)	XRF As (mg/kg)	Lab Pb (mg/kg)	Lab As (mg/kg)
ARXRH01	0-0.5	154.94	23.76	---	---
ARXRH02	0-0.5	35.2	17.17	27.4	17.3
ARXRH03	0-0.5	34.45	24.75	---	---
ARXRH04	0-0.5	255.61	31.28	---	---
ARXRH05	0-0.5	99.08	35.58	---	---
ARXRH06	0-0.5	75.29	35.19	---	---
ARXRH07	0-0.5	738.39	38.68	---	---
ARXRH08	0-0.5	190.76	29.63	---	---
ARXRH09	0-0.5	80.85	28.08	---	---
ARXRH10	0-0.5	1153.41	<45.47	---	---
ARXRH11	0-0.5	192.5	30.31	---	---
ARXRH12	0-0.5	55.65	40.04	86.8	44.1
ARXRH13	0-0.5	1988.88	<113.91	2500	15.4
ARXRH14	0-0.5	182.61	38.75	232	42.1
ARXRH15	0-0.5	161.38	52.62	---	---
ARXRH16	0-0.5	2686.58	127.98	---	---
ARXRH17	0-0.5	565.43	45.16	608	33
ARXRH18	0-0.5	340.77	27.26	---	---
ARXRH19	0-0.5	3837.23	264.15	---	---
ARXRH20	0-0.5	338.58	36.55	---	---
ARXRH21	0-0.5	145.83	28.83	---	---
ARXRH22	0-0.5	2706.17	119.61	---	---
ARXRH23	0-0.5	842.43	78.51	---	---
ARXRH24	0-0.5	490.08	47.18	---	---
ARXRH25	0-0.5	1824.06	74.24	1630	15.4
ARXRH26	0-0.5	154.26	31.81	---	---
ARXRH27	0-0.5	89.04	21.43	---	---
ARXRH28	0-0.5	407.57	<28.99	---	---
ARXRH29	0-0.5	165.99	<18.30	---	---
ARXRH30	0-0.5	96.9	<15.79	176	30.4
ARXRH31	0-0.5	266.55	<23.21	---	---
ARXRH32	0-0.5	269	33.06	---	---
ARXRH33	0-0.5	129	<17.37	---	---

* Bold value indicates result exceeds soil SLs.

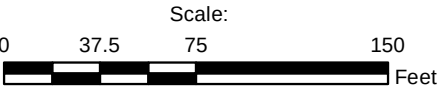
ArcGIS File: RFAAP_Fig4-6_ARSAAR_SEHill_Soil_Lab_Results_IM_RFI.mxd (3/5/2013 5:16:49 PM)



LEGEND

- Soil Lab Confirmation Sample Location
- Water Feature
- Surface Water Flow Direction
- Fence Line
- XRF Sample Grid
- Historic Feature
- MRS Boundary

- Notes:
- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
 - 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
 - 3) Soil results are from 2011.
 - 4) Only result values above screening levels are reported.
 - 5) Metal and PCB results are in mg/kg.
 - 6) Soil SLs were obtained from the USEPA Mid-Atlantic Region Regional Screening Level Summary Table, November 2012.
 - 7) Italicized result value indicates an r-SL exceedance, and underlined result value indicates an i-SL exceedance.



U.S. Army Corps of Engineers

Shaw Environmental, Inc.
(A CB&I Company)

FIGURE 4-6
Army Reserve Small Arms Range
Southeast Hillside Area
Soil Lab Confirmation Results
Radford Army Ammunition Plant,
Radford, VA

Table 4-8
Analytes Detected in Southeast Hillside Area Lab Confirmation Samples
Page 1 of 2

Analyte	Sample ID			ARSCH01					ARSCH02					ARSCH03					ARSCH04					ARSCH05					ARSCH06					ARSCH07					
	Sample Date			5/9/11					5/9/11					5/9/11					5/9/11					5/9/11					5/9/11					5/9/11					
	Sample Depth			0-0.5					0-0.5					0-0.5					0-0.5					0-0.5					0-0.5					0-0.5					
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL						
VOCs (ug/kg)																																							
Acetone	63000000	6100000	na	130	JB	B	81	1300	190	JB	B	100	1600	170	JB	B	70	1100	NT					NT					NT					NT					
SVOCs/PAHs (ug/kg)																																							
2-Methylnaphthalene	220000	23000	na	5.9			0.28	3.8	6.6			0.35	4.8	5.9			0.29	3.9	NT					NT					NT					NT					
Acenaphthylene	1700000	170000	na	3.8	U		0.3	3.8	4.8	U		0.39	4.8	3.9	U		0.31	3.9	NT					NT					NT					NT					
Benz(a)anthracene	2100	150	na	3.5	J	J	0.4	3.8	4.3	J	J	0.51	4.8	5.2			0.42	3.9	NT					NT					NT					NT					
Benzo(a)pyrene	210	15	na	2.9	J	J	0.35	6.3	1.8	J	J	0.45	8	3.3	J	J	0.37	6.5	NT					NT					NT					NT					
Benzo(b)fluoranthene	2100	150	na	7.3			0.5	3.8	5.1			0.64	4.8	8.4			0.52	3.9	NT					NT					NT					NT					
Benzo(g,h,i)perylene	1700000	170000	na	4		J	0.49	3.8	2.6	J	J	0.63	4.8	3.1	J	J	0.51	3.9	NT					NT					NT					NT					
Benzo(k)fluoranthene	21000	1500	na	3.8	U		0.46	3.8	4.8	U		0.59	4.8	1.7	J	J	0.48	3.9	NT					NT					NT					NT					
Benzoic acid	250000000	24000000	na	3800	U		360	3800	4800	U		470	4800	3900	U		380	3900	NT					NT					NT					NT					
Chrysene	210000	15000	na	4.9			0.44	3.8	3.7	J	J	0.56	4.8	7.4			0.46	3.9	NT					NT					NT					NT					
Fluoranthene	2200000	230000	na	9			0.45	3.8	12			0.58	4.8	15			0.47	3.9	NT					NT					NT					NT					
Fluorene	2200000	230000	na	3.8	U		0.45	3.8	4.8	U		0.58	4.8	3.9	U		0.47	3.9	NT					NT					NT					NT					
Indeno(1,2,3-cd)pyrene	2100	150	na	5.5			0.45	3.8	3.7	J	J	0.58	4.8	4.4			0.47	3.9	NT					NT					NT					NT					
Naphthalene	18000	3600	na	6.8			0.34	3.8	8.5			0.43	4.8	8.5			0.35	3.9	NT					NT					NT					NT					
Pentachlorophenol	2700	890	na	1300	U		300	1300	1600	U		390	1600	1300	U		310	1300	NT					NT					NT					NT					
Phenanthrene	1700000	170000	na	10			0.56	3.8	14			0.72	4.8	18			0.59	3.9	NT					NT					NT					NT					
Pyrene	1700000	170000	na	6.5			0.51	1.9	6.4			0.66	2.4	9.5			0.54	2	NT					NT					NT					NT					
Pesticides (ug/kg)																																							
4,4'-DDT	7000	1700	na	2.3	JP	J	0.63	3	5.7			0.79	3.8	3.1	U		0.64	3.1	NT					NT					NT					NT					
alpha-BHC	270	77	na	3	U		0.75	3	3.8	U		0.95	3.8	3.1	U		0.77	3.1	NT					NT					NT					NT					
beta-BHC	960	270	na	3	U		0.75	3	3.8	U		0.95	3.8	3.1	U		0.77	3.1	NT					NT					NT					NT					
Dieldrin	110	30	na	1.1	J	J	0.38	3	3.8	U		0.48	3.8	3.1	U		0.39	3.1	NT					NT					NT					NT					
Endosulfan II	na	na	na	3	U		0.38	3	3.8	U		0.48	3.8	3.1	U		0.39	3.1	NT					NT					NT					NT					
Endosulfan I	na	na	na	3	U		0.88	3	3.8	U		1.1	3.8	3.1	U		0.9	3.1	NT					NT					NT					NT					
Endosulfan sulfate	na	na	na	5	U		1.1	5	6.3	U		1.4	6.3	5.2	U		1.2	5.2	NT					NT					NT					NT					
Endrin aldehyde	na	na	na	5	U		1.4	5	6.3	U		1.7	6.3	5.2	U		1.4	5.2	NT					NT					NT					NT					
Endrin ketone	na	na	na	5	U		1	5	6.3	U		1.3	6.3	5.2	U		1	5.2	NT					NT					NT					NT					
Endrin	18000	1800	na	3	U		0.5	3	0.63	JP	J	0.63	3.8	3.1	U		0.52	3.1	NT					NT					NT					NT					
Heptachlor epoxide	190	53	na	3	U		0.63	3	3.8	U		0.79	3.8	3.1	U		0.64	3.1	NT					NT					NT					NT					
Lindane	2100	520	na	1.5	J	J	0.63	3	3.8	U		0.79	3.8	3.1	U		0.64	3.1	NT					NT					NT					NT					
Methoxychlor	310000	31000	na	2.4	J	J	0.88	3	5.7			1.1	3.8	3.1	U		0.9	3.1	NT					NT					NT					NT					
PCBs (mg/kg)																																							
PCB-1254	0.74	0.022	na	0.13	U		0.029	0.13	0.16	U		0.036	0.16	0.037	J	J	0.03	0.13	NT					NT					NT					NT					
Explosives (mg/kg)																																							
None detected																																							
Herbicides (ug/kg)																																							
None detected																																							
Metals (mg/kg)																																							
Aluminum	99000	7700	40041	6730			0.05	0.3	16200			0.064	0.38	8840			0.052	0.31	18400				0.056	0.34	18400			0.056	0.34	6010			0.055	0.33	5610			0.051	0.31
Antimony	41	3.1	na	0.29	J	L	0.1	0.68	1		L	0.13	0.86	1.2		L	0.1	0.7	0.71	J	L	0.11	0.76	1.8		L	0.11	0.76	2.7		L	0.11	0.75	6.1		L	0.1	0.69	
Arsenic	1.6	0.39	15.8	17.3	J		0.16	1.1	33	J		0.21	1.4	30.4	J		0.17	1.2	44.1	J		0.18	1.3	42.1	J		0.18	1.3	15.6	J		0.18	1.2	15.4		J	0.17	1.2	
Barium	19000	1500	209	49.6			0.05	0.3	106			0.064	0.38	53.6			0.052	0.31	131			0.056	0.34	134			0.056	0.34	61.6			0.055	0.33	60.1			0.051	0.31	
Beryllium	200	16	1.02	0.38		J	0.005	0.03	1		J	0.006	0.038	0.92		J	0.005	0.031	1.3		J	0.005	0.034	1.3		J	0.005	0.034	0.34	J		0.005	0.033	0.33	J		0.005	0.031	
Cadmium	80	7	0.69	0.43	M	J	0.007	0.053	0.58		J	0.009	0.067	0.0078	U	J	0.007	0.055	0.38		J	0.008	0.059	0.23		J	0.008	0.059	0.58	J		0.008	0.058	0.75		J	0.007	0.054	
Calcium	na	na	na	107000		J	0.38	5.6	49000			0.48	7.2	1080			0.39	5.9	9170			0.42	6.3	9190			0.42	6.3	118000			0.41	6.2	144000			0.38	5.8	
Chromium	150000	12000	65.3	8.3	M,Y	J	0.024	0.31	13.8		J	0.03	0.4	16.6		J	0.025	0.33	16.2		J	0.027	0.35	16.7		J	0.027	0.35	4.5	J		0.026	0.35	4.6	J		0.024	0.32	
Cobalt	30	2.3	72.3	3.4	M	J	0.019	0.12	9.5		J	0.024	0.16	6.6		J	0.02	0.13	12		J	0.021	0.14	11.8		J	0.021	0.14	2.7	J		0.021	0.14	2.6	J		0.019	0.13	
Copper	4100	310	53.5	11.2	M	J	0.075	0.48	60		J	0.096	0.61	39		J	0.078	0.49	28.4		J	0.084	0.53	34.2		J	0.084	0.53	52.1	J		0.083	0.52	114		J	0.077	0.49	
Iron	72000	5500	50962	26400	M,Y	J	0.38	2.3	35500		J	0.48	2.9	46500		J	2	12	60000	J		2.1	13	54700	J		2.1	13	12100		J	0.41	2.5	12100		J	0.38	2.3	
Lead	800	400	26.8	24.7		J	0.05	0.3	608	J		0.064	0.38	176	J		0.052	0.31	86.1		J	0.056	0.34	232		J	0.056	0.34	1630	J		0.055	0.33	2500	J		0.051	0.31	
Magnesium	na	na	na	62700			0.75	4.5	10200			0.19	1.2	1500			0.16	0.94	4690			0.17	1	4630			0.17	1	67700			0.83	5	71000			0.77	4.6	
Manganese	2300	180	2543	338	M	J	0.02	0.15	696			0.026	0.19	147		J	0.021	0.16	900		J	0.022	0.17	785		J	0.022	0.17	535		J	0.022	0.17	413		J	0.021	0.15	
Mercury	4.3	1.0	0.13	0.035		J	0.002	0.01	0.06		J	0.003	0.013	0.053		J	0.002	0.011	0.076		J	0.002	0.012	0.09		J	0.002	0.012	0.055		J	0.002	0.011	0.039		J	0.002	0.011	
Nickel	2000	150	62.8	4.5	M	J	0.023	0.15	19		J	0.029	0.19	13.8		J	0.023	0.16	20.4		J																		

****Refer to legend immediately following this table for a list of definitions and table notes.**

Table 4-8
Analytes Detected in Southeast Hillside Area Lab Confirmation Samples
Page 2 of 2

Analyte	Sample ID			ARSCH08					ARSCH09					ARSCH10					ARSCH11					ARSCH12				
	Sample Date			7/14/11					7/14/11					7/14/11					7/14/11					7/14/11				
	Sample Depth			0-0.5					0-0.5					0-0.5					0-0.5					0-0.5				
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (ug/kg)																												
Acetone	63000000	6100000	na	NT					590	U		75	590	NT					650	U		82	650	NT				
SVOCs/PAHs (ug/kg)																												
2-Methylnaphthalene	220000	23000	na	NT					6.7			0.29	3.9	NT					7			0.29	4	NT				
Acenaphthylene	1700000	170000	na	NT					2.1	J	J	0.31	3.9	NT					1.6	J	J	0.32	4	NT				
Benz(a)anthracene	2100	150	na	NT					7.6			0.42	3.9	NT					6.2			0.43	4	NT				
Benzo(a)pyrene	210	15	na	NT					6.5	U		0.37	6.5	NT					6.6	U		0.37	6.6	NT				
Benzo(b)fluoranthene	2100	150	na	NT					9.3			0.52	3.9	NT					12			0.53	4	NT				
Benzo(g,h,i)perylene	1700000	170000	na	NT					7.1			0.51	3.9	NT					7			0.52	4	NT				
Benzo(k)fluoranthene	21000	1500	na	NT					2.9	J	J	0.48	3.9	NT					3.3	J	J	0.49	4	NT				
Benzoic acid	250000000	24000000	na	NT					480	J	J	380	3900	NT					450	J	J	390	4000	NT				
Chrysene	2100000	150000	na	NT					6.7			0.46	3.9	NT					11			0.47	4	NT				
Fluoranthene	2200000	230000	na	NT					13			0.47	3.9	NT					18			0.48	4	NT				
Fluorene	2200000	230000	na	NT					2	J	J	0.47	3.9	NT					1.7	J	J	0.48	4	NT				
Indeno(1,2,3-cd)pyrene	2100	150	na	NT					5.6			0.47	3.9	NT					6.9			0.48	4	NT				
Naphthalene	18000	3600	na	NT					6.8			0.35	3.9	NT					8.8			0.36	4	NT				
Pentachlorophenol	2700	890	na	NT					1300	U		310	1300	NT					320	J	J	320	1300	NT				
Phenanthrene	1700000	170000	na	NT					14			0.59	3.9	NT					18			0.6	4	NT				
Pyrene	1700000	170000	na	NT					14			0.54	2	NT					12			0.54	2	NT				
Pesticides (ug/kg)																												
4,4'-DDT	7000	1700	na	NT					2.2	J	J	0.65	3.1	NT					2	JP	J	0.67	3.2	NT				
alpha-BHC	270	77	na	NT					1.8	JP	J	0.78	3.1	NT					3.2	U		0.8	3.2	NT				
beta-BHC	960	270	na	NT					3.1	U		0.78	3.1	NT					2.1	P	J	0.8	3.2	NT				
Dieldrin	110	30	na	NT					1.3	J	J	0.39	3.1	NT					1.1	J	J	0.4	3.2	NT				
Endosulfan II	na	na	na	NT					0.65	JP	J	0.39	3.1	NT					3.2	U		0.4	3.2	NT				
Endosulfan I	na	na	na	NT					1	JP	J	0.91	3.1	NT					2	J	J	0.94	3.2	NT				
Endosulfan sulfate	na	na	na	NT					1.7	JP	J	1.2	5.2	NT					5.4	U		1.2	5.4	NT				
Endrin aldehyde	na	na	na	NT					1.9	J	J	1.4	5.2	NT					5.4	U		1.5	5.4	NT				
Endrin ketone	na	na	na	NT					2.7	JP	J	1	5.2	NT					5.4	U		1.1	5.4	NT				
Endrin	18000	1800	na	NT					1.8	J	J	0.52	3.1	NT					3.2	U		0.54	3.2	NT				
Heptachlor epoxide	190	53	na	NT					1.3	J	J	0.65	3.1	NT					3.2	U		0.67	3.2	NT				
Lindane	2100	520	na	NT					3.1	U		0.65	3.1	NT					3.2	U		0.67	3.2	NT				
Methoxychlor	310000	31000	na	NT					2.5	J	J	0.91	3.1	NT					4.1			0.94	3.2	NT				
PCBs (mg/kg)																												
PCB-1254	0.74	0.022	na	NT					0.13	U		0.03	0.13	NT					0.13	U		0.031	0.13	NT				
Explosives (mg/kg)																												
None detected																												
Herbicides (ug/kg)																												
None detected																												
Metals (mg/kg)																												
Aluminum	99000	7700	40041	12100		J	0.052	0.31	15900	M	J	0.052	0.31	16200		J	0.053	0.32	17200		J	0.054	0.32	10300		J	0.051	0.3
Antimony	41	3.1	na	0.44	J	L	0.1	0.7	0.49	J	L	0.1	0.71	0.58	J	L	0.11	0.72	0.61	J	L	0.11	0.72	0.16	J	L	0.1	0.68
Arsenic	1.6	0.39	15.8	32.1		J	0.17	1.2	37.4		J	0.17	1.2	33.8		J	0.17	1.2	26.6		J	0.17	1.2	17.6		J	0.16	1.1
Barium	19000	1500	209	81.8		J	0.01	0.062	111	Y,M	J	0.1	0.63	110		J	0.011	0.064	116		J	0.011	0.064	70.4		J	0.01	0.061
Beryllium	200	16	1.02	1.1			0.005	0.031	1.5		M	0.005	0.031	1.5			0.005	0.032	1.6			0.005	0.032	1			0.005	0.03
Cadmium	80	7	0.69	0.039	UV	UJ	0.039	0.27	0.079	UV,M	UL	0.079	0.55	1.3		L	0.007	0.056	1.2		L	0.008	0.056	0.66		L	0.007	0.053
Calcium	na	na	na	70200		J	0.39	5.8	21400	M	J	0.079	1.2	5360		J	0.079	1.2	28600		J	0.081	1.2	69800		J	0.76	11
Chromium	150000	12000	65.3	10.9		J	0.024	0.32	14.2	M	J	0.025	0.33	17.2		J	0.025	0.33	14.6		J	0.026	0.34	9.3		J	0.024	0.32
Cobalt	30	2.3	72.3	7.8		J	0.019	0.13	10.2	M	J	0.02	0.13	14.5		J	0.02	0.13	7.7		J	0.02	0.13	4.6		J	0.019	0.12
Copper	4100	310	53.5	44.1			0.077	0.49	32.2			0.079	0.5	35.4			0.079	0.5	29.5			0.081	0.51	20.1			0.076	0.48
Iron	72000	5500	50962	57300		J	1.9	12	47200	Y,M	J	3.9	24	44400		J	0.79	4.8	37400		J	0.81	4.8	26600		J	0.76	4.5
Lead	800	400	26.8	200		J	0.26	1.5	72.4	M	J	0.52	3.1	72.5		J	0.053	0.32	97		J	0.054	0.32	40.7		J	0.051	0.3
Magnesium	na	na	na	23100		K	0.15	0.93	14300		K	0.16	0.94	3610		K	0.16	0.95	18200		K	0.16	0.97	38200	B	K	1.5	9.1
Manganese	2300	180	2543	1520		J	0.1	0.77	1290	Y	J	0.21	1.6	1210		J	0.042	0.32	993		J	0.043	0.32	669		J	0.04	0.3
Mercury	4.3	1.0	0.13	0.075		J	0.002	0.011	0.038	Y,M	J	0.002	0.011	0.083		J	0.002	0.011	0.085		J	0.002	0.011	0.042		J	0.002	0.01
Nickel	2000	150	62.8	9.8		J	0.023	0.15	14.5		J	0.024	0.16	17.1		J	0.024	0.16	14.6		J	0.024	0.16	8.1		J	0.023	0.15
Potassium	na	na	na	1100			14	85	1460			14	87	1470			15	87	1760			15	89	1330			14	83
Selenium	510	39	na	0.09	U	UL	0.09	0.54	0.092	UY	UL	0.092	0.55	0.093	U	UL	0.093	0.56	0.094	U	UL	0.094	0.56	0.088	U	UL	0.088	0.53
Silver	510	39	na	0.078	J	J	0.022	0.28	0.042	J	J	0.022	0.29	0.023	U		0.023	0.29	0.074	J	J	0.023	0.3	0.039	J	J	0.021	0.28
Sodium	na	na	na	231		K	5.2	67	238		K	5.2	68	226		K	5.3	69	187		K	5.4	70	255		K	5.1	66
Thallium	1	0.078	2.11	0.69	J	L	0.052	0.72	0.99	M	L	0.052	0.73	1.4		L	0.053	0.74	0.98		L	0.054	0.75	0.45	J	L	0.051	0.71
Vanadium	520	39	108	22.2		J	0.014	0.18	28.6		J	0.014	0.18	31.4		J	0.015	0.19	30.5</									

Table 4-8
Legend

12	J	Shading and black font indicate an industrial SL exceedance.
12	J	Bold outline indicates a residential SL exceedance.
12	J	Bold, underlined font indicates a background exceedance.
12	12	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

SLs for non-Carcinogenic compounds have been recalculated to an HI of 0.1.

The pyrene SLs were used for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene.

Inorganic results below background UTLs are not indicated as exceedances on the table.

SL = Screening Level (Source: ORNL Regional Screening Table, November 2012).

Lead screening values from Technical Review Workgroup for Lead: Guidance Document (USEPA, 1999).

mg/kg = milligrams per kilogram (parts per million).

µg/kg = micrograms per kilogram (parts per billion).

NA = not applicable.

NT = analyte not tested.

Lab Q = Lab Data Qualifiers

B = (organics) Blank contamination. Value detected in sample and associated blank.

J = (organics) Value <MRL and >MDL and is considered estimated.

M = Matrix spike and/or matrix spike duplicate recovery outside acceptance limits.

P = Concentration of analyte differs more than 40% between primary and confirmation analysis.

U = Analyte not-detected at the method reporting limit.

V = Raised Quantitation or Reporting Limit due to limited sample amount or dilution for matrix background interference.

Y = Replicate/Duplicate precision outside acceptance limits.

Val Q = Validation Data Qualifiers

B = blank contamination. Value detected in sample and associated blank.

J = estimated concentration.

K = estimated concentration bias high.

L = estimated concentration bias low.

UJ = estimated concentration non-detect.

UL = estimated concentration non-detect bias low.

Table 4-9
Summary of Analytes Detected in Southeast Hillside Area Lab Confirmation Samples
Page 1 of 2

Analyte	i-SL	r-SL	Background	# of i-SL Exceedances	# of r-SL Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/kg)											
Acetone	63000000	6100000	na	0	0	na	3	5	130	190	ARSCH02
SVOCs/PAHs (ug/kg)											
2-Methylnaphthalene	220000	23000	na	0	0	na	5	5	5.9	7	ARSCH11
Acenaphthylene	1700000	170000	na	0	0	na	2	5	1.6	2.1	ARSCH09
Benz(a)anthracene	2100	150	na	0	0	na	5	5	3.5	7.6	ARSCH09
Benzo(a)pyrene	210	15	na	0	0	na	3	5	1.8	3.3	ARSCH03
Benzo(b)fluoranthene	2100	150	na	0	0	na	5	5	5.1	12	ARSCH11
Benzo(g,h,i)perylene	1700000	170000	na	0	0	na	5	5	2.6	7.1	ARSCH09
Benzo(k)fluoranthene	21000	1500	na	0	0	na	3	5	1.7	3.3	ARSCH11
Benzoic acid	250000000	24000000	na	0	0	na	2	5	450	480	ARSCH09
Chrysene	210000	15000	na	0	0	na	5	5	3.7	11	ARSCH11
Fluoranthene	2200000	230000	na	0	0	na	5	5	9	18	ARSCH11
Fluorene	2200000	230000	na	0	0	na	2	5	1.7	2	ARSCH09
Indeno(1,2,3-cd)pyrene	2100	150	na	0	0	na	5	5	3.7	6.9	ARSCH11
Naphthalene	18000	3600	na	0	0	na	5	5	6.8	8.8	ARSCH11
Pentachlorophenol	2700	890	na	0	0	na	1	5	320	320	ARSCH11
Phenanthrene	1700000	170000	na	0	0	na	5	5	10	18	ARSCH03
Pyrene	1700000	170000	na	0	0	na	5	5	6.4	14	ARSCH09
Pesticides (ug/kg)											
4,4'-DDT	7000	1700	na	0	0	na	4	5	2	5.7	ARSCH02
alpha-BHC	270	77	na	0	0	na	1	5	1.8	1.8	ARSCH09
beta-BHC	960	270	na	0	0	na	1	5	21	21	ARSCH11
Dieldrin	110	30	na	0	0	na	3	5	1.1	1.3	ARSCH09
Endosulfan II	na	na	na	na	na	na	1	5	0.65	0.65	ARSCH09
Endosulfan I	na	na	na	na	na	na	2	5	1	2	ARSCH11
Endosulfan sulfate	na	na	na	na	na	na	1	5	1.7	1.7	ARSCH09
Endrin aldehyde	na	na	na	na	na	na	1	5	1.9	1.9	ARSCH09
Endrin ketone	na	na	na	na	na	na	1	5	2.7	2.7	ARSCH09
Endrin	18000	1800	na	0	0	na	2	5	0.63	1.8	ARSCH09
Heptachlor epoxide	190	53	na	0	0	na	1	5	1.3	1.3	ARSCH09
Lindane	2100	520	na	0	0	na	1	5	1.5	1.5	ARSCH01
Methoxychlor	310000	31000	na	0	0	na	4	5	2.4	5.7	ARSCH02
PCBs (mg/kg)											
PCB-1254	0.74	0.022	na	0	0	na	1	5	0.037	0.037	ARSCH03
Explosives (mg/kg) <i>None detected</i>											
Herbicides (ug/kg) <i>None detected</i>											
Metals (mg/kg)											
Aluminum	99000	7700	40041	0	0	0	12	12	5610	18400	ARSCH04
Antimony	41	3.1	na	0	1	na	12	12	0.16	6.1	ARSCH07
Arsenic	1.6	0.39	15.8	10	10	10	12	12	15.4	44.1	ARSCH04
Barium	19000	1500	209	0	0	0	12	12	49.6	134	ARSCH05
Beryllium	200	16	1.02	0	0	6	12	12	0.33	1.6	ARSCH11
Cadmium	80	7	0.69	0	0	3	9	12	0.23	1.3	ARSCH10
Calcium	na	na	na	na	na	na	12	12	1080	144000	ARSCH07
Chromium	150000	12000	65.3	0	0	0	12	12	4.5	17.2	ARSCH10
Cobalt	30	2.3	72.3	0	0	0	12	12	2.6	14.5	ARSCH10
Copper	4100	310	53.5	0	0	2	12	12	11.2	114	ARSCH07
Iron	72000	5500	50962	0	3	3	12	12	12100	60000	ARSCH04
Lead	800	400	26.8	2	3	11	12	12	24.7	2500	ARSCH07
Magnesium	na	na	na	na	na	na	12	12	1500	71000	ARSCH07
Manganese	2300	180	2543	0	0	0	12	12	147	1520	ARSCH08
Mercury	4.3	1.0	0.13	0	0	0	12	12	0.035	0.09	ARSCH05

Table 4-9
Summary of Analytes Detected in Southeast Hillside Area Lab Confirmation Samples
Page 2 of 2

Analyte	i-SL	r-SL	Background	# of i-SL Exceedances	# of r-SL Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Nickel	2000	150	62.8	0	0	0	12	12	4.5	20.4	ARSCH04
Potassium	na	na	na	na	na	na	12	12	616	1760	ARSCH11
Selenium	510	39	na	0	0	na	5	12	0.34	1.2	ARSCH03
Silver	510	39	na	0	0	na	9	12	0.039	0.1	ARSCH07
Sodium	na	na	na	na	na	na	12	12	8.3	255	ARSCH12
Thallium	1	0.078	2.11	0	0	0	11	12	0.26	1.4	ARSCH10
Vanadium	520	39	108	0	0	0	12	12	12.1	49.1	ARSCH05
Zinc	31000	2300	202	0	0	1	12	12	39.4	337	ARSCH02

Pesticides. Thirteen pesticides were detected in samples collected from the southeast hillside. None of the detected concentrations were above r-SLs or i-SLs.

PCBs. PCB-1254 was detected in one single sample (ARSch03) from the southeast hillside at a concentration (0.037 mg/kg) slightly exceeding the r-SL (0.022 mg/kg), but below the i-SL (0.74 mg/kg).

Explosives. Explosives were not detected in samples collected from the southeast hillside.

Herbicides. Herbicides were not detected in samples collected in the southeast hillside.

4.1.4 XRF Correlation

Approximately 30 XRF screening samples were collected and analyzed for lead and arsenic at a fixed-based lab to confirm the accuracy of the XRF data. In order to evaluate the accuracy of the XRF field screening results, the Pearson product moment correlation coefficient (r) (sometimes referred to as the MCV or PMCC) was used to compare the data sets. The correlation coefficient is a dimensionless index that ranges from -1 to +1 and reflects the degree of linear relationship between two variables or data sets. The equation for the Pearson product moment correlation coefficient used to calculate the correlation factor was as follows:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

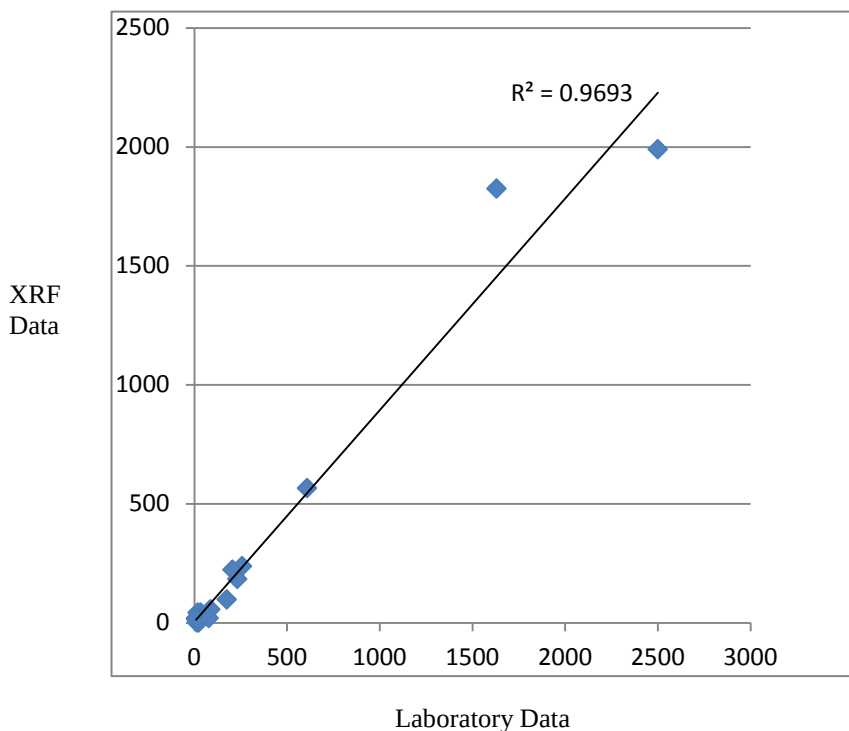
where:

- x = the XRF lead screening results
- $\bar{x}$ = the mean of the XRF lead screening results
- y = the fixed-based laboratory confirmation results
- $\bar{y}$ = the mean of the fixed-based laboratory confirmation results

A correlation factor of 1 indicates that there is a perfect positive linear relationship between variables, whereas a correlation factor of -1 is indicative of a perfect negative linear relationship between variables. A correlation of 0 means there is no linear relationship between the two variables. Correlations are rarely if ever 0, 1, or -1.

As shown on **Figure 4-7**, the XRF lead field screening results and fixed-based laboratory results were compared using the Pearson correlation. This comparison showed a correlation factor of 0.96 between the XRF lead field screening results and the fixed-based lab analytical results. This correlation factor indicates that the XRF data correlates well with the fixed-based laboratory results and can be used to accurately determine the area where lead is present above SLs.

Figure 4-7. Lead XRF v. Laboratory Correlation



The arsenic correlation is displayed on **Figure 4-8**. This comparison showed a correlation factor of 0.26 between the XRF arsenic screening results and the fixed-based lab analytical results. This correlation factor indicated that the XRF arsenic data correlates poorly with the fixed-based laboratory results. The XRF limit of detection for arsenic in the presence of lead is highly variable due to Pb-As interference. To illustrate this fact, two samples of note, ARSCH06 and ARSCH07, had XRF arsenic concentrations of 74.24 mg/kg and 113.91 mg/kg, respectively. These samples had laboratory concentrations of 15.6 mg/kg and 15.4 mg/kg, respectively. Comparatively, ARSCH06 and ARSCH07 contained lead concentrations of 1,630 mg/kg and 2,500 mg/kg. Removing these two “high-lead” outliers, the correlation factor increases to 0.69. On average, the XRF arsenic concentrations trended a higher mg/kg measurement than their laboratory counterparts.

4.2 Building Debris Sample Results

In March 2010, during the initial site reconnaissance, a sample (ARSS01) of the debris material was collected behind the ARSAR target berm to determine if the building debris posed an environmental threat (**Figure 3-1**). The sample was collected from a green material attached to concrete debris that comprised a small percentage of the total (<5 percent) debris. An off-site TCLP metals and asbestos analysis of the material was conducted. Approximately 5.2 tons of debris material was removed from the ARSAR to address the asbestos.

In addition to the 2010 conductive flooring debris sample, one soil sample (ARSSCF01) was collected from the soil located beneath building debris area (**Figure 3-1**) to assess whether the debris material posed an environmental threat. The sample was sent to an off-site laboratory and analyzed for TCLP metals and asbestos. Results detected in the laboratory samples are presented in **Table 4-10**.

TCLP Metals. No TCLP metals exceeded the RLs in the soil directly underlying the debris area.

Asbestos. Asbestos was encountered in ARSSCF01. Chrysotile was encountered at 1.3 percent.

Figure 4-8. Arsenic XRF v. Laboratory Correlation

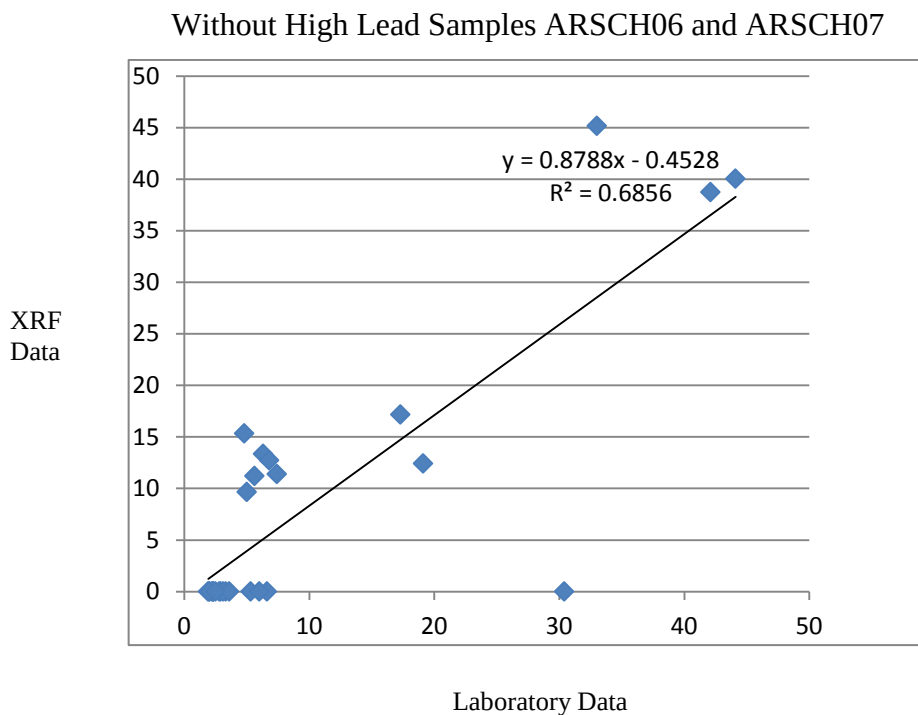
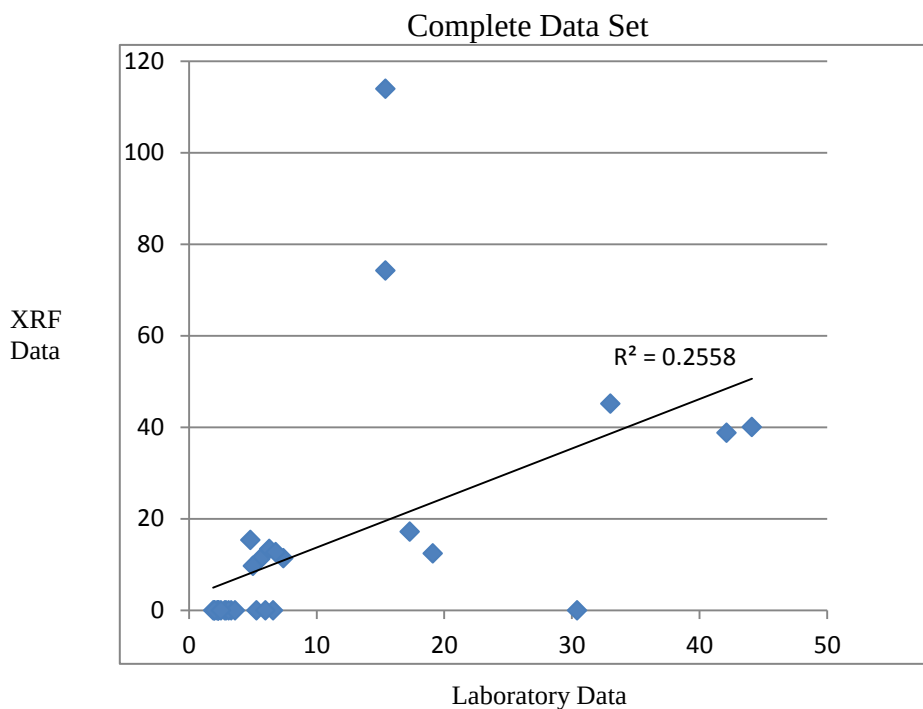


Table 4-10
ARSAR Building Debris Sample Results

Analyte	Sample ID	ARSS01		ARSSCF01	
	Matrix	Building Debris		Soil	
	Sample Date	3/18/2010		5/5/2011	
	TCLP RL	Result	Lab Q	Result	Lab Q
TCLP Metals (mg/L)					
TCLP Silver	5	0.1	U	0.00070	UY
TCLP Chromium	5	0.1	U	0.0019	JY
TCLP Cadmium	1	0.05	U	0.0029	Y
TCLP Lead	5	0.5	U	0.0040	JY
TCLP Arsenic	1	1	U	0.0092	JY
TCLP Selenium	100	0.2	U	0.031	Y
TCLP Barium	5	7.7	B	2.00	
TCLP Mercury	0.2	0.002	U	0.000030	U
Asbestos (%)					
Asbestos - Chrysotile		1.2		1.3	

J = Estimated value.

U = Analyte concentration was not above the detection level.

Y = Replicate/Duplicate precision outside acceptance limits.

B = Blank contamination: The analyte was detected above one-half the reporting limit in an associated blank.

4.3 Sediment Analytical Results

Five sediment (ARSD01 through ARSD05) samples collocated with surface water samples ARSW01 through ARSW05 were collected from Stroubles Creek (see **Figure 3-1**). Sediment samples ARSD01, ARSD03, and ARSD05 were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, and TAL metals. Sediment samples ARSD02 and ARSD04 were analyzed for TAL metals and explosives. Results detected in the laboratory samples are presented in **Table 4-11** and summarized in **Table 4-12**. Analytes detected above the SLs in sediment samples are illustrated on **Figure 4-9**.

TAL Metals. Twenty-two metals were detected in the sediment samples collected from Stroubles Creek. Of the 22 metals, ARSD03 had one background exceedance of copper. No TAL metal was detected at a concentration in excess of its respective i-SL or r-SL.

VOCs. Three VOCs (acetone, benzene, and toluene) were detected in the sediment samples. No VOCs were in excess of i-SLs or r-SLs.

SVOCs/PAHs. Seventeen SVOCs/PAHs were detected in the sediment samples. Three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene] exceeded their respective r-SLs. These presence of these PAHs are likely attributable to the deteriorating asphalt parking lot adjacent to the site and the creek.

Pesticides. Six pesticides were detected in the sediment samples at concentrations below their respective i-SLs and r-SLs.

PCBs. No PCBs were detected in sediment samples.

Explosives. Explosives were not detected in sediment samples.

Herbicides. Herbicides were not detected in sediment samples.

4.4 Surface Water Analytical Results

Five surface water (ARSW01 through ARSW05) samples collocated with sediment samples ARSD01 through ARSD05 were collected from Stroubles Creek (see **Figure 3-1**). Surface water samples ARSW01, ARSW03, and ARSW05 were analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCB, herbicides, explosives, TAL metals, and perchlorate. Results detected in the laboratory samples are presented in **Table 4-13** and summarized in **Table 4-14**. Analytes detected above the SLs in surface water samples are illustrated on **Figure 4-10**.

TAL Metals. Thirteen metals were detected in the surface water samples collected from Stroubles Creek. Aluminum (ARSW01 and ARSW02) and iron (ARSW02) were detected at concentrations greater than their secondary MCLs. Additionally, manganese was detected at a concentration greater than its tw-SL in ARSW02. It should be noted that the constituents of concern at the site including, antimony, arsenic, and lead were not detected in any of the five surface water samples.

VOCs. Three VOCs (acetone, chloromethane, and toluene) were detected at concentrations below their respective MCLs and tw-SLs.

SVOCs/PAHs. One SVOC/PAH (di-n-butylphthalate) was detected in ARSW03 at a concentration below its MCL and tw-SL.

Table 4-11
Analytes Detected in Stroubles Creek Sediment Samples

Analyte	Sample ID			ARSD01					ARSD02					ARSD03					ARSD04					ARSD05				
	Sample Date			5/10/11					5/10/11					5/10/11					5/10/11					5/10/11				
	Sample Depth			0-0.5					0-0.5					0-0.5					0-0.5					0-0.5				
	i-SL	r-SL	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (ug/kg)																												
Acetone	63000000	6100000	na	1300	U		81	1300	NT					92	JB	B	74	1200	NT					93	JB	B	73	1200
Benzene	5600	1100	na	46	J	J	6.5	65	NT					28	J	J	5.9	59	NT					17	J	J	5.8	58
Toluene	4500000	500000	na	45	J	J	9.1	65	NT					35	J	J	8.2	59	NT					28	J	J	8.2	58
SVOCs/PAH (ug/kg)																												
2-Methylnaphthalene	220000	23000	na	8.4	Q	K	0.28	3.8	NT					13	Q	K	0.3	4.1	NT					39	Q	J	0.3	4.1
Acenaphthene	3300000	340000	na	2.3	J	J	0.41	3.8	NT					2.2	J	J	0.45	4.1	NT					4.1	U	UL	0.45	4.1
Acenaphthylene	1700000	170000	na	0.88	J	J	0.3	3.8	NT					4.1	U		0.33	4.1	NT					2.6	J	L	0.33	4.1
Anthracene	17000000	1700000	na	47			0.39	3.8	NT					2.9	J	J	0.43	4.1	NT					15		L	0.42	4.1
Benz(a)anthracene	2100	150	na	61			0.4	3.8	NT					23			0.44	4.1	NT					100		J	0.43	4.1
Benzo(a)pyrene	210	15	na	68			0.35	6.3	NT					21			0.38	6.9	NT					120		J	0.38	6.8
Benzo(b)fluoranthene	2100	150	na	120			0.5	3.8	NT					54			0.55	4.1	NT					270		J	0.54	4.1
Benzo(g,h,i)perylene	1700000	170000	na	56			0.49	3.8	NT					22			0.53	4.1	NT					130		J	0.53	4.1
Benzo(k)fluoranthene	21000	1500	na	41			0.46	3.8	NT					16			0.51	4.1	NT					86		J	0.5	4.1
Chrysene	210000	15000	na	190			0.44	3.8	NT					45			0.48	4.1	NT					190		J	0.48	4.1
Dibenz(a,h)anthracene	210	15	na	11			0.44	3.8	NT					3.3	J	J	0.48	4.1	NT					23		J	0.48	4.1
Fluoranthene	2200000	230000	na	160			0.45	3.8	NT					74			0.49	4.1	NT					270		J	0.49	4.1
Fluorene	2200000	230000	na	5.9			0.45	3.8	NT					7			0.49	4.1	NT					15		J	0.49	4.1
Indeno(1,2,3-cd)pyrene	2100	150	na	62			0.45	3.8	NT					23			0.49	4.1	NT					140		J	0.49	4.1
Naphthalene	18000	3600	na	11			0.34	3.8	NT					18			0.37	4.1	NT					43		J	0.37	4.1
Phenanthrene	1700000	170000	na	62			0.56	3.8	NT					56			0.62	4.1	NT					130		J	0.61	4.1
Pyrene	1700000	170000	na	120			0.51	1.9	NT					52			0.56	2.1	NT					210		J	0.56	2
Pesticides (ug/kg)																												
4,4'-DDD	7200	2000	na	0.5	J	J	0.37	3	NT					3.3	U		0.41	3.3	NT					3.3	U		0.41	3.3
4,4'-DDE	5100	1400	na	3	UM	UL	0.37	3	NT					0.82	J	J	0.41	3.3	NT					0.95	JP	J	0.41	3.3
4,4'-DDT	7000	1700	na	2.2	J	J	0.62	3	NT					2.4	J	J	0.68	3.3	NT					4.1		J	0.68	3.3
Endrin	18000	1800	na	3	U		0.5	3	NT					3.3	U		0.54	3.3	NT					0.68	JP	J	0.55	3.3
Heptachlor	380	110	na	0.62	J	J	0.5	3	NT					0.54	JP	J	0.54	3.3	NT					0.55	JP	J	0.55	3.3
Methoxychlor	310000	31000	na	4.6	P	J	0.87	3	NT					3.5	P	J	0.95	3.3	NT					5.5	P	J	0.95	3.3
PCBs (mg/kg)																												
None detected																												
Explosives (mg/kg)																												
None detected																												
Herbicides (ug/kg)																												
None detected																												
Metals (mg/kg)																												
Aluminum	99000	7700	40041	5520			0.05	0.3	5100			0.06	0.36	4860			0.055	0.33	5080			0.055	0.33	6340			0.055	0.33
Antimony	41	3.1	na	0.13	J	J	0.1	0.68	0.2	J	J	0.12	0.82	0.2	J	J	0.11	0.74	0.4	J	J	0.11	0.74	0.21	J	J	0.11	0.74
Arsenic	1.6	0.39	15.8	4.5			0.16	1.1	4.5			0.2	1.4	5.2			0.18	1.2	5.7			0.18	1.2	3.9			0.18	1.2
Barium	19000	1500	209	116			0.05	0.3	89.1			0.06	0.36	98.6			0.055	0.33	97.7			0.055	0.33	91.4		J	0.055	0.33
Beryllium	200	16	1.02	0.47			0.005	0.03	0.44			0.006	0.036	0.42			0.005	0.033	0.45			0.005	0.033	0.43			0.005	0.033
Cadmium	80	7	0.69	0.16			0.007	0.053	0.22			0.009	0.063	0.23			0.008	0.058	0.25			0.008	0.057	0.34			0.008	0.058
Calcium	na	na	na	9850			0.38	5.6	13300			0.45	6.8	9620			0.41	6.2	11300			0.41	6.1	24800			0.41	6.2
Chromium	150000	12000	65.3	18.4			0.024	0.31	8.6			0.029	0.38	9.8			0.026	0.34	8.9			0.026	0.34	9.6			0.026	0.34
Cobalt	30	2.3	72.3	8.1			0.019	0.12	7.9			0.023	0.15	8.1			0.021	0.13	7.8			0.02	0.13	7.6			0.021	0.13
Copper	4100	310	53.5	14.7			0.075	0.48	11			0.091	0.57	80.8			0.082	0.52	10.9			0.082	0.52	11.1			0.082	0.52
Iron	72000	5500	50962	29600			0.38	2.3	19100			0.45	2.7	24900			0.41	2.5	24500			0.41	2.5	20100			0.41	2.5
Lead	800	400	26.8	9.4			0.05	0.3	11.9			0.06	0.36	11			0.055	0.33	25.4			0.055	0.33	11.1			0.055	0.33
Magnesium	na	na	na	4450			0.15	0.9	3970			0.18	1.1	4380			0.16	0.99	3990			0.16	0.98	7980			0.16	0.99
Manganese	2300	180	2543	398			0.02	0.15	423			0.024	0.18	356			0.022	0.16	433			0.022	0.16	380			0.022	0.16
Mercury	4.3	1.0	0.13	0.013			0.002	0.01	0.03			0.003	0.013	0.015			0.002	0.011	0.013			0.002	0.011	0.021			0.002	0.011
Nickel	2000	150	62.8	11.2			0.023	0.15	10.2			0.027	0.18	11.4			0.025	0.16	10.5			0.025	0.16	11.1			0.025	0.16
Potassium	na	na	na	552			14	180	585			17	220	603			15	200	556			15	200	654			15	200
Silver	510	39	na	0.021	U		0.021	0.28	0.049	J	J	0.026	0.33	0.023	U		0.023	0.3	0.15	J	J	0.023	0.3	0.045	J	J	0.023	0.3
Sodium	na	na	na	32.9	J	J	5	65	41.9	J	J	6	79	36	J	J	5.5	71	38.9	J	J	5.5	71	52.1	J	J	5.5	71
Thallium	1	0.078	2.11	0.23	JB	B	0.05	0.7	0.27	JB	B	0.06	0.85	0.27	JB	B	0.055	0.77	0.26	JB	B	0.055	0.76	0.26	JB	B	0.055	0.77
Vanadium	520	39	108	20.4			0.014	0.18	12.5			0.017	0.21	17.7			0.015	0.19	17.3			0.015	0.19	17.4		J	0.015	0.19
Zinc	31000	2300	202	43.9			0.05	0.6	47.6			0.06	0.73	50.3			0.055	0.66	43.7			0.055	0.65	47.9			0.055	0.66

**Refer to legend immediately following this table for a list of definitions and table notes.

Table 4-11
Legend

12	J	Shading and black font indicate an industrial SL exceedance.
12	J	Bold outline indicates a residential SL exceedance.
<u>12</u>	<u>J</u>	Bold, underlined font indicates a background exceedance.
12	12	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

SLs for non-Carcinogenic compounds have been recalculated to an HI of 0.1.

The pyrene SLs were used for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene.

Inorganic results below background UTLs are not indicated as exceedances on the table.

SL = Screening Level (Source: ORNL Regional Screening Table, November 2012).

Lead screening values from Technical Review Workgroup for Lead: Guidance Document (USEPA, 1999).

mg/kg = milligrams per kilogram (parts per million).

µg/kg = micrograms per kilogram (parts per billion).

NA = not applicable.

NT = analyte not tested.

Lab Q = Lab Data Qualifiers

B = (organics) Blank contamination. Value detected in sample and associated blank.

J = (organics) Value <MRL and >MDL and is considered estimated.

M = Matrix spike and/or matrix spike duplicate recovery outside acceptance limits.

P = Concentration of analyte differs more than 40% between primary and confirmation analysis.

Q = One or more quality control criteria failed (e.g., LCS recovery, surrogate spike recovery or CCV).

U = Analyte not-detected at the method reporting limit.

Val Q = Validation Data Qualifiers

B = blank contamination. Value detected in sample and associated blank.

J = estimated concentration.

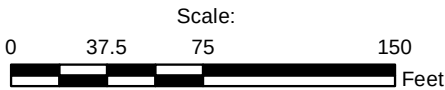
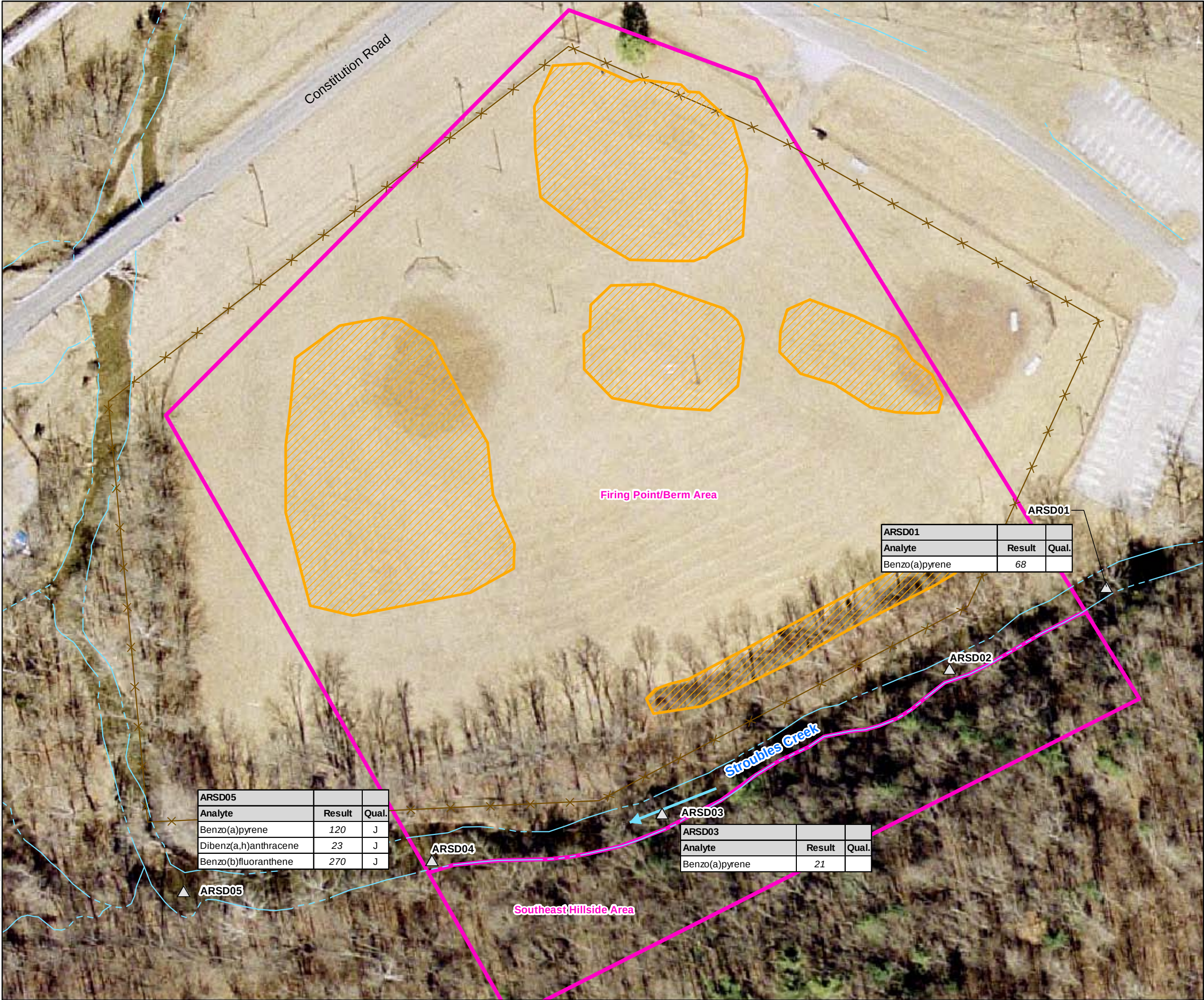
K = estimated concentration bias high.

UL = estimated concentration non-detect bias low.

Table 4-12
Summary of Analytes Detected in Stroubles Creek Sediment Samples

Analyte	i-SL	r-SL	Background	# of i-SL Exceedances	# of r-SL Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/kg)											
Acetone	63000000	6100000	na	0	0	na	2	3	92	93	ARSD05
Benzene	5600	1100	na	0	0	na	3	3	17	46	ARSD01
Toluene	4500000	500000	na	0	0	na	3	3	28	45	ARSD01
SVOCs/PAHs (ug/kg)											
2-Methylnaphthalene	220000	23000	na	0	0	na	3	3	8.4	39	ARSD05
Acenaphthene	3300000	340000	na	0	0	na	2	3	2.2	2.3	ARSD01
Acenaphthylene	1700000	170000	na	0	0	na	2	3	0.88	2.6	ARSD05
Anthracene	17000000	1700000	na	0	0	na	3	3	2.9	47	ARSD01
Benz(a)anthracene	2100	150	na	0	0	na	3	3	23	100	ARSD05
Benzo(a)pyrene	210	15	na	0	3	na	3	3	21	120	ARSD05
Benzo(b)fluoranthene	2100	150	na	0	1	na	3	3	54	270	ARSD05
Benzo(g,h,i)perylene	1700000	170000	na	0	0	na	3	3	22	130	ARSD05
Benzo(k)fluoranthene	21000	1500	na	0	0	na	3	3	16	86	ARSD05
Chrysene	210000	15000	na	0	0	na	3	3	45	190	ARSD01
Dibenz(a,h)anthracene	210	15	na	0	1	na	3	3	3.3	23	ARSD05
Fluoranthene	2200000	230000	na	0	0	na	3	3	74	270	ARSD05
Fluorene	2200000	230000	na	0	0	na	3	3	5.9	15	ARSD05
Indeno(1,2,3-cd)pyrene	2100	150	na	0	0	na	3	3	23	140	ARSD05
Naphthalene	18000	3600	na	0	0	na	3	3	11	43	ARSD05
Phenanthrene	1700000	170000	na	0	0	na	3	3	56	130	ARSD05
Pyrene	1700000	170000	na	0	0	na	3	3	52	210	ARSD05
Pesticides (ug/kg)											
4,4'-DDD	7200	2000	na	0	0	na	1	3	0.5	0.5	ARSD01
4,4'-DDE	5100	1400	na	0	0	na	2	3	0.82	0.95	ARSD05
4,4'-DDT	7000	1700	na	0	0	na	3	3	2.2	4.1	ARSD05
Endrin	18000	1800	na	0	0	na	1	3	0.68	0.68	ARSD05
Heptachlor	380	110	na	0	0	na	3	3	0.54	0.62	ARSD01
Methoxychlor	310000	31000	na	0	0	na	3	3	3.5	5.5	ARSD05
PCBs (mg/kg) None detected											
Explosives (mg/kg) None detected											
Herbicides (ug/kg) None detected											
Metals (mg/kg)											
Aluminum	99000	7700	40041	0	0	0	5	5	4860	6340	ARSD05
Antimony	41	3.1	na	0	0	na	5	5	0.13	0.4	ARSD04
Arsenic	1.6	0.39	15.8	0	0	0	5	5	3.9	5.7	ARSD04
Barium	19000	1500	209	0	0	0	5	5	89.1	116	ARSD01
Beryllium	200	16	1.02	0	0	0	5	5	0.42	0.47	ARSD01
Cadmium	80	7	0.69	0	0	0	5	5	0.16	0.34	ARSD05
Calcium	na	na	na	na	na	na	5	5	9620	24800	ARSD05
Chromium	150000	12000	65.3	0	0	0	5	5	8.6	18.4	ARSD01
Cobalt	30	2.3	72.3	0	0	0	5	5	7.6	8.1	ARSD01
Copper	4100	310	53.5	0	0	1	5	5	10.9	80.8	ARSD03
Iron	72000	5500	50962	0	0	0	5	5	19100	29600	ARSD01
Lead	800	400	26.8	0	0	0	5	5	9.4	25.4	ARSD04
Magnesium	na	na	na	na	na	na	5	5	3970	7980	ARSD05
Manganese	2300	180	2543	0	0	0	5	5	356	433	ARSD04
Mercury	4.3	1.0	0.13	0	0	0	5	5	0.013	0.03	ARSD02
Nickel	2000	150	62.8	0	0	0	5	5	10.2	11.4	ARSD03
Potassium	na	na	na	na	na	na	5	5	552	654	ARSD05
Silver	510	39	na	0	0	na	3	5	0.045	0.15	ARSD04
Sodium	na	na	na	na	na	na	5	5	32.9	52.1	ARSD05
Thallium	1	0.078	2.11	0	0	0	5	5	0.23	0.27	ARSD02
Vanadium	520	39	108	0	0	0	5	5	12.5	20.4	ARSD01
Zinc	31000	2300	202	0	0	0	5	5	43.7	50.3	ARSD03

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U.S. Army Corps of Engineers

Shaw Environmental, Inc.
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FIGURE 4-9
Army Reserve Small Arms Range
Sediment Results
Radford Army Ammunition Plant,
Radford, VA

Table 4-13
Analytes Detected in Stroubles Creek Surface Water Samples

Analyte	Sample ID		ARSW01					ARSW02					ARSW03					ARSW04					ARSW05				
	Sample Date		5/10/11					5/10/11					5/10/11					5/10/11					5/10/11				
	MCL	tw-SL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (ug/L)																											
Acetone	na	1200	3.2	J	B	1	4	NT					2.7	J	B	1	4	NT					1.8	J	B	1	4
Chloromethane	na	19	0.11	J	J	0.026	0.4	NT					0.056	J	J	0.026	0.4	NT					0.043	J	J	0.026	0.4
Toluene	1000	86	0.034	J	B	0.011	0.4	NT					0.04	J	B	0.011	0.4	NT					0.046	J	B	0.011	0.4
SVOCs/PAHs (ug/L)																											
Di-n-butylphthalate	na	67	3.2	U		0.71	3.2	NT					3.1	U		0.69	3.1	NT					0.97	J	J	0.71	3.2
Pesticides (ug/L)																											
Methoxychlor	40	2.7	0.015	JP	J	0.006	0.042	NT					0.042	U		0.006	0.042	NT					0.041	U		0.006	0.041
PCBs (ug/L)None detected																											
Explosives (ug/L)None detected																											
Herbicides (ug/L)None detected																											
Metals (ug/L)																											
Aluminum	50	1600	54.8	J	J	4	210	285			4	210	38.2	J	J	4	210	42.4	J	J	4	210	38.7	J	J	4	210
Barium	2000	290	42			0.26	1.8	46.8			0.26	1.8	42.1			0.26	1.8	41.3			0.26	1.8	40.5			0.26	1.8
Calcium	na	na	37500			15	100	38600			15	100	38200			15	100	37400			15	100	38000			15	100
Chromium	100	1600	0.7	U		0.7	4.2	0.97	J	J	0.7	4.2	0.7	U		0.7	4.2	0.7	U		0.7	4.2	0.7	U		0.7	4.2
Copper	1300	62	1.2	U		1.2	7.6	1.7	J	J	1.2	7.6	1.2	U		1.2	7.6	1.2	U		1.2	7.6	1.2	U		1.2	7.6
Iron	300	2600	84.7			9	54	440			9	54	58.5			9	54	66.5			9	54	47.7	J	J	9	54
Magnesium	na	na	16500			3	88	16900			3	88	16900			3	88	16600			3	88	16900			3	88
Manganese	50	32	5.8			0.7	4.2	36			0.7	4.2	3.8	J	J	0.7	4.2	4.7			0.7	4.2	4.1	J	J	0.7	4.2
Nickel	na	73	0.84	J	J	0.6	8.4	0.96	J	J	0.6	8.4	0.6	U		0.6	8.4	0.76	J	J	0.6	8.4	0.6	J	J	0.6	8.4
Potassium	na	na	1750	J	J	280	1800	1800			280	1800	1750	J	J	280	1800	1690	J	J	280	1800	1720	J	J	280	1800
Sodium	na	na	11700			100	680	11600		J	100	680	11800		J	100	680	11300		J	100	680	11300		J	100	680
Vanadium	na	7.8	0.5	U		0.5	6.8	1J J			0.5	6.8	0.5	U		0.5	6.8	0.5	U		0.5	6.8	0.5	U		0.5	6.8
Zinc	5000	470	1.8	U		1.8	24	3.3	J	J	1.8	24	1.8	U		1.8	24	1.8	U		1.8	24	1.8	U		1.8	24
Misc. (ug/L)																											
Perchlorate	na	1.1	0.222			0.1	0.2	0.211			0.1	0.2	0.22			0.1	0.2	0.236			0.1	0.2	0.222			0.1	0.2

**Refer to legend immediately following this table for a list of definitions and table notes.

Table 4-13
Legend

12	J	Shading and black font indicate an MCL exceedance.
12	J	Bold outline indicates a tw-SL exceedance.
12	12	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

tw-SLs for non-carcinogenic compounds have been recalculated to an HI of 0.1.

tw-SLs for carcinogenic compounds are shown in red font.

Secondary MCLs were used for aluminum, iron, manganese, silver, and zinc.

MCL Action Levels were used for copper and lead.

MCL = Maximum Contaminant Level (Source: 2012 Edition of the Drinking Water Standards and Health Advisories. USEPA, April 2012).

tw-SL = Tap Water Screening Level (Source: ORNL Regional Screening Table, November 2012).

µg/L = micrograms per liter (parts per billion).

NA = not applicable.

NT = analyte not tested.

Lab Q = Lab Data Qualifiers

J = (organics) Value <MRL and >MDL and is considered estimated.

P = Concentration of analyte differs more than 40% between primary and confirmation analysis.

U = Analyte not-detected at the method reporting limit.

Val Q = Validation Data Qualifiers

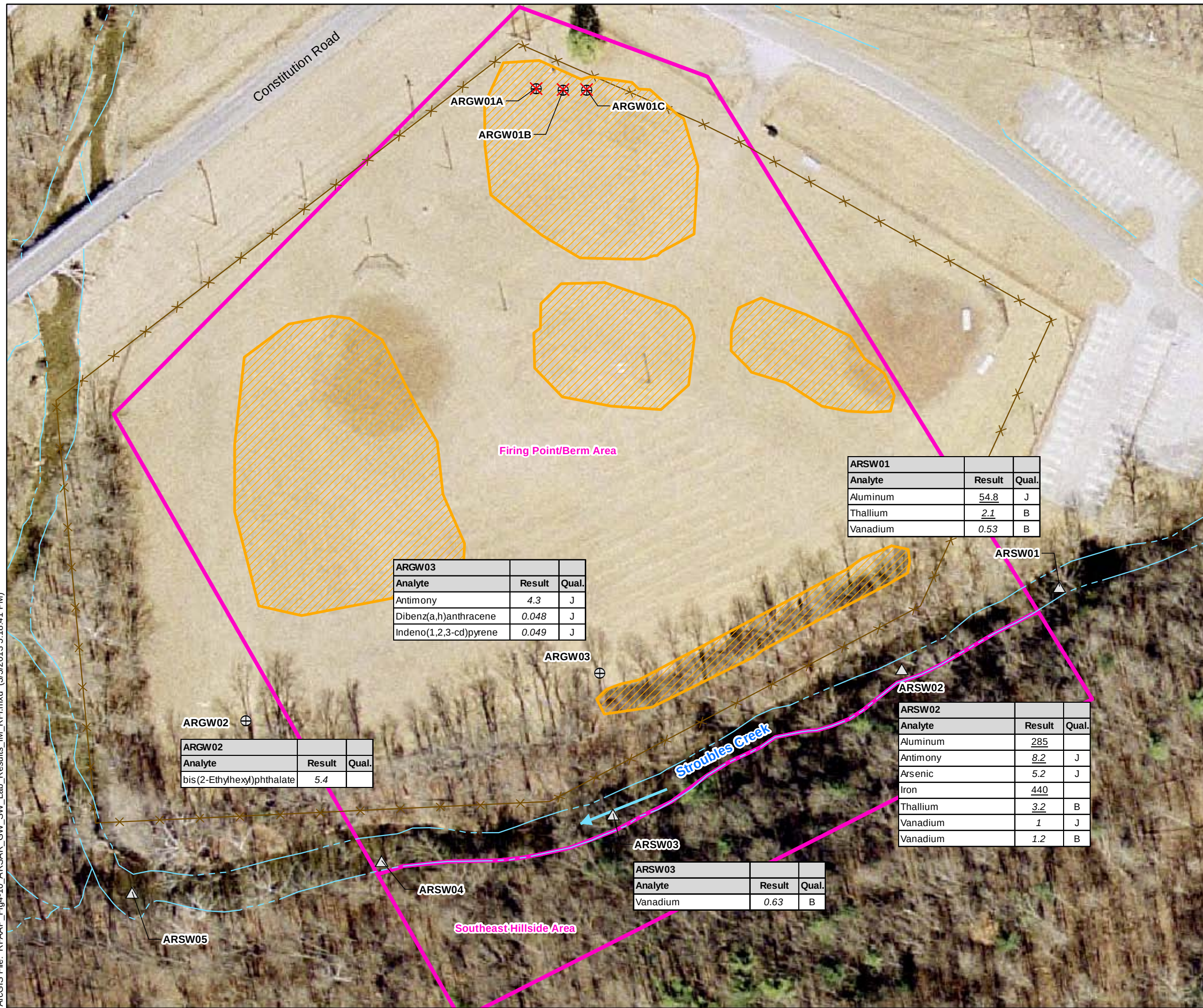
B = blank contamination. Value detected in sample and associated blank.

J = estimated concentration.

Table 4-14
Summary of Analytes Detected in Stroubles Creek Surface Water Samples

Analyte	MCL	tw-SL	# of MCL Exceedances	# of tw-SL Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/L)									
Acetone	na	1200	na	0	3	3	1.8	3.2	ARSW01
Chloromethane	na	19	na	0	3	3	0.043	0.11	ARSW01
Toluene	1000	86	0	0	3	3	0.034	0.046	ARSW05
SVOCs/PAHs (ug/L)									
Di-n-butylphthalate	na	67	na	0	1	3	0.97	0.97	ARSW05
Pesticides (ug/L)									
Methoxychlor	40	2.7	0	0	1	3	0.015	0.015	ARSW01
PCBs (ug/L)	None detected								
Explosives (ug/L)	None detected								
Herbicides (ug/L)	None detected								
Metals (ug/L)									
Aluminum	50	1600	2	0	5	5	38.2	285	ARSW02
Barium	2000	290	0	0	5	5	40.5	46.8	ARSW02
Calcium	na	na	na	na	5	5	37400	38600	ARSW02
Chromium	100	1600	0	0	1	5	0.97	0.97	ARSW02
Copper	1300	62	0	0	1	5	1.7	1.7	ARSW02
Iron	300	2600	1	0	5	5	47.7	440	ARSW02
Magnesium	na	na	na	na	5	5	16500	16900	ARSW02
Manganese	50	32	0	1	5	5	3.8	36	ARSW02
Nickel	na	30	na	0	4	5	0.6	0.96	ARSW02
Potassium	na	na	na	na	5	5	1690	1800	ARSW02
Sodium	na	na	na	na	5	5	11300	11800	ARSW03
Vanadium	na	7.8	na	0	1	5	1	1	ARSW02
Zinc	5000	470	0	0	1	5	3.3	3.3	ARSW02
Misc. (ug/L)									
Perchlorate	na	1.1	na	0	5	5	0.211	0.236	ARSW02

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LEGEND

- Direct Push Groundwater Sample Location (Not Sampled; Failed to Encounter Groundwater)
- Surface Water/Sediment Sample Location
- Direct Push Groundwater Sample Location
- Water Feature
- Surface Water Flow Direction
- Fence Line
- Historic Feature
- MRS Boundary

Notes:

- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
- 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
- 3) Groundwater and surface water results are from 2011.
- 4) Only result values above screening level are reported.
- 5) Metal and SVOC results are in ug/L.
- 6) tw-SL values were obtained from the USEPA Mid-Atlantic Region Regional Screening Level Summary Table, November 2012. MCL values were obtained from the USEPA 2006 Edition of the Drinking Water Standards and Health Advisories.
- 7) Italicized result value indicates a tw-SL exceedance, and underlined result value indicates an MCL exceedance.



Scale:
0 37.5 75 150
Feet



U.S. Army Corps of Engineers

Shaw Environmental, Inc.
(A CB&I Company)

FIGURE 4-10
Army Reserve Small Arms Range
Groundwater and Surface Water Results
Radford Army Ammunition Plant,
Radford, VA

Pesticides. One pesticide (methoxychlor) was detected in surface water. Methoxychlor was detected in ARSW01 at a concentration below its MCL and tw-SL.

PCBs. PCBs were not detected in surface water samples.

Explosives. Explosives were not detected in the surface water samples.

Herbicides. Herbicides were not detected in the surface water samples.

Perchlorate. Perchlorate was detected in all five surface water samples at concentrations below its tw-SL.

4.5 Groundwater Analytical Results

Two direct-push groundwater samples (ARGW02 and ARGW03) were collected within the firing range floor (**Figure 3-1**). Samples were analyzed at a fixed-based laboratory for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, TAL metals (total and dissolved), and perchlorate. Results detected in the laboratory samples are presented in **Table 4-15** and summarized in **Table 4-16**. Analytes detected above the SLs in groundwater samples are illustrated on **Figure 4-10**.

TAL Metals. Ten total metals (antimony, barium, beryllium, calcium, lead, magnesium, manganese, potassium, sodium, and zinc) and nine dissolved metals (barium, beryllium, calcium, magnesium, manganese, nickel, potassium, sodium, and zinc) were detected in groundwater samples at the ARSAR. None of the total or dissolved metals exceeded their respective MCLs in groundwater. Only one total metal (antimony) exceeded its tw-SL in a single sample (ARGW03); however, antimony was not detected in the dissolved metals fraction of either groundwater sample. Dissolved metals concentrations were all below their respective tw-SLs.

VOCs. Five VOCs (acetone, chloroform, chloromethane, ethylbenzene, and toluene) were detected in the groundwater samples. All five VOCs were detected at concentrations below their respective MCLs and tw-SLs.

SVOCs/PAHs. Eight SVOCs/PAHs were detected in the groundwater samples at the ARSAR. Three of the eight SVOCs/PAHs [bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were detected at concentrations exceeding their respective tw-SLs. Bis(2-ethylhexyl)phthalate exceeded its tw-SL in sample ARGW02. Concentrations of dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene exceeded their respective tw-SLs in sample ARGW03. Concentrations of the remaining five SVOCs/PAHs detected in the samples were below their respective MCLs and tw-SLs.

Pesticides. Pesticides were not detected in the groundwater samples.

PCBs. PCBs were not detected in the groundwater samples.

Explosives. Explosives were not detected in the groundwater samples.

Herbicides. Herbicides were not detected in the groundwater samples.

Perchlorate. Perchlorate was detected in both groundwater samples. The concentration was below the tw-SL in sample ARGW02 and exceeded the tw-SL in sample ARGW03.

Table 4-15
Analytes Detected in ARSAR Groundwater Samples

Analyte	Sample ID Sample Date		ARGW02 6/8/11					ARGW03 6/8/11				
	MCL	tw-SL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (ug/L)												
Acetone	na	2200	2.6	JB	B	1	4	5.4	B	B	1	4
Chloroform	80	0.19	0.024	J	J	0.01	0.2	0.2	U		0.01	0.2
Chloromethane	na	19	0.087	JB	B	0.026	0.2	0.28	B	B	0.026	0.2
Ethylbenzene	700	1.5	0.031	J	L	0.027	0.2	0.2	U	UL	0.027	0.2
Toluene	1000	230	0.028	J	B	0.011	0.2	0.018	J	B	0.011	0.2
SVOCs/PAHs (ug/L)												
Benzo(b)fluoranthene	na	0.029	0.076	U		0.013	0.076	0.019	J	J	0.013	0.077
Benzo(g,h,i)perylene	na	110	0.076	U		0.012	0.076	0.045	J	J	0.012	0.077
Benzo(k)fluoranthene	na	0.29	0.076	U		0.014	0.076	0.02	J	J	0.014	0.077
bis(2-Ethylhexyl)phthalate	6	4.8	5.4			0.44	3	2.1	J	J	0.45	3.1
Dibenz(a,h)anthracene	na	0.0029	0.076	U		0.021	0.076	0.048	J	J	0.021	0.077
Di-n-butylphthalate	na	370	0.98	J	J	0.68	3	3.1	U		0.68	3.1
Indeno(1,2,3-cd)pyrene	na	0.029	0.076	U		0.018	0.076	0.049	J	J	0.018	0.077
Naphthalene	na	0.14	0.016	J	J	0.014	0.076	0.077	U		0.014	0.077
Pesticides (ug/L) None detected												
PCBs (ug/L) None detected												
Explosives (ug/L) None detected												
Herbicides (ug/L) None detected												
Total Metals (ug/L)												
Antimony	6	0.6	4	U		4	32	4.3	J	J	4	32
Barium	2000	290	77.3			0.26	1.8	104			0.26	1.8
Beryllium	4	1.6	0.14	J	J	0.13	0.86	0.14	J	J	0.13	0.86
Calcium	na	na	49900			15	100	54300			15	100
Lead	15	na	1.5	U		1.5	9.8	1.5	J	J	1.5	9.8
Magnesium	na	na	20600			3	88	20600			3	88
Manganese	50	32	0.7	U		0.7	4.2	0.71	J	J	0.7	4.2
Potassium	na	na	2200			280	1800	1360	J	J	280	1800
Sodium	na	na	14300			100	680	11300			100	680
Zinc	5000	470	1.8	U		1.8	24	4.5	J	J	1.8	24
Dissolved Metals (ug/L)												
Barium	2000	290	80.6			0.26	1.8	102			0.26	1.8
Beryllium	4	1.6	0.13	U		0.13	0.86	0.13	J		0.13	0.86
Calcium	na	na	48200			15	100	55400			15	100
Magnesium	na	na	19600			3	88	21400			3	88
Manganese	50	32	1	J		0.7	4.2	0.75	J		0.7	4.2
Nickel	na	73	1.6	J		0.6	8.4	0.6	U		0.6	8.4
Potassium	na	na	2190			280	1800	1370	J		280	1800
Sodium	na	na	13700			100	680	11600			100	680
Zinc	5000	470	1.9	J		1.8	24	1.8	U		1.8	24
Misc. (ug/L)												
Perchlorate	na	1.1	0.242			0.1	0.2	1.14			0.1	0.2

**Refer to legend immediately following this table for a list of definitions and table notes.

Table 4-15
Legend

12	J	Shading and black font indicate an MCL exceedance.
12	J	Bold outline indicates a tw-SL exceedance.
12	12	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

tw-SLs for non-carcinogenic compounds have been recalculated to an HI of 0.1.

tw-SLs for carcinogenic compounds are shown in red font.

The pyrene SL was used for acenaphthylene, benzo(g,h,i)perylene and phenanthrene and is shown in blue.

Secondary MCLs were used for aluminum, iron, manganese, silver, and zinc.

MCL Action Levels were used for copper and lead.

MCL = Maximum Contaminant Level (Source: 2012 Edition of the Drinking Water Standards and Health Advisories. USEPA, April 2012).

tw-SL = Tap Water Screening Level (Source: ORNL Regional Screening Table, November 2012).

µg/L = micrograms per liter (parts per billion).

NA = not applicable.

Lab Q = Lab Data Qualifiers

B = Analyte detected in associated Method Blank.

J = (organics) Value <MRL and >MDL and is considered estimated.

U = Analyte not-detected at the method reporting limit.

Val Q = Validation Data Qualifiers

B = blank contamination. Value detected in sample and associated blank.

J = estimated concentration.

L = estimated concentration bias low.

UL = estimated concentration non-detect bias low.

Table 4-16
Summary of Analytes Detected in ARSAR Groundwater Samples

Analyte	MCL	tw-SL	# of MCL Exceedances	# of tw-SL Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/L)									
Acetone	na	1200	na	0	2	2	2.6	5.4	ARGW03
Chloroform	80	0.19	0	0	1	2	0.024	0.024	ARGW02
Chloromethane	na	19	na	0	2	2	0.087	0.28	ARGW03
Ethylbenzene	700	1.3	0	0	1	2	0.031	0.031	ARGW02
Toluene	1000	86	0	0	2	2	0.018	0.028	ARGW02
SVOCs/PAHs (ug/L)									
Benzo(b)fluoranthene	na	0.029	na	0	1	2	0.019	0.019	ARGW03
Benzo(g,h,i)perylene	na	8.7	na	0	1	2	0.045	0.045	ARGW03
Benzo(k)fluoranthene	na	0.29	na	0	1	2	0.02	0.02	ARGW03
bis(2-Ethylhexyl)phthalate	6	4.8	0	1	2	2	2.1	5.4	ARGW02
Dibenz(a,h)anthracene	na	0.0029	na	1	1	2	0.048	0.048	ARGW03
Di-n-butylphthalate	na	67	na	0	1	2	0.98	0.98	ARGW02
Indeno(1,2,3-cd)pyrene	na	0.029	na	1	1	2	0.049	0.049	ARGW03
Naphthalene	na	0.14	na	0	1	2	0.016	0.016	ARGW02
Pesticides (ug/L) None detected									
PCBs (ug/L) None detected									
Explosives (ug/L) None detected									
Herbicides (ug/L) None detected									
Total Metals (ug/L)									
Antimony	6	0.6	0	1	1	2	4.3	4.3	ARGW03
Barium	2000	290	0	0	2	2	77.3	104	ARGW03
Beryllium	4	1.6	0	0	2	2	0.14	0.14	ARGW02
Calcium	na	na	na	na	2	2	49900	54300	ARGW03
Lead	15	na	0	na	1	2	1.5	1.5	ARGW03
Magnesium	na	na	na	na	2	2	20600	20600	ARGW02
Manganese	50	32	0	0	1	2	0.71	0.71	ARGW03
Potassium	na	na	na	na	2	2	1360	2200	ARGW02
Sodium	na	na	na	na	2	2	11300	14300	ARGW02
Zinc	5000	470	0	0	1	2	4.5	4.5	ARGW03
Dissolved Metals (ug/L)									
Barium	2000	290	0	0	2	2	80.6	102	ARGW03
Beryllium	4	1.6	0	0	1	2	0.13	0.13	ARGW03
Calcium	na	na	na	na	2	2	48200	55400	ARGW03
Magnesium	na	na	na	na	2	2	19600	21400	ARGW03
Manganese	50	32	0	0	2	2	0.75	1	ARGW02
Nickel	na	73	na	0	1	2	1.6	1.6	ARGW02
Potassium	na	na	na	na	2	2	1370	2190	ARGW02
Sodium	na	na	na	na	2	2	11600	13700	ARGW02
Zinc	5000	470	0	0	1	2	1.9	1.9	ARGW02
Misc. (ug/L)									
Perchlorate	na	1.1	na	1	2	2	0.242	1.14	ARGW03

4.6 Soil Screening Level Comparison

As shown in **Table 4-17**, detected soil results from all ARSAR soil samples were compared to the current (November 2012) Oak Ridge National Laboratory (ORNL) Regional soil transfer to groundwater values using a dilution attenuation factor of 20 (USEPA, 2012b). As indicated in the table, one VOCs (benzene), three PAHs [benzo(a)pyrene, naphthalene, and pentachlorophenol], four pesticides (alpha-BHC, beta-BHC, dieldrin, and heptachlor epoxide), and six metals (antimony, arsenic, cobalt, iron, manganese, and thallium) exceeded the soil screening levels (SSLs). A more detailed analysis of the arsenic concentrations in the southeast hillside is presented in *Section 4.7.3*.

While concentrations above SSLs indicate a theoretical potential for impact to groundwater, empirical evidence in the form of actual groundwater chemical data and chemical analyses, soil characteristics/chemistry, and fate and transport analysis offer more concrete evidence of site conditions and potential impact to groundwater.

As discussed in *Section 4.2.3*, two direct-push groundwater samples were collected during the 2011 Investigation and analyzed for TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, TAL metals, and perchlorate. Groundwater results indicated that three SVOCs [bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene], and one total metal (antimony) were detected at concentrations above tw-SLs.

Based on SSL, groundwater screening results, and surface water screening results, no analytes were found to exceed both SSLs and groundwater SL criteria at the ARSAR. This indicates that the tested analytes are not migrating downward through the soil to groundwater.

4.7 Nature and Extent Summary Conclusions

4.7.1 Target Berm

The combined data set indicates that metals (primarily lead and antimony) were the constituents of concern at the ARSAR target berm. Through the IM discussed in *Section 2.7.3*, the source material of the constituents of concern has been removed. Confirmation samples collected after removal of the berm surface (top 1-2 ft) indicated that the IM was successful in removing soil with concentrations of lead greater than 400 mg/kg. Confirmation samples showed no constituents with concentrations greater than SLs in any of the samples.

4.7.2 Firing Range Floor and Potential Firing Point Analytical Results

Based on the analytical data collected from the ARSAR firing range floor, there are no constituents of concern for the firing range floor.

The SVOC/PAH and PCB detections were isolated exceedances within the firing range floor and not considered to be site-related. Arsenic was detected in one location, slightly above the background level, but within the 1.2 to 35.9 mg/kg range identified in the facility-wide background study (IT, 2001). Iron was detected in firing range floor samples at concentrations above soil SLs; however, iron was not detected in the total or dissolved metals fractions in groundwater, indicating that iron is not migrating vertically and negatively impacting site groundwater. Based on the data collected during the investigation, the firing range floor soil is not considered a concern at the ARSAR.

Table 4-17
ARSAR – SSL Comparison
Page 1 of 2

Analyte	SSL Transfer	# of SSL Transfer Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (ug/kg)							
Acetone	48000	0	7	21	61	190	ARSCH02
Benzene	4	1	1	21	13	13	ARSBSC01
Chloromethane	980	0	2	21	30	32	ARSCF01
SVOCs/PAHs (ug/kg)							
2-Methylnaphthalene	2800	0	12	21	0.97	13	ARSCF03
Acenaphthene	82000	0	2	21	1.1	16	ARSCF02
Acenaphthylene	190000	0	4	21	0.73	2.1	ARSCH09
Anthracene	840000	0	3	21	0.61	36	ARSCF02
Benz(a)anthracene	200	0	10	21	1.8	140	ARSCF02
Benzo(a)pyrene	70	1	8	21	0.92	130	ARSCF02
Benzo(b)fluoranthene	700	0	15	21	0.46	200	ARSCF02
Benzo(g,h,i)perylene	190000	0	10	21	1.4	81	ARSCF02
Benzo(k)fluoranthene	7000	0	6	21	1.7	65	ARSCF02
Benzoic acid	280000	0	2	21	450	480	ARSCH09
bis(2-Ethylhexyl)phthalate	22000	0	2	21	110	170	ARSCF08
Chrysene	22000	0	16	21	0.91	160	ARSCF02
Dibenz(a,h)anthracene	220	0	5	21	0.46	21	ARSCF02
Fluoranthene	1400000	0	14	21	0.89	270	ARSCF02
Fluorene	80000	0	3	21	1.7	12	ARSCF02
Indeno(1,2,3-cd)pyrene	4000	0	11	21	1.6	93	ARSCF02
Naphthalene	9.4	1	12	21	0.8	10	ARSCF03
Pentachlorophenol	7.2	1	1	21	320	320	ARSCH11
Phenanthrene	190000	0	14	21	1.3	140	ARSCF02
Pyrene	190000	0	13	21	0.97	230	ARSCF02
Pesticides (ug/kg)							
4,4'-DDD	128	0	1	21	1.2	1.2	ARSCF01
4,4'-DDE	920	0	8	21	1.7	9.2	ARSCF02
4,4'-DDT	1340	0	11	21	1.9	6.4	ARSCF02
alpha-BHC	0.72	1	1	21	1.8	1.8	ARSCH09
alpha-Chlordane	na	na	2	21	0.92	7.3	ARSCF01
beta-BHC	2.6	1	1	21	21	21	ARSCH11
delta-BHC	na	na	1	21	1.4	1.4	ARSCF02
Dieldrin	1.22	2	4	21	1.1	2.1	ARSCF02
Endosulfan I	na	na	2	21	1	2	ARSCH11
Endosulfan II	na	na	1	21	0.65	0.65	ARSCH09
Endosulfan sulfate	na	na	1	21	1.7	1.7	ARSCH09
Endrin aldehyde	na	na	1	21	1.9	1.9	ARSCH09
Endrin ketone	na	na	1	21	2.7	2.7	ARSCH09

Table 4-17
ARSAR – SSL Comparison
Page 2 of 2

Analyte	SSL Transfer	# of SSL Transfer Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Endrin	1360	0	3	21	0.63	12	ARSBSC09
Heptachlor epoxide	1.36	1	2	21	1.3	2.4	ARSCF02
Lindane	4.2	0	1	21	1.5	1.5	ARSCH01
Methoxychlor	30000	0	12	21	1.1	5.7	ARSCH02
PCBs (mg/kg)							
PCB-1254	0.176	0	2	21	0.037	0.047	ARSCF02
Explosives (mg/kg)							
2,6-Dinitrotoluene	0.4	0	1	21	0.13	0.13	ARSCF01
Herbicides (ug/kg) <i>None detected</i>							
Metals (mg/kg)							
Aluminum	460000	0	35	35	5610	18400	ARSCH04
Antimony	5.2	1	24	35	0.12	6.1	ARSCH07
Arsenic	0.026	35	35	35	1.9	44.1	ARSCH04
Barium	2400	0	35	35	29.4	134	ARSCH05
Beryllium	260	0	31	35	0.0072	1.6	ARSCH11
Cadmium	10.4	0	17	35	0.01	1.3	ARSCH10
Calcium	na	na	35	35	244	144000	ARSCH07
Chromium	560000000	0	35	35	4.5	46.1	ARSBSC02
Cobalt	4.2	27	34	35	2.6	28.1	ARSCF01
Copper	440	0	35	35	4.4	114	ARSCH07
Iron	5400	35	35	35	12100	90800	ARSCF05
Lead	na	na	35	35	9.8	2500	ARSCH07
Magnesium	na	na	35	35	366	71000	ARSCH07
Manganese	420	23	34	35	147	1910	ARSBSC14
Mercury	0.66	0	35	35	0.0082	0.13	ARSBSC02
Nickel	400	0	35	35	2.9	27	ARSCF05
Potassium	na	na	35	35	285	1760	ARSCH11
Selenium	8	0	20	35	0.24	1.5	ARSBSC14
Silver	12	0	11	35	0.03	0.1	ARSCH07
Sodium	na	na	20	35	6	255	ARSCH12
Thallium	0.22	33	33	35	0.23	1.4	ARSCH10
Vanadium	1560	0	35	35	12.1	76.5	ARSBSC14
Zinc	5800	0	35	35	10.3	337	ARSCH02

4.7.3 Southeast Hillside Area

The soil at the Southeast Hillside Area was investigated during the 2009 SSP and then again in 2011 in support of the 2011 RFI. The combined data set from these investigations indicates that metals, primarily lead and arsenic, are potential constituents of concern within the southeast hillside of the ARSAR. In addition to arsenic and lead, antimony and iron were detected at concentrations greater than screening criteria.

Based on the results from the soil investigations of the southeast hillside, lead concentrations were present at levels of concern approximately 10 to 30 ft up the southeast hillside. Although bullet fragments were not encountered in the southeast hillside, high lead concentrations at the base of the hill strongly indicates the use of the hillside as a backstop during the active periods of the firing range. Lead is present in a limited area of the hillside and based on surface water and sediment sample results, does not appear to be negatively impacting the stream.

Based on the XRF data, arsenic was detected at concentrations above the established background concentration over much of the southeast hillside, including areas where lead concentrations were minimal. As samples were collected in the 6- to 8-inch soil layer directly overlying the bedrock, it is believed the arsenic exceedances are a result of the weathering limestone/dolomite bedrock. As demonstrated in the sediment and surface water data collected from Stroubles Creek, arsenic does not appear to be mobile in the hillside soil.

In most uncontaminated oxic soils, arsenic exhibits an almost exclusive association with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). Arsenic exists in oxic soil pore fluid as oxyanions such as HAsO_4^{-2} and H_2AsO_4^- (Brookins, 1988), and these negatively charged species have a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge (Electric Power Research Institute, 1986). (As used here, the term “iron oxide” encompasses oxides, hydroxides, oxyhydroxides, and hydrous oxides of iron.) This association is expressed as covariance of arsenic concentrations and iron concentrations for uncontaminated samples: soil samples with a low percentage of iron oxides will contain proportionally lower arsenic concentrations, and soil samples that are enriched in iron oxides will contain proportionally higher arsenic concentrations. Although there is variability in the absolute concentrations of arsenic and iron in soil at a site, the As/Fe ratios of the samples will be relatively consistent if no contamination is present (Daskalakis and O'Connor, 1995). Samples that contain excess arsenic from a contaminant source (e.g., arsenical herbicides) will exhibit anomalously high As/Fe ratios compared to the uncontaminated samples.

The ARSAR iron and aluminum data indicate that the target berm soil samples and southeast hillside soil samples have iron oxide and clay content that is identical to that of the RFAAP background soil samples (**Figure 4-11**). In the plot, the background surface soil samples are represented by light circles (BG SS), background subsurface soil samples are represented by dark circles (BG SB), range floor soil samples are represented by triangles, target berm soil samples are represented by squares, and southeast hillside soil samples are represented by diamonds. Aluminum is a primary component of clay minerals, and its concentrations in uncontaminated soil samples serve as a qualitative indicator of clay content. Similarly, iron concentrations indicate the relative amount of iron oxide minerals in soil samples. Samples that are naturally enriched in these fine-grained minerals have naturally higher iron and aluminum concentrations. Such samples also have naturally higher concentrations of specific trace elements that have affinities to adsorb on the mineral surfaces (Kabata-Pendias, 2001; Cornell and Schwertmann,

2003). Most of the range-floor samples have higher iron concentrations relative to the target berm, hillside, and background samples (**Figure 4-11**), but their consistent Fe/Al ratios indicate a natural source for their iron and aluminum concentrations. These range-floor samples – collected from Quaternary alluvium that can have multiple sources and may include reworked channel deposits – have lower clay content compared to many of the background samples, and their iron-oxide content is higher. The remaining site samples have iron concentrations, aluminum concentrations, and Fe/Al ratios that are identical to background, indicating a natural source for the iron and aluminum detected in those samples.

In contrast to the Firing Point/Berm Area soil samples collected from Quaternary alluvium, the Southeast Hillside Area samples represent soil developed from the weathering of calcareous shale and limestone bedrock (the Devonian Millsboro Shale and Ordovician Martinsburg Formation), which is dominantly composed of calcium-carbonate (CaCO_3) and calcium-magnesium-carbonate [$\text{CaMg}(\text{CO}_3)_2$] minerals. Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. As a result of this behavior, the concentrations of these two elements can covary in uncontaminated soil samples. Most of the hillside soil samples have calcium and magnesium concentrations that are higher than those of the other samples (**Figure 4-12**). The hillside samples with the highest calcium and magnesium concentrations likely contain partially weathered fragments of limestone. One range-floor sample also has elevated calcium and magnesium, indicating that it, too, may contain such fragments. However, the consistent Ca/Mg ratios indicate a natural source for these major elements in the site samples.

As explained above, arsenic in oxic soil pore fluid is commonly present as oxyanions (H_2AsO_4^- , HAsO_4^{2-}) that have a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Covariance of arsenic and iron concentrations is typically observed for uncontaminated samples under those conditions. A plot of arsenic versus iron concentrations in the ARSAR site samples and background samples is provided on **Figure 4-13**. Some scatter is exhibited by the background samples, which may be due in part to the analytical uncertainty associated with the estimated (“J”-qualified and “B”-qualified) concentrations: 56 of the 85 background detections are estimated values. However, all of the site samples lie on or near the background samples on **Figure 4-13**.

Another perspective on the data sets is provided on **Figure 4-14**, which displays the arsenic concentrations of the site and background samples (y-axis) versus their corresponding As/Fe ratios (x-axis). If a site sample contained excess arsenic from a contaminant source, it would exhibit an anomalously high As/Fe ratio relative to background and would plot to the right of the background samples on **Figure 4-14**. However, the site samples exhibit As/Fe ratios ($4.18\text{E-}05$ to $9.30\text{E-}04$) that are within the background ratio range ($4.10\text{E-}05$ to $1.02\text{E-}03$) or – in the case of two regular hillside samples and one field duplicate with arsenic concentrations of 14.8 to 15.6 mg/kg (ratios of $1.10\text{E-}03$ to $1.29\text{E-}03$) – very close to the background ratio range. These observations suggest that the site samples do not contain excess arsenic from a contaminant source, and that their arsenic concentrations are natural. The fact that the site arsenic concentrations are identical or similar to the background concentrations (**Figure 4-13**) provides another line of evidence to support the contention that the site detections are natural.

Figure 4-11. Iron vs. Aluminum in Soil, Army Reserve Small Arms Range

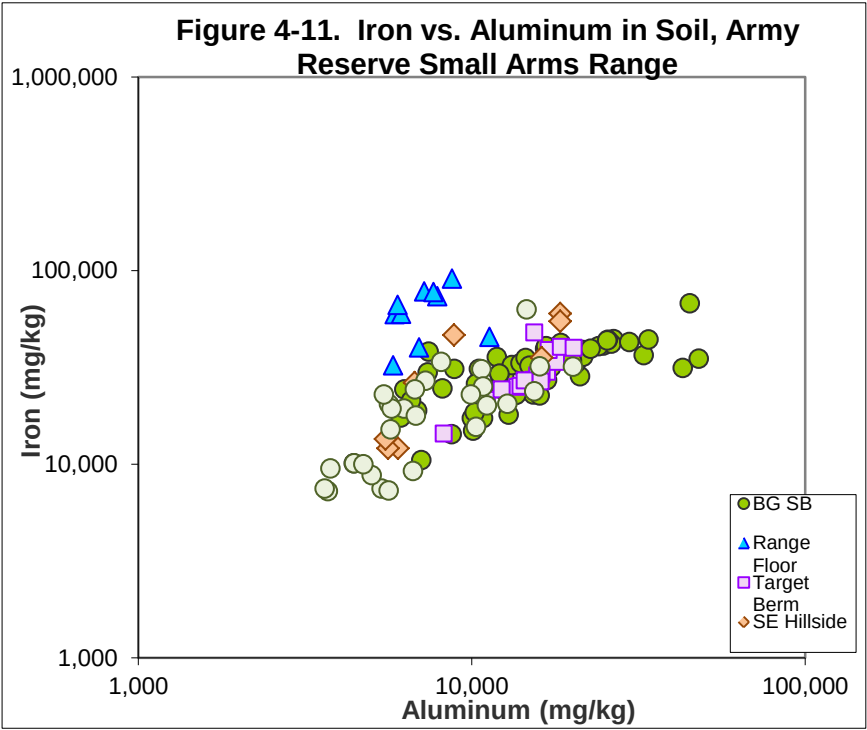


Figure 4-12. Calcium vs. Magnesium in Soil, Army Reserve Small Arms Range

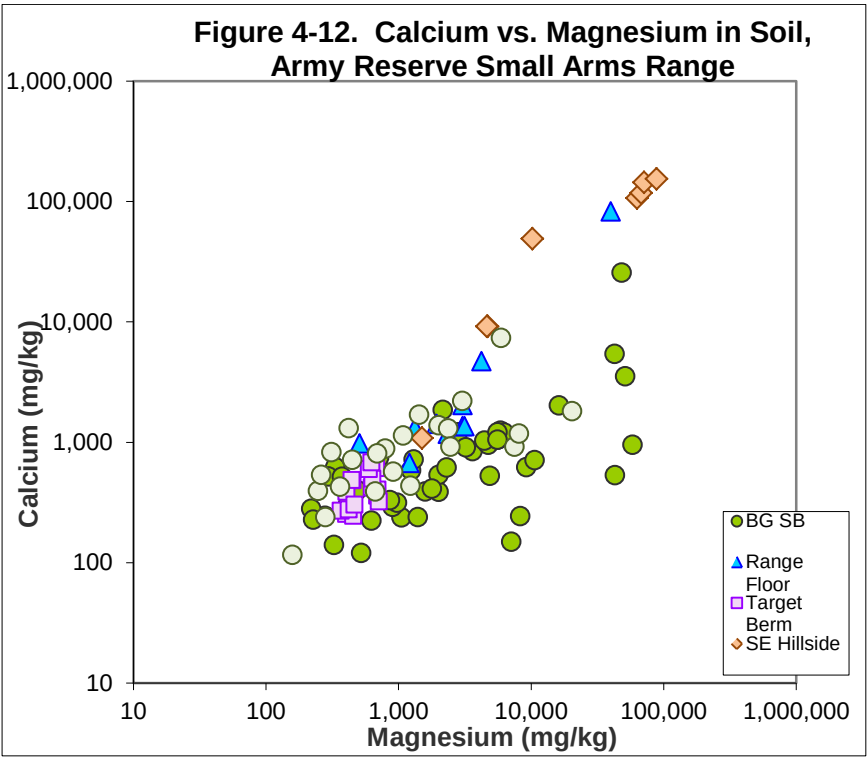


Figure 4-13. Arsenic vs. Iron in Soil, Army Reserve Small Arms Range

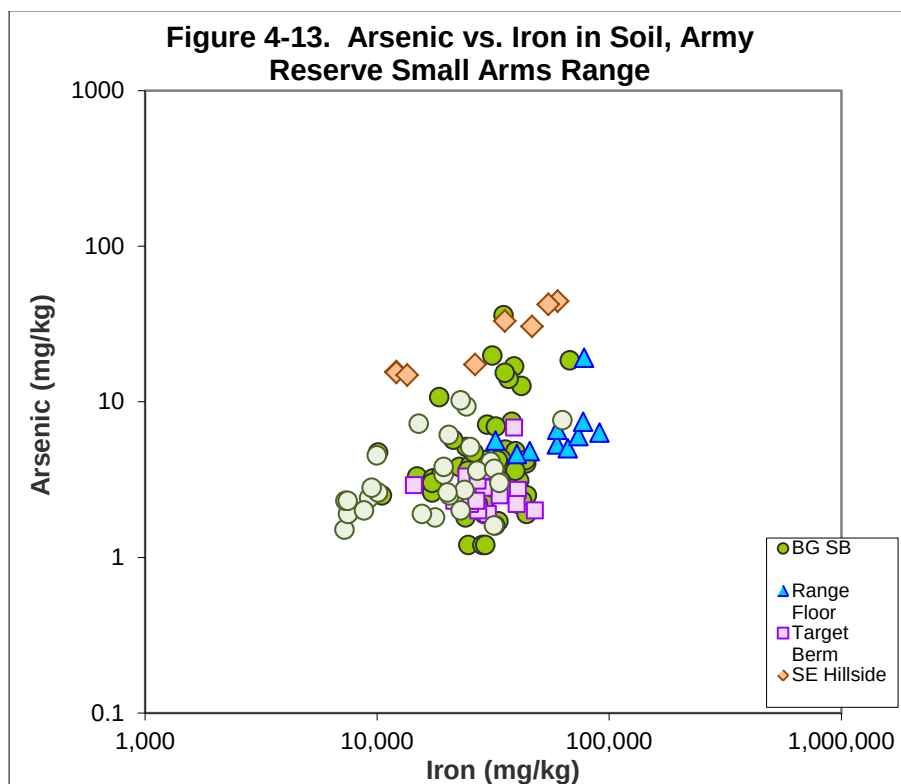
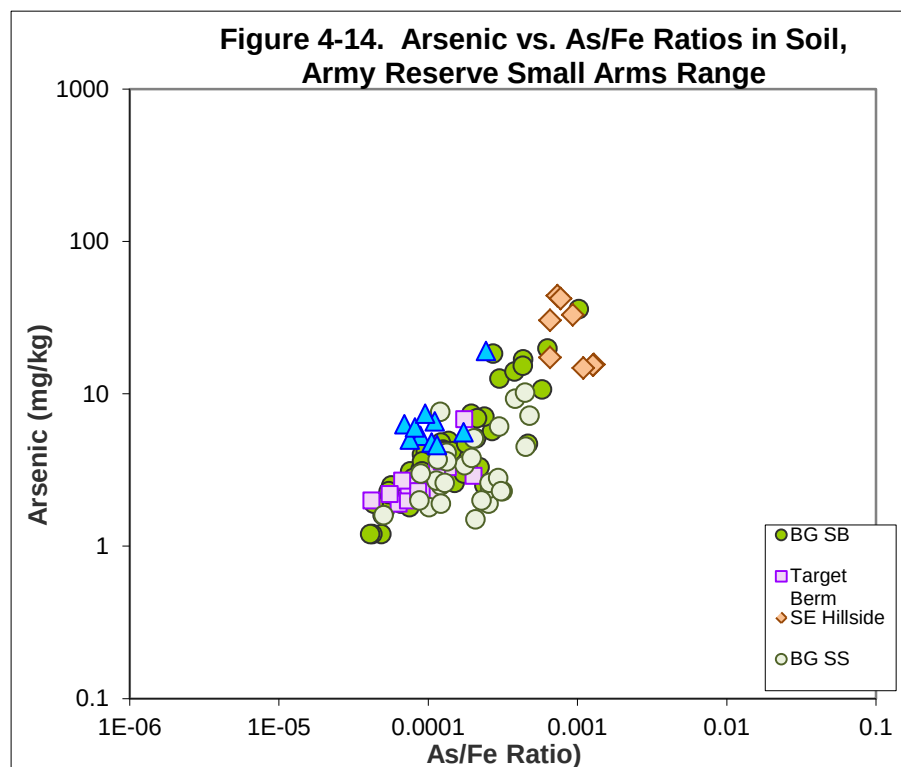


Figure 4-14. Arsenic vs. As/Fe Ratios in Soil, Army Reserve Small Arms Range



Of note is that each set of site samples has a unique range of arsenic concentrations and As/Fe ratios, which reflects the different source materials and differential weathering and soil development at the three sampled areas. The hillside samples, which have the highest As/Fe ratios, represent soil that is only 6 to 12 inches above the bedrock and thus reflect geologically recent in situ weathering of the bedrock. Unlike highly weathered soils, their trace-versus-major element ratios are expected to more closely resemble the ratios of the source rock. The hillside samples are also influenced by the tectonic window shown on the Radford North Geologic Quadrangle Map (Schultz and Bartholomew, 2009). This window exposes different bedrock units that do not exist within the rest of RFAAP. The range floor samples, in contrast, represent unconsolidated sediments of varying grain size, which were physically as well as chemically weathered during transport from their source rocks prior to deposition in the river valley. Over time, trace elements in these sediments would leach and reapportion themselves in the soil column, resulting in trace-versus-major element ratios that are different from the parent rock. The target berm samples represent fill material that was most likely obtained from a nearby source, which would explain why its major element concentrations and elemental ratios closely match those of the background samples (**Figures 4-11 and 4-12**).

Another important line of evidence is the lack of correlation between the arsenic and lead concentrations (not depicted). This lack of correlation argues against a munitions source for the detected arsenic. Arsenic has been used as a hardening agent in small-arms ammunition (less than 1 weight percent). If arsenic was present as a site-related contaminant, then its concentrations would be expected to covary with lead concentrations. However, no such correlation is observed. The samples with the highest lead do not contain higher arsenic.

Examination of the available data and multiple lines of evidence point to a natural source for the arsenic detected in the ARSAR soil samples.

4.7.4 Building Debris Area

The debris located within the ARSAR building debris area was investigated by Shaw during the initial site reconnaissance in 2010. The soil beneath the building debris area was investigated only during the 2011 sampling event in support of the 2011 RFI. Data from the samples indicated that there were no TCLP metal exceedances within the building debris area. Chrysotile was encountered within the sample at a level of 1.3 percent.

4.7.5 Sediment/Surface Water and Groundwater

Surface water, sediment, and groundwater samples were collected during the 2011 RFI. The five surface water and sediment sample pairs (one upgradient, two behind the berm, and two downgradient) were collected to assess the impact of the ARSAR activities on Stroubles Creek and assess the creek as a migration pathway for ARSAR constituents. Two direct-push groundwater samples were collected to assess whether ARSAR activities have impacted groundwater.

Data from the sediment samples indicated that SVOCs/PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene] were the only analytes detected at concentrations above sediment SLs. These PAHs were also encountered in an isolated sample in the firing range floor. These PAHs are asphalt constituents and their presence in Stroubles Creek sediments is likely from overland flow from the deteriorating asphalt roads and parking lots immediately adjacent to the creek.

Data from the surface water samples from Stroubles Creek indicated that only manganese was detected at a concentration exceeding its tw-SL in one out of five samples. Iron and aluminum were found to exceed their secondary MCLs. These isolated exceedances of naturally occurring metals do not pose a concern for Stroubles Creek surface water.

Two direct-push groundwater samples were collected to determine whether site soil was negatively impacting site groundwater. Groundwater results from the 2011 sampling event indicated that three SVOCs/PAHs [bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene] were detected at concentrations above tw-SLs.

Bis(2-ethylhexyl)phthalate was detected at a concentration below its MCL.

Bis(2-ethylhexyl)phthalate is a common laboratory contaminant and its presence in groundwater is not considered to be site-related. PAHs, including dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene, have a very low solubility in water and their presence in groundwater samples is likely the result of entrained sediment in the direct-push sample. Dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene are typically present in degraded asphalt.

Antimony was the only metal detected at a concentration greater than its groundwater SL in site groundwater samples. Antimony was not detected in the dissolved metals fraction of the groundwater samples collected at the site. The elevated concentration of antimony in the total metals fraction is likely due to the sediment entrained in the unfiltered direct-push sample.

Perchlorate was detected in one groundwater sample at a concentration slightly exceeding its tw-SL. Although the concentration slightly exceeded the tw-SL, perchlorate does not appear to be a concern in groundwater at the site. Perchlorate is not site-related and has consistently been detected at low levels throughout Radford since the adoption of the new LC/MS analytical method.

5.0 CONTAMINANT FATE AND TRANSPORT

This section presents a discussion of the fate and transport mechanisms for COPCs at the ARSAR. Physical and chemical properties of the impacted media and of the contaminant(s) affect the fate and persistence of contamination in the environment (Rosenblatt et al., 1975). A discussion of the physical and chemical properties affecting soil conditions at the ARSAR is presented as *Section 5.1*.

Of the soil samples collected at the ARSAR, three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene], one PCB (PCB-1254), and four metals (antimony, arsenic, iron, and lead) were detected at concentrations greater than their respective r-SLs. A generalized fate and transport discussion for those constituents identified as risk drivers is presented in *Section 5.2*.

5.1 Soil Properties Affecting Fate and Transport

Chemical and physical properties of soil influence the fate and transport of constituents through the environment. Grain size distribution, pH, and total organic carbon (TOC) are commonly used to assess these chemical and physical characteristics of the soil. A summary of each follows.

Grain Size Distribution. The grain size distribution measures the amount of clay, silt, sand, and gravel in a sample based on the diameter of the material. Soil particles less than 0.002 millimeters are classified as clay and have a very large specific surface area, allowing them a significant capacity to adsorb water and other substances. Clay composition greatly influences soil fertility and the physical conditions of the soil. Clay directly affects the permeability and the plasticity of soil by generally lowering the soil's permeability and increasing the plasticity. Because pores between clay particles are very small and convoluted, movement of both water and air is very slow. Fate and transport of chemical compounds are hindered when passing through a soil with a high composition of clay due to clay's ability to adsorb cations and to retain soil moisture.

Well-sorted sands and gravels have a smaller distribution of grain size and a higher permeability. Poorly sorted, clayey sands and gravels have a large range in grain size and lower permeability because the smaller clay and silt particles fill in the void spaces between the sand and gravel. Overall, the soil at the ARSAR appears to be fairly poorly-sorted and, therefore, aids in a slightly lower permeability rate.

Not much is known about the details of the soil composition at the ARSAR due to the lack of soil and well borings. What is known is that the firing range floor is underlain by the Weaver Soil. Weaver soils consist of moderately well drained and deep soil located in nearly level areas within flood plains. The Weaver Soil has a high available water capacity and surface runoff is generally slow. A typical profile of undisturbed soil consists of a 10-inch-thick surface layer of dark brown silt loam underlain by a 39-inch-thick subsoil of silt loam of variable soil.

The soil underlying the southeast hillside consists of Berks-Weikert Complex soil, which consists of well-drained soil on moderately steep to steep side slopes. Soil of the Berks-Weikert Complex are extremely to strongly acidic. Permeability ranges from moderate to moderately rapid with high to rapid surface water runoff. The Berks-Weikert Complex typically consists of a surface layer of shaley silt loam underlain by a subsoil of shaley silt loam. Shale bedrock is typically present from 20 to 40 inches (URS, 2003). These soils have been highly reworked through activities at RFAAP.

Soil pH. Soil pH is a measure of acidity or alkalinity and is an important chemical property because it is an indication of soil reaction potential. Soil reaction influences the fate of many pollutants, affecting their breakdown and potential movement. For example, hydrolysis is the reaction of a compound with water. It usually involves the introduction of a hydroxyl (-OH) group into an organic compound, usually at a point of unbalanced charge distribution. The hydrolysis reaction can displace halogens and may be catalyzed by the presence of acids, bases, or metal ions. Therefore, the rate of hydrolysis is pH and metal-ion concentration dependent. The transport of some contaminants is also affected by pH. This is less significant for neutral and slightly polarized organic compounds, which are somewhat affected by pH, but is significant for chemicals that tend to ionize (Lyman et al., 1990). When the pH of the groundwater is approximately 1.0 to 1.5 units above the negative log of the acid dissociation constant (pK_a), adsorption becomes significant, retarding transport rates. pH also affects the rate of biodegradation that may occur at a site. Most bacteria find the optimum pH range to be 6.5 to 7.5 and are not able to survive at pH values greater than 9.5 or below 4.0 (Knox et al., 1993).

Soil at RFAAP generally ranges in pH from slightly less than 4.0 to slightly more than 9.61. A review of pH results during the *Facility-Wide Background Study Report* (IT, 2001) across soil types at the MMA did not yield outstanding trends. Higher soil pH results were generally associated with limestone and shale parent material (IT, 2001).

pH soil measurements were taken from ARSAR in April 2011 soil samples. Results from these measurements indicated that soil at the ARSAR had a pH of 5.93. This pH indicates that the site soil has a below optimum pH for bacteria to thrive and degradation to occur.

TOC. Organic matter content is expressed as a percentage, by weight, of the soil material that is a composition of plant and animal residues in the soil at various stages of decomposition. Available water capacity and infiltration rate are affected by organic matter content. Sorption and desorption are two major mechanisms affecting the fate of contaminants in the subsurface. Sorption is the process by which a compound is retained onto a solid particle rather than remaining dissolved in solution. The sorption of contaminants to the soil matrix is an important factor affecting their transport in terrestrial environments. Hydrophobic contaminants will accumulate at an interface or partition into a nonpolar phase (e.g., associate with the organic content of the subsurface medium) rather than partition into the water phase. For nonionic organic chemicals and aquifer materials, sorption is largely controlled by the clay and organic carbon content of the soil. In addition, this means that the amount of TOC present in the soil matrix has a large affect on the fate of both organic and inorganic compounds. The degree to which TOC affects the fate of a chemical varies dependent on the properties of the chemical itself. Soil TOC concentrations at RFAAP range from 0.075 to 30.4 percent, with a median value of 0.5 percent.

5.2 Fate and Transport of Analytes Detected Above Screening Levels

5.2.1 Inorganic Compounds

Four metals (antimony, arsenic, iron, and lead) were detected in soil above r-SLs and background concentrations at the ARSAR. Specific characteristics of those metals antimony, arsenic, iron, and lead are discussed in the following sections.

5.2.1.1 Antimony

Antimony (Sb) was detected above the r-SL of 3.1 mg/kg in one single sample collected from the Southeast Hillside Area. Antimony was detected at a concentration of 6.1 mg/kg in sample

ARSCH07. Antimony concentrations were below the r-SL in all firing range floor and target berm confirmation soil samples. Because antimony was not detected during the Facility-Wide Background Study, there is no background value established for antimony at RFAAP (IT, 2001).

Antimony exists in the +3 oxidation state under reducing conditions, which are prevalent in ARSAR soil. The dominant species under these conditions is Sb(OH)_3^0 . Because most antimony compounds are highly soluble, antimony concentrations in soil are usually not solubility-limited (Rai et al., 1984). Therefore, adsorption may play an important role in limiting antimony mobility at the ARSAR. This mechanism appears to be effectively preventing migration of antimony from the soil to groundwater at the site, based on the lack of antimony detections in the dissolved metals fraction of ARSAR groundwater samples.

5.2.1.2 Arsenic

Arsenic (As) is a natural component of the earth's crust and can be released to the environment from natural sources (e.g., erosion of sulfide mineral deposits) as well as from human activities. Levels of arsenic are found in natural environmental media, ranging from 1 to 400 mg/kg in soil.

Arsenic exceeded both the background and r-SLs in 10 confirmation soil samples (ARSCH01 through ARSCH05 and ARSCH08 through ARSCH12) along the southeast hillside, with concentrations ranging from 15.4 to 44.1 mg/kg. Arsenic also exceeded the background and r-SLs in one sample (ARSCF06) within the firing range floor, with a concentration of 19.1 mg/kg.

The most common forms of arsenic found in nature (As^{+5} and As^{+3}) are found in aqueous solution as arsenate (AsO_4^{-3}) and arsenite (AsO_2^{-1}), respectively. However, the metallic (0 state) and -3 state may also occur. Both arsenate and arsenite are toxic; however, arsenite is the more toxic form, and arsenate is the most common form. Arsenate is relatively immobile in the environment due to its formation of insoluble complexes with iron, aluminum, and calcium. The presence of iron is most effective in controlling the mobility of arsenate. Iron is present at high elevated concentrations in some areas of the ARSAR firing range floor and southeast hillside. In contrast, arsenite compounds are 4 to 10 times more soluble than arsenate compounds. The adsorption of arsenite is also strongly pH dependent. One study found increased adsorption of arsenite by two clays over the pH range of 3 to 9, while another study found the maximum adsorption of arsenite by iron oxide occurred at pH 7 (USEPA, 1992). The ARSAR soil has a pH of approximately 5.93; indicating that adsorption of arsenic by the clayey soil would be high.

5.2.1.3 Iron

Iron (Fe) was detected in seven firing range floor and three southeast hillside surface soil samples at concentrations above its r-SL and above its i-SL in four firing range floor surface soil samples. Although iron was detected above applicable SLs in one surface water sample, it was not detected in total or dissolved metals fractions in ARSAR groundwater samples. Detected iron concentrations were below sediment SLs in all five sediment samples.

Iron, like most metals, is not found in the Earth's crust in an elemental state. Iron can be found in the crust only in combination with oxygen or sulfur. Most iron is found in various iron oxides, such as the minerals hematite, magnetite, and taconite.

Corrosion (chemical and biological) of iron is an electrochemical phenomenon in which ions go into solution (anodic reaction) and the electrons generated by the reaction diffuse through the metal to the cathode where they are consumed (cathodic reaction). Biologically induced

corrosion occurs when microorganisms are able to initiate, facilitate, or accelerate the corrosion reaction without changing the electrochemical nature of the process.

Given the acidic nature of soil at the ARSAR (5.93), there is a moderate potential for iron to solubilize and become mobile in soil. The moderately permeable soil at the Firing Range/Berm Area will generally limit the mobility of iron. This is evidenced by the lack of iron detections in groundwater samples collected at the site. Due to the steep nature of the southeast hillside, iron is not expected to vertically migrate through soil in this area.

5.2.1.4 Lead

Lead concentrations exceeded both the RFAAP background concentration and r-SLs in three southeast hillside laboratory confirmation samples (ARSCH02, ARSCH06, and ARSCH07) and numerous XRF screening samples collected along the southeast hillside. Concentrations of lead also exceeded the i-SL in samples ARSCH06 and ARSCH07. Lead concentrations were below applicable SLs in all other samples and media collected at the site.

Lead (Pb) is a naturally-occurring bluish-gray metal found in small amounts in the earth's crust. Lead can be found in all parts of our environment. Much of it comes from human activities including burning fossil fuels, mining, and manufacturing. Lead has many different uses. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Because of health concerns, lead from paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years.

The most common form of lead found in nature is Pb (II), although lead also exists to a lesser extent as Pb (IV) and in the organic form with up to four Pb-carbon bonds. Most lead deposited on surface soil is retained and eventually becomes mixed into the surface layer. The migration of lead in the subsurface environment is controlled by the solubility of lead complexes and adsorption to aquifer materials. Adsorption to soil greatly limits the mobility of lead in the environment. Lead may be immobilized by ion exchange with hydrous oxides or clays or by chelation with humic or fulvic acids in soil. Adsorption of lead increases with increasing pH with most lead precipitating out at a pH greater than 6 (USEPA, 1990).

5.2.2 Organic Compounds

5.2.2.1 PCBs

One PCB (PCB-1254) was detected in one southeast hillside sample (ARSCF02) and one firing range floor sample (ARSCH03) collected at the site. The concentration of PCB-1254 in sample ARSCF02 (0.047 mg/kg) and ARSCH03 (0.037 mg/kg) slightly exceeded its r-SL (0.022 mg/kg) in both samples. The detected concentrations were well below the i-SL of 0.74 mg/kg in both samples. PCBs were not detected in any surface water, sediment, or groundwater samples collected at the site, indicating that PCBs are not being transported at the site.

PCBs, which are also known by the trade name "Aroclor," were produced by the partial chlorination of biphenyl in the presence of a catalyst. The production of PCBs in large quantities began in 1929. Prior to 1974, PCBs were used both for nominally closed applications (e.g., capacitor and transformers, and heat transfer and hydraulic fluids) and in open-end applications (e.g., flame retardants, inks, adhesives, microencapsulation of dyes for carbonless duplicating paper, paints, pesticide extenders, plasticizers, polyolefin catalyst carriers, slide-mounting mediums for microscopes, surface coatings, wire insulators, and metal coatings) (Durfee, 1976; IARC, 1978; Orris et al., 1986; Safe, 1984; Welsh, 1995). The manufacture of PCBs in the

United States ceased in 1977 because of evidence that PCBs were toxic and accumulated in the environment.

PCBs are distinguished by a four-digit code in which the first two digits (e.g., 12) indicate the production process and the second two digits indicate the weight percent of chlorine (e.g., 48). Thus, Aroclor-1254 is a PCB with an average chlorine content of 54 percent. The water solubility for Aroclor-1254 is 4.1×10^{-2} mg/L. Therefore, this Aroclor is not soluble in water. The vapor pressure of Aroclor-1254 is 4.40×10^{-5} mm Hg. As a result of the low vapor pressure, this PCB will not volatilize to the atmosphere. This point is further supported by the Henry's Law Constant, which for this compound is 2.0×10^{-4} atm-m³/mole. The log K_{oc} and log K_{ow} values for Aroclor-1254 is 6.33 and 6.94, respectively. The log K_{oc} values indicate that the PCBs will tend to stay bound to the organic fraction of the soil instead of leaching into groundwater or surface water runoff. The log K_{ow} values support this argument indicating that PCBs have a stronger affinity for nonpolar soil particles than a polar water phase.

PCBs are highly immobile. PCBs are very persistent in the environment and are extremely resistant to oxidation and hydrolysis. The properties that made PCBs applicable for industrial use are the same properties that cause it to be persistent in the environment: chemical stability; thermal stability; resistance to hydrolysis by water, alkalis, and acids; and low flammability. Based on the K_{oc} and K_{ow} value, Aroclor-1254 will tend to remain in soil once released into the environment.

5.2.2.2 PAHs

Three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene] were detected in one firing range floor soil sample (ARSCF02) at concentrations above their respective r-SLs (but below the i-SL). In Stroubles Creek sediment samples, benzo(b)fluoranthene and dibenz(a,h)anthracene were detected at levels exceeding their r-SLs in one sample (ARSD05). Benzo(a)pyrene was detected at levels exceeding its r-SL in three sediment samples (ARSD01, ARSD03, and ARSD05). Dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene were detected at concentrations exceeding their respective tw-SLs in one direct-push groundwater sample (ARGW03).

PAHs are a group of more than 100 organic compounds of two or more aromatic rings. As a general rule, when PAH compounds grow in molecular weight, their solubility in water decreases, solubility in fat tissues increases, and their melting and boiling points increase (Environment Canada, 1997).

In addition, the vapor pressure ranges of the present PAHs indicate that these compounds do not readily volatilize into the atmosphere and this is further supported by the values of the Henry's law constants. The organic carbon/water partition coefficient (K_{oc}) is a measure of the tendency of a chemical to be sorbed to the organic fraction of soil. The logarithm (log₁₀) of the K_{oc} values for the PAHs detected indicates that these PAHs have high sorption potentials and will not tend to leach into surface water runoff. This is further supported by the octanol/water partition coefficient, K_{ow}, which is an indication of whether a compound will dissolve in a solvent (i.e., n-octanol) or water. The PAHs detected at the ARSAR are nonpolar and hydrophobic and, as mentioned above, will tend to sorb to soil rather than partition into the polar water phase. No contributing source of PAHs was used during previous on-site activities. The presence of PAH compounds is likely due to degrading asphalt parking lots and roads located on site.

6.0 HUMAN HEALTH RISK ASSESSMENT

These human health risk assessments (HHRAs) evaluate the probability and magnitude of potential adverse effects on human health associated with exposure to site-related chemicals in soil, surface water, sediment and groundwater. As described in *Section 2.1*, the ARSAR is an MRS being investigated under the MMRP. The ARSAR is an approximately 7.6-acre area located along the southeastern boundary of the MMA (**Figure 2-1**). Most of the site is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. This HHRA will evaluate the two areas of the ARSAR (**Figure 2-2**): the Firing Point/Berm Area and the Southeast Hillside Area. For this HHRA, the creek is evaluated as part of the Firing Point/Berm Area.

The HHRAs were conducted for each of the sites consistent with guidance included in USEPA's *Interim Final Risk Assessment Guidance for Superfund* (RAGS) and other current USEPA/USEPA Region III resources and guidance documents as noted throughout this section and on the RAGS Part D tables provided in **Appendices E-1 and E-2**. Additional information regarding the site background can be found in *Section 2.0*. The Conceptual Site Model (CSM) for this HHRA is outlined in **Appendix E-1, Table E.1-1** and **Appendix E-2, Table E.2-1**, and shown on **Figures 6-1 and 6-2**. This HHRA consists of the following six sections:

- **Section 6.1: Data Summary and Selection of COPCs:** Relevant site data are gathered, examined, and discussed. Basic constituent statistics and SLs are summarized. COPCs are identified by comparison to screening criteria as discussed in *Section 6.1.2*.
- **Section 6.2: Exposure Assessment:** Potentially exposed populations (e.g., receptors) and exposure routes are identified, and exposure point concentrations (EPCs) are calculated for COPCs. Standard exposure factors and health-protective assumptions are used to assess the magnitude, frequency, and duration of exposure for each exposure route and intakes are calculated.
- **Section 6.3: Toxicity Assessment:** Toxicity criteria for COPCs are compiled and presented.
- **Section 6.4: Risk Characterization:** Quantitative risks and hazards are estimated and summarized by combining toxicity criteria with intakes for each exposure route.
- **Section 6.5: Uncertainties Analysis:** Uncertainties, "including uncertainties in the physical setting definition for the site, in the models used, in the exposure parameters, and in the toxicity assessment" (USEPA, 1989a) are discussed.
- **Section 6.6: Summary and Conclusions:** The results of the HHRAs are summarized.

The tabulated risk assessment results are presented in accordance with USEPA guidance described in *RAGS: Volume I - Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments)* (USEPA, 2001). RAGS D requires the risk assessment results to be presented in a series of standardized tables, which are presented in **Appendix E-1** for the Firing Point/Berm Area and **Appendix E-2** for the Southeast Hillside Area.

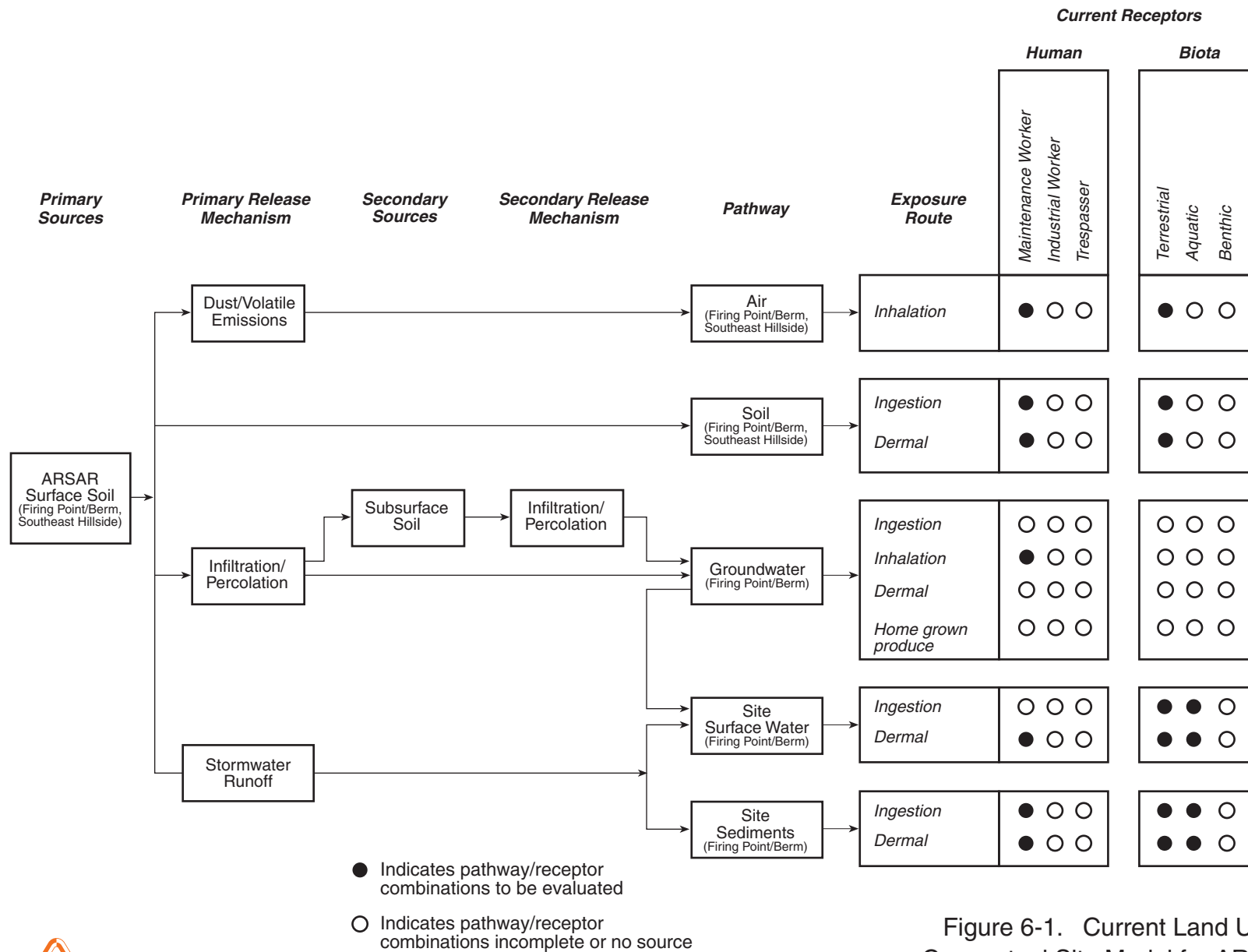


Figure 6-1. Current Land Use
Conceptual Site Model for ARSAR
Radford Army Ammunition Plant, Virginia

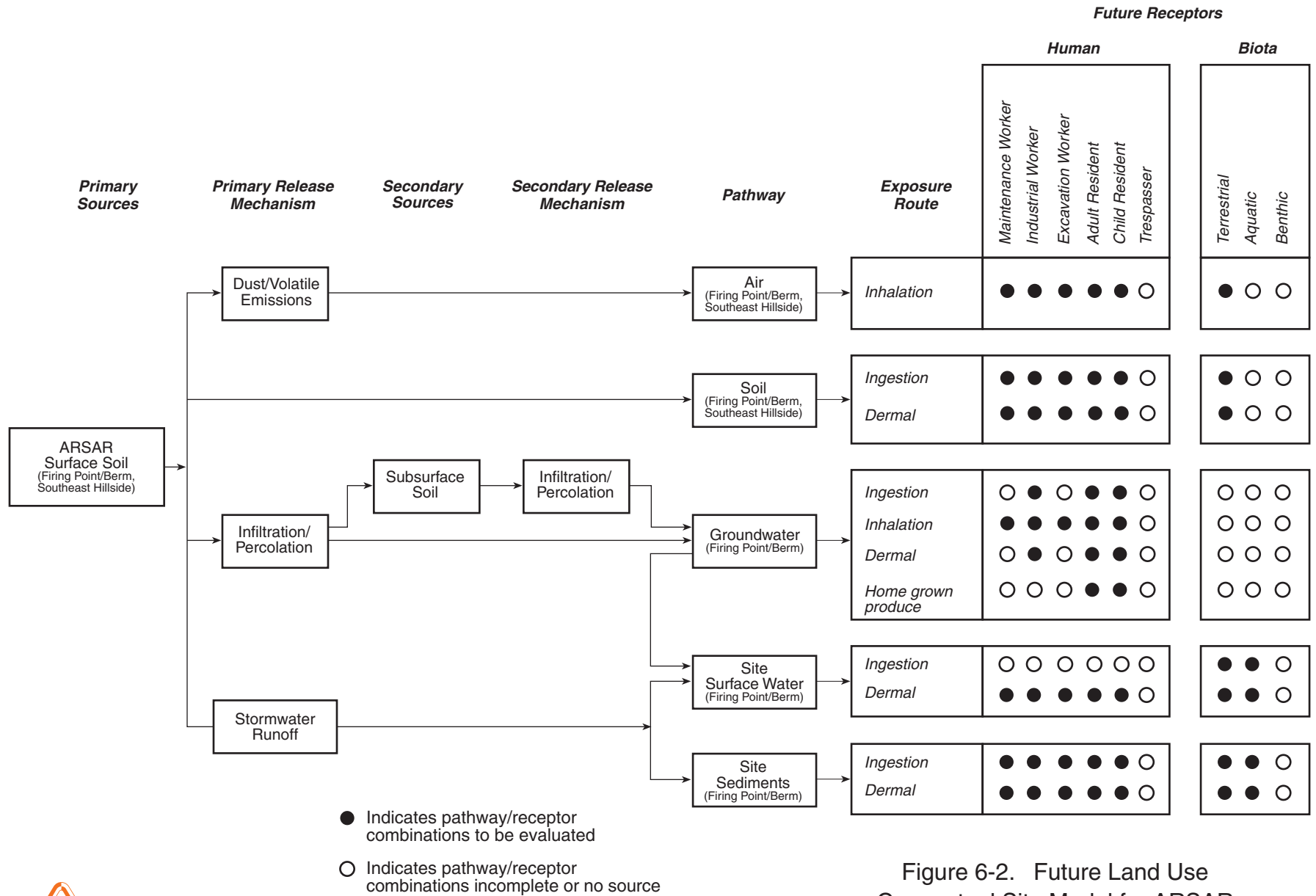


Figure 6-2. Future Land Use
Conceptual Site Model for ARSAR
Radford Army Ammunition Plant, Virginia

6.1 Data Summary and Selection of COPCs

6.1.1 Data Summary

Tables 6-1 and 6-2 identify the soil, surface water, sediment, and groundwater samples used in this HHRA. The complete data tables for detected analytes for each media are provided in *Section 4.0*. Additional information regarding the data used in the HHRA is summarized below:

- J-flagged data (estimated concentration) are considered detections and are used without modification.
- The qualification and validation of the analytical data included a comparison of the site data to corresponding blank (laboratory, equipment rinse, field, and trip) concentration data. If the detected concentration in a site sample was less than ten times (for common laboratory contaminants) or five times (for other compounds) the concentration in the corresponding blank sample, the sample was qualified with a “B.” According to USEPA Region III guidance (USEPA, 1995a, 2000b), it cannot be unequivocally stated that the result is not “non-detected” at that concentration. Therefore, B-qualified data are typically eliminated from the data set.
- Rejected results (R-flagged) are not used.
- Data from duplicate sample pairs are averaged and treated as one result. If an analyte is detected in one of the sample pair, one half the detection limit of the non-detect is averaged with the detected result and the result is considered detected.

Additional information regarding site-specific soil, sediment, surface water, and groundwater samples used in the HHRA is provided in *Sections 6.1.1.1 through 6.1.1.4*.

6.1.1.1 Surface Soil

The soil samples used for COPC screening for the Firing Point/Berm Area were collected during sampling events in May and July 2011. As presented in **Table 6-1**, a total of 23 surface soil samples were collected at depths from 0 to 0.5 ft bgs. No subsurface soil samples were collected for this HHRA.

The soil samples used for COPC screening for the Southeast Hillside Area were collected during sampling events in May and July 2011. As presented in **Table 6-2**, a total of 12 surface soil samples were collected at depths from 0 to 0.5 ft bgs. No subsurface soil samples were collected for this HHRA.

6.1.1.2 Sediment

For this HHRA, Stroubles Creek was considered to be part of the Firing Point/Berm Area. A total of five sediment samples were collected from Stroubles Creek at depths from 0 to 0.5 ft. These sampling events were completed in May 2011 and were used for the COPC screening for the Firing Point/Berm Area. These sample locations are listed in **Table 6-1**.

6.1.1.3 Surface Water

As part of the Firing Point/Berm Area, a total of five surface water samples were collected from Stroubles Creek during sampling events completed in May 2011 and were used for the COPC screening for the Firing Point/Berm Area. These sample locations are listed in **Table 6-1**.

Table 6-1
Firing Point/Berm Area Sample Groupings

Firing Point/ Berm Area	SURFACE SOIL^a		
	ARSBSC01	ARSBSC09	ARSCF03
	ARSBSC02	ARSBSC10	ARSCF04
	ARSBSC03	ARSBSC11	ARSCF05
	ARSBSC04	ARSBSC12	ARSCF06
	ARSBSC05	ARSBSC13	ARSCF07
	ARSBSC06	ARSBSC14	ARSCF08
	ARSBSC07	ARSCF01	ARSCF09
	ARSBSC08	ARSCF02	
	SEDIMENT^b		
	ARSD01	ARSD03	ARSD05
	ARSD02	ARSD04	
	SURFACE WATER		
	ARSW01	ARSW03	ARSW05
	ARSW02	ARSW04	
	GROUNDWATER		
	ARGW02	ARGW03	

(a) Surface soil samples consist of samples collected at depths of 0 to 2.0 feet.

(b) Sediment samples consist of samples collected at depths of 0 to 0.5 feet.

Table 6-2
Southeast Hillside Area Sample Groupings

Southeast Hillside Area	SURFACE SOIL^a		
	ARSCH01	ARSCH05	ARSCH09
	ARSCH02	ARSCH06	ARSCH10
	ARSCH03	ARSCH07	ARSCH11
	ARSCH04	ARSCH08	ARSCH12

(a) Surface soil samples consist of samples collected at depths of 0 to 0.5 feet.

6.1.1.4 Groundwater

Two groundwater samples were collected during June 2011 and were used for the COPC screening for the Firing Point/Berm Area. These sample locations are listed in **Table 6-1**.

6.1.2 Identification of COPCs

COPCs were identified for the sites by comparing the maximum detected concentration (MDC) with the following risk-based SLs for each media: USEPA r-SLs (surface soil and sediment) and USEPA tw-SLs (surface water and groundwater) as presented in the November 2012 USEPA Regional Screening Tables (USEPA, 2012b). In accordance with USEPA regional guidance, SLs for non-carcinogenic chemicals were adjusted downward to a hazard quotient (HQ) of 0.1 to ensure that chemicals with additive effects were not prematurely eliminated during screening. Although current and future land uses at ARSAR are most likely to be industrial in nature, r-SLs (rather than industrial) were used for comparisons with soil concentrations. Because the residential scenario was evaluated for this HHRA, r-SLs were used to screen chemicals in soil as a conservative measure. In addition, the lead action level of 400 mg/kg for residential soil and the drinking water action level of 15 micrograms per liter (µg/L) (USEPA, 2012a) were used in the COPC identification since toxicity criteria were not available for lead (USEPA, 1994).

For some COPCs without SLs, the values used for screening were based on surrogate chemicals with similar structures and properties served as surrogates. The surrogates for this HHRA were based on proxy compounds as identified in VDEQ's Risk Assessment Guidance, Risk-Based Screening Levels Proxy Values (VDEQ, 2012). It is noted that the screening value for chromium VI was conservatively used to screen chromium. Because there is no evidence that chromium VI would have been associated with past activities at the site, however, the toxicity value for chromium III is subsequently applied in the risk and hazard calculations.

The maximum concentrations of the four essential human nutrients that do not have SLs (i.e., calcium, magnesium, potassium, and sodium) were compared with dietary Allowable Daily Intakes. The essential nutrients calcium, magnesium, potassium and sodium were eliminated as COPCs. Although iron is also an essential nutrient, there is an SL available for iron. If iron concentrations in soil or water resulted in an HQ of 0.5 or greater, a "margin of exposure" evaluation was also performed. Risks from exposure to iron were characterized by comparing estimated iron intake to the Recommended Daily Allowance (RDA) and concentrations known to cause effects in children (USEPA, 1996).

Analytes detected at a maximum concentration greater than the corresponding adjusted SL or screening values identified above for nutrients and lead were selected as COPCs. Analytes for which no screening criteria exist were also selected as COPCs. COPC screening tables are presented in **Appendix E-1, Tables E.1-2** (COPC Determination Detects-Surface Soil), **E.1-4** (COPC Determination Detects-Sediment), **E.1-6** (COPC Determination Detects-Groundwater), and **E.1-8** (COPC Determination Detects-Surface Water) for the Firing Point/Berm Area and **Appendix E-2, Table E.2-2** (COPC Determination Detects-Surface Soil) for the Southeast Hillside Area. The COPCs selected for each medium at the Firing Point/Berm Area are summarized in **Table 6-3**. As shown in **Table 6-3**, no COPCs were identified in groundwater and surface water. The COPCs selected for surface soil at the Southeast Hillside Area are summarized in **Table 6-4**.

Table 6-3
Summary of Chemicals of Potential Concern – Firing Point/Berm Area

Chemical (a)	Surface Soil	Sediment	Surface Water	Groundwater
Organics				
Benzo(a)pyrene	X			
Benzo(b)fluoranthene	X			
Dibenz(a,h)anthracene	X			
Inorganics				
Aluminum	X			
Arsenic	X	X		
Chromium	X	X		
Cobalt	X			
Iron	X			
Manganese	X			
Thallium	X			
Vanadium	X			

(a) COPCs in all media at the Firing Point/Berm Area.

X = Selected as a COPC in this media.

Table 6-4
Summary of Chemicals of Potential Concern - Southeast Hillside Area

Chemical (a)	Surface Soil
Inorganics	
Aluminum	X
Antimony	X
Arsenic	X
Chromium	X
Cobalt	X
Iron	X
Lead	X
Manganese	X
Thallium	X
Vanadium	X

(a) COPCs in all media at the Southeast Hillside Area.

X = Selected as a COPC in this media.

Similarly, the reporting limits for those constituents that were not detected were compared with SLs for each medium. Chemicals that were not detected in at least one medium have not been included in the HHRA. The reporting limits for the non-detected constituents were screened against the SLs to ensure that the range of reporting limits was generally low enough to detect constituents that would be above SLs. The maximum reporting limits for these constituents were compared with SLs. The results of these comparisons are shown in **Appendix E-1, Tables E.1-3** (Non-Detect Screening-Surface Soil), **E.1-5** (Non-Detect Screening- Sediment), **E.1-7** (Non-Detect Screening-Groundwater), and **E.1-9** (Non-Detect Screening-Surface Water) for the Firing Point/Berm Area, and **Appendix E-2, Table E.2-3** (Non-Detect Screening-Surface Soil) for the Southeast Hillside Area. Detected constituents identified as COPCs were carried through the quantitative risk assessment. The reporting limits for constituents that were not detected in surface soil, sediment, groundwater, or surface water are evaluated with respect to their screening criteria and discussed in the uncertainty section (*Section 6.5.2*).

6.2 Exposure Assessment

The objective of the exposure assessment is to estimate “the type and magnitude of exposures to chemicals of potential concern” (USEPA, 1989a). When combined with chemical-specific toxicity information (summarized in the toxicity assessment), these exposures produce estimations of potential risks.

6.2.1 Conceptual Site Model/Receptor Characterization

Refined CSMs for two areas of the ARSAR, the Firing Point/Berm Area and the Southeast Hillside Area, are presented on **Figures 6-1 and 6-2** for current and future exposure scenarios, respectively. The ARSAR is an MRS and is being investigated under the MMRP. The ARSAR is an approximately 7.6-acre area located along the southeastern boundary of the MMA (**Figure 2-1**). Of this area, the Firing Point/Berm Area comprises approximately 6.56 acres and the Southeast Hillside Area is approximately 1.08 acres. Most of the site is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. As illustrated on **Figure 2-2**, a target berm that is approximately 8 ft high and 270 ft long, is located along the southeastern portion of the Firing Point Area was remediated in 2011. The Southeast Hillside Area is a steep, rocky hillside thought to have been used as a backstop prior to the construction of the target berm. A fence is located at the top of the southeast hillside, which precludes access to the site.

The site is located within a nearly level alluvial plain at an elevation of approximately 1,715 ft msl (**Figure 2-2**). The Southeast Hillside Area slopes steeply upward to an elevation greater than 1,950 ft msl. According to URS (2008), the ARSAR was a .30 caliber small arms firing range used by both the National Guard and the Army Reserve from approximately 1941 to 1968. The closed range consisted of an approximately 10-ft-high berm and four potential firing areas (see **Figure 2-2**). Currently, public access to RFAAP is controlled and includes the former range site although public access may have been possible in the past. The former range is now an unused grass baseball field surrounded by a fence.

The area surrounding RFAAP is not highly developed and land use in the vicinity of the facility is mostly rural, with less rugged areas having been primarily used for agriculture. Residential and recreational areas are located adjacent to the installation (IT, 2001).

There are currently no routine activities occurring at the ARSAR. To address occasional exposures due to grounds-keeping activities, such as mowing the grass or maintaining the storage area, it was conservatively assumed that maintenance workers are the most likely receptors at the site. The maintenance worker scenario was based on a worker who visits the site once per week for 50 weeks during the year. Due to Installation security, it is unlikely that trespassers could gain access to the ARSAR; however, risks associated with the maintenance worker are considered protective of the limited exposure experienced by the trespasser.

If future development occurs, maintenance workers, industrial/commercial workers, and excavation workers could be exposed to surface soil as well as sediment and surface water. Surface soil exposures were based on soil samples collected from ground surface to a depth of 2 ft. It was assumed that site activities at the ARSAR did not impact subsurface soil at depths greater than 2 ft. Therefore, no subsurface soil samples were collected.

The industrial/commercial worker represents a composite of the outdoor and indoor worker scenarios, assuming an exposure frequency of 225 days/year for an exposure duration of 25 years. For a potential future excavation worker at the Firing Point/Berm Area, a construction period of 250 days/year or 12 months was assumed on the basis of five-day work weeks. Given the steep, vegetated and rocky hillside, the potential for excavation or construction at the Southeast Hillside Area is very limited. Therefore, a construction period of 125 days/year or 6 months was assumed on the basis of five-day work weeks. The future industrial worker scenario is based on potential exposures to workers during routine outdoor and indoor activities at the site. Therefore, maintenance worker, industrial worker, and excavation worker exposures at the ARSAR were evaluated for surface soil, sediment and surface water at the Firing Point/Berm Area and surface soil at the Southeast Hillside Area. Although groundwater from the ARSAR is not expected to be used for potable purposes, hypothetical exposures to groundwater were included in the CSM.

RFAAP is likely to remain a military installation; therefore, a residential scenario is considered unlikely. However, the hypothetical residential scenario included exposures to on-site surface soil, sediment, surface water, and groundwater at both areas to assess clean closeout requirements under RCRA. No COPCs were identified in groundwater and surface water.

6.2.2 Identification of Exposure Pathways

The potential receptors identified for the sites include maintenance workers, industrial workers, excavation workers, hypothetical child residents, hypothetical adult residents, and hypothetical lifetime residents. **Appendix E-1, Table E.1-1 and Appendix E-2, Table E.2-1** summarize the selection of exposure pathways for each receptor listing the rationale for the inclusion or exclusion of each pathway at the ARSAR.

6.2.3 Calculation of EPCs

To calculate intakes, a 95 percent upper confidence limit of the mean concentration (95 percent UCL) for each COPC is used as a conservative estimate of the average concentration in a given environmental medium to which a receptor would be exposed. The 95 percent UCL estimate is referred to as the EPC. The 95 percent UCL is used rather than the mean concentration, to account for uncertainty when estimating EPCs from sample data (USEPA, 1989a). Methods used to calculate 95 percent UCLs are based on guidance provided in the documents *Calculating UCLs for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA, 2002a) and *ProUCL Version 4.1 Technical Guide* (USEPA, 2010a). It is noted that the EPC for lead was based on the

arithmetic mean concentration rather than the 95 percent UCL. Several of the USEPA default parameters are based on the central tendency (i.e., average) values because the lead models are probabilistic models. As discussed in *Section 6.3.2*, the arithmetic mean for surface soil served as the input value for the Adult Lead Model (ALM) and the Integrated Exposure Uptake Biokinetic (IEUBK) Model.

In general, the method used to calculate a 95 percent UCL depends on: 1) the prevalence of non-detects, 2) the data distribution (e.g., normal, gamma, or lognormal), and 3) number of samples. Non-detects introduce uncertainty in the data set because the true concentration may be between zero to just below the detection limit. Therefore, distributional assumptions are difficult to ascertain for COPCs with a high rate of non-detects. USEPA's (2010a) ProUCL 4.1.01 statistical program (USEPA, 2011a) was used to evaluate estimate 95 percent UCL values for nearly all the soil COPC data sets. For data sets with non-detects, ProUCL uses the Kaplan-Meier estimation method to derive a recommended 95 percent UCL (USEPA, 2010a). Where ProUCL recommends the results of more than one statistical approach, the most conservative (highest) 95 percent UCL value was used in the HHRA. Where fewer than 5 percent of samples had detected values, ProUCL does not recommend a 95 percent UCL value. If the sample size was adequate, EPCs for surface soil COPCs were calculated as 95 percent UCL values. Due to the small sample size for sediment (five samples), the MDC was used as the EPC.

EPCs for surface soil and sediment COPCs for the Firing Point/Berm Area are presented in **Appendix E-1, Tables E.1-10 and E.1-11** and surface soil COPCs for the Southeast Hillside Area are presented in **Appendix E-2, Tables E.2-4**. The output from ProUCL 4.1.01 for the Firing Point/Berm Area and the Southeast Hillside Area is provided in **Appendices E-3 and E-4**, respectively.

Models were used to estimate concentrations of COPCs in air from soil. These models are discussed in *Section 6.2.4*.

6.2.4 Quantification of Exposure: Calculation of Daily Intakes

For each receptor and pathway, chronic daily intake (CDI, expressed as milligrams of COPC per kilogram body weight per day) for each COPC is estimated by combining the EPC with exposure parameters such as ingestion rate, frequency of contact, duration, and frequency of exposure. In addition, intake parameters are selected so the combination of intake variables results in an estimate of the reasonable maximum exposure for that pathway (USEPA, 1989a). Intake formulas, exposure parameters, and chemical-specific parameters for each of the receptors for ARSAR are provided in **Appendix E-1, Tables E.1-12 through E.1-18** for the Firing Point/Berm Area and **Appendix E-2, Tables E.2-5 through E.2-9** for the Southeast Hillside Area.

The particulate emission factors (PEFs) used to calculate inhalation daily intakes associated with soil were calculated in accordance with the Supplemental Guidance for Developing Soil SLs for Superfund Sites (USEPA, 2002b), as provided in **Appendix E-1, Tables E.1-19 through E.1-21** for the Firing Point/Berm Area and **Appendix E-2, Tables E.2-10 through E.2-12** for the Southeast Hillside Area.

6.3 Toxicity Assessment

The methodology used for classifying health effects from exposure to chemicals is recommended by USEPA (2012c). The health effects analysis considers chronic (long-term) exposures. Using the following hierarchy (USEPA, 2003a), the chronic toxicity criteria were obtained from:

- Tier 1 – Integrated Risk Information System (IRIS) (USEPA, 2012c).
- Tier 2 – Provisional Peer Reviewed Toxicity Values (PPRTVs) - as developed on a chemical-specific basis by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (USEPA, 2003a).
- Tier 3 – Other Toxicity Values – including additional USEPA and non-USEPA sources of toxicity information, such as the Agency for Toxic Substances Disease Registry (ATSDR) Minimum Risk Levels (MRLs), California Environmental Protection Agency, and the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997).

Toxicity criteria used to quantify non-carcinogenic hazards (risk reference doses - RfDs) and carcinogenic risks (slope factors - CSFs) are presented in **Appendix E-1, Tables E.1-22 through E.1-25** for the Firing Point/Berm Area and **Appendix E-2, Tables E.2-13 through E.2-16** for the Southeast Hillside Area.

6.3.1 Calculations for COPCs with Mutagenic Mode of Action

Benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene were COPC in surface soil at the ARSAR. USEPA has determined that these compounds act via a mutagenic mode of action (USEPA, 2012b). The lifetime cancer risks for each of these PAHs were calculated in accordance with USEPA guidance (USEPA, 2005a, 2008, 2009a). Risks for these COPCs were estimated by applying age-dependent adjustment factors (ADAFs). The following ADAFs were applied to the following used: 10 for age 0-2, 3 for age 2-16, and 1 (i.e., no adjustment) for years 16 and older. In the following example, cancer risk associated with benzo(a)pyrene in surface soil at the Firing Point/Berm Area is calculated for residential exposures via the ingestion pathway:

Age 0-2

$$\frac{2.53E-02 \text{ mg/kg} \times 200 \text{ mg/day} \times 1.0E-06 \text{ kg/mg} \times 350 \text{ days/yr} \times 2 \text{ yr}}{365 \text{ days/yr} \times 70 \text{ yr} \times 15 \text{ kg}} \times \frac{7.3}{\text{mg/kg/day}} \times 10 = 6.75E-07$$

Age 2-6

$$\frac{2.53E-02 \text{ mg/kg} \times 200 \text{ mg/day} \times 1.0E-06 \text{ kg/mg} \times 350 \text{ days/yr} \times 4 \text{ yr}}{365 \text{ days/yr} \times 70 \text{ yr} \times 15 \text{ kg}} \times \frac{7.3}{\text{mg/kg/day}} \times 3 = 4.1E-07$$

Age 6-16

$$\frac{2.53E-02 \text{ mg/kg} \times 100 \text{ mg/day} \times 1.0E-06 \text{ kg/mg} \times 350 \text{ days/yr} \times 10 \text{ yr}}{365 \text{ days/yr} \times 70 \text{ yr} \times 70 \text{ kg}} \times \frac{7.3}{\text{mg/kg/day}} \times 3 = 1.1E-07$$

Age 16-30

$$\frac{2.53E-02 \text{ mg / kg} \times 100 \text{ mg / day} \times 1.0E-06 \text{ kg / mg} \times 350 \text{ days / yr} \times 14 \text{ yr}}{365 \text{ days / yr} \times 70 \text{ yr} \times 70 \text{ kg}} \times \frac{7.3}{\text{mg / kg / day}} \times 1 = 5.1E-08$$

Total Ingestion Risk

$$(6.75 \text{ E-07}) + (4.1 \text{ E-07}) + (1.1 \text{ E-07}) + (5.1 \text{ E-08}) = 1.2 \text{ E-06}$$

Therefore, using ADAFs, the cancer risk for benzo(a)pyrene in surface soil at the Firing Point/Berm Area is (1.2 E-06) for the ingestion pathway. Cancer risks for benzo(b)fluoranthene and dibenzo(a,h) anthracene for all pathways were calculated in a similar manner.

6.3.2 Evaluation of Lead

Quantitative oral toxicity criteria were available from IRIS (USEPA, 2012c), HEAST (USEPA, 1997), or USEPA's NCEA for the majority of the COPCs, with the exception of inorganic lead, which was selected as a COPC in surface soil at the ARSAR. An approach to assessing risks associated with adult exposures to lead was developed by USEPA's Technical Review Workgroup for Lead (USEPA, 2003b). The Adult Lead Methodology is used to evaluate risks associated with nonresidential adult exposures to lead in soil. The model focuses on estimating fetal blood concentrations in women exposed to lead in soil (USEPA, 2003b). It was used in this HHRA to be protective of potentially sensitive receptors within an industrial or commercial worker population. For the purpose of this HHRA, it was assumed that the worker would be potentially exposed to surface soil at the site. Because the lead model is a probabilistic model, several of the USEPA default parameters are based on central tendency (i.e., average) values (USEPA, 2003b, 2009b, 2009c). Therefore, the arithmetic means for surface soil served as input values for the soil concentrations.

Spreadsheets for the ALM (USEPA, 2009d) were used to calculate blood lead concentrations for surface soil for the site worker and the excavation worker. For the site worker, exposure parameters for the ALM were based on the default values. To be consistent with the use of average values as inputs to the ALM spreadsheets, a soil ingestion rate of 50 mg/day and an exposure frequency of 219 days/year were assumed. USEPA has provided additional guidance regarding exposure parameters for construction and excavation workers (USEPA, 2012d). The soil ingestion rate of 100 mg/day was used as a reasonable value for workers with contact-intensive exposures to soil. An exposure frequency of 125 days/year was assumed because the excavation worker would be expected to have full-time soil exposures during the entire period of construction. The ALM results are expressed as the predicted geometric mean blood lead level and the percent of the population potentially experiencing concentrations above 10 µg/dl (below which adverse manifestations are not expected). These results are discussed as part of the risk characterization (*Section 6.4*).

The potential risks associated with residential exposures to lead are addressed using the IEUBK Lead Model for Windows[®], Version 1.1, Build 11 (USEPA, 1994, 2007a, 2010b). The IEUBK model was designed to provide predictions of the probability of elevated blood lead levels for children. This model addresses three components of environmental risk assessments: the multimedia nature of exposures to lead, lead pharmacokinetics, and significant variability in exposure and risk, through estimation of probability distributions of blood lead levels for children exposed to similar environmental concentrations. The arithmetic mean of the lead concentration in on-site soil and arithmetic mean of the lead concentration in site-wide

groundwater were used in conjunction with the default input parameters to represent exposure area-specific exposures to lead. The predicted geometric mean blood lead level and the percent of the population potentially experiencing concentrations above 10 micrograms per deciliter ($\mu\text{g/dL}$) (below which adverse manifestations are not expected) are provided in the risk characterization (*Section 6.4*). Percentages below 5 percent are considered to be protective of human health.

It is noted that the Center for Disease Control and Prevention (CDCP) recently agreed to use a child blood lead level of 5 $\mu\text{g/dL}$ to identify children who are living or staying for long periods in environments that expose them to lead hazards. USEPA is currently evaluating the potential implications of the revised blood lead level (DoD, 2012).

6.4 Risk Characterization

Quantitative risks and hazards due to exposure to COPCs are estimated and summarized by combining toxicity criteria (presented in the Toxicity Assessment) with CDIs (calculated in the Exposure Assessment). Methods used to calculate risks and hazards are taken from USEPA (1989a).

For exposures to potential carcinogens, the individual upper-bound excess lifetime cancer risk was calculated by multiplying the estimated CDI by the CSF. In order to assess the individual excess lifetime cancer risks associated with simultaneous exposure to COPCs, the risks derived from the individual chemicals are summed within each exposure pathway. For the residential scenario, carcinogenic risk was evaluated for the lifetime resident. For cancer endpoints, the incremental lifetime cancer risks for residents were calculated by combining the cancer risks for the adult (exposure duration = 24 years) and child (exposure duration = 6 years).

Non-carcinogenic adverse health effects are calculated by dividing the CDI of each COPC by its RfD, forming an HQ. HQs with a value greater than one (1.0) indicate the potential for adverse health effects. To estimate non-carcinogenic adverse health effects due to simultaneous exposure to several COPCs, HQs for individual COPCs are summed within each exposure pathway to form an HI. As with HQs, HIs that are greater than 1.0 indicate potential adverse health effects. In such cases, COPCs are divided into categories based on the target organ affected (e.g., liver, kidney) and target organ-specific HIs are recalculated. Non-carcinogenic hazards were evaluated for both child and adult residents. As a conservative measure, noncancer hazards were calculated individually for the adult (exposure duration = 30 years) and child (exposure duration = 6 years) for noncancer endpoints.

Excess lifetime cancer risks derived in this report are compared with USEPA's acceptable risk range for Superfund sites of $1\text{E-}06$ to $1\text{E-}04$ (USEPA, 1989a). In addition, USEPA's Office of Solid Waste and Emergency Response has issued a directive (USEPA, 1991a) clarifying the role of HHRA in the Superfund process. The directive states that, if the cumulative carcinogenic risk to a receptor (based on reasonable maximum exposure for both current and future land use) is less than $1\text{E-}04$ and the non-carcinogenic HI is equal to or less than 1, action generally is not warranted unless adverse environmental effects are likely.

Calculation of risks and hazards due to exposure to COPCs are provided in **Appendix E-1, Tables E.1-26 through E.1-35** for the Firing Point/Berm Area and **Appendix E-2, Tables E.2-17 through E.2-26** for the Southeast Hillside Area. The risks and HIs for each receptor are presented in **Appendix E-1, Tables E.1-36 through E.1-40** and **Appendix E-2,**

Tables E.2-27 through E.2-31. These risks and hazards are summarized in **Tables 6-5 and 6-6** for the Firing Point/Berm Area and Southeast Hillside Area, respectively. A refinement of the HIs based on target organs is conducted by calculating HIs on a target organ-specific basis. In addition, **Appendix E-1, Tables E.1-41 through E.1-45** for the Firing Point/Berm Area and **Appendix E-2, Tables E.2-32 through E.2-36** for the Southeast Hillside Area summarize risks and hazards for risk/Hi drivers (i.e., those COPCs contributing to a total risk greater than 1.E-04 or a total target organ hazard greater than 1.0).

6.4.1 Lead Exposure Models

As a result of the removal action of lead at the berm, lead was not identified as a COPC at the Firing Point/Berm Area. At the Southeast Hillside Area, the MDC of lead (2,500 mg/kg) exceeded the action level for lead of 400 mg/kg. Therefore, the potential hazard associated with lead was evaluated using the ALM (USEPA, 2009d) for adult industrial/maintenance and excavation workers and the IEUBK model for the hypothetical child resident scenario (USEPA, 2010b). When applying the ALM and IEUBK models, the input value for the lead concentration is typically based on the arithmetic mean concentration for lead in the medium of interest. The input concentration for lead in the ALM and IEUBK calculation was 475 mg/kg. The assumptions and output of the modeling are presented in **Appendix E.2, Tables E.2-37a, E.2-37b, E.2-38a, and E.2-38b**. The results are summarized in this section.

Because the future water supply for the ARSAR is not known, the mean concentration for groundwater was conservatively assumed to be the action level for lead (15 µg/L) in drinking water. The assumptions and results of the model are presented in **Appendix E.2, Table E.2-48**. The corresponding input parameters and distribution probability plot are also provided with **Table E.2-39**. The IEUBK model predicts the probability of children expected to have blood levels of 10 µg/dL or greater. Percentages below 5 percent are considered to be protective of human health. As noted in *Section 6.3.2*, the CDCP recently agreed to use a child blood lead level of 5 µg/dL to identify children who are living or staying for long periods in environments that expose them to lead hazards (DoD, 2012).

Default parameters were utilized for the ALM model with the following ingestion rates and exposure frequencies: maintenance worker and industrial workers - ingestion rate (50 mg/day) and exposure frequency (219 days) with an averaging time of 365 days/year. The parameters for the excavation worker were ingestion rate (100 mg/day) and exposure frequency (125 days) with an averaging time of 182 days/year (USEPA, 2012d).

Default parameters were used for the IEUBK model. The arithmetic mean for lead in surface soil (475 mg/kg) was used and the ALM (current/future industrial/maintenance and future excavation workers) and in the IEUBK model (resident). The results of the lead assessments are provided below:

- Current/Future Maintenance/Industrial Worker (surface soil): 1.4 percent probability that fetal blood levels would exceed 10 µg/dL (≤5 percent; therefore passes).
- Future Excavation Worker (surface soil): 4.1 percent probability that fetal blood levels would exceed 10 µg/dL (≤5 percent; therefore passes).
- Hypothetical Future Child Resident (surface soil): 12.5 percent probability that child blood levels would exceed 10 µg/dL (≤5 percent; therefore fails).

Table 6-5
Summary of Risks and Hazards - Firing Point/Berm Area

Timeframe/Receptor	Risk	Risk Drivers	HI	Target Organ Segregation HI>1 ^a
Current/Future maintenance worker ^b	2.E-06	Surface Soil No individual COPC > 1.0E-06	6.E-02	N/A
Future industrial worker ^b	9.E-06	Surface Soil Arsenic Sediment Arsenic	3.E-01	N/A
Future excavation worker ^b	3.E-06	Surface Soil (Air) Cobalt	2.E+01	CNS (13.0) - Surface Soil (Air) [Aluminum - Inh (2.1); Arsenic - Inh (0.4); Manganese - Inh (10.0)] Respiratory Tract (2.0) - Surface Soil (Air) [Cobalt - Inh (2.0)] Lung (2.0) - Surface Soil (Air) [Cobalt - Inh (2.0)]
Future adult resident ^b	N/A	N/A	4.E-01	N/A
Future child resident ^b	2.E-05	Surface Soil Benzo(a)pyrene Arsenic Sediment Arsenic	4.E+00	Skin (1.4) - Surface Soil [Arsenic - Ing (0.36); Thallium - Ing (1.0)]
Future lifetime resident ^b	3.E-05	Surface Soil Benzo(a)pyrene Arsenic Sediment Arsenic	N/A	N/A

NA = Not Applicable

HI = Hazard Index

HQ = Hazard Quotient

Bold = Exceeds or equals USEPA Risk or Hazard Range.

Ing = Ingestion; Inh = Inhalation; Derm = Dermal

NOTE: For surface soil, site concentrations of arsenic and thallium are above background concentrations.

Note that the results for thallium are uncertain because the ProUCL analyses show thallium to be above background while the mean, median, and maximum site concentrations are below background.

(a) Cumulative HIs and individual HQs are rounded to the nearest tenth. HIs > 1 and HQs > 0.1 are listed.

(b) Site concentrations of lead in surface soil are below the health protective criterion for lead.

Table 6-6
Summary of Risks and Hazards - Southeast Hillside Area

Timeframe/Receptor	Risk	Risk Drivers	HI	Target Organ Segregation HI>1 ^a
Current/Future maintenance worker ^b	4.E-06	<u>Surface Soil</u> Arsenic	8.E-02	N/A
Future industrial worker ^b	2.E-05	<u>Surface Soil</u> Arsenic	4.E-01	N/A
Future excavation worker ^b	1.E-06	<u>Surface Soil</u> Arsenic	1.E+00	No Target Organ >1.0
Future adult resident ^c	N/A	N/A	5.E-01	N/A
Future child resident ^c	6.E-05	<u>Surface Soil</u> Arsenic	5.E+00	Skin (2.9) - Surface Soil [Arsenic - Ing (1.6); Thallium - Ing (1.3)] Vascular System (1.6) - Surface Soil [Arsenic - Ing (1.6)]
Future lifetime resident ^c	9.E-05	<u>Surface Soil</u> Arsenic	N/A	N/A

NA = Not Applicable

HI = Hazard Index

HQ = Hazard Quotient

Bold = Exceeds or equals USEPA Risk or Hazard Range.

Ing = Ingestion; Inh = Inhalation; Derm = Dermal

NOTE: For surface soil, site concentrations of arsenic, lead, and thallium are above background concentrations.

Note that the results for thallium are uncertain because the ProUCL analyses show thallium to be above background while the mean, median, and maximum site concentrations are below background.

(a) Cumulative HIs and individual HQs are rounded to the nearest tenth. HIs > 1 and HQs > 0.1 are listed.

(b) Site concentrations of lead in surface soil are below the health protective criterion for lead.

(c) Site concentrations of lead in surface soil are above the health protective criterion for lead.

Therefore, surface soil at the Southeast Hillside Area passes the lead exposure assessment for individual and excavation worker scenarios. Surface soil fails the lead exposure assessment for the residential scenario.

6.4.2 Iron Margin of Exposure Evaluation

Because iron concentrations in soil resulted in an HQ of 0.5 or higher for the child resident at the ARSAR, a “margin of exposure evaluation” was conducted. This evaluation consists of a comparison of estimated intake of iron to the RDA and concentrations known to cause adverse health effects in children. The calculated intake of iron via the route of ingestion is compared with amounts that are associated with an RDA of 10 mg/day (0.36 to 1.11 mg/kg-day) for children from 6 months to 10 years of age (USEPA, 1996). For the Firing Point/Berm Area, the calculated intake of iron via ingestion of surface soil was 0.66 mg/kg-day. Therefore, the total estimated intake of iron by ingestion was 0.66 mg/kg-day, which was within the allowable range (0.36 to 1.11 mg/kg-day). For the Southeast Hillside Area, the calculated intake of iron via ingestion of surface soil was 0.58 mg/kg-day. Therefore, the total estimated intake of iron by ingestion was 0.58 mg/kg-day, which was within the allowable range (0.36 to 1.11 mg/kg-day).

6.4.3 Background Metals Considerations

Statistical evaluations were conducted to compare concentrations of inorganic COPC drivers in surface soil at each site with background concentrations presented in the RFAAP Facility-Wide Background Study Report (IT, 2001). These evaluations followed the procedures outlined in the USEPA *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA, 2002d) and were conducted using USEPA’s ProUCL 4.1.01 statistical program (USEPA, 2010a, 2011a). Statistical analyses included distribution testing of site data sets and background data sets, evaluation of data using descriptive summary statistics, and comparisons of site data to background. Unless otherwise noted, Gehans test was conducted for each metal with background data sets to evaluate whether site concentrations were consistently higher or lower than the background data set. Gehans test was used because it was found to handle data sets with multiple detection limits better than the Wilcoxon Mann Whitney test.

For the Firing Point/Berm Area, there was one inorganic cancer risk driver (cobalt) with an individual risk greater than $1\text{E-}06$ for the excavation worker and one inorganic cancer risk driver (arsenic) with an individual risk greater than $1\text{E-}06$ for the child resident. There were three inorganic risk hazard drivers (aluminum, cobalt, and manganese) with individual HIs greater than 1 for the excavation worker. Although none of the inorganic COPCs for the child resident individually exceeded 1, the HI for thallium was equal to 1 and contributes to the exceedance of the target organ HI for skin. Inorganic COPCs that were not statistically different based on appropriate statistical tests are considered background related and potentially related to naturally-occurring soil concentrations (see *Section 6.1.2.3* for details). Based on information presented in **Table 6-7**, arsenic concentrations in surface soil at the Firing Point/Berm Area are considered to be potentially site-related and not attributable to background; however, this analysis relies on a purely statistical approach and does not take the underlying geology and soil chemistry into account. Aluminum, cobalt, and manganese are considered to background-related. Although ProUCL concluded that thallium was above background, it is noted that the mean (0.65 mg/kg), median (0.66 mg/kg), and maximum (1.3 mg/kg) concentrations of thallium for the site data set were all below the corresponding statistics for the background data set (1.85 mg/kg, 2 mg/kg, and 2.1 mg/kg, respectively). Notes on the methodology and the results of the background

evaluation are summarized in **Table 6-7**. The ProUCL 4.1.01 output for the Firing Point/Berm Area is provided in **Appendix E-5**.

Table 6-7
Background Comparison for Surface Soil at the Firing Point/Berm Area

Soil COPC	Gehan Test ^{a, b} Site > Background?	Considered to be Background?
Aluminum	No	Yes
Arsenic	Yes	No
Cobalt	No	Yes
Manganese	No	Yes
Thallium	Yes	No

^a Gehan test used unless otherwise noted. See **Appendix E-5** for backup statistics.

^b If both Site and Background data sets had normal distribution with 100% detects, the t-test was used.

For the Southeast Hillside Area, there was one inorganic cancer risk driver (arsenic) with an individual risk greater than 1E-06 for all receptors. There were two inorganic hazard drivers (arsenic and thallium) for the child resident. One COPC (lead) was evaluated using the ALM and IEUBK. The IEUBK results for the residential receptors indicated that concentrations of lead at the Southeast Hillside Area are above the health protection criterion for lead. Inorganic COPCs that were not statistically different based on appropriate statistical tests are considered background related and potentially related to naturally-occurring soil concentrations (see *Section 6.1.2.3* for details). Based on information presented in **Table 6-8**, arsenic, lead, and thallium concentrations in surface soil at the Southeast Hillside Area are considered to be potentially site-related and not attributable to background; however, this analysis relies on a purely statistical approach and does not take the underlying geology and soil chemistry into account. An investigation of the chemical properties of the hillside soil, discussed in *Section 4.7.3*, lends evidence to support the conclusion that the elevated arsenic is, in fact, the result of background concentrations rather than site related contamination. Although ProUCL concluded that thallium was above background, it is noted that the mean (0.85 mg/kg), median (0.79 mg/kg), and maximum (1.4 mg/kg) concentrations of thallium for the site data set were all below the corresponding statistics for the background data set (1.85 mg/kg, 2 mg/kg, and 2.1 mg/kg, respectively). Notes on the methodology and the results of the background evaluation are summarized in **Table 6-8**. The ProUCL 4.1.01 output for the Southeast Hillside Area is provided in **Appendix E-6**.

Table 6-8
Background Comparison for Surface Soil at the Southeast Hillside Area

Soil COPC	Gehan Test ^{a, b} Site > Background?	Considered to be Background?
Arsenic	Yes	No
Lead	Yes	No
Thallium	Yes	No

^a Gehan test used unless otherwise noted. See Appendix for backup statistics.

^b If both Site and Background data sets had normal distribution with 100% detects, the t-test was used.

6.5 Uncertainties

Risk assessments involve the use of assumptions, judgments, and incomplete data to varying degrees that contribute to the uncertainty of the final estimates of risk. Uncertainties result both from the use of assumptions or models in lieu of actual data and from the error inherent in the estimation of risk related parameters and may cause risk to be overestimated or underestimated. Based on the uncertainties described below, this risk assessment should not be construed as presenting an absolute estimate of risk to persons potentially exposed to COPCs.

Consideration of the uncertainty attached to various aspects of the risk assessment allows better interpretation of the risk assessment results and understanding of the potential adverse effects on human health. In general, the primary sources of uncertainty are associated with environmental sampling and analysis, selection of chemicals for evaluation, toxicological data, and exposure assessment. The effects of these uncertainties on the risk estimates are discussed below.

6.5.1 Environmental Sampling and Analysis

If the samples do not adequately represent media at ARSAR, hazard/risk estimates could be overestimated or underestimated. The sampling and analysis plan was designed to investigate anticipated areas of contamination and delineate area(s) of concern. Therefore, there is less chance that the hazard/risk estimates are biased low. Also, if the analytical methods used do not apply to some chemicals that are present at each area, risk could be underestimated. Because the analytical methods at the site were selected to address all chemicals that are known or suspected to be present on the basis of the history of each area, the potential for not identifying a COPC is reduced.

Uncertainty in environmental chemical analysis can stem from several sources including errors inherent in the sampling or analytical procedures. Analytical accuracy errors or sampling errors can result in rejection of data, which decreases the available data for use in the HHRA, or in the qualification of data, which increases the uncertainty in the detected chemical concentrations. There is uncertainty associated with chemicals reported in samples at concentrations below the method reporting limit but still included in data analysis and with those chemicals qualified “J” indicating that the concentrations are estimated. Another issue involves the amount of blank related (i.e., B-qualified) data in the data set. Although B-qualified were eliminated, however, the amount of B-qualified data in the data set was low.

As indicated in *Section 6.1.1.4*, two groundwater samples were collected at the ARSAR. Because the assessment of groundwater is based on two sample locations, it is uncertain as to whether risks and hazards could be over- or underestimated.

6.5.2 Selection of Chemicals for Evaluation

A comparison of maximum detected chemical concentrations to USEPA Regional SLs was conducted for surface soil, sediment, groundwater, and surface water. Chemicals with maximum concentrations below their respective SLs were not carried through the assessment. It is unlikely that this risk-based screening excluded chemicals that should be included, based on the conservative exposure assumptions and conservatively derived toxicity criteria that are the basis of the SLs. Although following this methodology does not provide a quantitative risk estimate for every chemical, it focuses the assessment on the chemicals accounting for the greatest risks (i.e., chemicals whose maximum concentrations are greater than their respective SLs) and the cumulative risk estimates would not be expected to be significantly greater. As presented on the

non-detect method detection limit (MDL) screening tables, the maximum MDL was greater than the adjusted SLs for several chemicals in surface soil, sediment, groundwater, and surface water; therefore, the site-related risks and hazards could be underestimated for the risk assessments due to inadequate detection limits. The results for the evaluations of non-detects at the ARSAR are discussed in the following sections.

The reporting limits for chemicals that were not detected in surface soil, sediment, groundwater, and surface water at the Firing Point/Berm Area were compared with SLs in **Appendix E-1, Tables E.1-3, E.1-5, E.1-7, and E.1-9**, respectively. As shown in **Appendix E-1, Table E.1-3**, reporting limits in surface soil were above SLs for 6 of 124 constituents (5 percent). These constituents include 4,6-dinitro-o-cresol, MCPA, nitroglycerin, n-nitroso-di-n-propylamine, pentachlorophenol (PCP), and vinyl chloride. For 9 of 124 constituents (7 percent) in surface soil, there were no SLs for comparison. These constituents include: 3,5-dinitroaniline, 4-bromophenoxybenzene, 4-chlorophenyl phenylether, carbazole, dichloroprop, dimethylphthalate, di-octylphthalate, o-nitrophenol, and p-nitrophenol. These chemicals are not known to be associated with past site activities at the ARSAR.

As shown in **Appendix E-1, Table E.1-5**, none of the reporting limits for 130 constituents in sediment were found to be above SLs. For 9 of 130 constituents (7 percent) in sediment, there were no SLs for comparison. These constituents include: 3,5-dinitroaniline, dichloroprop, dimethylphthalate, carbazole, di-octylphthalate, o-nitrophenol, p-nitrophenol, 4-bromophenoxybenzene, and 4-chlorophenyl phenylether. These chemicals are not known to be associated with past site activities at the ARSAR.

As shown in **Appendix E-1, Table E.1-7**, reporting limits in groundwater were greater than SLs for 57 of 156 constituents (37 percent). For 9 of 156 constituents (6 percent) in groundwater, there were no SLs for comparison. Some of the metals (arsenic, chromium, cobalt, and thallium) were identified as COPCs in surface soil at the Firing Point/Berm Area. In addition, several of these constituents were PAHs, including benzo(a)pyrene. Three PAHs (benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene) were identified as COPCs in surface soil. Although benzo(b)fluoranthene and dibenz(a,h)anthracene were detected in groundwater, these PAHs were present at very low levels and did not screen in as COPCs. Had benzo(a)pyrene been detected in groundwater, it is likely that it would not have been identified as a COPC. Although some of the constituents with reporting limits below SLs could potentially be site related, it is assumed that groundwater exposures at ARSAR involve limited exposure frequency and exposure duration for maintenance and industrial workers. In addition, while a residential scenario has been included for completeness, it is unlikely that ARSAR groundwater will be used for residential purposes in the future.

As shown in **Appendix E-1, Table E.1-9**, reporting limits in surface water were greater than SLs for 25 of 161 constituents (15 percent). These constituents include 2,6-DNT, 2,6-DNT, 3,3'-dichlorobenzidine, 4,6-dinitro-o-cresol, MCPP, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, Aroclor 1260, benzo(a)pyrene, bis(2-chloroethyl)ether, nitroglycerin, dibenz(a,h)anthracene, dieldrin, heptachlor, hexachlorobenzene, MCPA, n-nitroso-di-n-propylamine, PCP, toxaphene, vinyl chloride, arsenic, and thallium. Some of these compounds were selected as COPCs in other media at ARSAR. For example, benzo(a)pyrene, dibenz(a,h)anthracene, arsenic, and thallium are COPCs in surface soil; however, only arsenic is a COPC in sediment. If the reporting limits were compared with SLs based on 1E-05 and HQ of 1, most of them would not exceed. For 9 of 161 constituents (6 percent) in surface water, there

were no SLs for comparison. These constituents include: 3,5-dinitroaniline, 4-bromophenoxybenzene, 4-chlorophenyl phenylether, carbazole, dichloroprop, dimethylphthalate, di-octylphthalate, o-nitrophenol, and p-nitrophenol. These chemicals are not known to be associated with past site activities at the ARSAR.

The reporting limits for chemicals that were not detected in surface soil at the Southeast Hillside were compared with SLs in **Appendix E-2, Tables E.2-3**. As shown in **Appendix E-2, Table E.2-3**, reporting limits in surface soil were above SLs for 7 of 122 constituents (6 percent). These constituents include 4,6-dinitro-o-cresol, MCPP, Aroclor 1221, Aroclor 1232, MCPA, nitroglycerin, n-nitroso-di-n-propylamine, and vinyl chloride. For 9 of 122 constituents (7 percent) in surface soil, there were no SLs for comparison. These constituents include: 3,5-dinitroaniline, 4-bromo-phenoxybenzene, 4-chlorophenyl phenylether, carbazole, dichloroprop, dimethylphthalate, di-octylphthalate, o-nitrophenol, and p-nitrophenol. These chemicals are not known to be associated with past site activities at the ARSAR.

For some COPCs without SLs, the values used for screening were based on surrogate chemicals with similar structures and properties. The surrogates for this HHRA were based on proxy compounds as identified in VDEQ's Risk Assessment Guidance, Risk-Based Screening Levels Proxy Values (VDEQ, 2012). As noted in **Appendix E-1, Tables E.1-2, E.1-4, E.1-6, and E.1-8** surrogate values were used for acenaphthylene, benzo(g,h,i)perylene, delta-BHC, and phenanthrene. Use of the SLs of these compounds had no effect on the risks/hazards calculated in this HHRA. In **Appendix E-2, Table E.2-2**, surrogate values were used for acenaphthylene, benzo(g,h,i)perylene, chlordane, endosulfan II, endosulfan sulfate, endrin aldehyde, endrin ketone, and phenanthrene. Use of the SLs of these compounds had no effect on the risks/hazards calculated in this HHRA.

Screening criteria are derived from RDAs for essential human dietary minerals, trace elements, and electrolytes that are potentially toxic at very high doses (i.e., calcium, magnesium, potassium, and sodium). None of these elements were selected as COPCs in soil. Omitting these essential human nutrients from further evaluation is expected to have a low effect on risk and hazard estimates.

6.5.3 Exposure Assessment

The primary areas of uncertainty affecting exposure parameter estimation involve the assumptions regarding exposure pathways, the estimation of EPCs, and the exposure parameters used to estimate chemical doses. An underlying assumption in the HHRA is that individuals at the site would engage in activities that result in exposures via each selected pathway. For example, it was assumed that maintenance workers engage in regular activities (once a week) under current and future land use conditions resulting in exposure to COPCs. This assumption is conservative, in that it is more likely that the activity patterns occur occasionally.

The PEFs for the maintenance workers, industrial workers, and excavation workers were based on the actual sizes of the sites (6.56 acres for the Firing Points/Berm Area and 1.08 acres for the Southeast Hillside Area). Per USEPA guidance, the PEF for the residents was based on a 0.5-acre residential lot. Although neither of the sites at the ARSAR is 0.5 acre in size, the PEFs for the workers and residents were based on 0.5 acres because the factors for the Q/C calculations were derived for sites between 0.5 to 500 acres (USEPA, 2002b). The sampling program was not designed to address 0.5-acre subareas or to define exposure areas for residential lots (as described in Section 4.1.4 of the SSL guidance) because there are no plans for residential

development. Therefore, it was assumed that the sampling performed in each of the areas at the ARSAR would be representative of concentrations in any one subarea of the site and the Q/C term associated with a 0.5 acre area was used to calculate the PEF. This approach could result in over- or underestimating the actual EPC in any one hypothetical 0.5-acre parcel. This uncertainty would not be expected to impact the overall conclusions of the HHRA, however, because the contribution of the inhalation pathway to total risk/hazard for the residential scenario is much less than that of the ingestion and dermal absorption pathways.

For the Firing Point/Berm Area, the cumulative HI for the excavation worker exceeded 1 primarily due to the inhalation pathway. The non-cancer hazard estimates for the inhalation of dust emissions by the excavation worker receptor are based on the excavation worker PEF calculation. Under a construction or excavation scenario, fugitive dusts may be generated from surface soil by wind erosion, construction vehicle traffic on temporary unpaved roads, and other construction activities. Due to the potential for increased dust exposure from truck traffic on unpaved roads during construction, USEPA recommends that fugitive dusts associated with the construction scenario be evaluated for semivolatile compounds (SVOCs) and for all metals (USEPA, 2002b). The method used to calculate a site-specific particulate emission factor (PEF_{sc}) for potential excavation scenarios, is described in USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (Supplemental SSL Guidance; USEPA, 2002b).

Assumptions regarding the duration of excavation activities and type and number of construction vehicles were based on the acreage of the site because future plans for construction or excavation at the ARSAR are not known. As no specific information was available, conservative assumptions for these variables followed the example provided by USEPA (2002b). For example, the mean vehicle weight (W) was estimated by assuming the numbers and weights of different types of vehicles. It was assumed that the daily unpaved road traffic would consist of twenty 2-ton cars and ten 20-ton trucks. The sum of the fleet vehicle kilometers (km) traveled during construction (ΣVKT) was estimated based on the size of the area of the site, assuming the configuration of the unpaved road and the amount of vehicle traffic on the road. The area of soil contamination in acres or square meters (m^2) was assumed to be configured as a square, with the unpaved road segment dividing the square evenly. It was also assumed that each vehicle travels the length of the road once per day, 5 days per week, for a total of 12 months (consistent with the excavation worker's exposure duration of 1 year at the Firing Point/Berm Area). The use of these assumptions within the calculations ultimately compounds the level of uncertainty of the PEF value. In addition, there is generally a higher level of uncertainty associated with the use of modeled concentrations (i.e., PEF) than in the use of measured concentrations (i.e., air concentrations) if valid measurement data are available for the exposure medium and exposure location.

The cumulative HI for the excavation worker at the Firing Point/Berm Area (15.9) exceeded 1 primarily due to aluminum, cobalt, and manganese in surface soil for the inhalation pathway. Although the inhalation HI could be overestimated, the site concentrations for all three metals were found to be within the background range. Therefore, the uncertainties associated with the excavation worker PEF do not affect the conclusions of the HHRA.

In establishing EPCs, the concentrations of chemicals in the media evaluated are assumed to remain constant over time. Depending on the properties of the chemical and the media in which

it was detected, this assumption could overestimate or underestimate risks, based on the degree of chemical transport to other media or the rate and extent a chemical degrades over time.

When calculating EPCs from sample data using ProUCL, non-detect results are coded as “zeroes.” As indicated in the ProUCL output for the Firing Point/Berm Area (**Appendix E-3**) and the Southeast Hillside Area (**Appendix E-4**), summary statistics, such as the arithmetic mean, are based on detected values only. For calculation of the 95 percent UCL of the mean, the program substitutes surrogate values for the detection limits. Approaches that substitute values for non-detected chemical concentrations are associated with uncertainty, because chemicals that were not detected at the specified sample MDL may be absent from the medium or may be present at a concentration below the sample MDL. Furthermore, only the detected concentrations in each data set are used to determine the distribution of the data. For data sets with non-detects, the uncertainty associated with the distribution of the data could result in an over-estimation of the EPC.

The 95 percent UCL is used as the EPC for each medium if at least eight to ten samples are available. The ProUCL software typically gives a warning when data sets are too small (sample size < 10), which suggests that the 95 percent UCL values could be unreliable. If the 95 percent UCL exceeded the maximum detected value or if fewer than five samples are available, the maximum was conservatively used as a default EPC in this HHRA. The 95 percent UCL was used as the EPC for each chemical in soil. Therefore, the cancer risk/non-cancer hazard estimates are not likely to be biased high. The EPCs for sediment, however, were based on maximum values, which could result in an overestimation of risk or hazard. Using a value that is based on one sampling location (i.e., the maximum) has associated uncertainty and it adds a great deal of conservatism to the assessment. Using the maximum value, however, is less uncertain than using potentially unreliable results.

As stated in *Section 6.4.3*, the ProUCL results indicated that concentrations of thallium in surface soil at ARSAR are potentially site-related and not attributable to background. Although ProUCL concluded that thallium was above background, it is noted that the mean, median, and maximum site concentrations of thallium were all below background. The HI for thallium (HI = 1.3) is nearly equal to an HI of 1. As the HI is potentially over-estimated, thallium is unlikely to be a hazard “driver.”

The exposure parameters used to describe the extent, frequency, and duration of exposure is associated with uncertainty. Actual risks for individuals within an exposed population may differ from those predicted, depending upon their actual intake rates (e.g., soil ingestion rates), nutritional status, or body weight. Exposure assumptions were selected to produce an upper bound estimate of exposure in accordance with USEPA guidelines regarding evaluation of potential exposures at Superfund sites. For example, the exposure frequency for the industrial worker was assumed to be 225 days/year for 25 years. As stated in *Section 6.2.1*, the potential future industrial worker scenario represents a composite of the outdoor and indoor worker scenarios. This approach is consistent with previous HHRAs at RFAAP.

The EF for the industrial worker used in this HHRA (225 days/year) is different from the default exposure frequency of 250 days/year recommended by USEPA for the indoor worker (USEPA, 2002b). For soil, the difference in the EF is balanced by the difference in soil ingestion rates. For example, the incidental ingestion rate for the outdoor worker is 100 mg/day while the incidental ingestion rate for the indoor worker is 50 mg/day. Exposures to soil via the dermal

absorption and inhalation pathways for the indoor worker are assumed to be negligible. For example, for surface soil at the Firing Point/Berm Area, the difference between risks calculated for an exposure frequency of 250 days/year ($9.5\text{E-}06$) were slightly higher than risks calculated for 225 days/year ($9.0\text{E-}06$). The differences between the hazards indices (0.32 versus 0.26) were minimal as well. For surface soil at the Southeast Hillside Area, the difference between risks calculated for an exposure frequency of 250 days/year ($2.2\text{E-}05$) were slightly higher than risks calculated for 225 days/year ($1.9\text{E-}05$). The differences between the hazards indices (0.40 versus 0.36) were minimal as well. In either case, there was no change to the conclusions of the HHRA.

In addition, many USEPA (1991b, 2002b) default exposure parameters are highly conservative and are based on risk management interpretations of limited data. For example, although current USEPA guidance recommends default soil ingestion rates of 100 mg/day for individuals over 6 years of age, other studies, such as Calabrese et al. (1990), have shown that the USEPA default soil ingestion rate of 100 mg/day is likely to greatly overestimate adult exposures and risks. In addition, chemicals in soil are assumed 100 percent bioavailable; this assumes that ingested chemicals present in a soil matrix are absorbed through the GI tract, which is unlikely due to the affinity of contaminants for soil particles. Therefore, based on the conservative exposure assumptions used in the HHRA, exposures and estimated potential risks are likely to be overestimated for the ingestion of soil pathways.

Evaluation of the dermal absorption exposure pathway is affected by uncertainties in dermal exposure parameters. For example, there is uncertainty associated with the exposed skin surface areas used, since the choice of exposed body parts could slightly overestimate or underestimate risks. Uncertainties that are more significant are associated with the selection and use of dermal absorption factors. For this HHRA, the dermal absorption factors and calculations were based on USEPA Region III guidance, USEPA's *RAGS: Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA, 2004a). Very limited information is available on dermal absorption of chemicals from contacted soil under environmental conditions. In fact, there are not actual human epidemiological data to support the hypothesis that absorption of soil bound compounds under exposure conditions is a complete route of exposure. For example, the Public Health Statements from the Agency for Toxic Substance Disease Registry (ATSDR, 1992a, 1992b, 2000, 2004, 2006, 2007) indicate that metals such as thallium, vanadium, manganese, cobalt, aluminum, and arsenic are not known to result in human health effects by dermal absorption because very little can enter the body through the skin under normal circumstances (i.e., without exposure to very high concentrations for long periods or exposure to skin that is damaged). Therefore, using the dermal absorption factors to evaluate dermal absorption exposures to soil may result in an overestimation of risks.

The soil-to-skin adherence factors that were applied at the ARSAR are consistent with factors that are recommended in Exhibit 3-3 (Activity Specific-Surface Area Weighted Soil Adherence Factors) of USEPA's *Risk Assessment Guidance for Superfund Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA, 2004a). The guidance provides different adherence factors for dry and wet soil conditions. For this HHRA, it was assumed that exposure scenarios involving wading activities would result in direct exposure to sediment. All sediment exposures were treated as "wet soil" to be conservative. An adherence factor of 0.6 mg/cm^2 was applied for the maintenance and excavation workers, as suggested. Although there are no specific adherence factors listed in Exhibit 3-3 (RAGS, Part E) for adult resident exposures to wet soil, an adherence

factor of 0.2 mg/cm² was used. This value reflected the 95th percentile value for landscaping/rockery. It is also in the same range as the average value of adherence factors for farmers, rugby players, archaeologists, and reed gatherers (based on geometric mean) that are likely to have similar exposures to wet soil. The same value (0.2 mg/cm²) was also used as the adherence factor (based on the geometric mean) for children playing in wet soil. These factors are also consistent with those applied to sediment exposures in previous HHRA at RFAAP. These factors are conservative because some of the sediment would wash off during wading rather than adhere to the skin surface. Therefore, dermal exposures to sediment are likely to be over-estimated.

6.5.4 Toxicological Data

The HHRA relies on USEPA derived dose response criteria. These health effects criteria are conservative and are designed to be protective of sensitive subpopulations. The health criteria used to evaluate long-term exposures, such as RfDs or CSFs, are based on concepts and assumptions that bias an evaluation in the direction of overestimation of health risk. As USEPA notes in its *Guidelines for Carcinogenic Risk Assessment* (USEPA, 1986), there are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility, human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns, and other cultural factors.

These uncertainties are compensated for using upper bound 95 percent UCLs for CSFs (carcinogens), and safety factors for RfDs (non-carcinogens). The assumptions used here provide a rough but plausible estimate of the upper limit of risk; in other words, it is not likely that the true risk would be much more than the estimated risk, but it could very well be considerably lower, even approaching zero. More refined modeling in the area of dose response calculation (e.g., using maximum likelihood dose response values rather than the 95 percent UCL) would be expected to substantially lower the final risk.

For dermal absorption exposure pathways, the absence of dermal toxicity criteria necessitates the use of oral toxicity data. To calculate risk estimates for the dermal absorption pathway, absorbed dermal absorption doses are combined with oral toxicity values (also discussed above in Section 6.3). Oral toxicity values, which are typically expressed in terms of potential (or administered) doses, should be adjusted when assessing dermal absorption doses, which are expressed as internal (or absorbed) doses. In this assessment, absolute oral absorption factors that reflect the toxicity study conditions were used to modify the oral toxicity criteria. For those chemicals lacking sufficient information, a default oral absorption factor of 1.0 was used. The risk estimates for the dermal absorption pathways may be overestimated or underestimated, depending on how the values used in the HHRA reflect the difference between the oral and dermal routes.

Inhalation toxicity criteria are unavailable for many of the COPCs. For some COPCs, however, oral-based toxicity criteria were used to estimate risks from inhalation exposure through route-to-route extrapolation. The following uncertainties are associated with such a substitution:

- Many contaminants show portal-of-entry toxicity, that is, adverse health effects occur primarily at the tissue site at which the chemical is introduced into the body (e.g., GI tract, lung, or skin).

- Physiological and anatomical differences between the GI tract and respiratory systems invalidate a cross-route quantitative risk extrapolation. The small intestine of humans contains a very large surface area that readily absorbs most compounds by passive diffusion (Klaasen et al., 1986). The oral absorption of a few compounds, such as iron, is an energy-dependent (active-transport) process, wherein; the absorption rate is proportional to the body's current need for iron.
- The rate and extent of pulmonary absorption are much more complex and depend on such factors as particle size distribution of the airborne toxicant and blood-gas solubility of the toxicant (Klaasen et al., 1986). Particles with median aerodynamic diameters of approximately 1 micrometer or less are absorbed by the alveolar region of the human lung. Larger particles deposit in the tracheobronchial or nasopharyngeal regions where they are cleared by mucociliary mechanisms and subsequently swallowed or physically removed and exhaled. Therefore, pulmonary absorption is more highly dependent on the physiochemical properties of the material than oral absorption.
- Human inhalation risk estimates based on oral toxicity data in subhuman species are distorted by both route-to-route extrapolation and interspecies extrapolation. For example, the rodent GI tract, which includes a structurally unique stomach, is anatomically and functionally distinct from the human lung, which contains a very large alveolar surface area for extensive absorption. The rate and extent of absorption across these distinct physiological systems are not alike.

The lack of toxicity values for the inhalation pathway could result in an underestimation of risk or hazard. With the exception of the excavation worker, however, risks and hazards associated with dusts and particulates are typically small relative to the ingestion and dermal pathways.

In addition, for inhalation exposure to substances present as dusts, vapors, gases, or airborne particulate matter, dose extrapolation is far more complex, and therefore associated with uncertainty. The major confounding factors that prohibit a direct dose extrapolation of an inhaled toxicant are the following:

- Over 40 functionally different cell types in the lung - the distribution, consequent metabolic reactions, and air exchange rates vary widely across species.
- Differential concentration and activity of the detoxifying protein glutathione.
- Interspecies and intraspecies differences in the ability to repair pulmonary cell damage, and to clear toxic contaminants and immune complexes from the respiratory tract. For example, species vary in the ability to activate macrophages - nonspecific immune cells that can both protect the inner lining of the respiratory system and, at high concentrations, damage healthy tissues.
- Anatomical variations in the respiratory pathway, which affect both absorption rates and time to reach steady-state blood levels.
- Sensitivity to solubility and concentration variables; because of metabolic saturation (i.e., the exhaustion of normal metabolic activity caused by exposure to high concentrations), highly soluble contaminants deviate from first-order kinetics - which makes it difficult to predict the rates and extent of biotransformation and detoxification reactions. Furthermore, intermittent inhalation exposure to highly blood-soluble chemicals results in

bioaccumulation in fat tissue because of the insufficient time between exposure sessions for complete clearance of the contaminant. Such slow release from the fat compartment to other body tissues can result in toxicological and metabolic effects that are difficult to assess and vary across species.

For chemicals without IRIS toxicity criteria, provisional toxicity criteria were used where available (**Appendix E-1, Tables E.1-22 through E.1-25** and **Appendix E-2, Tables E.2-13 through E.2-16**). Provisional toxicity criteria (i.e., PPRTVs) present a source of uncertainty, since USEPA has evaluated the compound, but consensus has not been established on the toxicity criteria. PPRTVs or other oral toxicity provisional values were used for PAHs [benzo(b)fluoranthene and dibenzo(a,h)anthracene], aluminum, cobalt, iron, thallium, and vanadium. For thallium, the provisional oral RfD of 1.0E-5 mg/kg-day is from an appendix to the Derivation Support Document dated October 2010 (USEPA, 2010c), and the uncertainty associated with this RfD is greater than usual, compared with other chemical PPRTVs. In particular, it was stated in the supporting documentation for the PPRTVs for thallium compounds (USEPA, 2010c) that it was inappropriate to derive a provisional subchronic or chronic provisional-RfD for thallium. However, information was available that, although insufficient to support derivation of a provisional toxicity value under current guidelines, may be of limited use to risk assessors. In such cases, the Superfund Health Risk Technical Support Center summarizes available information in an appendix and develops a screening value. Users of screening toxicity values in an appendix to a PPRTV assessment should understand that there is considerably more uncertainty associated with the derivation of a supplemental screening toxicity value than for a value presented in the body of the assessment. Therefore, the elevated HQ (above 1.0) estimated for potential exposure to thallium in surface soil at ARSAR should be viewed as screening-level HQs only. In addition, provisional inhalation toxicity values were used for PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene], aluminum, arsenic, cobalt, and thallium. However, because these toxicity criteria have not been formally accepted by USEPA, there is uncertainty with these values and, therefore, with the risks and hazards calculated using these toxicity criteria.

For some chemicals, toxicity criteria were unavailable (**Appendix E-1, Tables E.1-22 through E.1-25** and **Appendix E-2, Tables E.2-13 through E.2-16**). In some cases, chemicals with similar structures and properties served as surrogates. The values for these surrogates were consistent with those shown in VDEQ's Risk Assessment Guidance, Tables 4.1 and 4.2 (VDEQ, 2012). For the COPC selection, there were several detected constituents that did not have screening criteria (**Appendix E-1, Tables E.1-2, E.1-4, E.1-6, and E.1-8** and **Appendix E-2, Table E.2-2**). These constituents and surrogates were, as follows: acenaphthylene (pyrene), benzo(g,h,i)perylene (pyrene), delta-BHC (alpha-BHC), alpha-chlordane (chlordane), gamma-chlordane (chlordane), endosulfan II (endosulfan I), endosulfan sulfate (endosulfan I), endrin aldehyde (endrin), endrin ketone (endrin), and phenanthrene (pyrene). None of these constituents were carried through the HHRA as COPCs. In addition, as noted in *Section 6.1.2*, that the screening value for chromium VI was conservatively used to screen chromium. Because there is no evidence that chromium VI would have been associated with past activities at the site, however, the toxicity value for chromium III was applied in the risk and hazard calculations.

It is noted that the Supplemental SSL Guidance (USEPA, 2002b) recommends that toxicity values for subchronic exposures be used to calculate the HQs for exposures by the excavation

worker. Although subchronic values for some chemicals are included in USEPA's database of PPRTVs, this web site cannot be accessed without authorization. The overall lack of subchronic toxicity values for the COPCs at these sites contributes to the uncertainty of the HIs. Typically, subchronic toxicity values are ten-fold greater than chronic toxicity values. Chronic toxicity values were used for all COPCs and, therefore, the calculated hazards are likely to be overestimated. This uncertainty did not impact the conclusions, however, because these COPCs were found to be background-related.

Lead was not included in the quantitative risk estimates because a dose-response toxicity value is not available for this chemical. Lead was selected as a COPC in surface soil at the Southeast Hillside Area. Adult exposures to lead were evaluated by using the ALM developed by USEPA's Technical Review Workgroup for lead to calculate blood lead concentrations for non-residential adults (USEPA, 2003b; 2009b,c,d). Residential exposures to lead were evaluated using the IEUBK model (USEPA, 1994, 2007a, 2010b). Because the non-carcinogenic effects from lead are evaluated separately, these effects are not represented in the cumulative HI. Two key default parameters for the ALM have been updated based on more recent data. These data were obtained from the *Update of the Adult Lead Methodology's Default Baseline Blood Lead Concentrations and Geometric Standard Deviation Parameters* from the National Health and Nutrition Examination Survey (NHANES) conducted in 1999 through 2004 (USEPA, 2009b,c). Previously, these values had been based on data from USEPA's document, *Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from Phases 1 and 2 of the National Health and Nutrition Evaluation Survey (NHANES III)* in 2002. The first parameter, the geometric mean blood lead concentration (GM), is intended to represent the best estimate of a reasonable central value of blood lead concentration in women of child-bearing age who are not exposed to lead-contaminated nonresidential soil or dust at the site (USEPA, 2003b). The updated value is 1.0 µg/dL (USEPA, 2009c), compared with 1.5 µg/dL from the 2002 document. The second parameter, the geometric standard deviation (GSD), is a measure of the inter-individual variability in blood lead concentrations in a population whose members are exposed to the same nonresidential environmental lead levels. This value reflects the homogeneity or heterogeneity of the exposed population with respect to socioeconomic, ethnic, and geographic factors. The updated value is 1.8 (USEPA, 2009c), compared with 2.1 from the 2002 document (USEPA, 2002c). Because the Office of Superfund Remediation and Technology Innovation is in the process of developing a new soil lead policy to address this new information (USEPA, 2009b,c), both sets of GM and GSD values were conservatively applied in the ALM spreadsheets.

As discussed in Section 6.3.2, the CDCP recently lowered the childhood blood lead level from 10 µg/dL to 5 µg/dL (DoD, 2012). This revision is based on a growing body of studies concluding that blood lead levels less than 10 µg/dL have adverse effects on the health of children. If the new blood lead level of 5 µg/dL is applied in the ALM, the probability of exceeding 5 µg/dL at the Southeast Hillside would range from 2.1 to 10.4 percent for the industrial worker and 9.4 to 21.2 percent for the excavation worker. The upper range values for both receptors would be above the 5 percent target set by CDCP. The new blood lead level has not yet been incorporated into the IEUBK model. As stated in Section 6.3.2, USEPA is currently evaluating the potential implications of the revised blood lead level.

In addition, the ALM was used to evaluate exposures of workers to lead in soil (USEPA, 2009d), as discussed in Section 5.4.1. Because the ALM is a probabilistic model, the default parameters

are based on central tendency values. For example, the range of lead concentrations detected in surface soil at the Southeast Hillside Area was 21.9 to 2,500 mg/kg. The arithmetic mean applied in the ALM was 475 mg/kg, which is above the residential RSL for lead (400 mg/kg), but below the industrial RSL (800 mg/kg).

For example, the incidental ingestion rate for soil that is assumed for the model is 50 mg/day, whereas an incidental ingestion rate of 100 mg/day was used for the excavation worker. Another area of uncertainty, however, is the exposure frequency. The default exposure frequency for the ALM is 219 days/year, while the exposure frequency for the excavation worker is 125 days/year. According to the guidance for the ALM (USEPA, 2003b), infrequent exposures (i.e., less than 1 day per week) over a minimum duration of 90 days would be expected to produce oscillations in blood lead concentrations associated with the absorption and subsequent clearance of lead from the blood between each exposure event. The exposure parameters for the excavation worker also differed from the parameters used in the ALM. The incidental ingestion rate for the excavation worker was 330 mg/day. However, the suggested default value for exposure to an excavation worker via incidental ingestion is 100 mg/day (USEPA, 2012d).

6.5.5 Risk Characterization

Minor uncertainty is associated with rounding of the risk and hazard estimates. Thus, the actual risk or hazard may be slightly greater or less than the presented values. A related issue is that rounding results in differences between summed risk and hazard values, depending on how the summing is performed. For example, the RAGS Table 7 and 8 spreadsheets in **Appendix E-1, Tables E.1-26 through E.1-35** and **Appendix E-2, Tables E.2-17 through E.2-26** present risks and hazards that are summed for exposure route, exposure point, exposure medium, and medium total. The individual chemical-specific risks and hazards are summed only for the initial exposure route in deriving the total. For the subsequent summations (exposure point, exposure medium, and medium total), each is the summation of the preceding sums. For this reason, there can also be or rounding-related differences between the “same” values presented in RAGS Table 9 and 10 spreadsheets in **Appendix E-1, Tables E.1-36 through E.1-40** and **Appendix E-2, Tables E.2-27 through E.2-31**.

6.6 HHRA Summary and Conclusions

This HHRA was performed to evaluate the potential human health effects associated with previous activities at the ARSAR. Receptors evaluated for both areas included current/future maintenance worker, future industrial worker, future excavation worker, future adult resident, future child resident, and lifetime resident.

Firing Point/Berm Area Summary

As presented in *Section 6.4* for the Firing Point/Berm Area, the total cancer risk for current/future maintenance worker exposures to surface soil (1E-06) was equal to the lower limit of the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (1E-06) was equal to the lower limit of the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For future industrial worker exposures to surface soil, the total cancer risk for exposures to surface soil (5E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (4E-06)

was within the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the future excavation worker, the total cancer risk for exposures to surface soil (3E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to cobalt. Based on the background comparison, cobalt was found to be background-related. The total HI for surface soil (16) was above 1 due to aluminum, cobalt, and manganese. Based on background comparisons, however, these COPCs were found to be background-related. The total cancer risk for exposures to sediment (5E-07) was below the acceptable risk range. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the future hypothetical lifetime resident, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic and benzo(a)pyrene. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (2E-06) was within the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the hypothetical child resident, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic and benzo(a)pyrene. The total HI for surface soil (HI = 4) is above an acceptable HI of 1 primarily due to iron and thallium with individual HIs that were each equal to 1. The margin of exposure evaluation for iron indicated that concentrations of iron were within the allowable range. While the HI for thallium did not exceed 1, it was equal to 1 and contributed to the exceedance of the target organ HI for skin. The results from ProUCL concluded that thallium was above background; however, it is noted that the mean, median, and maximum concentrations of thallium for the site data set were all below the corresponding statistics for the background data set. The total cancer risk for exposures to sediment (1E-06) was equal to the lower limit of the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

Southeast Hillside Area Summary

As presented in *Section 6.4* for the Southeast Hillside Area, the total cancer risk for current/future maintenance worker exposures to surface soil (4E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. A geologic and geochemical analysis of the arsenic concentrations and distribution strongly suggests a natural source for the elevated arsenic concentrations in the Southeast Hillside Area. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For future industrial worker exposures to surface soil, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. A geologic and geochemical analysis of the arsenic concentrations and distribution also strongly suggests a natural source for the elevated arsenic concentrations in the Southeast Hillside Area. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For the future excavation worker, the total cancer risk for exposures to surface soil (1E-06) was equal to the lower limit of the acceptable risk range of 1E-06 to 1E-04. The total HI for surface soil was equal to 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For the future hypothetical lifetime resident, the total cancer risk for exposures to surface soil ($9\text{E-}05$) was within the acceptable risk range of $1\text{E-}06$ to $1\text{E-}04$ due to arsenic. A geologic and geochemical analysis of the arsenic concentrations and distribution also strongly suggests a natural source for the elevated arsenic concentrations in the Southeast Hillside Area. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are above the health protective criterion for lead.

For the hypothetical child resident, the total cancer risk for exposures to surface soil ($6\text{E-}05$) was within the acceptable risk range of $1\text{E-}06$ to $1\text{E-}04$ due to arsenic. The total HI for surface soil ($\text{HI} = 5$) is above an acceptable HI of 1 due to arsenic and thallium. Although ProUCL concluded that thallium was above background, it is noted that the mean, median, and maximum concentrations of thallium for the site data set were all below the corresponding statistics for the background data set. A geologic and geochemical analysis of the arsenic concentrations and distribution also strongly suggests a natural source for the elevated arsenic concentrations in the Southeast Hillside Area. Site concentrations of lead in surface soil are above the health protective criterion for lead.

7.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

Screening level ecological risk assessments (SLERAs) were performed at the ARSAR Firing Point/Berm Area and ARSAR Southeast Hillside Area to provide an estimate of current and future ecological risk associated with potential hazardous substance releases at each site. The results of the SLERAs contribute to the overall characterization of the sites, and the scientific/management decision points reached include one of the following:

- There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the sites on the basis of ecological risk.
- The information is not adequate to make a decision at this point and further refinement of data is needed to augment the ecological risk screening.
- The information collected and presented indicates that a more thorough assessment is warranted.

The SLERAs were performed following the *Tri-Service Procedural Guidelines for Ecological Risk Assessments* (Wentsel et al., 1996), and Steps 1, 2 and 3a of the *Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997c). Steps 1, 2 and 3a were completed as part of the SLERAs. The addition of Step 3a focuses the outcome of the SLERAs, streamlines the review process, and allows one assessment to function as the initial forum for ecological risk management decision making at the sites.

The primary objective of the SLERAs is to assess whether there is enough information to state that there is the potential for unacceptable risks to ecological receptors as a result of potential hazardous substance releases. Characterizing the ecological communities in the vicinity of the Firing Point/Berm Area and Southeast Hillside Area, assessing the particular hazardous substances being released, identifying pathways for receptor exposure, and estimating the magnitude and likelihood of potential risk to identified receptors meets this objective. The SLERAs address the potential for adverse effects to vegetation, the soil invertebrate community, wildlife, endangered and threatened species, and wetlands or other sensitive habitats that may be associated with the ARSAR sites.

Concentrations of chemicals were measured in surface soil, sediment, surface water, and groundwater at the Firing Point/Berm Area and in surface soil at the Southeast Hillside Area, which were the relevant environmental media at the sites.

Using available concentration data, the SLERAs were performed by following Steps 1 and 2 of USEPA (1997c). Step 1 includes a screening-level problem formulation and ecological effects evaluation, and Step 2 includes an SL preliminary exposure estimate and risk calculation. The SLERAs are organized as follows: General RFAAP Site Characterization (*Section 7.1.1*); ARSAR Site Characterization (*Section 7.1.2*); Methodologies for the Identification of Chemicals of Potential Ecological Concern (COPECs) and Concentration Statistics (*Section 7.1.3*); Identification of Exposure Pathways and Potential Receptors for Analysis (*Section 7.1.4*); Identification of Assessment and Measurement Endpoints (*Section 7.1.5*); Exposure Estimation (*Section 7.1.6*); Ecological Effects Assessment (*Section 7.1.7*); Risk Characterization (*Section 7.1.8*); Direct Contact Toxicity (*Section 7.1.9*); Background Metals Evaluation (*Section 7.1.10*); General Uncertainty Analysis (*Section 7.1.11*); Firing Point/Berm Area Screening Level

Ecological Risk Assessment (Section 7.2); and Southeast Hillside Area Screening Level Ecological Risk Assessment (Section 7.3).

7.1 SLERA Methods and Procedures

7.1.1 General ARSAR Site Characterization

This section includes a discussion of the ARSAR, vegetative communities, a species inventory, and a discussion on threatened and endangered species.

The Virginia Department of Game and Inland Fisheries (1999) conducted the most recent Installation-wide biological survey at RFAAP. Major objectives of this survey were to sample flora and fauna, identify and delineate the major habitat community types, and provide management recommendations for both community types and threatened, endangered or species of concern. Eight community types were identified at RFAAP:

- Bottomland forest.
- Calcareous forest.
- Cliffs.
- Grasslands.
- Oak forest.
- Pine plantation.
- Successional forest.
- Water.

Endangered plants or animals were not observed at the ARSAR during the Installation-wide biological survey of 1999. Five state-listed rare plants were observed at RFAAP during this survey: *Clematis coattails*, *Cystopteris tennesseensis*, *Hasteola suaveolens*, *Sagittaria rigida*, and *Eleocharis intermedia*. State threatened animals located at RFAAP include the invertebrate *Speyeria idalia* and the birds *Ammodramus henslowii* (Henslow's sparrow) and *Lanius ludovicianus* (loggerhead shrike).

An earlier comprehensive inventory of the mammals, birds, reptiles, aquatic invertebrates, trees, and plants found on the Installation, and of fish inhabiting the New River where it flows through the Installation, was conducted in 1976 during the RFAAP Installation Assessment (USATHAMA, 1976). Information from that assessment was summarized in previous documents (Dames and Moore, 1992). The summarized information was updated for the RFI through personal communication with RFAAP biologists and is presented in the following paragraphs (from URS, 2003).

Many of the reptiles, mammals, and birds listed in the assessment (USATHAMA, 1976) are believed to breed on the Installation. Migratory waterfowl are found throughout the spring and winter near the New River because the Installation is on the Atlantic Flyway. Public fishing occurs in the New River where it flows through RFAAP.

The Virginia Department of Game and Inland Fisheries identified the following terrestrial flora and fauna as endangered or threatened for Pulaski and Montgomery Counties:

- Plant species - six endangered, three threatened.

- Insect species - one endangered, four threatened.
- Bird species - three endangered.
- The locally endangered mountain lion.

In addition, a fish, salamander, four additional bird species, and the river otter are identified as species of concern in the two counties in which RFAAP is located.

Tree species at RFAAP include the shortleaf pine, loblolly pine, eastern white pine, yellow poplar, and black walnut. There are 2,537 acres of managed woodland on site (personal communication with T. Thompson, RFAAP Conservation Specialist 1995, as cited in URS, 2003).

RFAAP is located at the boundary of the central Appalachian Ridges and Valleys Ecoregion and the central Appalachian Ecoregion (Omernik, 1986). These two Ecoregions are characterized in **Table 7-1**.

Table 7-1
Ecoregions of RFAAP

Ecoregion	Land Surface Form	Potential Natural Vegetation	Land Use
Central Appalachian Ridges and Valleys	Open low hills to open low mountains	Appalachian oak in undisturbed areas	Mosaic of cropland and pasture with some woodland and forest
Central Appalachian	Open low to high hills, open mountains	Mixed mesophytic forest ¹ , Appalachian oak, northern hardwoods ²	Forest and woodland mostly ungrazed

¹maple, buckeye, beech, tuliptree, oak, linden

²maple, birch, beech, hemlock

As part of these SLERAs, relevant information was obtained, including topographic maps, township, county, or other appropriate maps. This information was used to identify the location of potential ecological units such as streams, creeks, ponds, grasslands, forest, and wetlands near the ARSAR. Additionally, the Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey, which identifies the locations of threatened and endangered species at RFAAP, was reviewed. The location of known or potential contaminant sources affecting the ARSAR and the probable gradient of the pathway by which contaminants may be released to the surrounding environment were identified.

7.1.2 Army Reserve Small Arms Range Characterization

The ARSAR is an MRS being investigated under the MMRP. The ARSAR is an approximately 7.6-acre area located along the southeastern boundary of the MMA (**Figure 2-1**). Most of the site is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. As illustrated on **Figure 2-2**, the site is divided into two areas consisting of the Firing Point/Berm Area (6.56 acres) and the Southeast Hillside Area (1.08 acres). A target berm, which is approximately 8 ft high and 270 ft long, is located along the southeastern portion of the Firing Point Area that was remediated in 2011. The Southeast Hillside Area is a steep, rocky hillside thought to have been used as a backstop prior to the construction of the target berm. According to URS (2008), the ARSAR was a .30 caliber

small arms firing range used by both the National Guard and the Army Reserve from approximately 1941 to 1968. The former range is now an unused grass baseball field surrounded by a fence.

The ARSAR is located within a nearly level alluvial plain at an elevation of approximately 1,715 ft msl (**Figure 2-2**). The Southeast Hillside Area slopes steeply upward to an elevation greater than 1,950 ft msl.

7.1.2.1 Surface Water

Stroubles Creek is a perennial stream that flows along the southern portion of the Firing Point/Berm Area and then turns northward towards the New River where it discharges approximately 3,000 ft north of the site. The ARSAR has no other surface water bodies.

It is assumed that overland storm water flow is directed toward Stroubles Creek. In the area of the target berm, runoff from the north side of the berm would flow away from Stroubles Creek for a short distance north, and infiltrate into the grassy field. Due to its location on a flood plain, areas adjacent to Stroubles Creek may experience inundation during periods of high flow and flooding.

7.1.2.2 Groundwater

Groundwater is being evaluated separately under the Horseshoe Area Groundwater Study. Groundwater is expected to flow south through the unconsolidated sediments and discharge in Stroubles Creek. Surface water and sediment samples were collected in Stroubles Creek and are the likely exposure points for ecological receptors; therefore, groundwater was not evaluated as part of the SLERA.

7.1.2.3 Wetlands

According to the information presented in the Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey there are no wetlands at the ARSAR. There are also no wetlands close enough to the sites that could potentially be impacted or receive surface water drainage from the sites.

7.1.2.4 Vegetative Communities

Vegetative communities at the site, as presented in the Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey, were verified using **Figures 2-1 and 2-2** as well as the site photographs presented in **Appendix F-1**. As shown in the figures and photographs, the ARSAR is primarily maintained grass and the area surrounding the ARSAR is primarily maintained grass and paved roadways to the north and east, and bordered by successional forest habitat to the south and west.

These two habitat types (grass and successional forest edge) can be expected to support different wildlife species assemblages; however, given the close proximity of the habitats to each other, many species would be expected to spend some amount of time within each community type.

Based on information from the Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey, and confirmed during a review of available site information, the following community description is presented for typical grassland communities at RFAAP.

The grassland communities at RFAAP are an aggregation of several community types that are so intermingled that delineation is impractical. Grassland may conveniently be subdivided into old field, meadow, and cultivated field. The term old field is used here to denote areas that were formerly open and subsequently abandoned, but are still open. In most cases, these areas were formerly pasture or hayfield. Trees or shrubs may be present individually or in small groups, but a canopy is lacking. There is successional forest habitat just beyond the edges of the site. Old fields, in most cases, are dominated by native, warm-season species with a wide variety of other grasses, sedges, and herbs mixed in. The two dominants are little bluestem (*Schizachyrium scoparium*) and broomsedge (*Andropogon virginicus*) with others such as *Tridens flavus*, *Panicum oligosanthos*, *Panicum anceps*, *Eragrostis spectabilis*, *Setaria glauca*, *Sorghastrum nutans*, and *Paspalum* being frequent. Much of the old-field community is mowed (on an infrequent basis) to help keep woody plants maintained.

Meadows are areas that are mowed regularly and, in most cases, have been planted in forage grasses for haying. These are typically non-native, cool-season species such as *Festuca elatior*, *Poa pratensis*, *Phleum pratense*, *Agrostis gigantea*, *Bromus inermis*, *Dactylis glomerata*, and *Arrhenatherum elatius*. These species may also be mixed with native species characteristic of old fields.

Cultivated fields are areas that have been plowed and seeded with various cover crops. These areas have a major ruderal component that persists after abandonment. Principal weed species are *Cirsium arvense*, *Carduus acanthoides*, *Carduus nutans*, *Erechtites hieracifolia*, *Hypochaeris radicata*, *Verbascum thapsus*, *Hieracium pilosella*, and *Datura stramonium*.

Grassland communities at RFAAP comprise 4,379 acres, or about 63 percent of the 6,901-acre total [Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey].

7.1.2.5 Species Inventory

As presented in the Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey, six different taxa and several species were recorded during the survey.

Table 7-2 presents the numbers of species recorded at RFAAP that may be within or near the grassland community type.

Table 7-2
Species Inventory within RFAAP's Grassland Community Type

Taxa	Number of Species	Typical Examples
Plants	24	little bluestem, broomsedge, panic grass, orchard grass, foxtail, timothy, thistle, fireweed, hawkweed
Invertebrates	~250 in 17 taxonomic orders	millipedes, beetles, flies, springtails, seed bugs, bees, ants, moths, butterflies, dragonflies, mantis, caddisflies, isopods, pill bugs, amphipods
Reptiles and amphibians	24	salamanders, toads, frogs, turtles, snakes
Fish	12	sunfish, minnows, trout (not expected at the site)
Birds	83	robin, swift, dove, sparrow, warbler, wren, hawk
Mammals	13	red fox, white-tailed deer, shrew, meadow vole

7.1.2.6 Threatened, Rare and Endangered Species Information

Threatened, rare, or endangered species found within the grassland community type at RFAAP include those presented in **Table 7-3** [Virginia Department of Game and Inland Fisheries (1999) Installation-Wide Biological Survey]. Given the grassland community type at the sites, it is possible these species could also occur at the sites; however, no threatened, rare, or endangered species have been documented at the ARSAR. Although a unique community type (calcareous fen) exists within the RFAAP grassland community type, it is not found at or near the ARSAR.

Table 7-3
Threatened, Rare, and Endangered Species in RFAAP's Grassland Community

Common Name	Scientific Name	Federal Status	State Status
Midland sedge	<i>Carex mesochorea</i>	not available	Watchlist
Shaggy false gromwell	<i>Onosmodium hispidissimum</i>	not available	Watchlist
Regal fritillary butterfly	<i>Speyeria idalia</i>	not available	State threatened
Henslow's sparrow	<i>Ammodramus henslowii</i>	not available	State threatened
Loggerhead shrike	<i>Lanius ludovicianus</i>	not available	State threatened

7.1.3 Methodologies for the Identification of COPECs and Concentration Statistics

The following section details the selection of COPECs and statistics used for the SLERAs.

7.1.3.1 Data Organization

The data for each chemical at each ARSAR site have been sorted by medium. To assess potential ecological impacts, soil data from 0-2 ft bgs, as well as sediment and surface water data from Stroubles Creek, have been considered. The 0-2 ft soil depth interval was selected for three primary reasons: 1) to maintain consistency with other RFAAP ecological risk assessment documents that used 0-2 ft, or a similar depth interval (e.g., Ecological Risk Assessment Approach, IT, 1998; Screening Ecological Risk Assessment, IT, 1999); 2) to address the most important ecological soil depth exposure interval, as soil depths below 2 ft would be infrequently contacted; and 3) to focus on the soil depth interval expected to have the highest COPEC concentrations, as site-related COPECs were primarily from surficial sources. Although some burrowing wildlife (e.g., the red fox) may actually burrow to depths greater than 2 ft, their prey items would be primarily associated with surface soil, and incidental contact by the fox with deeper soil is expected to be insignificant compared to exposures associated with soil in the 0-2 ft depth range.

Chemicals that were not detected at least once in a medium are not included in the risk assessment, although non-detected constituents are discussed in the Uncertainty Analysis sections (*Sections 7.2.6 and 7.3.6*).

The analytical data may have qualifiers from the analytical laboratory QC or from the data validation process that reflect the level of confidence in the data. Some of the more common qualifiers and their meanings from USEPA (1989a) are discussed, along with other data issues in **Appendix A-2**.

Using the chemical results from environmental media samples collected at the ARSAR, a subset of the chemicals detected having data of good quality and that were not a result of non-site sources are identified.

7.1.3.2 Summary of COPEC Selection

COPECs were selected as a concern for the direct contact exposure pathway if the constituent was detected in an environmental medium. For food chain exposure pathways, detected COPECs were selected if they were important bioaccumulative constituents (USEPA, 2000c) or explosives.

COPEC selection tables have been prepared for detected constituents within their respective media types with the following information:

- CAS number.
- Chemical name.
- Range of detected concentrations, and associated qualifiers.
- Concentration units.
- Location of MDC.
- Frequency of detection.
- Range of detection limits.
- COPEC selection conclusion: YES or NO.
- Rationale for selection or rejection of the COPEC.

The tables are presented in *Sections 7.2.2 (Firing Point/Berm Area)* and *7.3.2 (Southeast Hillside Area)*, respectively.

It should be noted that USEPA recommends that aluminum should only be identified as a COPEC for those sites with soil with a pH less than 5.5 (USEPA, 2000c). The technical basis for this rationale is that soluble and toxic forms of aluminum are present in soil with soil pH values of less than 5.5. Soil at RFAAP generally ranges in pH from slightly less than 4.0 to slightly more than 9.61. A review of pH results during the *Facility-Wide Background Study Report* (IT, 2001) across soil types at the MMA did not yield outstanding trends. Geometric surface soil pH measurements taken at the MMA in resulted in a pH of 5.92. Since the pH from the ARSAR soil is slightly above 5.5, it is unlikely that aluminum is a concern for direct contact exposure. However, aluminum will be carried through to the direct contact evaluation because it was detected. In addition, aluminum is not considered by USEPA to be an important bioaccumulator (USEPA, 2000c); therefore, it was not selected as a COPEC for food chain exposure.

The list of samples used for the ARSAR Firing Point/Berm Area and Southeast Hillside Area SLERAs is presented in **Table 7-4**.

**Table 7-4
ARSAR Sample Groupings**

Firing Point/Berm Area	SURFACE SOIL	
	ARSBSC01	ARSBSC13
	ARSBSC02	ARSBTM03 (duplicate)
	ARSBSC03	ARSBSC14
	ARSBSC04	ARSCF01
	ARSBSC05	ARSTM01 (duplicate)
	ARSBSC06	ARSCF02
	ARSBSC07	ARSCF03
	ARSBSC08	ARSCF04
	ARSBSC09	ARSCF05
	ARSBTM02 (duplicate)	ARSCF06
	ARSBSC10	ARSCF07
Southeast Hillside Area	ARSBSC11	ARSCF08
	ARSBSC12	ARSCF09
	SEDIMENT	
	ARSD01	ARSD04
	ARSD02	ARSD05
	ARSD03	ARTM03 (duplicate)
	SURFACE WATER	
	ARSW01	ARSW04
	ARSW02	ARSW05
	ARSW03	
	SURFACE SOIL	
	ARSCH01	ARSCH07
	ARSCHTM01 (duplicate)	ARSCH08
	ARSCH02	ARSCHTM02 (duplicate)
	ARSCH03	ARSCH09
	ARSCH04	ARSCH10
	ARSCH05	ARSCH11
	ARSCH06	ARSCH12

7.1.3.3 Descriptive Statistical Calculations

Because of the uncertainty associated with characterizing contamination in environmental media, the 95 percent UCL of the mean has been estimated for chemicals selected as COPECs. The calculation of EPCs follows the same procedure used for the HHRA (*Section 6.2.3*) and is summarized below.

To calculate intakes and assess direct contact exposure, a 95 percent UCL of the mean concentration for each COPEC is used as a conservative estimate of the average concentration in a given environmental medium to which a receptor would be exposed. The 95 percent UCL estimate is referred to as the EPC. The 95 percent UCL is used rather than the mean concentration, to account for uncertainty when estimating EPCs from sample data (USEPA, 1989a). Methods used to calculate 95 percent UCLs are based on guidance provided in the documents *Calculating UCLs*

for Exposure Point Concentrations at Hazardous Waste Sites (USEPA, 2002a) and *ProUCL Version 4.1 Technical Guide* (USEPA, 2010a).

In general, the method used to calculate a 95 percent UCL depends on: 1) the prevalence of non-detects; 2) the data distribution (e.g., normal, gamma, or lognormal); and 3) the number of samples in the data set. Non-detects introduce uncertainty in the data set because the true concentration may be between zero to just below the detection limit. Therefore, distributional assumptions are difficult to ascertain for COPECs with a high rate of non-detects. USEPA's (2011a) ProUCL v.4.1 statistical program was used to estimate 95 percent UCL values for all COPEC data sets. For data sets with non-detects, ProUCL uses the Kaplan-Meier estimation method to derive a recommended 95 percent UCL (USEPA, 2011a). Where ProUCL recommends the results of more than one statistical approach, the most conservative (highest) 95 percent UCL value was used in the SLERA. Where fewer than three samples had detected values, ProUCL does not recommend a 95 percent UCL value. In these cases, the MDC was conservatively used as the EPC for the SLERA.

The EPC calculation tables are presented in *Sections 7.2.3* (Firing Point/Berm Area) and *7.3.3* (Southeast Hillside Area), respectively.

7.1.3.4 Frequency of Detection

Chemicals that are detected infrequently may be artifacts in the data that may not reflect site-related activity or disposal practices. These chemicals, however, have been included in the risk evaluation and a low frequency of detection was not used to deselect COPECs.

7.1.3.5 Natural Site Constituents (Essential Nutrients)

As a conservative step, the essential nutrients calcium, magnesium, potassium, and sodium were assessed in the SLERA.

7.1.4 Identification of Exposure Pathways and Potential Receptors for Analysis

Terrestrial and aquatic wildlife may be exposed to COPECs by several pathways, including: 1) the ingestion of impacted soil, sediment, surface water, or food while foraging; 2) dermal absorption of chemicals from soil, sediment, or surface water; and, 3) inhalation of chemicals that have been wind-eroded from soil or have volatilized from soil or water. Among these potential exposure pathways, the greatest potential for exposure to chemicals is likely to result from the ingestion of chemicals in food and surface water. The incidental ingestion of impacted soil or sediment (while foraging) is a less important exposure route. The ingestion of food, soil, sediment, and surface water, however, are viable exposure pathways and were considered in the SLERAs, if relevant.

Receptor-specific exposures via inhalation or dermal absorption were not selected for further evaluation because of a lack of appropriate exposure data, and the expectation that these pathways would be insignificant in comparison to the other exposure pathways quantified. Inhalation exposure would be expected to be minimal due to dilution of airborne COPECs in ambient air. Dermal exposure would also be expected to be minimal due to the expectation that wildlife fur or feathers would act to impede the transport the COPECs to the dermal layer.

The appropriate assessment receptors have been selected for evaluation in the SLERAs. In order to narrow the exposure characterization portion of the SLERAs on species or components that are the most likely to be affected, the SLERAs have focused the selection process on species,

groups of species, or functional groups, rather than higher organization levels such as communities or ecosystems. Site biota are organized into major functional groups. For terrestrial communities, the major groups are plants and wildlife, including terrestrial invertebrates, mammals, and birds. For aquatic and/or wetland communities, the major groups are flora and fauna, including vertebrates (waterfowl and fish), aquatic invertebrates, and semi-aquatic mammals and birds. Species presence was assessed during a literature review and during the site reconnaissance prior to identification of target receptor species.

Primary criteria for selecting appropriate assessment receptors included, but were not limited to, the following:

- The assessment receptor will have a relatively high likelihood of contacting chemicals via direct or indirect exposure.
- The assessment receptor will exhibit marked sensitivity to the COPECs given their mode of toxicity, propensity to bioaccumulate, etc.
- The assessment receptor will be a key component of ecosystem structure or function (e.g., importance in the food web, ecological relevance).

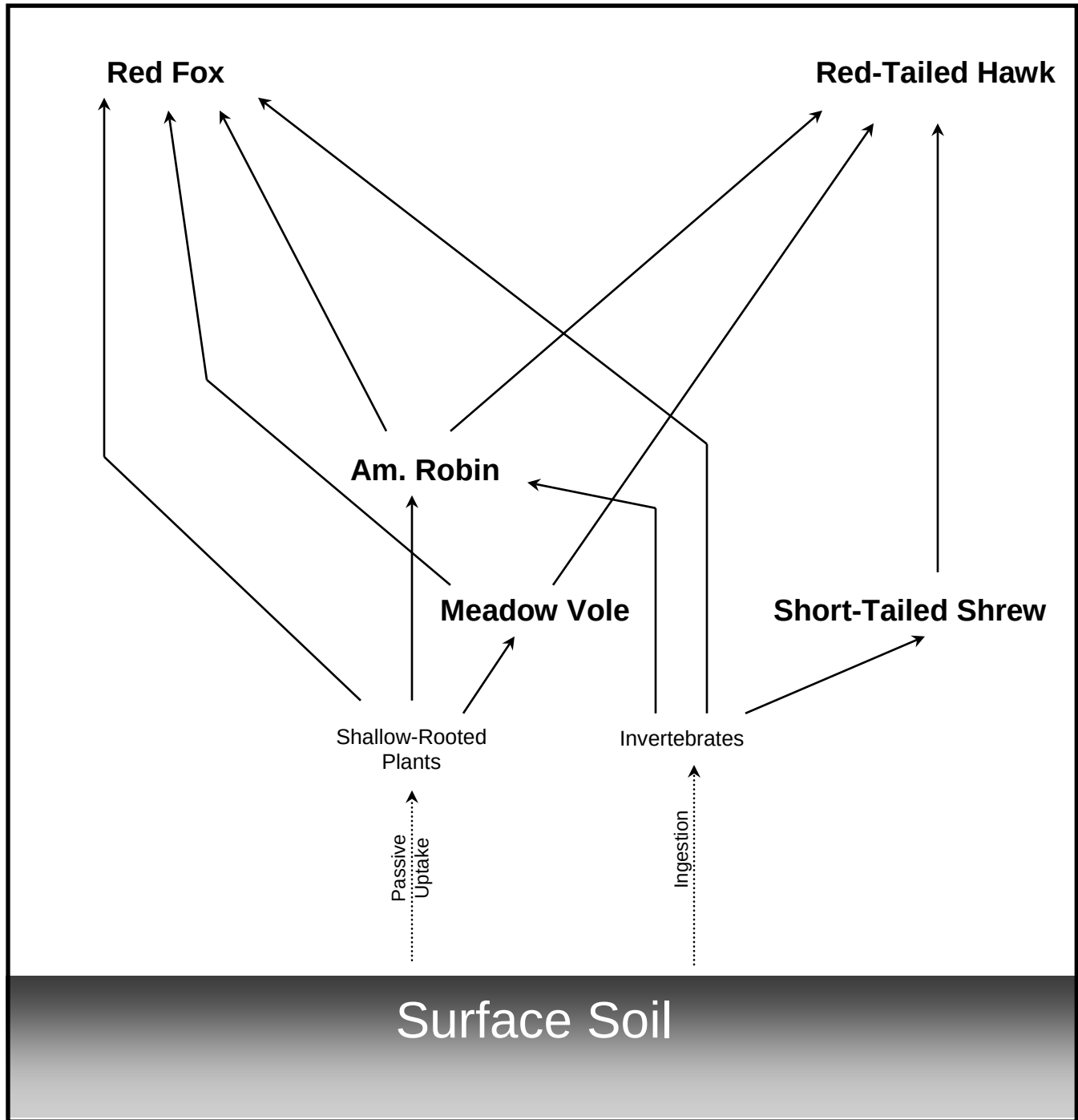
7.1.4.1 Terrestrial Receptors

Five representative receptor species that are expected or possible in the ARSAR area were selected as indicator species for the potential effects of COPECs. These indicator species represent two classes of vertebrate wildlife (mammals and birds) and a range of both body size and food habits, including herbivory, omnivory, and carnivory. Note: potential impacts to terrestrial plants were considered by documenting the presence or absence of vegetative stress at the site as well as by comparing soil concentrations with conservative screening values. The five animal species selected include the meadow vole (*Microtus pennsylvanicus*) (small, herbivorous mammal), short-tailed shrew (*Blarina brevicauda*) (small, insectivorous mammal), American robin (*Turdus migratorius*) (small omnivorous bird), red-tailed hawk (*Buteo jamaicensis*) (large, carnivorous bird), and red fox (*Vulpes vulpes*) (medium, carnivorous mammal). Data used to model exposure for these species are summarized in **Appendix F-2, Table F-1**.

The meadow vole, shrew, and robin represent the prey base for the larger predators of the area (represented by the red-tailed hawk and the red fox). A terrestrial food web is presented on **Figure 7-1**. Many of these species have limited home ranges, particularly the meadow vole, shrew, and American robin, which make them particularly vulnerable to exposure from site constituents. Receptor profiles for these five selected species are presented in the following five sections.

Meadow Vole. The meadow vole inhabits grassy areas (upland and wetland) and obtains a significant portion of its herbivorous diet from the site. The vole resides in every area of the United States and Canada where there is good grass cover, ranges in size from about 9 to 13 centimeters in length, and weighs between 17 and 52 grams (USEPA, 1993). The meadow vole has a limited foraging range, increasing its potential to be exposed (directly or indirectly) to COPECs in on-site surface soil. The vole has an average home range of 0.09 acres, with summer ranges larger than winter ranges. The vole does not hibernate and is active year-round. Population densities can range up to several hundred per hectare (USEPA, 1993).

Figure 7-1
Simplified Terrestrial Food Web
Conceptual Site Exposure Model (CSEM)



Short-Tailed Shrew. The short-tailed shrew is an insectivore that feeds largely on soil invertebrates. It would be potentially exposed to COPECs through prey items and have a relatively high rate of incidental ingestion of soil while foraging on earthworms. This short-tailed shrew weighs between 15 and 29 grams (Whitaker, 1995). Total length of this shrew is 76 to 102 millimeters (Burt and Grossenheider, 1980). The range of this shrew extends from southeastern Canada and the northeastern U.S. to Nebraska, Missouri, Kentucky, and in the mountains to Alabama (Whitaker, 1995). Preferable habitat for the shrew includes forests, grasslands, marshes, and brushy areas. It will make a nest of dry leaves, grass, and hair beneath logs, stumps, rocks, or debris (Burt and Grossenheider, 1980). This mammal has a voracious appetite, and will consume earthworms, other terrestrial invertebrates, and sometimes young mice (Whitaker, 1995). Mean population densities range from 5.7, in the winter, to 28 per acre in the summer (USEPA, 1993). Their home range varies from 0.5 to 1 acre (Burt and Grossenheider, 1980) and an average value of 0.96 acres has been used in the SLERAs (Appendix F-2, Table F-1).

American Robin. The American robin is an omnivore that feeds on both plants (primarily fruit) and terrestrial invertebrates including earthworms. The robin occurs throughout most of the continental United States and Canada during the breeding season and winters in the southern half of the United States and Mexico and Central America. They live in a variety of habitats, including woodlands, wetlands, suburbs and parks. Robins are likely to forage throughout RFAAP and are present year-round. Most robins build nests of mud and vegetation on the ground or in the crotches of trees or shrubs. Robins forage primarily on the ground and in low vegetation by probing and gleaning. They are approximately 25 centimeters in size, have a body weight range of 63 to 103 grams, and an average home range of 1.2 acres (USEPA, 1993).

Red-Tailed Hawk. The red-tailed hawk is a common predator in the mixed landscapes typifying RFAAP. The wooded habitats and riverside trees within RFAAP are considered ideal foraging and nesting habitats for these raptors. This hawk is one of the most common and widespread members of the genus *Buteo* in the continental United States and Canada (Brown and Amadon, 1968). Red-tailed hawks live in a variety of habitats, such as farmlands, woodlands, mountains, and deserts, as long as there is open country interspersed with woods, bluffs, or streamside trees. They are primarily carnivorous, feeding on small rodents, as well as fish. Other prey items include amphibians, reptiles, crayfish, and other birds (Adamcik et al., 1979; Ehrlich et al., 1988). Home range has been reported as small as 66.8 acres, with a population density of 0.16 pairs per acre (Janes, 1984), although USEPA (1993) reports an average territory size of 2,081 acres. Breeding population density is one nest per 0.009 acre or one individual per 0.004 acre. Body weight for male red-tails is 1,028.6 to 1,142.9 grams, and for females 1,371.4 to 1,600 grams (Brown and Amadon, 1968), although USEPA (1993) reports an average body weight of 1,134 grams. More northerly populations are migratory, while the more southerly are year-round residents.

Red Fox. The red fox is a carnivorous predator that occurs in a wide range of habitats typical of RFAAP. Red fox use many types of habitat, including cropland, rolling farmland, brush, pastures, hardwood stands, and coniferous forests. They are present throughout the United States and Canada, and are the most widely distributed carnivore in the world. These foxes have a length of 56 to 63 centimeters, with a 35 to 41 centimeter tail and an average weight of 4,530 grams. They do not undergo hibernation, and most often occupy abandoned burrows or dens of other species.

One fox family per 100 to 1,000 hectares is typical, and the average home range is 892 hectares (2,204 acres) (USEPA, 1993). Fecundity is higher in areas of high mortality and low population density.

7.1.4.2 Aquatic Receptors

Two representative aquatic receptor species that are expected or possible in the area of the ARSAR were selected as indicator species for the potential effects of COPECs. These indicator species represent two classes of vertebrate wildlife (mammals and birds) and a range of both body size and food habits, including herbivory, omnivory, and carnivory. Note: potential impacts to aquatic plants and other aquatic biota were assessed by comparing measured surface water and sediment COPEC concentrations with available direct-contact criteria. The two animal species selected include the great blue heron (medium, piscivorous bird) and the mink, (small, omnivorous mammal). Data used to model exposure for these species are summarized in **Appendix F-2, Table F-1**.

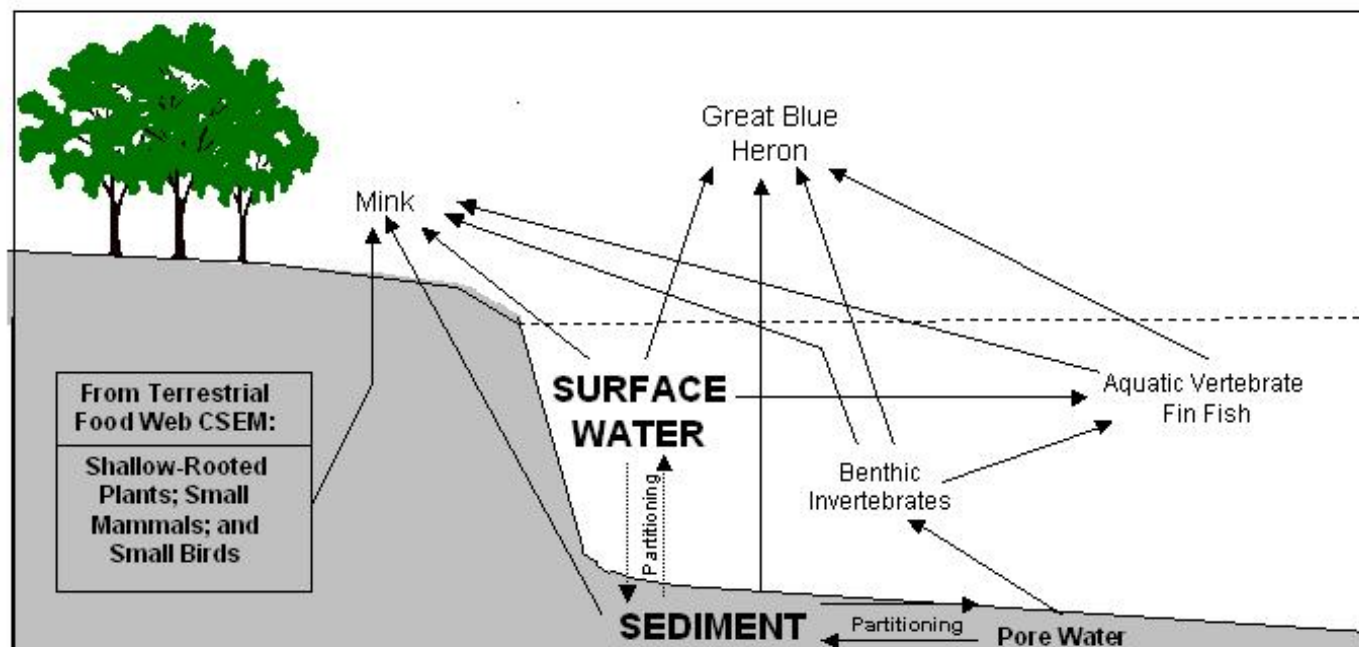
An aquatic food web is presented on **Figure 7-2**. The selected aquatic receptor species have a potential for high abundance at the sites that have adequate aquatic habitat; also, sufficient toxicological information (with the exception of some COPECs for the bird species) is available in the literature for comparative and interpretive purposes. Both of the species are considered important to the stability of the local ecological food chain and biotic community. Finally, the selected species have readily-available exposure data, as summarized in the *Wildlife Exposure Factors Handbook* (USEPA, 1993).

Receptor profiles for these two selected species are presented in the following paragraphs.

Great Blue Heron. The great blue heron is the largest member of its group in North America (99 to 132 centimeters) (Bull and Farrand, 1995), with body weights ranging from 2.2 to 2.58 kg (USEPA, 1993). It ranges from coastal Alaska, and Nova Scotia south to Mexico (Bull and Farrand, 1995). Habitat of this heron includes both fresh and marine waters, including freshwater lakes and rivers, brackish marshes, lagoons, mangroves, and coastal wetlands, particularly where small fish are plentiful (USEPA, 1993). Great blues tend to nest in dense colonies, or heronries. The location of the heronry is generally close to foraging grounds, and tall trees are preferred over shorter trees or bushes for nest sites. Fish are the preferred prey, but the heron will also eat crustaceans, amphibians, reptiles, insects, birds, and mammals. Foraging home range may be as great as 24 kilometers; however, an average home range of 21 acres is used in the current assessment. Population densities along streams and rivers range from 2.3 to 3.6 birds per kilometer (USEPA, 1993). Once a year the female will lay 2 to 7 eggs (Bull and Farrand, 1995), and the first year mortality rate is approximately 64 percent (USEPA, 1993).

Mink. The mink is the most abundant and widespread carnivorous mammal in North America. Mink are distributed throughout North America, except in the extreme north of Canada, Mexico, and arid areas of the southwestern United States. Mink do not undergo hibernation and are active year-round. Mink are particularly sensitive to PCBs and similar chemicals. Mink body size varies greatly throughout its range, with males weighing markedly more than females. Males measure from 33 to 43 cm with an 18 to 23 cm tail, and females measure from 30 to 36 cm, with a 13 to 20 cm tail. An average body weight of 1.02 kg has been used for purposes of the current assessment, and body weights range from 0.55 to 1.73 kg (USEPA, 1993).

Figure 7-2
Simplified Aquatic Food Web Conceptual Site Exposure Model (CSEM)



Mink are found associated with aquatic habitats of every kind, including waterways such as rivers, streams, lakes, and ditches, as well as swamps, marshes, and backwater areas. Mink prefer irregular shorelines to more open exposed banks. They also tend to use brushy or woody cover adjacent to the water, where cover for prey is abundant and where downfall and debris provide den sites. Mink are predominantly nocturnal hunters. Shorelines and emergent vegetation are the mink's principal hunting areas. Mink are opportunistic feeders, taking whatever is abundant. Mammals can be the mink's most important prey year-round, but mink also hunt aquatic prey such as fish, amphibians, and crustaceans and other terrestrial prey such as birds, reptiles, and insects, depending on the season. In winter, mink often supplement their diet with fish.

The home range of mink encompasses both their foraging areas around waterways and their dens. Home range depends mostly on food abundance, but also on the age and sex of the mink, season, and social stability. In winter, mink spend more time near dens and use a smaller portion of their range than in summer. Adult male home ranges are generally larger than female home ranges, particularly during the mating season when males may range over 1,000 hectares. For the purposes of this assessment an average home range of 35 acres was used (USEPA, 1993).

7.1.5 Identification of Assessment and Measurement Endpoints

The protection of ecological resources, such as habitats and species of plants and animals, is a principal motivation for conducting the SLERAs. To assess whether the protection of these resources are met at the site, assessment and measurement endpoints have been formulated to define the specific ecological values to be protected and to define the degree to which each may be protected.

Unlike the HHRA process, which focuses on individual receptors, a SLERA focuses on populations or groups of interbreeding nonhuman, nondomesticated receptors. In the SLERA process, the risks to individuals are generally assessed if they are protected under the Endangered Species Act.

Selected assessment endpoints reflect environmental values that are protected by law, are critical resources, and/or have relevance to ecological functions that may be impaired. Both the entity and attribute are identified for each assessment endpoint (Suter, 1993).

Assessment endpoints are inferred from effects to one or more measurement endpoints. The measurement endpoint is a measurable response to a stressor that is related to the valued attribute of the chosen assessment endpoint. It serves as a surrogate attribute of the ecological entity of interest (or of a closely related ecological entity) that can be used to draw a predictive conclusion about the potential for effects to the assessment endpoint.

Measurement endpoints for the SLERAs are based on toxicity values from the available literature. When possible, receptors and endpoints have been concurrently selected by identifying those that are known to be adversely affected by chemicals at the site based on published literature.

7.1.5.1 Assessment Endpoints

ERAGS (USEPA, 1997c) states: "For the screening-level ecological risk assessment, assessment endpoints are any adverse effects on ecological receptors, where receptors are plant and animal populations and communities, habitats, and sensitive environments. Adverse effects on populations can be inferred from measures related to impaired reproduction, growth, and

survival. Adverse effects on communities can be inferred from changes in community structure or function. Adverse effects on habitats can be inferred from changes in composition and characteristics that reduce the habitats' ability to support plant and animal populations and communities.”

The selected assessment endpoints for ARSAR are stated as the protection of long-term survival and reproductive capabilities for populations of herbivorous, insectivorous, and carnivorous mammals, and omnivorous, piscivorous, and carnivorous birds. The corresponding null hypothesis (H_0) for each of the assessment endpoints is stated as: the presence of site contaminants within soil, surface water, sediment, vegetation, and prey will have no adverse effect on the survival or reproductive capabilities of populations of herbivorous, insectivorous, and carnivorous mammals, and omnivorous, piscivorous, and carnivorous birds. In addition, assessment endpoints for the base of the food chain are stated as the protection of long-term survival and reproduction of terrestrial plants and soil/sediment dwelling invertebrates.

The food web CSEMs were developed to illustrate how the selected terrestrial and aquatic species are ecologically linked. For terrestrial and aquatic invertebrates, small prey items, fish, and plants, partitioning coefficients and simple empirical uptake models were employed to estimate COPEC concentrations within tissues (*Section 7.1.6*). These tissue concentrations were then used as input values for exposure to higher trophic level receptors through the dietary route of exposure.

7.1.5.2 Measurement Endpoints

Measurement endpoints are frequently numerical expressions of observations (e.g., toxicity test results or community diversity indices) that can be compared statistically to detect adverse responses to a site contaminant (USEPA, 1997c).

As two of the selected receptor species (the American robin and the short-tailed shrew) feed on terrestrial invertebrates, a reduction in the abundance of these invertebrates could result in an adverse impact due to food shortages. Therefore, the direct contact toxicity of COPECs to soil invertebrates was selected as a measurement endpoint for protection of long-term survival and reproductive capabilities for populations of insectivorous mammals and omnivorous birds.

7.1.6 Exposure Estimation

This section includes a discussion of how COPEC exposures were quantified, including intake (*Section 7.1.6.1*) and bioaccumulation (*Section 7.1.6.2*).

An estimate of the nature, extent, and magnitude of potential exposure of assessment receptors to COPECs that are present at or migrating from the site was developed, considering both current and reasonably plausible future use scenarios.

Ecological routes of exposure for biota may be direct (bioconcentration) or through the food web via the consumption of contaminated organisms (bioaccumulation). Food web exposure can occur when terrestrial or aquatic fauna consume contaminated biota. Direct exposure routes include dermal contact, absorption, inhalation, and ingestion. Examples of direct exposure include animals incidentally ingesting contaminated soil or sediment; animals ingesting surface water; plants absorbing contaminants by uptake from contaminated soil or sediment; and the dermal contact of aquatic organisms with contaminated surface water or sediment. In addition, as discussed in *Section 7.1.4*, dermal contact and inhalation exposures are considered insignificant compared to other quantified routes of exposure.

Bioavailability of a chemical is an important contaminant characteristic that influences the degree of chemical-receptor interaction. For purposes of the SLERAs, bioavailability is conservatively assumed to be 100 percent.

For terrestrial and aquatic faunal receptors, calculation of exposure rates relies upon determination of an organism's exposure to COPECs found in surface soil, surface water, or sediment, and on transfer factors used for food-chain exposure. Exposure rates for terrestrial and aquatic wildlife receptors in these SLERAs are based solely upon ingestion of contaminants from these media and from consumption of other organisms.

7.1.6.1 Intake

The first step in estimating exposure rates for terrestrial and aquatic wildlife involves the calculation of food ingestion and drinking water intake rates for site receptors. USEPA (1993) includes a variety of exposure information for a number of avian and mammalian species. Information regarding feeding rates, watering rates, and dietary composition are available for many species, or may be estimated using allometric equations (Nagy, 2001). Data have also been gathered on incidental ingestion of soil, and are incorporated for the receptor species. This information is summarized in **Appendix F-2, Table F-1**. For the SLERAs, conservative Tier 1 exposures are based on maximum dietary intake, maximum incidental soil intake, minimum body weight, 100 percent site exposure [i.e., area use factor (AUF) set equal to unity], and the use of COPEC MDCs as EPCs. Less conservative but more realistic Tier 2 exposures are based on average dietary and incidental soil intake, average body weight, calculated AUF based on site area and home range of the receptor species, and COPEC EPCs set equal to 95 percent UCLs. These Tier 2 exposures may be considered as a portion of Step 3a of the ERAGS 8-step process.

Algorithms have been evaluated for calculating exposure for terrestrial vertebrates that account for exposure via ingestion of contaminated water, incidental ingestion of contaminated soil, ingestion of plants grown in contaminated soil, and prey items. Results for these algorithms for the Firing Point/Berm Area are presented in **Appendix F-2, Tables F-2 through F-15**, and an example calculation is presented in **Appendix F-2, Table F-16**. Results for these algorithms for the Southeast Hillside are presented in **Appendix F-2, Tables F-17 through F-26**.

The basic equation for estimating dose through the dietary pathway is:

$$D_p = \sum_{k=1}^m (C_k \times F_k \times I_k) / W$$

where:

- D_p = the potential average daily dose (mg/kg-day),
- C_k = the average COPEC concentration in the k^{th} food type (mg/kg dry weight)
- F_k = the fraction of the k^{th} food type that is contaminated
- I_k = the ingestion rate of the k^{th} food type (kg dry weight/day)
- W = the body weight of the receptor (kg wet weight).

Literature values for animal-specific sediment ingestion have been used if available. However, such values generally are not available in the literature. Where sediment ingestion rates could not be found, the animal-specific incidental soil ingestion rate is used for sediment ingestion as well, if the receptors life history profile suggests a significant aquatic component, and if sediment is a medium of concern at the site.

The estimated chemical intakes for the exposed receptors for the relevant pathway and scenario are presented in the risk characterization tables (**Appendix F-2, Tables F-2 through F-26**).

7.1.6.2 Bioaccumulation and Bioconcentration Factors

For the current SLERAs, bioaccumulation factors (BAFs) and bioconcentration factors (BCFs) for soil-to-plants, soil-to-earthworms, and soil-to-small mammals and birds, sediment-to-aquatic invertebrates, and surface water-to-fish are presented in **Appendix F-2, Tables F-27, F-28, F-29, F-30, and F-31**. BAFs and/or BCFs were not available for every COPEC, but were estimated as described in the footnotes to these tables. For each BAF/BCF pathway, both a Tier 1 and Tier 2 value is presented. The Tier 1 BAF/BCF is generally the upper-bound value found in the literature, to represent a worst-case exposure scenario, while the Tier 2 BAF/BCF represents a conservative, yet more realistic exposure value.

7.1.6.2.1 Soil-to-Plant BAF/BCF Values

Soil-to-plant BAF/BCF values (**Appendix F-2, Table F-27**) are based on information from USEPA (2007b), Efroymson (2001), Baes et al. (1984), and International Atomic Energy Agency (2010). Tier 1 and 2 values are based on regression equations, if available, that produce a BAF/BCF value that scales in a non-linear fashion with the soil COPEC concentration. If a regression equation is not available or not recommended for a particular COPEC, a median value is used for the Tier 2 assessment (Note: the median is used for the Tier 2 because this is the reported BAF/BCF). It should be noted that as the Tier 2 regression equation predicts COPEC concentrations in plants, the actual BAF/BCF value is estimated by dividing the estimated plant COPEC concentration by the soil COPEC concentration. For organic COPEC without available BAF/BCF values, the K_{ow} regression equation from USEPA (2007b) is used, as shown as follows:

$$\text{Log BAF / BCF} = -0.4057 \times \text{Log } K_{ow} + 1.781$$

where:

Log K_{ow} = log octanol-water partition coefficient (see **Appendix F-2, Table F-27**)

In order to estimate Tier 1 and Tier 2 BAF/BCF plant uptake values using the USEPA (2007b) regression equation, the log K_{ow} from USEPA EPI Suite program v4.1 (USEPA, 2011b) was used (as plant uptake is inversely related to K_{ow}). It should be noted that the log K_{ow} values in the EPI Suite program are estimated using Syracuse Research Corporation's atom/fragment contribution method, based on the method developed by Meylan and Howard (1995). As an example, the BAF/BCF value estimated for DDD using the USEPA (2007b) regression equation (and log K_{ow}) was 0.294 (**Appendix F-2, Table F-27**).

7.1.6.2.2 Soil-to-Earthworm BAF/BCF Values

Soil-to-earthworm BAF/BCF values (**Appendix F-2, Table F-28**) are based on information from USEPA (2007b), Sample et al. (1998a), and Sample et al. (1999) and earthworms are used as a surrogate species to represent terrestrial invertebrates including insects. Tier 1 and 2 values are based on regression equations, if available, that produce a BAF/BCF value that scales in a non-linear fashion with the soil COPEC concentration. If a regression equation is not available or not recommended for a particular COPEC, an upper-bound value is used. It should be noted that as the regression equation predicts COPEC concentrations in earthworms, the actual BAF/BCF value is estimated by dividing the earthworm COPEC concentration by the soil COPEC concentration.

7.1.6.2.3 Soil-to-Small Mammal and Small Bird BAF/BCF Values

Soil-to-small mammal and small bird BAF/BCF values (**Appendix F-2, Table F-29**) are based on information from USEPA (2007b) and Sample et al. (1998b). Tier 2 values are based on regression equations (USEPA, 2007b) or upper-bound BAF/BCF values if no regression equation is available.

7.1.6.2.4 Sediment-to-Aquatic Invertebrate Plant BAF/BCF Values

Sediment-to-aquatic invertebrate BAF/BCF values (**Appendix F-2, Table F-30**) are based on information from Bechtel Jacobs (1998b). If no uptake value was available for inorganic COPECs, geometric means of the available inorganic uptake values from Bechtel Jacobs (1998a) were used: the geometric mean of the 90th percentile values (2.1) was used for the Tier 1 BAF/BCF value and the geometric mean of the median values (0.42) was used for the Tier 2 BAF/BCF value. If no uptake value was available for organic COPECs, a soil-to-terrestrial invertebrate BAF/BCF value was used (see **Appendix F-2, Table F-28**).

7.1.6.2.5 Water-to-Fish BAF/BCF Values

Water-to-fish BAF/BCF values (**Appendix F-2, Table F-21**) are based on information from IAEA (2010), Bintein and Devillers (1993), USEPA (1999), and USEPA (1989b). The Tier 1 value was the maximum BAF/BCF value available from the literature, while the Tier 2 value used represents a conservative, yet more realistic midpoint uptake value that is lower than the maximum BAF/BCF.

7.1.7 Ecological Effects Characterization

This ecological effects characterization section presents the selection of literature benchmark values and the development of reference toxicity values.

7.1.7.1 Selection of Literature Benchmark Values

Appropriate sources for literature benchmark values have been consulted, such as Ecological Soil Screening Level (EcoSSL) chemical-specific documents (USEPA, 2005b and 2007b); Toxicological Benchmarks for Wildlife (Sample et al., 1996); Ecorisk Database, Release 3.1 (LANL, 2012); Toxicological Profile for Silver, U.S. Public Health Service (ATSDR, 1990); Toxicological Profile for 1,1,2,2-TCA, U.S. Public Health Service (ATSDR, 1996); PAH Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review (Eisler, 1987); TERRETOX, <http://www.epa.gov/ecotox>; Terrestrial Toxicity Database (USACHPPM, 2002); SLERA Protocol for Hazardous Waste Combustion Facilities (USEPA, 1999); OPP (Office of Pesticide Programs) Environmental Effects Database (USEPA, 2000d); and IRIS (USEPA, 2012c). Some

values were extrapolated to chronic no-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level (LOAEL) values using recommended Tri-Service (Wentsel et al., 1996) uncertainty factors (UFs).

7.1.7.2 Development of Toxicity Reference Values

Toxicity reference values (TRVs) were selected from available data for use in the SLERA. These TRVs focus on the growth, survival, and reproduction of species and/or populations. Empirical data are available for the specific receptor-endpoint combinations in some instances. However, for some COPECs, data on surrogate species and/or on endpoints other than the NOAEL and LOAEL had to be used. The NOAEL is a dose of each COPEC that will produce no known adverse effects in the test species. The NOAEL was judged to be an appropriate toxicological endpoint for the Tier 1 approach since it would provide the greatest degree of protection to the receptor species; however, both NOAELs and LOAELs are used for informational purposes in the Tier. Both the NOAEL and the LOAEL were also used in the Tier 2 approach; however, the LOAEL is recommended as a point of comparison for decision-making for risk management purposes. In general, LOAELs for growth, reproduction and/or developmental endpoints are thought to be protective at the population level of biological organization. In addition, in instances where data are unavailable for a site-associated COPEC, toxicological information for surrogate chemicals had to be used. Safety factors are used to adjust for these differences and extrapolate risks to the site's receptors at the NOAEL and/or LOAEL endpoint. This process is described below and the values are presented in **Appendix F-2, Tables F-32 and F-33** for NOAEL and LOAEL TRVs, respectively.

Toxicity information pertinent to identified receptors has been gathered for those analytes identified as COPECs. Because the measurement endpoint ranges from the NOAEL to the LOAEL, preference was given to chronic studies noting concentrations at which no adverse effects were observed and ones for which the lowest concentrations associated with adverse effects were observed.

Using the relevant toxicity information, TRVs have been calculated for each of the COPECs. TRVs represent NOAELs and LOAELs with safety factors incorporated for toxicity information derived from studies other than no-effects or lowest-effects studies.

TRVs have been calculated from LD₅₀ values, when required, using safety factors specified in Ford et al. (1992) and reported in Wentsel et al. (1996) and summarized in the footnotes to **Appendix F-2, Tables F-32 and F-33**. As recommended by Allard et al. (2009), allometric dose scaling using body mass was not performed for chronic TRVs because this approach is not scientifically defensible and interclass toxicity extrapolations were not performed as physiological differences between classes are too great to be addressed with the use of simplistic safety factors. Separate UFs were used to account for extrapolation to the no-effects or lowest-effects endpoints, for study duration, and for extrapolation across taxonomic groups (e.g., species, genus, family, order), as shown in **Appendix F-2, Table F-34** for the receptors used in the SLERAs. Although additional safety factors may be employed for endangered species, no endangered species were selected as representative receptors and these additional safety factors were not required.

These factors were used together to derive a final adjusted TRV, as shown in the risk characterization spreadsheets referenced in *Section 7.1.8*. TRVs provide a reference point for the

comparison of toxicological effects upon exposure to a contaminant. To complete this comparison, receptor exposures to site contaminants are calculated.

7.1.8 Risk Characterization

The risk characterization phase integrates information on exposure, exposure-effects relationships, and defined or presumed target populations. The result is a determination of the likelihood, severity, and characteristics of adverse effects to environmental stressors present at a site. Qualitative and semi-quantitative approaches have been taken to estimate the likelihood of adverse effects occurring as a result of exposure of the selected site receptors to COPECs.

For this assessment, TRVs and exposure rates have been calculated and are used to generate HQs (Wentsel et al., 1996), by dividing the receptor exposure rate for each contaminant by the calculated TRV. Ecological effects quotients (EEQs) or HQs are a means of estimating the potential for adverse effects to organisms at a contaminated site, and for assessing the potential that toxicological effects will occur among site receptors.

7.1.8.1 Terrestrial Plant Impact Assessment

To assess the potential impact of COPEC concentrations in surface soil on terrestrial plant species, qualitative visual observations were recorded during the site reconnaissance. The overall health of the plant community at the site was comparable to the plant communities in the surrounding areas (based on available site photographs, **Appendix F-1**). Plants were not quantitatively evaluated in the SLERA due to the invasive and successive nature of plant communities and because of an inadequate plant toxicity database, plants as receptors do not typically warrant a detailed examination of effects. However, terrestrial plant impacts are discussed further as a component of direct contact toxicity in *Sections 7.2.4 (Firing Point/Berm Area)* and *7.3.4 (Southeast Hillside Area)*.

It should also be noted that plants (and invertebrates) are included in the SLERAs as media through which the wildlife receptors may be exposed indirectly to COPECs in the soil by means of the food chain.

7.1.8.2 Predictive Risk Estimation for Terrestrial Wildlife

The potential wildlife risks associated with the ARSAR are estimated in *Sections 7.2.3* and *7.3.3*. The risk estimation has been performed through a series of quantitative HQ calculations that compare receptor-specific exposure values with TRVs. The EEQs (or HQs) are compared to HQ guidelines for assessing the risk posed from contaminants. It should be noted that HQs are not measures of risk, are not population-based statistics, and are not linearly-scaled statistics, and therefore, an HQ above 1, even exceedingly so, does not guarantee that there is even one individual expressing the toxicological effect associated with a given chemical to which it was exposed (Allard et al., 2009; Tannenbaum, 2001; Bartell, 1996).

The simple summed HQ ratios are summed to provide conservative HI estimates for chemicals and exposure pathways for a given receptor. The criterion used to decide if HQ summation is appropriate and scientifically defensible includes those chemicals that have a similar mode of toxicological action. While individual contaminants may affect distinct target organs or systems within an organism, classes of chemicals may act in similar ways, thus being additive in effect.

The summation of HQs into an HI was performed in the SLERAs as a conservative approach. To assess whether or not individual COPEC HQs should be segregated based on dissimilar

modes of toxicological action, individual COPEC effects were evaluated. However, as risk drivers resulted in HQs ranging from less than 1 to 362 (Firing Point/Berm Area) and less than 1 to 525 (Southeast Hillside Area), segregation of COPECs by mode of toxicological action was not necessary (*Sections 7.2.3 and 7.3.3*, respectively).

Tier 1 and Tier 2 individual COPEC EEQs and HIs (summed EEQs) for terrestrial and aquatic receptors at the Firing Point/Berm Area are presented in risk characterization tables (**Appendix F-2, Tables F-2 through F-15**) for the seven selected receptor species. An example EEQ calculation is presented in **Appendix F-2, Table F-16**.

Tier 1 and Tier 2 individual COPEC EEQs and HIs (summed EEQs) for terrestrial receptors at ARSAR Southeast Hillside are presented in risk characterization tables (**Appendix F-2, Tables F-17 through F-26**) for the five selected receptor species.

Summarized results for Tier 1 and Tier 2 summed EEQs (generally rounded to two significant figures) are presented in *Sections 7.2.3 and 7.3.3*, along with the hazard driver [COPEC(s) contributing the majority of the total estimated EEQ], and the exposure pathway of concern (the pathway contributing the most to the total estimated EEQ).

7.1.9 Approach for the Evaluation of Direct Contact Toxicity

To evaluate direct contact exposure, for those organisms that live within an environmental medium, COPEC media (surface soil, sediment, and surface water) concentrations are compared with a variety of direct contact screening values. Intake is not calculated because potential adverse effects are assessed by evaluating the COPEC concentrations. For direct contact exposure for COPECs in surface soil (Firing Point/Berm Area and Southeast Hillside Area), sediment (Firing Point/Berm Area only), and surface water (Firing Point/Berm Area only), measured COPEC concentrations were simply compared with direct contact benchmarks appropriate for communities that reside in these media.

7.1.9.1 Surface Soil

As there are no promulgated soil screening criteria for organisms potentially exposed to COPECs in surface soil collected from the ARSAR, a two-step process was used to assess direct contact soil toxicity. First, the maximum detected soil concentration was compared with the lowest available EcoSSL (USEPA, 2007b), or if an EcoSSL was not available, with the lowest Biological Technical Assistance Group (BTAG) (USEPA, 1995b) soil screening value. A chemical was only retained as a COPEC if the MDC exceeded the EcoSSL, or in the absence of an EcoSSL, if the MDC exceeded the BTAG soil screening value. If no EcoSSL or BTAG value was available, the value was also carried forward for comparison to other available screening values (listed below).

In the second step, the MDCs and EPCs of the chemicals carried-forward were compared with up to five individual soil screening:

- Most conservative non-EcoSSL value used from NOAA, 2008 SQuiRT Tables.
- Canadian Council of Ministers of the Environment (CCME), Canadian Environmental Quality Guidelines, December 2003.
- Lowest EcoSSL value for direct contact toxicity for either plants or terrestrial invertebrates (USEPA, 2007b).

- ORNL (1997a, ES/ER/TM-85/R3), screening benchmarks for plants.
- ORNL (1997b, ES/ER/TM-126/R2), screening benchmarks for earthworms.

For this second step, a weight-of-evidence approach was used. The more soil benchmarks exceeded by the COPEC concentration, the greater the potential for adverse effects. For this SLERA, an exceedance threshold of 50 percent is used to make recommendations.

It should be noted that chromium was screened against Cr III and Cr VI. The results of the soil screening for Firing Point/Berm Area and Southeast Hillside Area are provided in *Sections 7.2.4.1 and 7.3.4.1*, respectively.

7.1.9.2 Sediment

As there are no promulgated sediment screening criteria for aquatic organisms potentially exposed to COPECs in sediment collected from the Firing Point/Berm Area, a weight-of-evidence approach was used, where the more sediment benchmarks exceeded by the COPEC concentration, the greater the potential for adverse effects. As most sediment-dwelling aquatic biota are relatively non-mobile, maximum detected sediment concentrations are used. An exposure concentration more representative of potential community-level effects, expressed as the 95 percent UCL, is usually used in the evaluation; however, the 95 percent UCL EPC was not calculated because the sample size was less than or equal to five for all COPECs. Sediment benchmarks used to assess direct contact exposure include the following:

- BTAG Screening Values (USEPA, 2006).
- Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems (MacDonald et al., 2000).
- Assessment and Remediation of Contaminated Sediments (ARCS) program USEPA, 1996; presented in Jones, D.S. and Suter, G.W. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota, [assumed TOC of 1 percent], (ORNL, 1997c).
- NOAA ER-L and ER-M values presented in Jones, D.S. and Suter, G.W. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision (ORNL, 1997c).
- The lowest of the Eq P-derived sediment quality benchmarks presented in Jones, D.S. and Suter, G.W. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision (ORNL, 1997c).
- Canadian Interim Sediment Quality Guidelines (CCME, 2003).
- Canadian Probable Effects Levels (CCME, 2003).

Similar to the direct contact approach used for soil, a weight-of-evidence approach was used for sediment. The more sediment benchmarks exceeded by the COPEC concentration, the greater the potential for adverse effects. For this SLERA, an exceedance threshold of 50 percent is used to make recommendations. The results for the Firing Point/Berm Area screen are summarized in *Section 7.2.4.2* (sediment was included with the Southeast Hillside Area).

7.1.9.3 Surface Water

For aquatic organisms potentially exposed to COPECs in surface water collected from the Firing Point/Berm Area, comparisons of the MDC and EPC to promulgated water quality criteria, or a weight-of-evidence approach (for constituents without promulgated criteria) was utilized. It should be noted that because of the nature of various benchmark sources, promulgated water quality criteria [e.g., National Recommended Water Quality Criteria (NRWQC) and Virginia Water Quality Standards] were determined to be more critical during the evaluation than non-promulgated benchmarks. Surface water benchmarks used to assess direct contact exposure include the following:

- USEPA National Recommended Water Quality Criteria, Freshwater, January 2013. <http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm>.
- Virginia Water Quality Standards, 9 VAC 25-260, Freshwater, January 2011.
- USEPA Region 3 BTAG Screening Levels, Freshwater, July 2006.
- Suter, G.W. and C.L. Tsao, 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision, ES/ER/TM-96/R2 (ORNL, 1996).
- USEPA Region 4 Ecological Benchmark Screening Values for Surface Water (USEPA, 2000e).

A finding of limited ecological concern was based on whether or not promulgated criteria were exceeded or when no promulgated criteria were available, whether more than half of the available surface water benchmarks were exceeded. As some aquatic biota are relatively non-mobile, maximum detected surface water concentrations are used. Although a more realistic exposure concentration is expressed as the 95 percent UCL, this EPC was not calculated because the sample size was less than or equal to five for all COPECs. The results for the Firing Point/Berm Area screen are summarized in *Section 7.2.4.3* (surface water was not a medium assessed for the Southeast Hillside Area).

7.1.10 Background Considerations

A background evaluation was conducted on the soil analytical results to determine if any inorganics identified as COPEC drivers are potentially related to naturally occurring soil concentrations (see *Section 6.4.3* for additional background evaluation details). Background considerations for the Firing Point/Berm Area and the Southeast Hillside Area are discussed in *Sections 7.2.5 and 7.3.5*, respectively.

7.1.11 General Uncertainty Analysis

The results of the SLERAs are influenced to some degree by variability and uncertainty. In theory, investigators might reduce variability by increasing sample size of the media or species sampled. Alternatively, uncertainty within the risk analysis can be reduced by using species-specific and site-specific data (i.e., to better quantify contamination of media, vegetation, and prey through: direct field measurements, toxicity testing of site-specific media, and field studies using site-specific receptor species). Detailed media, prey, and receptor field studies are costly; thus, the preliminary analyses of risk have been conducted to limit the potential use of these resource-intensive techniques to those COPECs that continue to show a relatively high potential for ecological risk. Since assessment criteria were developed based on conservative

assumptions, the result of the assessment errs on the side of conservatism. This has the effect of maximizing the likelihood of accepting a false positive (Type I error: the rejection of a true null hypothesis) and simultaneously minimizing the likelihood of accepting a true negative (Type II error: the acceptance of a false null hypothesis).

The general uncertainty analysis is presented in **Table 7-5** and lists some of the major assumptions made for the SLERAs; the direction of bias caused by each assumption (i.e., if the uncertainty results in an overestimate or underestimate of risk); the likely magnitude of impact [quantitative (percent difference), or qualitative (high, medium, low, or unknown)]; if possible, a description of recommendations for minimizing the identified uncertainties if the SLERA progresses to higher level assessment phases; and the ease of implementing the recommendation (USEPA, 1997c).

The uncertainty analysis identifies and, if possible, quantifies the uncertainty in the individual preliminary scoping assessment, problem formulation, exposure and effects assessment, and risk characterization phases of the SLERAs. Based on this uncertainty analysis, the most important biases that may result in an overestimation of risk include the following:

- Assuming that COPECs are 100 percent bioavailable.
- Using some laboratory-derived or empirically-estimated partitioning and transfer factors to predict COPEC concentrations in plants, invertebrates, and/or prey species.
- Use of the HQ method to estimate risks to populations or communities.

Table 7-5
General Uncertainty Analysis

Component	Bias	Magnitude	Ways to Minimize Uncertainty	Additional Comments
Use of 95% UCL as source-term concentration	Overestimates Risk	Medium	Use central tendency	Easy to implement, but may not be acceptable to Agency
Use of representative receptor species for site ecological community	Underestimates Risk	Low	Select additional receptor species	Easy to implement, but unlikely to change conclusions
Use of conservative foraging factors (i.e., 100%) for some species	Overestimates Risk	Medium	Use more site-specific foraging factors, i.e., less than 100%	May be difficult to obtain site-specific foraging factors
Assumption that COPECs are 100% bioavailable	Overestimates Risk	Medium to High	Obtain medium- and COPEC-specific bioavailability factors	Would be very difficult and costly to obtain these bioavailability factors
Discounting of dermal and inhalation exposure routes	Underestimates Risk	Low	Include dermal and inhalation routes of exposure	Would be difficult to quantify these routes of exposure
Use of partitioning and transfer factors to estimate COPEC concentrations in plants, invertebrates, and prey items	Overestimates Risk	Medium to High	Measure COPEC concentrations in site plants, invertebrates, and/or other prey species	Would be costly to implement, but could significantly reduce EEQs

**Table 7-5
General Uncertainty Analysis (Continued)**

Component	Bias	Magnitude	Ways to Minimize Uncertainty	Additional Comments
Use of safety factors to convert LOAEL and/or LD ₅₀ toxicity data to NOAELs	Overestimates Risk	Medium	Obtain COPEC-specific NOAEL data	Would be costly to implement, unless data available in the literature
Use of uncertainty factor of 8 to extrapolate TRVs between most species within the same class	Overestimates Risk	Medium	1) Assume TRVs similar for species in the same genus, family, or order; or 2) obtain species-specific NOAEL data	1) May not be accepted by Agency 2) Would be very difficult to obtain species-specific NOAEL data
Use of surrogate constituents to estimate toxicity for those COPECs without available toxicity data	Over- or underestimates Risk	Low to Medium	Obtain COPEC-specific toxicity data	Would be very costly to obtain COPEC-specific toxicity data, unless available in the literature
Use of hazard quotient method to estimate risks to populations or communities may be biased	Overestimates Risk	High	Perform population or community studies	Would be very costly to perform

7.2 Firing Point/Berm Area Screening Level Ecological Risk Assessment

7.2.1 Site Characterization

The ARSAR is an MRS covering approximately 7.6 acres located along the southeastern boundary of the MMA (**Figure 2-1**). Most of the site is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. As illustrated on **Figure 2-2**, the site is divided into two areas consisting of the Firing Point/Berm Area (6.56 acres) and the Southeast Hillside Area (1.08 acres). The Firing Point/Berm Area is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. A target berm, which is approximately 8 ft high and 270 ft long, is located along the southeastern portion of the Firing Point/Berm Area that was remediated in 2011. The ecological media of concern at the Firing Point/Berm Area includes surface soil, surface water, and sediment.

7.2.2 Summary of COPEC Selection

As described in *Section 7.1.3.2*, direct contact and foodchain COPECs were selected as shown in **Tables 7-6 and 7-7** (surface soil), **7-8 and 7-9** (sediment), and **7-10 and 7-11** (surface water). In general, COPECs were selected as a concern for the direct contact exposure pathway if the constituent was detected in an environmental medium. For food chain exposure pathways, detected COPECs that were identified as important bioaccumulators (USEPA, 2000c) or explosives were selected (note: there were no detected explosives at the ARSAR).

Table 7-6
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure - Surface Soil
Firing Point/Berm Area
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Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	91-57-6	2-Methylnaphthalene	5.10E-03 J	1.30E-02	mg/kg	ARSCF03	4/13	3.40E-03 - 3.80E-03	Yes	DET
	72-54-8	4,4'-DDD	1.25E-03 J	1.25E-03 J	mg/kg	ARSCF01	1/16	2.80E-03 - 3.00E-03	Yes	DET
	72-55-9	4,4'-DDE	1.65E-03 J	9.20E-03	mg/kg	ARSCF02	8/16	2.80E-03 - 3.00E-03	Yes	DET
	50-29-3	4,4'-DDT	1.90E-03 J	6.40E-03	mg/kg	ARSCF02	7/16	2.80E-03 - 3.00E-03	Yes	DET
	83-32-9	Acenaphthene	1.45E-03 J	1.60E-02	mg/kg	ARSCF02	2/16	3.40E-03 - 3.80E-03	Yes	DET
	208-96-8	Acenaphthylene	1.10E-03 J	1.27E-03 J	mg/kg	ARSCF01	2/16	3.40E-03 - 3.80E-03	Yes	DET
	5103-71-9	alpha-Chlordane	9.20E-04 J	7.10E-03 J	mg/kg	ARSCF01	2/16	2.80E-03 - 3.00E-03	Yes	DET
	120-12-7	Anthracene	1.21E-03 J	3.60E-02	mg/kg	ARSCF02	3/16	3.40E-03 - 3.80E-03	Yes	DET
	11097-69-1	Aroclor 1254	4.70E-02 J	4.70E-02 J	mg/kg	ARSCF02	1/16	1.10E-01 - 1.30E-01	Yes	DET
	71-43-2	Benzene	1.30E-02 J	1.30E-02 J	mg/kg	ARSBSC01	1/16	4.40E-02 - 6.30E-02	Yes	DET
	56-55-3	Benzo(a)anthracene	1.80E-03 J	1.40E-01	mg/kg	ARSCF02	5/16	3.40E-03 - 3.80E-03	Yes	DET
	50-32-8	Benzo(a)pyrene	9.20E-04 J	1.30E-01	mg/kg	ARSCF02	5/16	5.70E-03 - 6.40E-03	Yes	DET
	205-99-2	Benzo(b)fluoranthene	4.60E-04 J	2.00E-01	mg/kg	ARSCF02	10/16	3.50E-03 - 3.80E-03	Yes	DET
	191-24-2	Benzo(ghi)perylene	1.40E-03 J	8.10E-02	mg/kg	ARSCF02	5/16	3.40E-03 - 3.80E-03	Yes	DET
	207-08-9	Benzo(k)fluoranthene	1.30E-03 J	6.50E-02	mg/kg	ARSCF02	3/16	3.40E-03 - 3.80E-03	Yes	DET
	117-81-7	Bis(2-ethylhexyl)phthalate (BEHP)	1.10E-01 J	1.70E-01 J	mg/kg	ARSCF08	2/16	4.60E-01 - 5.10E-01	Yes	DET
	218-01-9	Chrysene	9.10E-04 L	1.60E-01	mg/kg	ARSCF02	11/16	3.40E-03 - 3.80E-03	Yes	DET
	319-86-8	delta-BHC	1.40E-03 J	1.40E-03 J	mg/kg	ARSCF02	1/16	2.80E-03 - 3.00E-03	Yes	DET
	53-70-3	Dibenzo(a,h)anthracene	4.60E-04 J	2.10E-02	mg/kg	ARSCF02	5/16	3.40E-03 - 3.80E-03	Yes	DET
	60-57-1	Dieldrin	2.10E-03 J	2.10E-03 J	mg/kg	ARSCF02	1/16	2.80E-03 - 3.00E-03	Yes	DET
	72-20-8	Endrin	6.75E-03 J	6.75E-03 J	mg/kg	ARSBSC09	1/16	2.80E-03 - 3.00E-03	Yes	DET
	206-44-0	Fluoranthene	8.90E-04 J	2.70E-01	mg/kg	ARSCF02	9/16	3.40E-03 - 3.80E-03	Yes	DET
	86-73-7	Fluorene	1.20E-02	1.20E-02	mg/kg	ARSCF02	1/16	3.40E-03 - 3.80E-03	Yes	DET
	5103-74-2	gamma-Chlordane	5.40E-04 J	5.90E-03	mg/kg	ARSCF02	4/16	2.80E-03 - 3.00E-03	Yes	DET
	1024-57-3	Heptachlor epoxide	2.40E-03 J	2.40E-03 J	mg/kg	ARSCF02	1/16	2.80E-03 - 3.00E-03	Yes	DET
	193-39-5	Indeno(1,2,3-cd)pyrene	1.60E-03 J	9.30E-02	mg/kg	ARSCF02	6/16	3.40E-03 - 3.80E-03	Yes	DET
	72-43-5	Methoxychlor	1.10E-03 J	3.50E-03	mg/kg	ARSBSC11	8/16	2.80E-03 - 3.00E-03	Yes	DET
	91-20-3	Naphthalene	8.00E-04 J	1.00E-02	mg/kg	ARSCF03	7/16	3.40E-03 - 3.80E-03	Yes	DET
	85-01-8	Phenanthrene	1.58E-03 J	1.40E-01	mg/kg	ARSCF02	9/16	3.40E-03 - 3.80E-03	Yes	DET
	129-00-0	Pyrene	9.70E-04 J	2.30E-01	mg/kg	ARSCF02	8/16	1.70E-03 - 1.90E-03	Yes	DET
	7429-90-5	Aluminum	5.87E+03	1.91E+04 J	mg/kg	ARSBSC13	23/23	N/A	Yes	DET
	7440-36-0	Antimony	1.15E-01 L	1.40E+00 L	mg/kg	ARSBSC01	12/23	9.80E-02 - 4.85E-01	Yes	DET

Table 7-6
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure - Surface Soil
Firing Point/Berm Area
Page 2 of 2

Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	7440-38-2	Arsenic	1.90E+00 L	1.91E+01 K	mg/kg	ARSCF06	23/23	N/A	Yes	DET
	7440-39-3	Barium	2.94E+01 J	1.24E+02 J	mg/kg	ARSCF09	23/23	N/A	Yes	DET
	7440-41-7	Beryllium	7.20E-03 J	1.40E+00 K	mg/kg	ARSCF06	19/23	4.90E-03 - 5.00E-03	Yes	DET
	7440-43-9	Cadmium	6.80E-03 J	9.80E-02	mg/kg	ARSCF02	9/23	7.10E-03 - 7.60E-03	Yes	DET
	7440-70-2	Calcium	2.44E+02 J	8.29E+04 J	mg/kg	ARSCF02	23/23	N/A	Yes	DET
	7440-47-3	Chromium	9.90E+00	4.61E+01 K	mg/kg	ARSBSC02	23/23	N/A	Yes	DET
	7440-48-4	Cobalt	3.40E+00	2.08E+01 J	mg/kg	ARSCF01	22/22	N/A	Yes	DET
	7440-50-8	Copper	4.40E+00 J	8.03E+01 J	mg/kg	ARSBSC08	23/23	N/A	Yes	DET
	7439-89-6	Iron	1.44E+04 J	9.08E+04 J	mg/kg	ARSCF05	23/23	N/A	Yes	DET
	7439-92-1	Lead	9.80E+00 J	2.59E+02 J	mg/kg	ARSBSC06	23/23	N/A	Yes	DET
	7439-95-4	Magnesium	3.66E+02 J	3.99E+04 J	mg/kg	ARSCF02	23/23	N/A	Yes	DET
	7439-96-5	Manganese	2.02E+02 K	1.91E+03	mg/kg	ARSBSC14	22/22	N/A	Yes	DET
	7439-97-6	Mercury	8.20E-03 J	1.30E-01 J	mg/kg	ARSBSC02	23/23	N/A	Yes	DET
	7440-02-0	Nickel	2.90E+00 J	2.70E+01 J	mg/kg	ARSCF05	23/23	N/A	Yes	DET
	7440-09-7	Potassium	2.85E+02 L	6.65E+02	mg/kg	ARSCF05	23/23	N/A	Yes	DET
	7782-49-2	Selenium	2.40E-01 J	1.50E+00 L	mg/kg	ARSBSC14	15/23	8.00E-02 - 1.29E-01	Yes	DET
	7440-22-4	Silver	3.00E-02 J	3.50E-02	mg/kg	ARSBSC14	2/23	1.90E-02 - 2.10E-02	Yes	DET
	7440-23-5	Sodium	6.00E+00 J	3.38E+01 J	mg/kg	ARSCF02	8/23	4.60E+00 - 5.10E+00	Yes	DET
	7440-28-0	Thallium	2.80E-01 L	1.30E+00 L	mg/kg	ARSBSC14	17/17	N/A	Yes	DET
	7440-62-2	Vanadium	2.59E+01 J	7.65E+01 J	mg/kg	ARSBSC14	23/23	N/A	Yes	DET
	7440-66-6	Zinc	1.03E+01 J	6.45E+01 J	mg/kg	ARSCF02	23/23	N/A	Yes	DET

COPEC Selection Rationale Codes

Selection Reason: Detected constituent (DET)

Notes/Definitions:

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/kg = milligrams per kilogram

Table 7-7
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure - Surface Soil
Firing Point/Berm Area
Page 1 of 2

Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Food Chain COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	91-57-6	2-Methylnaphthalene	5.10E-03 J	1.30E-02	mg/kg	ARSCF03	4/13	3.40E-03 - 3.80E-03	No	NIBC
	72-54-8	4,4'-DDD	1.25E-03 J	1.25E-03 J	mg/kg	ARSCF01	1/16	2.80E-03 - 3.00E-03	Yes	IBC
	72-55-9	4,4'-DDE	1.65E-03 J	9.20E-03	mg/kg	ARSCF02	8/16	2.80E-03 - 3.00E-03	Yes	IBC
	50-29-3	4,4'-DDT	1.90E-03 J	6.40E-03	mg/kg	ARSCF02	7/16	2.80E-03 - 3.00E-03	Yes	IBC
	83-32-9	Acenaphthene	1.45E-03 J	1.60E-02	mg/kg	ARSCF02	2/16	3.40E-03 - 3.80E-03	Yes	IBC
	208-96-8	Acenaphthylene	1.10E-03 J	1.27E-03 J	mg/kg	ARSCF01	2/16	3.40E-03 - 3.80E-03	Yes	IBC
	5103-71-9	alpha-Chlordane	9.20E-04 J	7.10E-03 J	mg/kg	ARSCF01	2/16	2.80E-03 - 3.00E-03	Yes	IBC
	120-12-7	Anthracene	1.21E-03 J	3.60E-02	mg/kg	ARSCF02	3/16	3.40E-03 - 3.80E-03	Yes	IBC
	11097-69-1	Aroclor 1254	4.70E-02 J	4.70E-02 J	mg/kg	ARSCF02	1/16	1.10E-01 - 1.30E-01	Yes	IBC
	71-43-2	Benzene	1.30E-02 J	1.30E-02 J	mg/kg	ARSBSC01	1/16	4.40E-02 - 6.30E-02	No	NIBC
	56-55-3	Benzo(a)anthracene	1.80E-03 J	1.40E-01	mg/kg	ARSCF02	5/16	3.40E-03 - 3.80E-03	Yes	IBC
	50-32-8	Benzo(a)pyrene	9.20E-04 J	1.30E-01	mg/kg	ARSCF02	5/16	5.70E-03 - 6.40E-03	Yes	IBC
	205-99-2	Benzo(b)fluoranthene	4.60E-04 J	2.00E-01	mg/kg	ARSCF02	10/16	3.50E-03 - 3.80E-03	Yes	IBC
	191-24-2	Benzo(ghi)perylene	1.40E-03 J	8.10E-02	mg/kg	ARSCF02	5/16	3.40E-03 - 3.80E-03	Yes	IBC
	207-08-9	Benzo(k)fluoranthene	1.30E-03 J	6.50E-02	mg/kg	ARSCF02	3/16	3.40E-03 - 3.80E-03	Yes	IBC
	117-81-7	Bis(2-ethylhexyl)phthalate (BEHP)	1.10E-01 J	1.70E-01 J	mg/kg	ARSCF08	2/16	4.60E-01 - 5.10E-01	No	NIBC
	218-01-9	Chrysene	9.10E-04 L	1.60E-01	mg/kg	ARSCF02	11/16	3.40E-03 - 3.80E-03	Yes	IBC
	319-86-8	delta-BHC	1.40E-03 J	1.40E-03 J	mg/kg	ARSCF02	1/16	2.80E-03 - 3.00E-03	Yes	IBC
	53-70-3	Dibenzo(a,h)anthracene	4.60E-04 J	2.10E-02	mg/kg	ARSCF02	5/16	3.40E-03 - 3.80E-03	Yes	IBC
	60-57-1	Dieldrin	2.10E-03 J	2.10E-03 J	mg/kg	ARSCF02	1/16	2.80E-03 - 3.00E-03	Yes	IBC
	72-20-8	Endrin	6.75E-03 J	6.75E-03 J	mg/kg	ARSBSC09	1/16	2.80E-03 - 3.00E-03	Yes	IBC
	206-44-0	Fluoranthene	8.90E-04 J	2.70E-01	mg/kg	ARSCF02	9/16	3.40E-03 - 3.80E-03	Yes	IBC
	86-73-7	Fluorene	1.20E-02	1.20E-02	mg/kg	ARSCF02	1/16	3.40E-03 - 3.80E-03	Yes	IBC
	5103-74-2	gamma-Chlordane	5.40E-04 J	5.90E-03	mg/kg	ARSCF02	4/16	2.80E-03 - 3.00E-03	Yes	IBC
	1024-57-3	Heptachlor epoxide	2.40E-03 J	2.40E-03 J	mg/kg	ARSCF02	1/16	2.80E-03 - 3.00E-03	Yes	IBC
	193-39-5	Indeno(1,2,3-cd)pyrene	1.60E-03 J	9.30E-02	mg/kg	ARSCF02	6/16	3.40E-03 - 3.80E-03	Yes	IBC
	72-43-5	Methoxychlor	1.10E-03 J	3.50E-03	mg/kg	ARSBSC11	8/16	2.80E-03 - 3.00E-03	Yes	IBC
	91-20-3	Naphthalene	8.00E-04 J	1.00E-02	mg/kg	ARSCF03	7/16	3.40E-03 - 3.80E-03	No	NIBC
	85-01-8	Phenanthrene	1.58E-03 J	1.40E-01	mg/kg	ARSCF02	9/16	3.40E-03 - 3.80E-03	Yes	IBC
	129-00-0	Pyrene	9.70E-04 J	2.30E-01	mg/kg	ARSCF02	8/16	1.70E-03 - 1.90E-03	Yes	IBC
	7429-90-5	Aluminum	5.87E+03	1.91E+04 J	mg/kg	ARSBSC13	23/23	N/A	No	NIBC
	7440-36-0	Antimony	1.15E-01 L	1.40E+00 L	mg/kg	ARSBSC01	12/23	9.80E-02 - 4.85E-01	No	NIBC

Table 7-7
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure - Surface Soil
Firing Point/Berm Area
Page 2 of 2

Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Food Chain COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	7440-38-2	Arsenic	1.90E+00 L	1.91E+01 K	mg/kg	ARSCF06	23/23	N/A	Yes	IBC
	7440-39-3	Barium	2.94E+01 J	1.24E+02 J	mg/kg	ARSCF09	23/23	N/A	No	NIBC
	7440-41-7	Beryllium	7.20E-03 J	1.40E+00 K	mg/kg	ARSCF06	19/23	4.90E-03 - 5.00E-03	No	NIBC
	7440-43-9	Cadmium	6.80E-03 J	9.80E-02	mg/kg	ARSCF02	9/23	7.10E-03 - 7.60E-03	Yes	IBC
	7440-70-2	Calcium	2.44E+02 J	8.29E+04 J	mg/kg	ARSCF02	23/23	N/A	No	NIBC
	7440-47-3	Chromium	9.90E+00	4.61E+01 K	mg/kg	ARSBSC02	23/23	N/A	Yes	IBC
	7440-48-4	Cobalt	3.40E+00	2.08E+01 J	mg/kg	ARSCF01	22/22	N/A	No	NIBC
	7440-50-8	Copper	4.40E+00 J	8.03E+01 J	mg/kg	ARSBSC08	23/23	N/A	Yes	IBC
	7439-89-6	Iron	1.44E+04 J	9.08E+04 J	mg/kg	ARSCF05	23/23	N/A	No	NIBC
	7439-92-1	Lead	9.80E+00 J	2.59E+02 J	mg/kg	ARSBSC06	23/23	N/A	Yes	IBC
	7439-95-4	Magnesium	3.66E+02 J	3.99E+04 J	mg/kg	ARSCF02	23/23	N/A	No	NIBC
	7439-96-5	Manganese	2.02E+02 K	1.91E+03	mg/kg	ARSBSC14	22/22	N/A	No	NIBC
	7439-97-6	Mercury	8.20E-03 J	1.30E-01 J	mg/kg	ARSBSC02	23/23	N/A	Yes	IBC
	7440-02-0	Nickel	2.90E+00 J	2.70E+01 J	mg/kg	ARSCF05	23/23	N/A	Yes	IBC
	7440-09-7	Potassium	2.85E+02 L	6.65E+02	mg/kg	ARSCF05	23/23	N/A	No	NIBC
	7782-49-2	Selenium	2.40E-01 J	1.50E+00 L	mg/kg	ARSBSC14	15/23	8.00E-02 - 1.29E-01	Yes	IBC
	7440-22-4	Silver	3.00E-02 J	3.50E-02	mg/kg	ARSBSC14	2/23	1.90E-02 - 2.10E-02	Yes	IBC
	7440-23-5	Sodium	6.00E+00 J	3.38E+01 J	mg/kg	ARSCF02	8/23	4.60E+00 - 5.10E+00	No	NIBC
	7440-28-0	Thallium	2.80E-01 L	1.30E+00 L	mg/kg	ARSBSC14	17/17	N/A	No	NIBC
	7440-62-2	Vanadium	2.59E+01 J	7.65E+01 J	mg/kg	ARSBSC14	23/23	N/A	No	NIBC
	7440-66-6	Zinc	1.03E+01 J	6.45E+01 J	mg/kg	ARSCF02	23/23	N/A	Yes	IBC

COPEC Selection Rationale Codes

Selection Reason: Important Bioaccumulative Compounds (IBC) [as defined in Table 4-2, of USEPA 823-R-00-001, February 2000]

Deletion Reason: Not Important Bioaccumulative Compound (NIBC)

Notes/Definitions

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/kg = milligrams per kilogram

Table 7-8
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure – Sediment
Firing Point/Berm Area
Page 1 of 2

Scenario Timeframe: Current/Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Sediment	91-57-6	2-Methylnaphthalene	8.40E-03 K	2.75E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	72-54-8	4,4'-DDD	5.00E-04 J	5.00E-04 J	mg/kg	ARSD01	1/3	3.30E-03 - 3.30E-03	Yes	DET
	72-55-9	4,4'-DDE	8.20E-04 J	1.08E-03 J	mg/kg	ARSD05	2/3	3.00E-03 - 3.00E-03	Yes	DET
	50-29-3	4,4'-DDT	2.20E-03 J	2.88E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	83-32-9	Acenaphthene	2.20E-03 J	2.63E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	208-96-8	Acenaphthylene	8.80E-04 J	2.30E-03 L	mg/kg	ARSD05	2/3	4.10E-03 - 4.10E-03	Yes	DET
	120-12-7	Anthracene	2.90E-03 J	4.70E-02	mg/kg	ARSD01	3/3	N/A	Yes	DET
	11097-69-1	Aroclor 1254	6.75E-02 J	6.75E-02 J	mg/kg	ARSD05	1/3	1.20E-01 - 1.40E-01	Yes	DET
	71-43-2	Benzene	1.65E-02 J	4.60E-02 J	mg/kg	ARSD01	3/3	N/A	Yes	DET
	56-55-3	Benzo(a)anthracene	2.30E-02	7.50E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	50-32-8	Benzo(a)pyrene	2.10E-02	8.85E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	205-99-2	Benzo(b)fluoranthene	5.40E-02	2.00E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	191-24-2	Benzo(ghi)perylene	2.20E-02	9.75E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	207-08-9	Benzo(k)fluoranthene	1.60E-02	6.15E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	218-01-9	Chrysene	4.50E-02	1.90E-01	mg/kg	ARSD01	3/3	N/A	Yes	DET
	53-70-3	Dibenzo(a,h)anthracene	3.30E-03 J	1.75E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	72-20-8	Endrin	1.17E-03 J	1.17E-03 J	mg/kg	ARSD05	1/3	3.00E-03 - 3.30E-03	Yes	DET
	206-44-0	Fluoranthene	7.40E-02	2.00E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	86-73-7	Fluorene	5.90E-03	1.14E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	76-44-8	Heptachlor	5.40E-04 J	1.10E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	193-39-5	Indeno(1,2,3-cd)pyrene	2.30E-02	1.05E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	72-43-5	Methoxychlor	3.50E-03 J	5.45E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	91-20-3	Naphthalene	1.10E-02	3.15E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	85-01-8	Phenanthrene	5.60E-02	1.04E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	129-00-0	Pyrene	5.20E-02	1.54E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	DET
	108-88-3	Toluene	2.50E-02 J	4.50E-02 J	mg/kg	ARSD01	3/3	N/A	Yes	DET
	7429-90-5	Aluminum	4.86E+03	5.77E+03	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7440-36-0	Antimony	1.30E-01 J	4.00E-01 J	mg/kg	ARSD04	5/5	N/A	Yes	DET
	7440-38-2	Arsenic	4.00E+00	5.70E+00	mg/kg	ARSD04	5/5	N/A	Yes	DET

Table 7-8
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure – Sediment
Firing Point/Berm Area
Page 2 of 2

Scenario Timeframe: Current/Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Sediment	7440-39-3	Barium	8.91E+01	1.21E+02 J	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7440-41-7	Beryllium	4.20E-01	4.70E-01	mg/kg	ARSD01	5/5	N/A	Yes	DET
	7440-43-9	Cadmium	1.60E-01	3.30E-01	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7440-70-2	Calcium	9.62E+03	2.16E+04	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7440-47-3	Chromium	8.60E+00	1.84E+01	mg/kg	ARSD01	5/5	N/A	Yes	DET
	7440-48-4	Cobalt	7.45E+00	8.10E+00	mg/kg	ARSD01	5/5	N/A	Yes	DET
	7440-50-8	Copper	1.09E+01	8.08E+01	mg/kg	ARSD03	5/5	N/A	Yes	DET
	7439-89-6	Iron	1.90E+04	2.96E+04	mg/kg	ARSD01	5/5	N/A	Yes	DET
	7439-92-1	Lead	9.40E+00	2.54E+01	mg/kg	ARSD04	5/5	N/A	Yes	DET
	7439-95-4	Magnesium	3.97E+03	6.87E+03	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7439-96-5	Manganese	3.56E+02	4.33E+02	mg/kg	ARSD04	5/5	N/A	Yes	DET
	7439-97-6	Mercury	1.30E-02	3.00E-02	mg/kg	ARSD02	5/5	N/A	Yes	DET
	7440-02-0	Nickel	1.02E+01	1.14E+01	mg/kg	ARSD03	5/5	N/A	Yes	DET
	7440-09-7	Potassium	5.52E+02	6.35E+02	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7440-22-4	Silver	4.30E-02 J	1.50E-01	mg/kg	ARSD04	3/5	2.10E-02 - 2.30E-02	Yes	DET
	7440-23-5	Sodium	3.29E+01 J	5.46E+01 J	mg/kg	ARSD05	5/5	N/A	Yes	DET
	7440-62-2	Vanadium	1.25E+01	2.04E+01	mg/kg	ARSD01	5/5	N/A	Yes	DET
	7440-66-6	Zinc	4.37E+01	5.03E+01	mg/kg	ARSD03	5/5	N/A	Yes	DET

COPEC Selection Rationale Codes

Selection Reason: Detected constituent (DET)

Notes/Definitions:

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/kg = milligrams per kilogram

Table 7-9
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure – Sediment
Firing Point/Berm Area
Page 1 of 2

Scenario Timeframe: Current/Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Food Chain COPEC (Y/N)	Rationale for Selection or Deletion
Sediment	91-57-6	2-Methylnaphthalene	8.40E-03 K	2.75E-02 J	mg/kg	ARSD05	3/3	N/A	No	NIBC
	72-54-8	4,4'-DDD	5.00E-04 J	5.00E-04 J	mg/kg	ARSD01	1/3	3.30E-03 - 3.30E-03	Yes	IBC
	72-55-9	4,4'-DDE	8.20E-04 J	1.08E-03 J	mg/kg	ARSD05	2/3	3.00E-03 - 3.00E-03	Yes	IBC
	50-29-3	4,4'-DDT	2.20E-03 J	2.88E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	83-32-9	Acenaphthene	2.20E-03 J	2.63E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	208-96-8	Acenaphthylene	8.80E-04 J	2.30E-03 L	mg/kg	ARSD05	2/3	4.10E-03 - 4.10E-03	Yes	IBC
	120-12-7	Anthracene	2.90E-03 J	4.70E-02	mg/kg	ARSD01	3/3	N/A	Yes	IBC
	11097-69-1	Aroclor 1254	6.75E-02 J	6.75E-02 J	mg/kg	ARSD05	1/3	1.20E-01 - 1.40E-01	Yes	IBC
	71-43-2	Benzene	1.65E-02 J	4.60E-02 J	mg/kg	ARSD01	3/3	N/A	No	NIBC
	56-55-3	Benzo(a)anthracene	2.30E-02	7.50E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	50-32-8	Benzo(a)pyrene	2.10E-02	8.85E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	205-99-2	Benzo(b)fluoranthene	5.40E-02	2.00E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	191-24-2	Benzo(ghi)perylene	2.20E-02	9.75E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	207-08-9	Benzo(k)fluoranthene	1.60E-02	6.15E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	218-01-9	Chrysene	4.50E-02	1.90E-01	mg/kg	ARSD01	3/3	N/A	Yes	IBC
	53-70-3	Dibenzo(a,h)anthracene	3.30E-03 J	1.75E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	72-20-8	Endrin	1.17E-03 J	1.17E-03 J	mg/kg	ARSD05	1/3	3.00E-03 - 3.30E-03	Yes	IBC
	206-44-0	Fluoranthene	7.40E-02	2.00E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	86-73-7	Fluorene	5.90E-03	1.14E-02 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	76-44-8	Heptachlor	5.40E-04 J	1.10E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	193-39-5	Indeno(1,2,3-cd)pyrene	2.30E-02	1.05E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	72-43-5	Methoxychlor	3.50E-03 J	5.45E-03 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	91-20-3	Naphthalene	1.10E-02	3.15E-02 J	mg/kg	ARSD05	3/3	N/A	No	NIBC
	85-01-8	Phenanthrene	5.60E-02	1.04E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	129-00-0	Pyrene	5.20E-02	1.54E-01 J	mg/kg	ARSD05	3/3	N/A	Yes	IBC
	108-88-3	Toluene	2.50E-02 J	4.50E-02 J	mg/kg	ARSD01	3/3	N/A	No	NIBC
	7429-90-5	Aluminum	4.86E+03	5.77E+03	mg/kg	ARSD05	5/5	N/A	No	NIBC
	7440-36-0	Antimony	1.30E-01 J	4.00E-01 J	mg/kg	ARSD04	5/5	N/A	No	NIBC
	7440-38-2	Arsenic	4.00E+00	5.70E+00	mg/kg	ARSD04	5/5	N/A	Yes	IBC
	7440-39-3	Barium	8.91E+01	1.21E+02 J	mg/kg	ARSD05	5/5	N/A	No	NIBC

Table 7-9
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure – Sediment
Firing Point/Berm Area
Page 2 of 2

Scenario Timeframe: Current/Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Food Chain COPEC (Y/N)	Rationale for Selection or Deletion
Sediment	7440-41-7	Beryllium	4.20E-01	4.70E-01	mg/kg	ARSD01	5/5	N/A	No	NIBC
	7440-43-9	Cadmium	1.60E-01	3.30E-01	mg/kg	ARSD05	5/5	N/A	Yes	IBC
	7440-70-2	Calcium	9.62E+03	2.16E+04	mg/kg	ARSD05	5/5	N/A	No	NIBC
	7440-47-3	Chromium	8.60E+00	1.84E+01	mg/kg	ARSD01	5/5	N/A	Yes	IBC
	7440-48-4	Cobalt	7.45E+00	8.10E+00	mg/kg	ARSD01	5/5	N/A	No	NIBC
	7440-50-8	Copper	1.09E+01	8.08E+01	mg/kg	ARSD03	5/5	N/A	Yes	IBC
	7439-89-6	Iron	1.90E+04	2.96E+04	mg/kg	ARSD01	5/5	N/A	No	NIBC
	7439-92-1	Lead	9.40E+00	2.54E+01	mg/kg	ARSD04	5/5	N/A	Yes	IBC
	7439-95-4	Magnesium	3.97E+03	6.87E+03	mg/kg	ARSD05	5/5	N/A	No	NIBC
	7439-96-5	Manganese	3.56E+02	4.33E+02	mg/kg	ARSD04	5/5	N/A	No	NIBC
	7439-97-6	Mercury	1.30E-02	3.00E-02	mg/kg	ARSD02	5/5	N/A	Yes	IBC
	7440-02-0	Nickel	1.02E+01	1.14E+01	mg/kg	ARSD03	5/5	N/A	Yes	IBC
	7440-09-7	Potassium	5.52E+02	6.35E+02	mg/kg	ARSD05	5/5	N/A	No	NIBC
	7440-22-4	Silver	4.30E-02 J	1.50E-01	mg/kg	ARSD04	3/5	2.10E-02 - 2.30E-02	Yes	IBC
	7440-23-5	Sodium	3.29E+01 J	5.46E+01 J	mg/kg	ARSD05	5/5	N/A	No	NIBC
	7440-62-2	Vanadium	1.25E+01	2.04E+01	mg/kg	ARSD01	5/5	N/A	No	NIBC
	7440-66-6	Zinc	4.37E+01	5.03E+01	mg/kg	ARSD03	5/5	N/A	Yes	IBC

COPEC Selection Rationale Codes

Selection Reason: Important Bioaccumulative Compounds (IBC) [as defined in Table 4-2, of USEPA 823-R-00-001, February 2000]

Deletion Reason: Not Important Bioaccumulative Compound (NIBC)

Notes/Definitions

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/kg = milligrams per kilogram

Table 7-10
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure - Surface Water
Firing Point/Berm Area

Scenario Timeframe: Current/Future
Medium: Surface Water
Exposure Medium: Surface Water

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Surface Water	84-74-2	Di-n-butyl phthalate	9.70E-04 J	9.70E-04 J	mg/l	ARSW05	1/3	3.10E-03 - 3.20E-03	Yes	DET
	72-43-5	Methoxychlor	1.50E-05 J	1.50E-05 J	mg/l	ARSW01	1/3	4.10E-05 - 4.20E-05	Yes	DET
	74-87-3	Methyl chloride	4.30E-05 J	1.10E-04 J	mg/l	ARSW01	3/3	N/A	Yes	DET
	14797-73-0	Perchlorate	1.00E-04	2.36E-04	mg/l	ARSW02	5/5	N/A	Yes	DET
	7429-90-5	Aluminum	3.82E-02 J	2.85E-01	mg/l	ARSW02	5/5	N/A	Yes	DET
	7440-39-3	Barium	4.05E-02	4.68E-02	mg/l	ARSW02	5/5	N/A	Yes	DET
	7440-70-2	Calcium	3.74E+01	3.86E+01	mg/l	ARSW02	5/5	N/A	Yes	DET
	7440-47-3	Chromium	9.70E-04 J	9.70E-04 J	mg/l	ARSW02	1/5	7.00E-04 - 7.00E-04	Yes	DET
	7440-50-8	Copper	1.70E-03 J	1.70E-03 J	mg/l	ARSW02	1/5	1.20E-03 - 1.20E-03	Yes	DET
	7439-89-6	Iron	4.77E-02 J	4.40E-01	mg/l	ARSW02	5/5	N/A	Yes	DET
	7439-95-4	Magnesium	1.65E+01	1.69E+01	mg/l	ARSW03	5/5	N/A	Yes	DET
	7439-96-5	Manganese	3.80E-03 J	3.60E-02	mg/l	ARSW02	5/5	N/A	Yes	DET
	7440-02-0	Nickel	6.00E-04	9.60E-04 J	mg/l	ARSW02	4/5	6.00E-04 - 6.00E-04	Yes	DET
	7440-09-7	Potassium	1.69E+00 J	1.80E+00	mg/l	ARSW02	5/5	N/A	Yes	DET
	7440-23-5	Sodium	1.13E+01 J	1.18E+01 J	mg/l	ARSW03	5/5	N/A	Yes	DET
	7440-62-2	Vanadium	1.00E-03 J	1.00E-03 J	mg/l	ARSW02	1/5	5.00E-04 - 5.00E-04	Yes	DET
	7440-66-6	Zinc	3.30E-03 J	3.30E-03 J	mg/l	ARSW02	1/5	1.80E-03 - 1.80E-03	Yes	DET

COPEC Selection Rationale Codes

Selection Reason: Detected constituent (DET)

Notes/Definitions:

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/l = milligrams per liter

Table 7-11
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure - Surface Water
Firing Point/Berm Area

Scenario Timeframe: Current/Future
Medium: Surface Water
Exposure Medium: Surface Water

Exposure Point	CAS Number	Chemical	Minimm Concentration (Qalifier)	Maximm Concentration (Qalifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Rationale for Selection or Deletion (4)
Surface Water	84-74-2	Di-n-butyl phthalate	9.70E-04 J	9.70E-04 J	mg/l	ARSW05	1/3	3.10E-03 - 3.20E-03	No	NIBC
	72-43-5	Methoxychlor	1.50E-05 J	1.50E-05 J	mg/l	ARSW01	1/3	4.10E-05 - 4.20E-05	Yes	IBC
	74-87-3	Methyl chloride	4.30E-05 J	1.10E-04 J	mg/l	ARSW01	3/3	N/A	No	NIBC
	14797-73-0	Perchlorate	1.00E-04	2.36E-04	mg/l	ARSW02	5/5	N/A	No	NIBC
	7429-90-5	Aluminum	3.82E-02 J	2.85E-01	mg/l	ARSW02	5/5	N/A	No	NIBC
	7440-39-3	Barium	4.05E-02	4.68E-02	mg/l	ARSW02	5/5	N/A	No	NIBC
	7440-70-2	Calcium	3.74E+01	3.86E+01	mg/l	ARSW02	5/5	N/A	No	NIBC
	7440-47-3	Chromium	9.70E-04 J	9.70E-04 J	mg/l	ARSW02	1/5	7.00E-04 - 7.00E-04	Yes	IBC
	7440-50-8	Copper	1.70E-03 J	1.70E-03 J	mg/l	ARSW02	1/5	1.20E-03 - 1.20E-03	Yes	IBC
	7439-89-6	Iron	4.77E-02 J	4.40E-01	mg/l	ARSW02	5/5	N/A	No	NIBC
	7439-95-4	Magnesium	1.65E+01	1.69E+01	mg/l	ARSW03	5/5	N/A	No	NIBC
	7439-96-5	Manganese	3.80E-03 J	3.60E-02	mg/l	ARSW02	5/5	N/A	No	NIBC
	7440-02-0	Nickel	6.00E-04	9.60E-04 J	mg/l	ARSW02	4/5	6.00E-04 - 6.00E-04	Yes	IBC
	7440-09-7	Potassium	1.69E+00 J	1.80E+00	mg/l	ARSW02	5/5	N/A	No	NIBC
	7440-23-5	Sodium	1.13E+01 J	1.18E+01 J	mg/l	ARSW03	5/5	N/A	No	NIBC
	7440-62-2	Vanadium	1.00E-03 J	1.00E-03 J	mg/l	ARSW02	1/5	5.00E-04 - 5.00E-04	No	NIBC
	7440-66-6	Zinc	3.30E-03 J	3.30E-03 J	mg/l	ARSW02	1/5	1.80E-03 - 1.80E-03	Yes	IBC

COPEC Selection Rationale Codes

Selection Reason: Important Bioaccumulative Compounds (IBC) [as defined in Table 4-2, of USEPA 823-R-00-001, February 2000]

Deletion Reason: Not Important Bioaccumulative Compound (NIBC)

Notes/Definitions

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/l = milligrams per liter

Fifty-three COPECs (**Table 7-6**) were evaluated for surface soil direct contact exposure (*Section 7.2.4*) and 36 (**Table 7-7**) for food chain exposure (*Section 7.2.3*).

Forty-seven COPECs (**Table 7-8**) were evaluated for sediment direct contact exposure (*Section 7.2.4*) and 31 (**Table 7-9**) for food chain exposure (*Section 7.2.3*).

Seventeen COPECs (**Table 7-10**) were evaluated for surface water direct contact exposure (*Section 7.2.4*) and five (**Table 7-11**) for food chain exposure (*Section 7.2.3*).

EPCs based on the statistical procedures discussed in *Section 7.1.3.3* are presented in **Tables 7-12, 7-13, and 7-14** and have been prepared for surface soil, sediment, and surface water, respectively. Arithmetic mean concentrations are presented for informational purposes.

7.2.3 Risk Characterization

Tier 1 and Tier 2 individual COPEC EEQs and HIs (summed EEQs) for terrestrial and aquatic receptors at the Firing Point/Berm Area are presented in risk characterization tables (**Appendix F-2, Tables F-2 through F-15**) for the seven selected receptor species. An example EEQ calculation is presented in **Appendix F-2, Table F-16**.

The summed EEQs are presented in **Table 7-15** (generally rounded to two significant figures), along with the hazard driver [COPEC(s) contributing the majority of the total estimated EEQ] and the exposure pathway of concern (the pathway contributing the most to the total estimated EEQ).

As shown in **Table 7-15**, Tier 1 total EEQs ranged from 4.6 to 362 for the seven receptor species, using TRVs based on either NOAEL or LOAEL values. The short-tailed shrew was predicted to be the most impacted, followed by the American robin, the meadow vole, the mink, the red fox, the red-tailed hawk, and the great blue heron. The inorganic constituents lead, nickel, selenium, and copper contributed the most to the total EEQs for these receptors. Exposure pathways of most concern, based on the results of the Tier 1 food chain modeling were: plant, terrestrial invertebrate, small mammal, aquatic invertebrate, fish, and incidental soil ingestion.

More realistic Tier 2 total EEQs were also elevated, especially values based on NOAEL TRVs, which ranged from 0.01 to 51. However, Tier 2 total EEQs were much lower than Tier 1 total EEQs, and both the NOAEL and LOAEL Tier 2 total EEQs for the red-tailed hawk, red fox, mink, and great blue heron were below one (**Table 7-15**). Lead, nickel, and selenium were identified as the main hazard drivers for the wildlife receptors, based on terrestrial invertebrate ingestion for the short-tailed shrew and the American robin, and soil and plant ingestion for the meadow vole.

The specific results of the Tier 2 risk estimation for the meadow vole, short-tailed shrew, and American robin are discussed below. The specific results for the red-tailed hawk, red fox, mink, and great blue heron are not discussed because the summed EEQs are below one.

Meadow Vole. The total EEQs for both NOAEL and LOAEL TRVs exceeded 1 (14 and 8.6, respectively). Five COPECs had individual NOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): selenium (3.9), copper (2.7), cadmium (2.2), chromium (1.2), and lead (1.1). Four COPECs had individual LOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): cadmium (2.0), selenium (1.9), copper (1.3), and lead (1.0). The primary exposure

Table 7-12
Medium-Specific Exposure Point Concentration Summary for Surface Soil at the Firing Point/Berm Area

Scenario Timeframe: Current/Future Medium: Soil Exposure Medium: Surface Soil										
Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Surface Soil	2-Methylnaphthalene	mg/kg	7.80E-03	Yes	8.69E-03 (N)	1.30E-02	8.69E-03	mg/kg	95% KM-% Btstrp	Test (1)
	4,4'-DDD	mg/kg	N/A	N/A	N/A	1.25E-03	1.25E-03	mg/kg	Max	Test (8)
	4,4'-DDE	mg/kg	3.97E-03	Yes	3.69E-03 (G)	9.20E-03	3.69E-03	mg/kg	95% KM-t	Test (1)
	4,4'-DDT	mg/kg	2.99E-03	Yes	3.12E-03 (G)	6.40E-03	3.12E-03	mg/kg	95% KM-t	Test (1)
	Acenaphthene	mg/kg	8.73E-03	Yes	1.01E-02 (NP)	1.60E-02	1.01E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Acenaphthylene	mg/kg	1.18E-03	Yes	1.33E-03 (NP)	1.27E-03	1.33E-03	mg/kg	95% KM-t	Test (1)
	alpha-Chlordane	mg/kg	4.01E-03	Yes	7.10E-03 (NP)	7.10E-03	7.10E-03	mg/kg	Max	Test (2)
	Anthracene	mg/kg	1.29E-02	Yes	1.95E-02 (L)	3.60E-02	1.95E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Aroclor 1254	mg/kg	N/A	N/A	N/A	4.70E-02	4.70E-02	mg/kg	Max	Test (8)
	Benzene	mg/kg	N/A	N/A	N/A	1.30E-02	1.30E-02	mg/kg	Max	Test (8)
	Benzo(a)anthracene	mg/kg	3.08E-02	Yes	6.92E-02 (L)	1.40E-01	6.92E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Benzo(a)pyrene	mg/kg	2.81E-02	Yes	2.53E-02 (G)	1.30E-01	2.53E-02	mg/kg	95% KM-t	Test (1)
	Benzo(b)fluoranthene	mg/kg	2.47E-02	Yes	1.41E-01 (L)	2.00E-01	1.41E-01	mg/kg	99% KM-Cheby	Test (1)
	Benzo(ghi)perylene	mg/kg	1.85E-02	Yes	4.06E-02 (L)	8.10E-02	4.06E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Benzo(k)fluoranthene	mg/kg	2.41E-02	Yes	6.50E-02 (N)	6.50E-02	6.50E-02	mg/kg	Max	Test (2)
	Bis(2-ethylhexyl)phthalate (BEHP)	mg/kg	1.40E-01	Yes	1.92E-01 (NP)	1.70E-01	1.70E-01	mg/kg	Max	Test (2)
	Chrysene	mg/kg	1.78E-02	Yes	7.52E-02 (NP)	1.60E-01	7.52E-02	mg/kg	97.5% KM-Cheby	Test (1)
	delta-BHC	mg/kg	N/A	N/A	N/A	1.40E-03	1.40E-03	mg/kg	Max	Test (8)
	Dibenzo(a,h)anthracene	mg/kg	4.88E-03	Yes	1.07E-02 (L)	2.10E-02	1.07E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Dieldrin	mg/kg	N/A	N/A	N/A	2.10E-03	2.10E-03	mg/kg	Max	Test (8)
	Endrin	mg/kg	N/A	N/A	N/A	6.75E-03	6.75E-03	mg/kg	Max	Test (8)
	Fluoranthene	mg/kg	3.34E-02	Yes	1.90E-01 (NP)	2.70E-01	1.90E-01	mg/kg	99% KM-Cheby	Test (1)
	Fluorene	mg/kg	N/A	N/A	N/A	1.20E-02	1.20E-02	mg/kg	Max	Test (8)
	gamma-Chlordane	mg/kg	2.16E-03	Yes	1.90E-03 (G)	5.90E-03	1.90E-03	mg/kg	95% KM-t	Test (1)
	Heptachlor epoxide	mg/kg	N/A	N/A	N/A	2.40E-03	2.40E-03	mg/kg	Max	Test (8)
	Indeno(1,2,3-cd)pyrene	mg/kg	1.83E-02	Yes	4.56E-02 (NP)	9.30E-02	4.56E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Methoxychlor	mg/kg	1.73E-03	Yes	1.90E-03 (G)	3.50E-03	1.90E-03	mg/kg	95% KM-t	Test (1)
	Naphthalene	mg/kg	5.04E-03	Yes	4.93E-03 (N)	1.00E-02	4.93E-03	mg/kg	95% KM-% Btstrp	Test (1)
	Phenanthrene	mg/kg	2.10E-02	Yes	6.74E-02 (NP)	1.40E-01	6.74E-02	mg/kg	97.5% KM-Cheby	Test (1)
	Pyrene	mg/kg	3.18E-02	Yes	1.63E-01 (NP)	2.30E-01	1.63E-01	mg/kg	99% KM-Cheby	Test (1)
	Aluminum	mg/kg	1.19E+04	No	1.37E+04 (G)	1.91E+04	1.37E+04	mg/kg	95% Approx. Gamma	Test (6)
	Antimony	mg/kg	3.90E-01	Yes	4.02E-01 (L)	1.40E+00	4.02E-01	mg/kg	95% KM-% Btstrp	Test (1)
	Arsenic	mg/kg	4.57E+00	No	7.88E+00 (NP)	1.91E+01	7.88E+00	mg/kg	95% Cheby, Mean, Sd	Test (3)

Table 7-12
Medium-Specific Exposure Point Concentration Summary for Surface Soil at the Firing Point/Berm Area

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Surface Soil	Barium	mg/kg	6.29E+01	No	7.31E+01 (L)	1.24E+02	7.31E+01	mg/kg	95% Modified-t	Test (5)
	Beryllium	mg/kg	5.13E-01	Yes	1.57E+00 (NP)	1.40E+00	1.57E+00	mg/kg	99% KM-Cheby	Test (1)
	Cadmium	mg/kg	4.72E-02	Yes	3.97E-02 (N)	9.80E-02	3.97E-02	mg/kg	95% KM-% Bstpr	Test (1)
	Calcium	mg/kg	4.46E+03	No	2.00E+04 (NP)	8.29E+04	2.00E+04	mg/kg	95% Cheby, Mean, Sd	Test (3)
	Chromium	mg/kg	2.40E+01	No	2.77E+01 (N)	4.61E+01	2.77E+01	mg/kg	95% Student's-t	Test (4)
	Cobalt	mg/kg	1.03E+01	No	1.61E+01 (NP)	2.08E+01	1.61E+01	mg/kg	95% Cheby, Mean, Sd	Test (3)
	Copper	mg/kg	1.68E+01	No	3.19E+01 (NP)	8.03E+01	3.19E+01	mg/kg	95% Cheby, Mean, Sd	Test (3)
	Iron	mg/kg	4.33E+04	No	5.20E+04 (G)	9.08E+04	5.20E+04	mg/kg	95% Approx. Gamma	Test (6)
	Lead	mg/kg	3.94E+01	No	9.68E+01 (NP)	2.59E+02	9.68E+01	mg/kg	95% Cheby, Mean, Sd	Test (3)
	Magnesium	mg/kg	2.90E+03	No	1.03E+04 (NP)	3.99E+04	1.03E+04	mg/kg	95% Cheby, Mean, Sd	Test (3)
	Manganese	mg/kg	5.49E+02	No	6.93E+02 (G)	1.91E+03	6.93E+02	mg/kg	95% Approx. Gamma	Test (6)
	Mercury	mg/kg	6.66E-02	No	8.71E-02 (G)	1.30E-01	8.71E-02	mg/kg	95% Approx. Gamma	Test (6)
	Nickel	mg/kg	9.11E+00	No	1.62E+01 (NP)	2.70E+01	1.62E+01	mg/kg	95% Cheby, Mean, Sd	Test (3)
	Potassium	mg/kg	4.68E+02	No	5.05E+02 (N)	6.65E+02	5.05E+02	mg/kg	95% Student's-t	Test (4)
	Selenium	mg/kg	6.27E-01	Yes	6.18E-01 (G)	1.50E+00	6.18E-01	mg/kg	95% KM-% Bstpr	Test (1)
	Silver	mg/kg	3.25E-02	Yes	3.50E-02 (NP)	3.50E-02	3.50E-02	mg/kg	Max	Test (2)
	Sodium	mg/kg	1.22E+01	Yes	1.06E+01 (NP)	3.38E+01	1.06E+01	mg/kg	95% KM-t	Test (1)
	Thallium	mg/kg	6.49E-01	No	7.74E-01 (N)	1.30E+00	7.74E-01	mg/kg	95% Student's-t	Test (4)
	Vanadium	mg/kg	4.45E+01	No	4.96E+01 (N)	7.65E+01	4.96E+01	mg/kg	95% Student's-t	Test (4)
	Zinc	mg/kg	2.85E+01	No	4.40E+01 (NP)	6.45E+01	4.40E+01	mg/kg	95% Cheby, Mean, Sd	Test (3)

Notes: N/A = Not applicable

¹ ProUCL software (version 4.1, USEPA, 2011) recommends use of Kaplan-Meier method if there are multiple detection limits.

² Statistical Distribution and 95% UCL as determined by ProUCL (unless otherwise noted): (G) the data were determined to follow gamma distribution; (L) the data were determined to follow lognormal distribution; (NP) the data were determined to be non-parametric; (N) the data were determined to be normally distributed.

³ Statistic: Maximum Detected Value (Max); 95% KM Chebyshev (95% KM-Cheby); 97.5% KM Chebyshev (97.5% KM-Cheby); 99% KM Chebyshev (99% KM-Cheby);

95% KM Percentile Bootstrap (95% KM-% Bstpr); 95% KM-t (95% KM-t); 95% KM-BCA (95% KM-BCA); 95% H-UCL (95% H-UCL); 95% Chebyshev -Mean, SD- UCL (95% Cheby, Mean, SD);

97.5% Chebyshev -Mean, SD- UCL (97.5% Cheby, Mean, SD); 99% Chebyshev -Mean, SD- UCL (99% Cheby, Mean, SD); 95% UCL of Log-transformed Data (95% UCL-T)

95% Student's-t (95% Student's-t); 95% Modified-t (95% Modified-t); 95% UCL based on bootstrap statistic (95% UCL-Bst); 95% Approximate Gamma UCL (95% Approx. Gamma);

95% KM Chebyshev-MVUE (95% KM-Cheby-MVUE).

⁴ Unless otherwise noted (see footnote 5), ProUCL EPC selection rationale based on, detection limit values, distribution, standard deviation, and sample size (see ProUCL output in appendix for further details):

Test (1): Kaplan-Meier method recommended by ProUCL due to multiple detection limits.

Test (2): 95% UCL exceeds or equals the maximum detected concentration, therefore, maximum concentration used for EPC.

Test (3): Shapiro-Wilk W test, Kolmogorov-Smirnov (K-S), and Anderson-Darling (A-D) tests, indicate data follow nonparametric distribution.

Test (4): Shapiro-Wilk W test indicates data are normally distributed.

Test (5): Shapiro-Wilk W test indicates data are log-normally distributed.

Test (6): Kolmogorov-Smirnov (K-S) and/or Anderson-Darling (A-D) tests indicate data follow gamma distribution.

Test (7): Sample size is less than or equal to 5, therefore, maximum concentration used for EPC.

Test (8): Infrequent detection resulted in ProUCL modeling error for this constituent, therefore, maximum concentration used for EPC.

Table 7-13
Medium-Specific Exposure Point Concentration Summary for Sediment at the Firing Point/Berm Area

Scenario Timeframe: Current/Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Sediment	2-Methylnaphthalene	mg/kg	1.63E-02	N/A	N/A	2.75E-02	2.75E-02	mg/kg	Max	Test (7)
	4,4'-DDD	mg/kg	N/A	N/A	N/A	5.00E-04	5.00E-04	mg/kg	Max	Test (7)
	4,4'-DDE	mg/kg	9.48E-04	N/A	N/A	1.08E-03	1.08E-03	mg/kg	Max	Test (7)
	4,4'-DDT	mg/kg	2.49E-03	N/A	N/A	2.88E-03	2.88E-03	mg/kg	Max	Test (7)
	Acenaphthene	mg/kg	2.38E-03	N/A	N/A	2.63E-03	2.63E-03	mg/kg	Max	Test (7)
	Acenaphthylene	mg/kg	1.59E-03	N/A	N/A	2.30E-03	2.30E-03	mg/kg	Max	Test (7)
	Anthracene	mg/kg	2.07E-02	N/A	N/A	4.70E-02	4.70E-02	mg/kg	Max	Test (7)
	Aroclor 1254	mg/kg	N/A	N/A	N/A	6.75E-02	6.75E-02	mg/kg	Max	Test (7)
	Benzene	mg/kg	3.02E-02	N/A	N/A	4.60E-02	4.60E-02	mg/kg	Max	Test (7)
	Benzo(a)anthracene	mg/kg	5.30E-02	N/A	N/A	7.50E-02	7.50E-02	mg/kg	Max	Test (7)
	Benzo(a)pyrene	mg/kg	5.92E-02	N/A	N/A	8.85E-02	8.85E-02	mg/kg	Max	Test (7)
	Benzo(b)fluoranthene	mg/kg	1.25E-01	N/A	N/A	2.00E-01	2.00E-01	mg/kg	Max	Test (7)
	Benzo(ghi)perylene	mg/kg	5.85E-02	N/A	N/A	9.75E-02	9.75E-02	mg/kg	Max	Test (7)
	Benzo(k)fluoranthene	mg/kg	3.95E-02	N/A	N/A	6.15E-02	6.15E-02	mg/kg	Max	Test (7)
	Chrysene	mg/kg	1.25E-01	N/A	N/A	1.90E-01	1.90E-01	mg/kg	Max	Test (7)
	Dibenzo(a,h)anthracene	mg/kg	1.06E-02	N/A	N/A	1.75E-02	1.75E-02	mg/kg	Max	Test (7)
	Endrin	mg/kg	N/A	N/A	N/A	1.17E-03	1.17E-03	mg/kg	Max	Test (7)
	Fluoranthene	mg/kg	1.45E-01	N/A	N/A	2.00E-01	2.00E-01	mg/kg	Max	Test (7)
	Fluorene	mg/kg	8.08E-03	N/A	N/A	1.14E-02	1.14E-02	mg/kg	Max	Test (7)
	Heptachlor	mg/kg	7.53E-04	N/A	N/A	1.10E-03	1.10E-03	mg/kg	Max	Test (7)
	Indeno(1,2,3-cd)pyrene	mg/kg	6.33E-02	N/A	N/A	1.05E-01	1.05E-01	mg/kg	Max	Test (7)
	Methoxychlor	mg/kg	4.52E-03	N/A	N/A	5.45E-03	5.45E-03	mg/kg	Max	Test (7)
	Naphthalene	mg/kg	2.02E-02	N/A	N/A	3.15E-02	3.15E-02	mg/kg	Max	Test (7)
	Phenanthrene	mg/kg	7.38E-02	N/A	N/A	1.04E-01	1.04E-01	mg/kg	Max	Test (7)
	Pyrene	mg/kg	1.09E-01	N/A	N/A	1.54E-01	1.54E-01	mg/kg	Max	Test (7)
	Toluene	mg/kg	3.50E-02	N/A	N/A	4.50E-02	4.50E-02	mg/kg	Max	Test (7)
	Aluminum	mg/kg	5.27E+03	N/A	N/A	5.77E+03	5.77E+03	mg/kg	Max	Test (7)
	Antimony	mg/kg	2.28E-01	N/A	N/A	4.00E-01	4.00E-01	mg/kg	Max	Test (7)
	Arsenic	mg/kg	4.78E+00	N/A	N/A	5.70E+00	5.70E+00	mg/kg	Max	Test (7)

Table 7-13
Medium-Specific Exposure Point Concentration Summary for Sediment at the Firing Point/Berm Area

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Sediment	Barium	mg/kg	1.05E+02	N/A	N/A	1.21E+02	1.21E+02	mg/kg	Max	Test (7)
	Beryllium	mg/kg	4.41E-01	N/A	N/A	4.70E-01	4.70E-01	mg/kg	Max	Test (7)
	Cadmium	mg/kg	2.38E-01	N/A	N/A	3.30E-01	3.30E-01	mg/kg	Max	Test (7)
	Calcium	mg/kg	1.31E+04	N/A	N/A	2.16E+04	2.16E+04	mg/kg	Max	Test (7)
	Chromium	mg/kg	1.10E+01	N/A	N/A	1.84E+01	1.84E+01	mg/kg	Max	Test (7)
	Cobalt	mg/kg	7.87E+00	N/A	N/A	8.10E+00	8.10E+00	mg/kg	Max	Test (7)
	Copper	mg/kg	2.61E+01	N/A	N/A	8.08E+01	8.08E+01	mg/kg	Max	Test (7)
	Iron	mg/kg	2.34E+04	N/A	N/A	2.96E+04	2.96E+04	mg/kg	Max	Test (7)
	Lead	mg/kg	1.39E+01	N/A	N/A	2.54E+01	2.54E+01	mg/kg	Max	Test (7)
	Magnesium	mg/kg	4.73E+03	N/A	N/A	6.87E+03	6.87E+03	mg/kg	Max	Test (7)
	Manganese	mg/kg	4.03E+02	N/A	N/A	4.33E+02	4.33E+02	mg/kg	Max	Test (7)
	Mercury	mg/kg	1.94E-02	N/A	N/A	3.00E-02	3.00E-02	mg/kg	Max	Test (7)
	Nickel	mg/kg	1.08E+01	N/A	N/A	1.14E+01	1.14E+01	mg/kg	Max	Test (7)
	Potassium	mg/kg	5.86E+02	N/A	N/A	6.35E+02	6.35E+02	mg/kg	Max	Test (7)
	Silver	mg/kg	8.07E-02	N/A	N/A	1.50E-01	1.50E-01	mg/kg	Max	Test (7)
	Sodium	mg/kg	4.09E+01	N/A	N/A	5.46E+01	5.46E+01	mg/kg	Max	Test (7)
	Vanadium	mg/kg	1.65E+01	N/A	N/A	2.04E+01	2.04E+01	mg/kg	Max	Test (7)
	Zinc	mg/kg	4.69E+01	N/A	N/A	5.03E+01	5.03E+01	mg/kg	Max	Test (7)

Notes: N/A = Not applicable

¹ ProUCL software (version 4.1, USEPA, 2011) recommends use of Kaplan-Meier method if there are multiple detection limits.

² Statistical Distribution and 95% UCL as determined by ProUCL (unless otherwise noted): (G) the data were determined to follow gamma distribution; (L) the data were determined to follow lognormal distribution; (NP) the data were determined to be non-parametric; (N) the data were determined to be normally distributed.

³ Statistic: Maximum Detected Value (Max); 95% KM Chebyshev (95% KM-Cheby); 97.5% KM Chebyshev (97.5% KM-Cheby); 99% KM Chebyshev (99% KM-Cheby); 95% KM Percentile Bootstrap (95% KM-% Bstpr); 95% KM-t (95% KM-t); 95% KM-BCA (95% KM-BCA); 95% H-UCL (95% H-UCL); 95% Chebyshev -Mean, SD- UCL (95% Cheby, Mean, SD); 97.5% Chebyshev -Mean, SD- UCL (97.5% Cheby, Mean, SD); 99% Chebyshev -Mean, SD- UCL (99% Cheby, Mean, SD); 95% UCL of Log-transformed Data (95% UCL-T) 95% Student's-t (95% Student's-t); 95% Modified-t (95% Modified-t); 95% UCL based on bootstrap statistic (95% UCL-Bst); 95% Approximate Gamma UCL (95% Approx. Gamma); 95% KM Chebyshev-MVUE (95% KM-Cheby-MVUE).

⁴ Unless otherwise noted (see footnote 5), ProUCL EPC selection rationale based on, detection limit values, distribution, standard deviation, and sample size (see ProUCL output in appendix for further details):

Test (1): Kaplan-Meier method recommended by ProUCL due to multiple detection limits.

Test (2): 95% UCL exceeds or equals the maximum detected concentration, therefore, maximum concentration used for EPC.

Test (3): Shapiro-Wilk W test, Kolmogorov-Smirnov (K-S), and Anderson-Darling (A-D) tests, indicate data follow nonparametric distribution.

Test (4): Shapiro-Wilk W test indicates data are normally distributed.

Test (5): Shapiro-Wilk W test indicates data are log-normally distributed.

Test (6): Kolmogorov-Smirnov (K-S) and/or Anderson-Darling (A-D) tests indicate data follow gamma distribution.

Test (7): Sample size is less than or equal to 5, therefore, maximum concentration used for EPC.

Test (8): Infrequent detection resulted in ProUCL modeling error for this constituent, therefore, maximum concentration used for EPC.

Table 7-14
Medium-Specific Exposure Point Concentration Summary for Surface Water at the Firing Point/Berm Area

Scenario Timeframe: Current/Future
Medium: Surface Water
Exposure Medium: Surface Water

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Surface Water	Di-n-butyl phthalate	mg/L	N/A	N/A	N/A	9.70E-04	9.70E-04	mg/L	Max	Test (7)
	Methoxychlor	mg/L	N/A	N/A	N/A	1.50E-05	1.50E-05	mg/L	Max	Test (7)
	Methyl chloride	mg/L	6.97E-05	N/A	N/A	1.10E-04	1.10E-04	mg/L	Max	Test (7)
	Perchlorate	mg/L	2.00E-04	N/A	N/A	2.36E-04	2.36E-04	mg/L	Max	Test (7)
	Aluminum	mg/L	9.18E-02	N/A	N/A	2.85E-01	2.85E-01	mg/L	Max	Test (7)
	Barium	mg/L	4.25E-02	N/A	N/A	4.68E-02	4.68E-02	mg/L	Max	Test (7)
	Calcium	mg/L	3.79E+01	N/A	N/A	3.86E+01	3.86E+01	mg/L	Max	Test (7)
	Chromium	mg/L	N/A	N/A	N/A	9.70E-04	9.70E-04	mg/L	Max	Test (7)
	Copper	mg/L	N/A	N/A	N/A	1.70E-03	1.70E-03	mg/L	Max	Test (7)
	Iron	mg/L	1.39E-01	N/A	N/A	4.40E-01	4.40E-01	mg/L	Max	Test (7)
	Magnesium	mg/L	1.68E+01	N/A	N/A	1.69E+01	1.69E+01	mg/L	Max	Test (7)
	Manganese	mg/L	1.09E-02	N/A	N/A	3.60E-02	3.60E-02	mg/L	Max	Test (7)
	Nickel	mg/L	7.90E-04	N/A	N/A	9.60E-04	9.60E-04	mg/L	Max	Test (7)
	Potassium	mg/L	1.74E+00	N/A	N/A	1.80E+00	1.80E+00	mg/L	Max	Test (7)
	Sodium	mg/L	1.15E+01	N/A	N/A	1.18E+01	1.18E+01	mg/L	Max	Test (7)
	Vanadium	mg/L	N/A	N/A	N/A	1.00E-03	1.00E-03	mg/L	Max	Test (7)
	Zinc	mg/L	N/A	N/A	N/A	3.30E-03	3.30E-03	mg/L	Max	Test (7)

Notes: N/A = Not applicable

¹ ProUCL software (version 4.1, USEPA, 2011) recommends use of Kaplan-Meier method if there are multiple detection limits.

² Statistical Distribution and 95% UCL as determined by ProUCL (unless otherwise noted): (G) the data were determined to follow gamma distribution; (L) the data were determined to follow lognormal distribution; (NP) the data were determined to be non-parametric; (N) the data were determined to be normally distributed.

³ Statistic: Maximum Detected Value (Max); 95% KM Chebyshev (95% KM-Cheby); 97.5% KM Chebyshev (97.5% KM-Cheby); 99% KM Chebyshev (99% KM-Cheby); 95% KM Percentile Bootstrap (95% KM-% Bstpr); 95% KM-t (95% KM-t); 95% KM-BCA (95% KM-BCA); 95% H-UCL (95% H-UCL); 95% Chebyshev -Mean, SD- UCL (95% Cheby, Mean, SD); 97.5% Chebyshev -Mean, SD- UCL (97.5% Cheby, Mean, SD); 99% Chebyshev -Mean, SD- UCL (99% Cheby, Mean, SD); 95% UCL of Log-transformed Data (95% UCL-T) 95% Student's-t (95% Student's-t); 95% Modified-t (95% Modified-t); 95% UCL based on bootstrap statistic (95% UCL-Bst); 95% Approximate Gamma UCL (95% Approx. Gamma); 95% KM Chebyshev-MVUE (95% KM-Cheby-MVUE).

⁴ Unless otherwise noted (see footnote 5), ProUCL EPC selection rationale based on, detection limit values, distribution, standard deviation, and sample size (see ProUCL output in appendix for further details):

Test (1): Kaplan-Meier method recommended by ProUCL due to multiple detection limits.

Test (2): 95% UCL exceeds or equals the maximum detected concentration, therefore, maximum concentration used for EPC.

Test (3): Shapiro-Wilk W test, Kolmogorov-Smirnov (K-S), and Anderson-Darling (A-D) tests, indicate data follow nonparametric distribution.

Test (4): Shapiro-Wilk W test indicates data are normally distributed.

Test (5): Shapiro-Wilk W test indicates data are log-normally distributed.

Test (6): Kolmogorov-Smirnov (K-S) and/or Anderson-Darling (A-D) tests indicate data follow gamma distribution.

Test (7): Sample size is less than or equal to 5, therefore, maximum concentration used for EPC.

Test (8): Infrequent detection resulted in ProUCL modeling error for this constituent, therefore, maximum concentration used for EPC.

Table 7-15
Wildlife Summed EEQ Hazard Summary for Food Chain Exposure
Firing Point/Berm Area

Receptor	Tier 1 ^a		Tier 2 ^b	
	NOAEL-Based EEQ	LOAEL-Based EEQ	NOAEL-Based EEQ	LOAEL-Based EEQ
Meadow vole	69	38	14	8.6
Hazard Driver(s) ^c :	<u>Selenium</u> - plant ingestion		<u>Lead and Selenium</u> - soil and plant ingestion	
Short-tailed shrew	362	225	51	35
Hazard Driver(s) ^c :	<u>Nickel</u> - terrestrial invertebrate ingestion		<u>Lead and Nickel</u> - terrestrial invertebrate ingestion	
American robin	118	88	29	24
Hazard Driver(s) ^c :	<u>Lead and Nickel</u> - terrestrial invertebrate ingestion		<u>Lead</u> - terrestrial invertebrate ingestion	
Red-tailed hawk	15	12	0.03	0.02
Hazard Driver(s) ^c :	<u>Lead and Copper</u> - small mammal ingestion		--	
Red fox	19	14	0.01	0.01
Hazard Driver(s) ^c :	<u>Lead and Copper</u> - terrestrial invertebrate and small mammal ingestion		--	
Mink	22	19	0.6	0.5
Hazard Driver(s) ^c :	<u>Copper</u> - aquatic invertebrate ingestion		--	
Great blue heron	5.6	4.6	0.5	0.5
Hazard Driver(s) ^c :	<u>Copper</u> - aquatic invertebrate ingestion		--	

^a Tier 1 = Max EEQ using max EPC, max BAF/BCF, max Intake Rates, min BW, and FHR =1.

^b Tier 2 = EEQ using 95% EPC, non-max BAF/BCF, avg Intake Rates, avg BW and calculated FHR less than or equal to 1.

^c Hazard drivers are those chemicals contributing the most to the total estimated EEQ, and the primary route of exposure associated with this driver.

Notes:

"---" = Total EEQ < 1

BAF/BCF = Bioaccumulation Factor/Bioconcentration Factor

BW = Body Weight

EEQ = Ecological Effects Quotient

EPC = Exposure Point Concentration

FHR = Fraction Home Range

LOAEL = Lowest-Observed-Adverse-Effect Level

NOAEL = No-Observed-Adverse-Effect Level

pathway was the ingestion of plants and soil. The results of the Tier 2 risk evaluation for meadow voles are presented in **Appendix F-2, Table F-3**.

Short-tailed Shrew. The total EEQs for both NOAEL and LOAEL TRVs exceeded 1 (51 and 35, respectively). Ten COPECs had individual NOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): nickel (11), lead (9.6), selenium (5.4), chromium (4.3), zinc (4.3), copper (3.8), dieldrin (2.2), arsenic (1.9), endrin (1.7), and fluoranthene (1.0). Eight COPECs had individual LOAEL-based EEQs that exceeded 1 (EEQ in parenthesis): lead (9.0), nickel (6.8), selenium (5.3), zinc (4.2), copper (3.7), chromium (1.3), arsenic (1.2), and dieldrin (1.1). The primary exposure pathway was the ingestion of terrestrial invertebrates and soil. The results of the short-tailed shrew Tier 2 risk evaluation are presented in **Appendix F-2, Table F-5**.

American Robin. The total EEQs for both NOAEL and LOAEL TRVs exceeded 1 (29 and 24, respectively). Seven COPECs had individual NOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (13), copper (3.6), zinc (2.5), chromium (2.3), cadmium (2.0), selenium (1.9), and nickel (1.3). Seven COPECs had individual LOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (11), copper (3.0), zinc (2.5), chromium (2.2), selenium (1.5), cadmium (1.3), and nickel (1.0). The primary exposure pathway was the ingestion of terrestrial invertebrates. The results of the Tier 2 risk evaluation for American robins are presented in **Appendix F-2, Table F-7**.

7.2.4 Approach for the Evaluation of Direct Contact Toxicity

To evaluate direct contact exposure, for those organisms that live within an environmental medium, COPEC media (surface soil, sediment, and surface water) concentrations were compared with a variety of direct contact screening values. Intake was not calculated because potential adverse effects are assessed by evaluating the COPEC concentrations. Measured COPEC concentrations were simply compared with direct contact benchmarks appropriate for communities that reside in these media. The results are summarized below.

7.2.4.1 Surface Soil

As there are no promulgated soil screening criteria for organisms potentially exposed to COPECs in surface soil collected from the ARSAR, a two-step process was used to assess direct contact soil toxicity (see *Section 7.1.9* for more details). The results are summarized in **Table 7-16**.

Fifty-three surface soil COPECs were compared with the soil screening values and the results are as follows:

- Five analytes were carried forward for further evaluation because there were no BTAG or EcoSSL screening benchmarks available [2-methylnaphthalene, bis(2-ethylhexyl)phthalate, calcium, potassium, and sodium]. Of these, 2-methylnaphthalene was detected in four of 13 samples; bis(2-ethylhexyl)phthalate was detected in two of 16 samples; calcium and potassium were detected in all 23 surface soil samples; and sodium was detected in eight of 23 samples.
 - o There were no available soil benchmarks for 2-methylnaphthalene.
 - o The bis(2-ethylhexyl)phthalate MDC exceeded the one additional screening value based on the Dutch target value for the sum of all phthalates. The target value indicates the level at which there is sustainable soil quality and indicates negligible risks to the ecosystem. Besides the target value, a Dutch intervention value also is

Table 7-16
Direct Toxicity Evaluation for Surface Soil at the Firing Point/Berm Area
Page 2 of 2

Chemical (1)	Detection Frequency	MDC (mg/kg)	EPC (mg/kg)	BTAG or USEPA EcoSSL Screening Toxicity Value (2)	Retain COPEC as Max Conc > BTAG or EcoSSL Value?	If Retained as COPEC, Comment on BTAG or EcoSSL Value	NOAA SQuiRT Value (3)	CCME Value (4)	USEPA EcoSSL Direct Contact Value (5)	ORNL Screening Benchmark for Plants (6)	ORNL Screening Benchmark for Invertebrates (7)	COPEC Weight of Evidence Summary - Number of Direct Contact Benchmarks Exceeded Using MDC	COPEC Weight of Evidence Summary - Number of Direct Contact Benchmarks Exceeded Using EPC	Comment
Cadmium	9/23	9.80E-02	3.97E-02	3.60E-01	No	Mammal tox	1.20E+01	1.40E+00	3.20E+01	4.00E+00	2.00E+01	0/5		No exceedences
Calcium	23/23	8.29E+04	2.00E+04	NVA	Yes	---	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening values
Chromium (Cr III tox)	23/23	4.61E+01	2.77E+01	2.60E+01	Yes	Bird tox	2.20E+02	NVA	NVA	1.00E+00	4.00E-01	2/3	2/3	ORNL-plant for total Cr, EcoSSL says data insufficient to derive direct contact SSL
Chromium (Cr VI tox)	23/23	4.61E+01	2.77E+01	1.30E+02	No									
														EcoSSL and ORNL plant tox, EcoSSL says data insufficient to derive direct contact invertebrate SSL
Cobalt	22/22	2.08E+01	1.61E+01	1.30E+01	Yes	Plant tox	1.80E+02	4.00E+01	1.30E+01	2.00E+01	NVA	2/4	1/4	
Copper	23/23	8.03E+01	3.19E+01	2.80E+01	Yes	Bird tox	9.60E+01	6.30E+01	7.00E+01	1.00E+02	5.00E+01	3/5	0/5	EcoSSL and ORNL plant tox
Iron	23/23	9.08E+04	5.20E+04	5 ≤ pH ≤ 8	No (pH is between 5 and 8)									pH = 5.93
Lead	23/23	2.59E+02	9.68E+01	1.10E+01		Bird tox	5.30E+02	7.00E+01	1.20E+02	5.00E+01	5.00E+02	3/5	2/5	
Magnesium	23/23	3.99E+04	1.03E+04	4.40E+03	Yes	No reference	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening values
Manganese	22/22	1.91E+03	6.93E+02	2.20E+02	Yes	Plant tox	NVA	NVA	2.20E+02	5.00E+02	NVA	2/2	2/2	EcoSSL and ORNL plant tox
Mercury	23/23	1.30E-01	8.71E-02	5.80E-02	Yes	No reference	1.00E+01	6.60E+00	NVA	3.00E-01	1.00E-01	1/4	0/4	No reference for BTAG
Nickel	23/23	2.70E+01	1.62E+01	3.80E+01	No									
Potassium	23/23	6.65E+02	5.05E+02	NVA	Yes	---	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening values
Selenium	15/23	1.50E+00	6.18E-01	5.20E-01	Yes	Plant tox	1.00E+02	1.00E+00	5.20E-01	1.00E+00	7.00E+01	3/5	1/5	EcoSSL and ORNL plant tox
Silver	2/23	3.50E-02	3.50E-02	4.20E+00	No									
Sodium	8/23	3.38E+01	1.06E+01	NVA	Yes	---	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening values
Thallium	17/17	1.30E+00	7.74E-01	1.00E-03	Yes	Plant tox (no ref)	1.50E+01	1.00E+00	NVA	1.00E+00	NVA	2/3	0/3	ORNL plant tox, no reference for BTAG plant tox, no EcoSSL
Vanadium	23/23	7.65E+01	4.96E+01	7.80E+00	Yes	Bird tox	2.50E+02	1.30E+02	NVA	2.00E+00	NVA	1/3	1/3	
Zinc	23/23	6.45E+01	4.40E+01	4.60E+01	Yes	Plant tox (OHMTADS)	3.50E+02	2.00E+02	1.20E+02	5.00E+01	2.00E+02	1/5	0/5	ORNL plant tox

All values presented in mg/kg.
MDC = Maximum detected concentration.
EPC = Exposure Point Concentration. The 95% UCL was selected as the EPC unless it exceeded the maximum detected concentration, in which case the MDC was chosen as the EPC.
NVA = No Value Available
LMW = Low Molecular Weight PAH
HMW = High Molecular Weight PAH
IFD = Infrequently Detected (≤5%)
Surface soil pH of 5.92 based geometric mean of surface soil samples from MMA.

- (1) Direct contact COPECs are for all detected constituents.
(2) Screening toxicity values from BTAG (1995) or EcoSSL (USEPA, 2007). EcoSSLs given highest priority as they are more definitive.
(3) NOAA SQuiRT 2008 (non-EcoSSL and non-microbe values used).
(4) Canadian Council of Ministers of the Environment (CCME), Canadian Environmental Quality Guidelines, December 2003.
(5) Lowest EcoSSL value for direct contact toxicity for either plants or terrestrial invertebrates (USEPA, 2007).
(6) Screening benchmarks for plants from ORNL (1997, ES/ER/TM-85/R3).
(7) Screening benchmarks for earthworms from ORNL (1997, ES/ER/TM-126/R2).
(8) EcoSSL (USEPA, 2007) for LMW PAHs and HMW PAHs.
LMW and HMW PAHs based on the number of ring structures (less than 4 rings = LMW; 4 or more rings = HWM).

published for phthalates, which is 60 mg/kg, representing functional properties of soil for humans, plants, and animal life are seriously impaired or threatened. As the bis(2-ethylhexyl)phthalate MDC of 0.17 mg/kg is only 0.3 percent of the intervention value, and exceeds the target value by less than two-fold, concerns for this COPEC are deemed minimal.

- o Calcium, potassium, and sodium are essential nutrients and not considered direct contact COPECs in surface soil at the Firing Point/Berm Area.
- Although magnesium was detected in all 23 samples and the MDC exceeded the BTAG benchmark (the only available benchmark), the value is not based on direct contact toxicity. In addition, magnesium is an essential nutrient and not considered a direct contact COPEC. Therefore magnesium is not considered a direct contact hazard in surface soil at the Firing Point/Berm Area.
- Aluminum was detected in all 23 surface soil samples. However, aluminum in soil is not considered readily bioavailable in soils with a pH above 5.5 (USEPA, 2007b). As the geometric mean surface soil pH at the MMA was 5.92, aluminum is not considered a significant direct contact hazard at the Firing Point/Berm Area.
- Iron was also detected in all 23 surface soil samples. However, iron in soil is not considered readily bioavailable in soils with a pH between 5.0 and 8.0 (USEPA, 2007b). As the geometric mean surface soil pH at the MMA was 5.92, iron is not considered a significant direct contact hazard at the Firing Point/Berm Area.
- The following 35 analytes: silver, nickel, chromium (Cr VI), cadmium, beryllium, barium, pyrene, phenanthrene, naphthalene, methoxychlor, indeno(1,2,3-cd)pyrene, heptachlor epoxide, gamma-chlordane, fluorene, fluoranthene, endrin, dieldrin, dibenzo(a,h)anthracene, delta-BHC, chrysene, beta-BHC, benzo(k)fluoranthene, benzo(ghi)perylene, benzo(b)fluoranthene, benzo(a)pyrene, benzo(a)anthracene, benzene, Aroclor 1254, anthracene, alpha-chlordane, acenaphthylene, acenaphthene, 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, had MDCs and EPCs that did not exceed the EcoSSL or BTAG soil screening benchmarks. Therefore, no further action is required for these constituents in surface soil at the Firing Point/Berm Area.
- Antimony had an MDC that exceeded the initial EcoSSL or BTAG soil screening benchmarks, but none of the four additional direct contact screening benchmarks for antimony was exceeded by the MDC. As less than 50 percent of these benchmarks were exceeded, no further action is required for antimony in surface soil at the Firing Point/Berm Area.
- Cobalt, mercury, vanadium, and zinc had MDCs that exceeded the initial EcoSSL or BTAG soil screening benchmarks, but the MDC did not exceed more than half of the additional soil benchmarks. In addition, all of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity (or, for mercury, the EPC was below the screening values), and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. Therefore, no further action is required for cobalt, mercury, or vanadium in surface soil at the Firing Point/Berm Area.
- The following seven analytes: arsenic, chromium (Cr III), copper, lead, manganese, selenium, and thallium, had MDCs that exceeded the initial EcoSSL or BTAG soil

screening benchmarks and more than half of the additional soil benchmarks and are discussed below:

- o Arsenic was detected in all 23 surface soil samples and the MDC exceeded three of the five additional soil benchmarks. However, two of the exceeded benchmarks (ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the soil EPC did not exceed any of the additional benchmarks, and the EcoSSL guidance indicates there is insufficient data to derive a direct contact SSL. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for arsenic in surface soil at the Firing Point/Berm Area.
- o Chromium was detected in all 23 surface soil samples and the MDC and EPC exceeded two of the three additional soil benchmarks for Cr III. However, one of the exceeded benchmarks (ORNL) was for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the EcoSSL guidance indicates there is insufficient data to derive a direct contact SSL for invertebrates and plants. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for chromium in surface soil at the Firing Point/Berm Area.
- o Copper was detected in all 23 surface soil samples and the MDC exceeded three of the five additional soil benchmarks. However, the soil EPC did not exceed any of the five additional benchmarks. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for copper in surface soil at the Firing Point/Berm Area.
- o Lead was detected in all 23 surface soil samples and the MDC exceeded three of five additional soil benchmarks but the EPC only exceeded two of the additional benchmarks. Two of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the direct contact SSL for invertebrates is 1,700 mg/kg, and the MDC (259 mg/kg) and EPC of (97 mg/kg) do not exceed this invertebrate SSL for lead. Therefore, the potential for direct contact toxicity may not be significant enough to recommend further action for lead in surface soil at the site. However, it should be noted that lead is already a concern for wildlife based on foodchain modeling.
- o Manganese was detected in all 34 surface soil samples and the MDC and EPC exceeded both additional soil benchmarks. However, both of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. It should be noted that the MDC and EPC exceed the EcoSSL direct contact value for invertebrates (450 mg/kg), therefore, there is potential for direct contact toxicity for manganese at the site. This may or may not result in the reduction of terrestrial invertebrates as a food source at the Firing Point/Berm Area.
- o Selenium was detected in 15 of 23 surface soil samples and the MDC exceeded three of five additional soil benchmarks. However, two of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*,

plant toxicity is not an overriding concern for the site. Furthermore, the soil EPC only exceeded one of the five additional benchmarks (which was for plant toxicity). Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for selenium in surface soil at the Firing Point/Berm Area.

- o Thallium was detected in all 17 surface soil samples and the MDC exceeded two of three additional soil benchmarks. However, one of the exceeded benchmarks (ORNL) was for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the soil EPC did not exceed any of the additional benchmarks. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for thallium in surface soil at the Firing Point/Berm Area.

These results suggest that direct contact toxicity for COPECs in surface soil may be a concern for manganese. It should also be noted that toxicity to terrestrial invertebrates is assessed indirectly, as terrestrial invertebrates such as earthworms are included in the food chain models used in the assessments.

7.2.4.2 Sediment

Similar to the direct contact approach used for soil, a weight-of-evidence approach was used for sediment. The more sediment benchmarks exceeded by the COPEC concentration, the greater the potential for adverse effects. For this SLERA, an exceedance threshold of 50 percent is used to assess direct contact sediment toxicity (see *Section 7.1.9.2* for more details). The results are summarized in **Table 7-17**.

Forty-seven sediment COPECs were compared with the individual sediment screening values and the results are as follows:

- Seven analytes had no sediment screening benchmarks available: barium, beryllium, calcium, magnesium, potassium, sodium, and vanadium. Calcium, magnesium, potassium, and sodium are essential nutrients and not considered direct contact COPECs in sediment at the Firing Point/Berm Area.
- The copper MDC exceeded seven of ten sediment benchmarks. Therefore, there is potential for direct contact toxicity for copper at the Firing Point/Berm Area. Based on this finding, it is possible that organisms inhabiting the stream sediment near the Firing Point/Berm Area may be adversely impacted by levels of copper.
- The iron MDC exceeded the only available sediment benchmark for iron. Therefore, there is potential for direct contact toxicity for iron at the Firing Point/Berm Area. Based on this finding, it is possible that organisms inhabiting the stream sediment near the Firing Point/Berm Area may be adversely impacted by levels of iron.
- The benzo(b)fluoranthene MDC exceeded two of three available sediment benchmark for benzo(b)fluoranthene. Therefore, there is potential for direct contact toxicity for benzo(b)fluoranthene at the Firing Point/Berm Area. Based on this finding, it is possible that organisms inhabiting the stream sediment near the Firing Point/Berm Area may be adversely impacted by levels of benzo(b)fluoranthene.

Table 7-17
Direct Contact Toxicity Evaluation for Sediment at the Firing Point/Berm Area
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COPEC	MDC (mg/kg)	EPC (mg/kg)	Frequency of Detection	USEPA Region 3 BTAG (mg/kg) ^A	ARCS ^B			SQB (mg/kg) ^{B,C}	Canadian ISQG (mg/kg) ^D	Canadian PEL (mg/kg) ^D	NOAA ^B		MacDonald et al., 2000 ^E		Weight of Evidence Exceedence	
					TEC (mg/kg)	PEC (mg/kg)	NEC (mg/kg)				ER-L (mg/kg)	ER-M (mg/kg)	Consensus- based TEC (mg/kg)	Consensus- based PEC (mg/kg)	Using MDC	Using EPC
2-Methylnaphthalene	2.75E-02	--- ^F	3/3	2.02E-02	---	---	---	---	2.02E-02	2.01E-01	7.00E-02	6.70E-01	---	---	2 / 5	---
4,4'-DDD	5.00E-04	--- ^F	1/3	4.88E-03	---	---	---	1.10E-01	3.54E-03	8.51E-03	2.00E-03	2.00E-02	4.88E-03	2.80E-02	0 / 8	---
4,4'-DDE	1.08E-03	--- ^F	2/3	3.16E-03	---	---	---	---	1.42E-03	6.75E-03	2.20E-03	2.70E-02	3.16E-03	3.13E-02	0 / 7	---
4,4'-DDT	2.88E-03	--- ^F	3/3	4.16E-03	---	---	---	3.40E-01	1.19E-03	4.77E-03	1.00E-03	7.00E-03	4.16E-03	6.29E-02	2 / 8	---
Acenaphthene	2.63E-03	--- ^F	3/3	6.70E-03	---	---	---	1.30E+00	6.71E-03	8.89E-02	1.60E-02	5.00E-01	---	---	0 / 6	---
Acenaphthylene	2.30E-03	--- ^F	2/3	5.90E-03	---	---	---	---	5.87E-03	1.28E-01	4.40E-02	6.40E-01	---	---	0 / 5	---
Anthracene	4.70E-02	--- ^F	3/3	5.72E-02	3.16E-02	5.48E-01	1.70E+00	2.70E-02	4.69E-02	2.45E-01	8.53E-02	1.10E+00	5.72E-02	8.45E-01	3 / 11	---
Aroclor 1254	6.75E-02	--- ^F	1/3	---	---	---	---	8.10E-01	6.00E-02	3.40E-01	---	---	---	---	1 / 3	---
Benzene	4.60E-02	--- ^F	3/3	---	---	---	---	1.60E-01	---	---	---	---	---	---	0 / 1	---
Benzo(a)anthracene	7.50E-02	--- ^F	3/3	1.08E-01	2.60E-01	4.20E+00	3.50E+00	1.10E-01	3.17E-02	3.85E-01	2.61E-01	1.60E+00	1.08E-01	1.05E+00	1 / 11	---
Benzo(a)pyrene	8.85E-02	--- ^F	3/3	1.50E-01	3.50E-01	3.94E-01	4.40E-01	1.40E-01	3.19E-02	7.82E-01	4.30E-01	1.60E+00	1.50E-01	1.45E+00	1 / 11	---
Benzo(b)fluoranthene	2.00E-01	--- ^F	3/3	2.72E-02	2.72E-02	---	4.00E+00	---	---	---	---	---	---	---	2 / 3	---
Benzo(ghi)perylene	9.75E-02	--- ^F	3/3	1.70E-01	2.90E-01	6.30E+00	3.80E+00	---	---	---	---	---	---	---	0 / 4	---
Benzo(k)fluoranthene	6.15E-02	--- ^F	3/3	2.40E-01	---	---	---	---	---	---	---	---	---	---	0 / 1	---
Chrysene	1.90E-01	--- ^F	3/3	1.66E-01	5.00E-01	5.20E+00	4.00E+00	---	5.71E-02	8.62E-01	3.84E-01	2.80E+00	1.66E-01	1.29E+00	3 / 10	---
Dibenzo(a,h)anthracene	1.75E-02	--- ^F	3/3	3.30E-02	---	2.82E-02	8.70E-01	---	6.22E-03	1.35E-01	6.34E-02	2.60E-01	3.30E-02	---	1 / 8	---
Endrin	1.17E-03	--- ^F	1/3	2.22E-03	---	---	---	4.20E-02	2.67E-03	6.24E-02	2.00E-04	4.50E-02	2.20E-03	2.07E-01	1 / 8	---
Fluoranthene	2.00E-01	--- ^F	3/3	4.23E-01	6.42E-02	8.34E-01	7.50E+00	6.20E+00	1.11E-01	2.36E+00	6.00E-01	5.10E+00	4.23E-01	2.23E+00	2 / 11	---
Fluorene	1.14E-02	--- ^F	3/3	7.74E-02	3.46E-02	6.52E-01	1.80E+00	5.40E-01	2.12E-02	1.44E-01	1.90E-02	5.40E-01	7.74E-02	5.36E-01	0 / 11	---
Heptachlor	1.10E-03	--- ^F	3/3	6.80E-02	---	---	---	6.80E-02	6.00E-04	2.74E-03	---	---	---	---	1 / 4	---
Indeno(1,2,3-cd)pyrene	1.05E-01	--- ^F	3/3	1.90E-01	7.80E-02	8.37E-01	3.80E+00	---	---	---	---	---	---	---	1 / 4	---
Methoxychlor	5.45E-03	--- ^F	3/3	1.87E-02	---	---	---	1.90E-02	---	---	---	---	---	---	0 / 2	---
Naphthalene	3.15E-02	--- ^F	3/3	1.76E-01	3.28E-02	6.87E-01	2.90E-01	2.40E-01	3.46E-02	3.91E-01	1.60E-01	2.10E+00	1.76E-01	5.61E-01	0 / 11	---
Phenanthrene	1.04E-01	--- ^F	3/3	2.04E-01	---	---	---	1.80E+00	4.19E-02	5.15E-01	2.40E-01	1.50E+00	2.04E-01	1.17E+00	1 / 8	---
Pyrene	1.54E-01	--- ^F	3/3	1.95E-01	5.70E-01	3.23E+00	6.10E+00	---	5.30E-02	8.75E-01	6.65E-01	2.60E+00	1.95E-01	1.52E+00	1 / 10	---
Toluene	4.50E-02	--- ^F	3/3	---	---	---	---	5.00E-02	---	---	---	---	---	---	0 / 1	---
Aluminum	5.77E+03	--- ^F	5/5	---	---	5.80E+04	7.32E+04	---	---	---	---	---	---	---	0 / 2	---
Antimony	4.00E-01	--- ^F	5/5	2.00E+00	---	---	---	---	---	---	2.00E+00	2.50E+01	---	---	0 / 3	---
Arsenic	5.70E+00	--- ^F	5/5	9.80E+00	1.21E+01	5.70E+01	9.29E+01	---	5.90E+00	1.70E+01	8.20E+00	7.00E+01	9.79E+00	3.30E+01	0 / 10	---
Barium	1.21E+02	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Beryllium	4.70E-01	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Cadmium	3.30E-01	--- ^F	5/5	9.90E-01	5.92E-01	1.17E+01	4.11E+01	---	6.00E-01	3.50E+00	1.20E+00	9.60E+00	9.90E-01	4.98E+00	0 / 10	---
Calcium	2.16E+04	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Chromium	1.84E+01	--- ^F	5/5	4.34E+01	5.60E+01	1.59E+02	3.12E+02	---	3.73E+01	9.00E+01	8.10E+01	3.70E+02	4.34E+01	1.11E+02	0 / 10	---
Cobalt	8.10E+00	--- ^F	5/5	5.00E+01	---	---	---	---	---	---	---	---	---	---	0 / 1	---
Copper	8.08E+01	--- ^F	5/5	3.16E+01	2.80E+01	7.77E+01	5.48E+01	---	3.57E+01	1.97E+02	3.40E+01	2.70E+02	3.16E+01	1.49E+02	7 / 10	---
Iron	2.96E+04	--- ^F	5/5	2.00E+04	---	---	---	---	---	---	---	---	---	---	1 / 1	---
Lead	2.54E+01	--- ^F	5/5	3.58E+01	3.42E+01	3.96E+02	6.87E+01	---	3.50E+01	9.13E+01	4.67E+01	2.18E+02	3.58E+01	1.28E+02	0 / 10	---
Magnesium	6.87E+03	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Manganese	4.33E+02	--- ^F	5/5	4.60E+02	1.67E+03	1.08E+03	8.19E+02	---	---	---	---	---	---	---	0 / 4	---

Table 7-17
Direct Contact Toxicity Evaluation for Sediment at the Firing Point/Berm Area
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COPEC	MDC (mg/kg)	EPC (mg/kg)	Frequency of Detection	USEPA Region 3 BTAG (mg/kg) ^A	ARCS ^B			SQB (mg/kg) ^{B,C}	Canadian ISQG (mg/kg) ^D	Canadian PEL (mg/kg) ^D	NOAA ^B		MacDonald et al., 2000 ^E		Weight of Evidence Exceedence	
					TEC (mg/kg)	PEC (mg/kg)	NEC (mg/kg)				ER-L (mg/kg)	ER-M (mg/kg)	Consensus- based TEC (mg/kg)	Consensus- based PEC (mg/kg)	Using MDC	Using EPC
Mercury	3.00E-02	--- ^F	5/5	1.80E-01	---	---	---	---	1.70E-01	4.86E-01	1.50E-01	7.10E-01	1.80E-01	1.06E+00	0 / 7	---
Nickel	1.14E+01	--- ^F	5/5	2.27E+01	3.96E+01	3.85E+01	3.79E+01	---	---	---	2.09E+01	5.16E+01	2.27E+01	4.86E+01	0 / 8	---
Potassium	6.35E+02	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Silver	1.50E-01	--- ^F	3/5	1.00E+00	---	---	---	---	---	---	1.00E+00	3.70E+00	---	---	0 / 3	---
Sodium	5.46E+01	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Vanadium	2.04E+01	--- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Zinc	5.03E+01	--- ^F	5/5	1.21E+02	1.59E+02	1.53E+03	5.41E+02	---	1.23E+02	3.15E+02	1.50E+02	4.10E+02	1.21E+02	4.59E+02	0 / 10	---

--- No Value Available

ARCS = Assessment and Remediation of Contaminated Sediment

COPEC = Chemical of Potential Ecological Concern.

EPC = Exposure Point Concentration. The 95% upper confidence limit concentration was selected as the EPC unless it exceeded the maximum detected concentration, in which case the MDC was chosen as the EPC.

ER-L = Effect Range-Low

ER-M = Effect Range Median

FDEP = Florida Department of Environmental Protection

ISQG = Interim Sediment Quality Guideline

MDC = Maximum detected concentration.

NEC = High No Effect Concentration

NOAA = National Oceanic and Atmospheric Administration

PEC = Probable Effect Concentration

PEL = Probably Effect Level

SQB = Sediment Quality Benchmark

TEC = Threshold Effect Concentration

TEL = Threshold Effect Level

ARCS, SQB, and Canadian values for freshwater environments.

NOAA and FDEP values for estuarine and marine environments, but may be used for screening purposes.

^A Screening toxicity values from USEPA Region 3 BTAG, August 2006.

^B Values from Jones, D.S and Suter, G.W. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision. ES/ER/TM-95/R4.

^C The lowest of the Eq P-derived sediment quality benchmarks presented in Jones, D.S and Suter, G.W. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision. ES/ER/TM-95/R4. is presented here (assumed TOC of 1%).

^D Values from Canadian Council of Ministers of the Environment (CCME). 2003. Canadian Environmental Quality Guidelines. Summary Table Update 2003.

^E Consensus-based sediment quality guidelines, threshold effect concentrations (TECs) and probable effect concentrations (PECs), MacDonald et al., 2000.

^F The 95% UCL EPC was not calculated because the sample size was less than or equal to five.

- The remaining 36 COPECs: (2-methylnaphthalene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, acenaphthene, acenaphthylene, anthracene, Aroclor-1254, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, endrin, fluoranthene, fluorene, heptachlor, indeno(1,2,3-cd)pyrene, methoxychlor, naphthalene, phenanthrene, pyrene, toluene, aluminum, antimony, arsenic, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and silver) had MDCs that exceeded less than half of their respective sediment benchmarks. Therefore, no further action is required for these COPECs in sediment at the Firing Point/Berm Area.

These results suggest that direct contact toxicity for COPECs in sediment may be a concern for copper, iron, and benzo(b)fluoranthene at the Firing Point/Berm Area.

7.2.4.3 Surface Water

For aquatic organisms potentially exposed to COPECs in surface water collected from the Firing Point/Berm Area, comparisons of the MDC to promulgated water quality criteria, or a weight-of-evidence approach (for constituents without promulgated criteria) was utilized (see Section 7.1.9.3 for more details). The results are summarized in **Table 7-18**.

- It should be noted that, for copper, the current version of the NRWQC (USEPA, 2013) recommends the use of the Biotic Ligand Model (BLM) to derive site-specific copper criteria for freshwater environments. However, as the BLM requires ten site-specific water quality parameter inputs, which are not available for the ARSAR surface water, the copper criteria from NRWQC was not used.

Seventeen surface water COPECs were compared with the individual surface water screening values. The results of the surface water screening are as follows (note: chromium was screened against Cr III and Cr VI):

- There were no promulgated water quality criteria or alternate surface water screening benchmarks available for perchlorate in the sources discussed above. However, USACHPPM (2007) has a recommended perchlorate screening concentration of 23 µg/L for the protection of amphibians. As the perchlorate EPC at the Firing Point/Berm Area was 0.236 µg/L, perchlorate is not an ecological concern.
- The aluminum MDC and EPC only exceeded three of the seven available benchmarks for aluminum. However, aluminum exceeded the NRWQC for chronic exposure. It should be noted that the aluminum chronic criterion of 87 µg/L is based on a toxicity test with striped bass in water with pH that ranged from 6.5 to 6.6 and a hardness less than 10 mg/L. As stated in USEPA (2013), data in Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia (May 1994), which was used for the criterion development, indicate that aluminum is substantially less toxic at higher pH and hardness, but the effects of pH and hardness are not well quantified. As the hardness in the surface water at the site is expected to be much greater than 10 mg/L (average calculated hardness based on five magnesium and calcium samples collected at the site was 164 mg/L as CaCO₃), and the pH is only slightly below 6.6 (geometric mean of pH based on five field pH measurements collected at the site was 5.9), aluminum is not expected to be toxic to sensitive aquatic life at the site. Based on this finding, it is

Table 7-18
Surface Water Direct Contact Assessment for Aquatic Life at the Firing Point/Berm Area

COPEC	MDC (ug/L)	EPC (ug/L)	Frequency of Detection	USEPA Region 3 BTAG (ug/L) ^A	NRWQC (ug/L) ^B		Virginia Criteria (ug/L) ^C		Tier II Secondary Values (ug/L) ^D		Lowest Chronic Values (ug/L) ^D				USEPA Region 4 Benchmark Screening Values (ug/L) ^E	Weight of Evidence Exceedence	
					Acute	Chronic	Acute	Chronic	Acute	Chronic	Fish	Daphnids	Non-Daphnids	Aquatic Plants		Using MDC	Using EPC
Di-n-butyl phthalate	9.70E-01	-- ^F	1/3	1.90E+01	---	---	---	---	1.90E+02	3.50E+01	7.17E+02	6.97E+02	---	---	9.40E+00	0 / 6	---
Methoxychlor	1.50E-02	-- ^F	1/3	1.90E-02	---	---	---	3.00E-02	---	1.90E-02	---	---	---	---	3.00E-02	0 / 4	---
Methyl chloride	1.10E-01	-- ^F	3/3	---	---	---	---	---	---	---	---	---	---	---	5.50E+03	0 / 1	---
Perchlorate	2.36E-01	-- ^F	5/5	---	---	---	---	---	---	---	---	---	---	---	---	0 / 0	---
Aluminum	2.85E+02	-- ^F	5/5	8.70E+01	7.50E+02	8.70E+01	---	---	---	---	3.29E+03	1.90E+03	---	4.60E+02	8.70E+01	3 / 7	---
Barium	4.68E+01	-- ^F	5/5	4.00E+00	---	---	---	---	1.10E+02	4.00E+00	---	---	---	---	3.90E+00	3 / 4	---
Calcium	3.86E+04	-- ^F	5/5	1.16E+05	---	---	---	---	---	---	---	1.16E+05	---	---	1.16E+05	0 / 3	---
Chromium (III)	9.70E-01	-- ^F	1/5	7.40E+01	5.70E+02	7.40E+01	5.70E+02	7.40E+01	---	---	6.86E+01	4.40E+01	---	3.97E+02	1.17E+02	0 / 9	---
Chromium (VI)	9.70E-01	-- ^F	1/5	1.10E+01	1.60E+01	1.10E+01	1.60E+01	1.10E+01	---	---	7.32E+01	6.13E+00	---	2.00E+00	1.10E+01	0 / 9	---
Copper	1.70E+00	-- ^F	1/5	9.00E+00	--- ^G	--- ^G	1.30E+01	9.00E+00	---	---	3.80E+00	2.30E-01	6.07E+00	1.00E+00	6.54E+00	2 / 8	---
Iron	4.40E+02	-- ^F	5/5	3.00E+02	---	1.00E+03	---	---	---	---	1.30E+03	1.58E+02	---	---	1.00E+03	2 / 5	---
Magnesium	1.69E+04	-- ^F	5/5	8.20E+04	---	---	---	---	---	---	---	8.20E+04	---	---	8.20E+04	0 / 3	---
Manganese	3.60E+01	-- ^F	5/5	1.20E+02	---	---	---	---	2.30E+03	1.20E+02	1.78E+03	1.10E+03	---	---	8.00E+01	0 / 6	---
Nickel	9.60E-01	-- ^F	4/5	5.20E+01	4.70E+02	5.20E+01	1.80E+02	2.00E+01	---	---	3.50E+01	5.00E+00	1.28E+02	5.00E+00	8.77E+01	0 / 9	---
Potassium	1.80E+03	-- ^F	5/5	5.30E+04	---	---	---	---	---	---	---	5.30E+04	---	---	5.30E+04	0 / 3	---
Sodium	1.18E+04	-- ^F	5/5	6.80E+05	---	---	---	---	---	---	---	6.80E+05	---	---	6.80E+05	0 / 3	---
Vanadium	1.00E+00	-- ^F	1/5	2.00E+01	---	---	---	---	2.80E+02	2.00E+01	8.00E+01	1.90E+03	---	---	1.90E+01	0 / 6	---
Zinc	3.30E+00	-- ^F	1/5	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	---	---	3.64E+01	4.67E+01	5.24E+03	3.00E+01	5.89E+01	0 / 10	---

Bold value indicates an exceedance of the NRWQC and/or Virginia WQS.

--- = No Value Available.

COPEC = Chemical of potential ecological concern.

EPC = Exposure Point Concentration. The 95% UCL was selected as the EPC unless it exceeded the maximum detected concentration, in which case the MDC was chosen as the EPC.

MDC = Maximum detected concentration.

NRWQC = National Recommended Water Quality Criteria.

95% UCL = 95% upper confidence limit concentration.

^A Values from USEPA Region 3 BTAG Screening Levels (July 2006). Values are for freshwater.

^B Unless otherwise noted, freshwater values from USEPA National Recommended Water Quality Criteria, updated January 2013. Source: <http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm>, accessed 03/11/13.

^C Values from Virginia Water Quality Standards, 9 VAC 25-260, January 2011.

^D Unless otherwise noted, values from Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision, ES/ER/TM-96/R2.

^E Values from USEPA Region 4 Ecological Benchmark Screening Values for Surface Water (2000).

^F The 95% UCL EPC was not calculated because the sample size was less than or equal to five.

^G The Biotic-Ligand Model (BLM) is used to determine the copper freshwater criteria. All of the required site-specific chemical input parameters are not available for the BLM.

possible, but unlikely, that organisms inhabiting the stream near the Firing Point/Berm Area may be adversely impacted by levels of aluminum.

- The barium MDC and EPC exceeded three of the four available benchmarks for barium. Therefore, there is potential for direct contact toxicity for barium at the Firing Point/Berm Area. Based on this finding, it is possible that organisms inhabiting the stream near the Firing Point/Berm Area may be adversely impacted by levels of barium.
- The remaining 15 COPECs: [di-n-butyl phthalate, methoxychlor, methyl chloride, calcium, chromium (III), chromium (VI), copper, iron, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc] had MDCs that did not exceed promulgated criteria (if available) and exceeded less than half of their respective surface water benchmarks. Therefore, no further action is required for these COPECs in surface water at the Firing Point/Berm Area.

These results suggest that direct contact toxicity for COPECs in surface water may be a concern for aluminum and barium at the ARSAR.

7.2.6 Background Metals Considerations

Based on the Tier 2 LOAEL foodchain assessment, there were eight inorganic COPEC drivers (arsenic, cadmium, chromium, copper, lead, nickel, selenium, and zinc) with EEQs greater than one. The COPEC hazard driver for the surface soil direct contact assessment was manganese. Inorganic COPECs that were not statistically different based on appropriate statistical tests are considered background related (see *Section 6.4.3* for additional details of background evaluation). Based on information presented in **Table 7-19**, copper and selenium are the only COPECs in surface soil considered to be potentially site related and not attributed to background at the Firing Point/Berm Area. However, it should be noted that for selenium, the mean and median of the detected site values were below the mean and median of the detected background values, and the failure of the statistical test may have been due to the unequal detection frequency of the site compared with the background data set (65 percent vs. 7 percent, respectively) and differing detection limits.

Table 7-19
Background Comparison for Surface Soil at the Firing Point/Berm Area

Soil COPEC	Gehan Test ^{a, b} Site > Background?	Considered to be Background?
Arsenic	No	Yes
Cadmium	No	Yes
Chromium	No	Yes
Copper	Yes	No
Lead	No	Yes
Manganese	No	Yes
Nickel	No	Yes
Selenium	Yes	No
Zinc	No	Yes

^a Gehan test used unless otherwise noted. See Appendix for backup statistics.

^b If both site and background data sets had normal distribution with 100% detects, the t-test was used (Note: None of the COPECs listed above met this condition).

7.2.7 Uncertainty Analysis

There were 123, 130, and 161 chemical constituents not detected in surface soil, sediment, and surface water analytical samples, respectively. **Appendix F-2, Tables F-35** (surface soil), **F-36** (sediment), and **F-37** (surface water) evaluate the uncertainty associated with these constituents' detection limits by presenting a comparison of the maximum detection limit for each non-detect constituent with a conservative ecological toxicity screening value. Region III BTAG soil SLs are antiquated (last published in 1995 and no longer readily available) relative to Region III BTAG surface water and sediment values (updated in 2006); therefore, non-detect soil values were compared to BTAG soil levels as well as additional soil screening values presented in **Appendix F-2, Table F-38**. Region III BTAG sediment and surface water screening values were used for the sediment and surface water comparison.

Thirty-two of the non-detect surface soil, 45 of the non-detect sediment, and 35 of the non-detect surface water constituents had maximum detection limits that exceeded the available screening criteria, respectively. These findings are not unexpected, given the conservative and numerically low screening values.

7.2.7.1 Uncertainties with Surface Soil EEQs

The inorganic COPECs cadmium, chromium, copper, lead, nickel, selenium, and zinc had Tier 2 LOAEL-based EEQs that exceeded 1 when round to one significant figure. Given the uncertainties associated with the SLERA process, the key parameters associated with these elevated EEQs (greater than 1 when rounded to one significant figure) were examined in more detail.

Cadmium. For cadmium, the mammalian-LOAEL TRV of 1.6 mg/kg-day was based on a laboratory rat study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 4 for the vole (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the cadmium shrew EEQ of 2.0 dropping to 1.0.

Chromium. For chromium, the avian-LOAEL TRV of 2.78 mg/kg-day was based on a laboratory black duck study, as cited in USEPA (2007b), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the robin (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 4 would result in the chromium robin EEQ of 2.2 dropping to 1.

Copper. For copper, the mammalian-LOAEL TRV of 5.78 mg/kg-day was based on a laboratory rat study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the copper shrew EEQ of 3.7 dropping to less than 1. The avian-LOAEL TRV of 4.88 mg/kg-day was based on a laboratory turkey study, as cited in USEPA (2007b), therefore, the EEQ calculation used a TRV extrapolation UF of 8 (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the copper robin EEQ of 3.0 dropping to less than 1.

Lead. For lead, the mammalian-LOAEL TRV of 5 mg/kg-day was based on a rat study cited in Eco-SSL (2005), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an

alternative UF of 1 would result in the lead shrew EEQ of 9.0 dropping to 1 when rounded to one significant figure. The avian-LOAEL TRV of 1.94 mg/kg-day was based on a quail study cited in Eco-SSL (2005), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the robin (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of 1 would result in the lead robin EEQ of 11 dropping to 1 when rounded to one significant figure.

Nickel. For nickel, the mammalian-LOAEL TRV of 2.71 mg/kg-day was based on a laboratory rat study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of 1 would result in the nickel shrew EEQ of 6.8 dropping to less than 1.

Selenium. For selenium, the mammalian-LOAEL TRV of 0.145 mg/kg-day was based on a laboratory mouse study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew and 4 for the vole (**Appendix F-2, Table F-34**). The use of these UFs is quite conservative, and the use of alternative UFs of approximately 2 would result in the selenium shrew EEQ of 5.3 dropping to 1 when rounded to one significant figure and the vole EEQ of 1.9 dropping to less than 1. The avian-LOAEL TRV of 0.368 mg/kg-day was based on a laboratory chicken study, as cited in USEPA (2007b), therefore, the EEQ calculation used a TRV extrapolation UF of 8 (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 5 would result in the selenium robin EEQ of 1.5 dropping to less than 1.

Zinc. For zinc, the mammalian-LOAEL TRV of 75.7 mg/kg-day was based on a laboratory sheep study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UFs of approximately 2 for the shrew would result in the zinc shrew EEQ of 4.2 dropping to 1 when rounded to one significant figure. The avian-LOAEL TRV of 66.5 mg/kg-day was based on a laboratory chicken study, as cited in USEPA (2007b), therefore, the EEQ calculation used a TRV extrapolation UF of 8 (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the zinc robin EEQ of 2.5 dropping to less than 1.

Based on this evaluation for the LOAEL-based risk drivers cadmium, chromium, copper, lead, nickel, selenium, and zinc, the use of alternative factors (e.g., an alternative UF for TRV species extrapolation), would reduce the estimated LOAEL-based EEQs to 1 (when rounded to one significant figure) or less than one for all receptors.

7.2.7.2 Uncertainties with Sediment EEQs

No Tier 2 LOAEL-based EEQs exceeded one for COPECs in sediment; therefore, uncertainties associated with sediment EEQs were not evaluated.

7.2.7.3 Uncertainties with Surface Water EEQs

No Tier 2 LOAEL-based EEQs exceeded one for COPECs in surface water; therefore, uncertainties associated with surface water EEQs were not evaluated.

7.2.8 SLERA Results and Conclusions

The SLERA evaluated risks to ecological populations inhabiting terrestrial and aquatic habitats at the Firing Point/Berm Area. Conclusions are derived from the risk assessment and are based on the responses to the assessment hypotheses and assessment endpoints. The assessment results for food chain exposure are summarized in **Table 7-15**, and direct contact exposure results for terrestrial and aquatic invertebrates, which may serve as a food source for wildlife, are summarized in **Tables 7-16, 7-17, and 7-18**, and discussed in *Sections 7.2.3 and 7.2.4*.

The food chain assessment suggests potential adverse impacts to terrestrial wildlife, especially shrews, robins, and voles for modeled contact with cadmium, chromium, copper, lead, nickel, selenium, and zinc in surface soil. However, the use of alternative UFs (e.g., alternative UFs for TRV species extrapolation), would reduce the estimated LOAEL-based EEQs to 1 (when rounded to one significant figure) or less than one for all receptors at the Firing Point/Berm Area.

The direct contact assessment results suggest a potential reduction in wildlife food supply (i.e., plants, soil invertebrates, surface water biota, and sediment biota) due to manganese in surface soil; copper, iron, and benzo(b)fluoranthene in sediment; and aluminum and barium in surface water. However, manganese in surface soil is background related (*Section 7.2.5*) and is not considered further. Although some aluminum concentrations in surface water exceed the promulgated chronic criterion for the protection of aquatic life, aluminum toxicity is expected to be minimal due to the expected presence of moderately hard water at the site and associated reduced bioavailability (*Section 7.2.4.3*).

These SLERA assessment results may serve as the foci of discussions with risk managers and regulatory agencies. It is very important to note that many conservative assumptions and modeling approaches were used in the assessment, and actual hazards to wildlife may be orders of magnitude lower than predicted herein.

7.3 Southeast Hillside Area Screening Level Ecological Risk Assessment

7.3.1 Site Characterization

The ARSAR is an MRS covering approximately 7.6 acres located along the southeastern boundary of the MMA (**Figure 2-1**). Most of the site is an open grass field with wooded areas located along the banks of Stroubles Creek, which is located along the southern portion of the site. As illustrated on **Figure 2-2**, the site is divided into two areas consisting of the Firing Point/Berm Area (6.56 acres) and the Southeast Hillside Area (1.08 acres). The Southeast Hillside Area is a steep, rocky hillside thought to have been used as a backstop prior to the construction of the ARSAR target berm. A fence is located at the top of the southeast hillside. The only ecological medium of concern at the Southeast Hillside Area is surface soil.

7.3.2 Summary of COPEC Selection

As described in *Section 7.1.3.2*, direct contact and foodchain COPECs were selected as shown in **Tables 7-20 and 7-21** (surface soil). In general, COPECs were selected as a concern for the direct contact exposure pathway if the constituent was detected in an environmental medium. For food chain exposure pathways, detected COPECs that were identified as important bioaccumulators (USEPA, 2000c) or explosives were selected (note: there were no detected explosives at the ARSAR).

Table 7-20
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure - Surface Soil
Southeast Hillside Area
Page 1 of 2

Scenario Timeframe: Current/Future

Medium: Soil

Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	91-57-6	2-Methylnaphthalene	5.30E-03	7.00E-03	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	72-55-9	4,4'-DDE	1.25E-03 J	1.25E-03 J	mg/kg	AR SCH01	1/5	3.10E-03 - 3.80E-03	Yes	DET
	50-29-3	4,4'-DDT	1.93E-03 J	5.70E-03	mg/kg	AR SCH02	4/5	3.10E-03 - 3.10E-03	Yes	DET
	208-96-8	Acenaphthylene	1.60E-03 J	2.10E-03 J	mg/kg	AR SCH09	2/5	3.80E-03 - 4.80E-03	Yes	DET
	319-84-6	alpha-BHC	1.80E-03 J	1.80E-03 J	mg/kg	AR SCH09	1/5	3.05E-03 - 3.80E-03	Yes	DET
	11097-69-1	Aroclor 1254	3.70E-02 J	3.70E-02 J	mg/kg	AR SCH03	1/5	1.30E-01 - 1.60E-01	Yes	DET
	56-55-3	Benzo(a)anthracene	3.40E-03 J	7.60E-03	mg/kg	AR SCH09	5/5	N/A	Yes	DET
	50-32-8	Benzo(a)pyrene	1.80E-03 J	3.30E-03 J	mg/kg	AR SCH03	3/5	6.50E-03 - 6.60E-03	Yes	DET
	205-99-2	Benzo(b)fluoranthene	5.10E-03	1.20E-02	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	191-24-2	Benzo(ghi)perylene	2.60E-03 J	7.10E-03	mg/kg	AR SCH09	5/5	N/A	Yes	DET
	207-08-9	Benzo(k)fluoranthene	1.21E-03 J	3.30E-03 J	mg/kg	AR SCH11	4/5	4.80E-03 - 4.80E-03	Yes	DET
	65-85-0	Benzoic Acid	4.50E-01 J	4.80E-01 J	mg/kg	AR SCH09	2/5	3.80E+00 - 4.80E+00	Yes	DET
	319-85-7	beta-BHC	2.10E-02 J	2.10E-02 J	mg/kg	AR SCH11	1/5	3.05E-03 - 3.80E-03	Yes	DET
	218-01-9	Chrysene	3.70E-03 J	1.10E-02	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	60-57-1	Dieldrin	1.10E-03 J	1.33E-03 J	mg/kg	AR SCH01	3/5	3.10E-03 - 3.80E-03	Yes	DET
	959-98-8	Endosulfan I	1.00E-03 J	2.00E-03 J	mg/kg	AR SCH11	2/5	3.05E-03 - 3.80E-03	Yes	DET
	33213-65-9	Endosulfan II	6.50E-04 J	6.50E-04 J	mg/kg	AR SCH09	1/5	3.05E-03 - 3.80E-03	Yes	DET
	1031-07-8	Endosulfan sulfate	1.70E-03 J	1.70E-03 J	mg/kg	AR SCH09	1/5	5.05E-03 - 6.30E-03	Yes	DET
	72-20-8	Endrin	6.30E-04 J	2.55E-03 J	mg/kg	AR SCH01	3/5	3.10E-03 - 3.20E-03	Yes	DET
	7421-93-4	Endrin aldehyde	1.90E-03 J	1.90E-03 J	mg/kg	AR SCH09	1/5	5.05E-03 - 6.30E-03	Yes	DET
	53494-70-5	Endrin ketone	2.70E-03 J	2.70E-03 J	mg/kg	AR SCH09	1/5	5.05E-03 - 6.30E-03	Yes	DET
	206-44-0	Fluoranthene	7.85E-03	1.80E-02	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	86-73-7	Fluorene	1.70E-03 J	2.00E-03 J	mg/kg	AR SCH09	2/5	3.80E-03 - 4.80E-03	Yes	DET
	5103-74-2	gamma-Chlordane	1.00E-03 J	1.28E-03 J	mg/kg	AR SCH01	2/5	3.10E-03 - 3.80E-03	Yes	DET
	1024-57-3	Heptachlor epoxide	1.30E-03 J	1.30E-03 J	mg/kg	AR SCH09	1/5	3.05E-03 - 3.80E-03	Yes	DET
	193-39-5	Indeno(1,2,3-cd)pyrene	3.70E-03 J	6.90E-03	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	58-89-9	Lindane	1.53E-03 J	1.53E-03 J	mg/kg	AR SCH01	1/5	3.10E-03 - 3.80E-03	Yes	DET
	72-43-5	Methoxychlor	1.98E-03 J	5.70E-03	mg/kg	AR SCH02	4/5	3.10E-03 - 3.10E-03	Yes	DET
	91-20-3	Naphthalene	5.90E-03	8.80E-03	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	87-86-5	Pentachlorophenol	3.20E-01 J	3.20E-01 J	mg/kg	AR SCH11	1/5	1.30E+00 - 1.60E+00	Yes	DET
	85-01-8	Phenanthrene	9.55E-03	1.80E-02	mg/kg	AR SCH11	5/5	N/A	Yes	DET
	129-00-0	Pyrene	5.55E-03	1.40E-02	mg/kg	AR SCH09	5/5	N/A	Yes	DET
	7429-90-5	Aluminum	5.61E+03	1.84E+04	mg/kg	AR SCH04	12/12	N/A	Yes	DET

Table 7-20
Occurrence, Distribution and Selection of COPCs for Direct Contact Exposure - Surface Soil
Southeast Hillside Area
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Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Direct Contact COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	7440-36-0	Antimony	1.60E-01 L	6.10E+00 L	mg/kg	ARSCH07	12/12	N/A	Yes	DET
	7440-38-2	Arsenic	1.54E+01 J	4.41E+01 J	mg/kg	ARSCH04	12/12	N/A	Yes	DET
	7440-39-3	Barium	5.05E+01	1.34E+02	mg/kg	ARSCH05	12/12	N/A	Yes	DET
	7440-41-7	Beryllium	3.30E-01 J	1.60E+00	mg/kg	ARSCH11	12/12	N/A	Yes	DET
	7440-43-9	Cadmium	7.80E-03 J	1.30E+00 L	mg/kg	ARSCH10	11/12	7.90E-02 - 7.90E-02	Yes	DET
	7440-70-2	Calcium	1.08E+03	1.44E+05	mg/kg	ARSCH07	12/12	N/A	Yes	DET
	7440-47-3	Chromium	4.50E+00 J	1.72E+01 J	mg/kg	ARSCH10	12/12	N/A	Yes	DET
	7440-48-4	Cobalt	2.60E+00 J	1.45E+01 J	mg/kg	ARSCH10	12/12	N/A	Yes	DET
	7440-50-8	Copper	1.07E+01 J	1.14E+02 J	mg/kg	ARSCH07	12/12	N/A	Yes	DET
	7439-89-6	Iron	1.21E+04 J	6.00E+04 J	mg/kg	ARSCH04	12/12	N/A	Yes	DET
	7439-92-1	Lead	2.19E+01 J	2.50E+03 J	mg/kg	ARSCH07	12/12	N/A	Yes	DET
	7439-95-4	Magnesium	1.50E+03	7.55E+04	mg/kg	ARSCH01	12/12	N/A	Yes	DET
	7439-96-5	Manganese	1.47E+02 J	1.29E+03 J	mg/kg	ARSCH09	12/12	N/A	Yes	DET
	7439-97-6	Mercury	2.95E-02 J	9.00E-02 J	mg/kg	ARSCH05	12/12	N/A	Yes	DET
	7440-02-0	Nickel	4.05E+00 J	2.04E+01 J	mg/kg	ARSCH04	12/12	N/A	Yes	DET
	7440-09-7	Potassium	5.92E+02	1.76E+03	mg/kg	ARSCH11	12/12	N/A	Yes	DET
	7782-49-2	Selenium	3.40E-01 L	1.20E+00 L	mg/kg	ARSCH03	5/12	8.80E-02 - 9.40E-02	Yes	DET
	7440-22-4	Silver	3.90E-02 J	1.00E-01	mg/kg	ARSCH07	9/12	2.15E-02 - 2.30E-02	Yes	DET
	7440-23-5	Sodium	8.30E+00 J	2.55E+02 K	mg/kg	ARSCH12	12/12	N/A	Yes	DET
	7440-28-0	Thallium	4.50E-01 L	1.40E+00 L	mg/kg	ARSCH10	8/9	5.20E-02 - 5.20E-02	Yes	DET
	7440-62-2	Vanadium	1.21E+01 L	4.91E+01 L	mg/kg	ARSCH05	12/12	N/A	Yes	DET
	7440-66-6	Zinc	3.22E+01 J	3.37E+02 L	mg/kg	ARSCH02	12/12	N/A	Yes	DET

COPEC Selection Rationale Codes

Selection Reason: Detected constituent (DET)

Notes/Definitions:

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/kg = milligrams per kilogram

Table 7-21
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure - Surface Soil
Southeast Hillside Area
Page 1 of 2

Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Food Chain COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	91-57-6	2-Methylnaphthalene	5.30E-03	7.00E-03	mg/kg	ARSCH11	5/5	N/A	No	NIBC
	72-55-9	4,4'-DDE	1.25E-03 J	1.25E-03 J	mg/kg	ARSCH01	1/5	3.10E-03 - 3.80E-03	Yes	IBC
	50-29-3	4,4'-DDT	1.93E-03 J	5.70E-03	mg/kg	ARSCH02	4/5	3.10E-03 - 3.10E-03	Yes	IBC
	208-96-8	Acenaphthylene	1.60E-03 J	2.10E-03 J	mg/kg	ARSCH09	2/5	3.80E-03 - 4.80E-03	Yes	IBC
	319-84-6	alpha-BHC	1.80E-03 J	1.80E-03 J	mg/kg	ARSCH09	1/5	3.05E-03 - 3.80E-03	Yes	IBC
	11097-69-1	Aroclor 1254	3.70E-02 J	3.70E-02 J	mg/kg	ARSCH03	1/5	1.30E-01 - 1.60E-01	Yes	IBC
	56-55-3	Benzo(a)anthracene	3.40E-03 J	7.60E-03	mg/kg	ARSCH09	5/5	N/A	Yes	IBC
	50-32-8	Benzo(a)pyrene	1.80E-03 J	3.30E-03 J	mg/kg	ARSCH03	3/5	6.50E-03 - 6.60E-03	Yes	IBC
	205-99-2	Benzo(b)fluoranthene	5.10E-03	1.20E-02	mg/kg	ARSCH11	5/5	N/A	Yes	IBC
	191-24-2	Benzo(ghi)perylene	2.60E-03 J	7.10E-03	mg/kg	ARSCH09	5/5	N/A	Yes	IBC
	207-08-9	Benzo(k)fluoranthene	1.21E-03 J	3.30E-03 J	mg/kg	ARSCH11	4/5	4.80E-03 - 4.80E-03	Yes	IBC
	65-85-0	Benzoic Acid	4.50E-01 J	4.80E-01 J	mg/kg	ARSCH09	2/5	3.80E+00 - 4.80E+00	No	NIBC
	319-85-7	beta-BHC	2.10E-02 J	2.10E-02 J	mg/kg	ARSCH11	1/5	3.05E-03 - 3.80E-03	Yes	IBC
	218-01-9	Chrysene	3.70E-03 J	1.10E-02	mg/kg	ARSCH11	5/5	N/A	Yes	IBC
	60-57-1	Dieldrin	1.10E-03 J	1.33E-03 J	mg/kg	ARSCH01	3/5	3.10E-03 - 3.80E-03	Yes	IBC
	959-98-8	Endosulfan I	1.00E-03 J	2.00E-03 J	mg/kg	ARSCH11	2/5	3.05E-03 - 3.80E-03	Yes	IBC
	33213-65-9	Endosulfan II	6.50E-04 J	6.50E-04 J	mg/kg	ARSCH09	1/5	3.05E-03 - 3.80E-03	Yes	IBC
	1031-07-8	Endosulfan sulfate	1.70E-03 J	1.70E-03 J	mg/kg	ARSCH09	1/5	5.05E-03 - 6.30E-03	Yes	IBC
	72-20-8	Endrin	6.30E-04 J	2.55E-03 J	mg/kg	ARSCH01	3/5	3.10E-03 - 3.20E-03	Yes	IBC
	7421-93-4	Endrin aldehyde	1.90E-03 J	1.90E-03 J	mg/kg	ARSCH09	1/5	5.05E-03 - 6.30E-03	Yes	IBC
	53494-70-5	Endrin ketone	2.70E-03 J	2.70E-03 J	mg/kg	ARSCH09	1/5	5.05E-03 - 6.30E-03	Yes	IBC
	206-44-0	Fluoranthene	7.85E-03	1.80E-02	mg/kg	ARSCH11	5/5	N/A	Yes	IBC
	86-73-7	Fluorene	1.70E-03 J	2.00E-03 J	mg/kg	ARSCH09	2/5	3.80E-03 - 4.80E-03	Yes	IBC
	5103-74-2	gamma-Chlordane	1.00E-03 J	1.28E-03 J	mg/kg	ARSCH01	2/5	3.10E-03 - 3.80E-03	Yes	IBC
	1024-57-3	Heptachlor epoxide	1.30E-03 J	1.30E-03 J	mg/kg	ARSCH09	1/5	3.05E-03 - 3.80E-03	Yes	IBC
	193-39-5	Indeno(1,2,3-cd)pyrene	3.70E-03 J	6.90E-03	mg/kg	ARSCH11	5/5	N/A	Yes	IBC
	58-89-9	gamma-BHC (Lindane)	1.53E-03 J	1.53E-03 J	mg/kg	ARSCH01	1/5	3.10E-03 - 3.80E-03	Yes	IBC
	72-43-5	Methoxychlor	1.98E-03 J	5.70E-03	mg/kg	ARSCH02	4/5	3.10E-03 - 3.10E-03	Yes	IBC
	91-20-3	Naphthalene	5.90E-03	8.80E-03	mg/kg	ARSCH11	5/5	N/A	No	NIBC
	87-86-5	Pentachlorophenol	3.20E-01 J	3.20E-01 J	mg/kg	ARSCH11	1/5	1.30E+00 - 1.60E+00	Yes	IBC
	85-01-8	Phenanthrene	9.55E-03	1.80E-02	mg/kg	ARSCH11	5/5	N/A	Yes	IBC
	129-00-0	Pyrene	5.55E-03	1.40E-02	mg/kg	ARSCH09	5/5	N/A	Yes	IBC
	7429-90-5	Aluminum	5.61E+03	1.84E+04	mg/kg	ARSCH04	12/12	N/A	No	NIBC

Table 7-21
Occurrence, Distribution and Selection of COPCs for Food Chain Exposure - Surface Soil
Southeast Hillside Area
Page 2 of 2

Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil (0-2 feet bgs)

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier)	Maximum Concentration (Qualifier)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Food Chain COPEC (Y/N)	Rationale for Selection or Deletion
Surface Soil	7440-36-0	Antimony	1.60E-01 L	6.10E+00 L	mg/kg	ARSCH07	12/12	N/A	No	NIBC
	7440-38-2	Arsenic	1.54E+01 J	4.41E+01 J	mg/kg	ARSCH04	12/12	N/A	Yes	IBC
	7440-39-3	Barium	5.05E+01	1.34E+02	mg/kg	ARSCH05	12/12	N/A	No	NIBC
	7440-41-7	Beryllium	3.30E-01 J	1.60E+00	mg/kg	ARSCH11	12/12	N/A	No	NIBC
	7440-43-9	Cadmium	7.80E-03 J	1.30E+00 L	mg/kg	ARSCH10	11/12	7.90E-02 - 7.90E-02	Yes	IBC
	7440-70-2	Calcium	1.08E+03	1.44E+05	mg/kg	ARSCH07	12/12	N/A	No	NIBC
	7440-47-3	Chromium	4.50E+00 J	1.72E+01 J	mg/kg	ARSCH10	12/12	N/A	Yes	IBC
	7440-48-4	Cobalt	2.60E+00 J	1.45E+01 J	mg/kg	ARSCH10	12/12	N/A	No	NIBC
	7440-50-8	Copper	1.07E+01 J	1.14E+02 J	mg/kg	ARSCH07	12/12	N/A	Yes	IBC
	7439-89-6	Iron	1.21E+04 J	6.00E+04 J	mg/kg	ARSCH04	12/12	N/A	No	NIBC
	7439-92-1	Lead	2.19E+01 J	2.50E+03 J	mg/kg	ARSCH07	12/12	N/A	Yes	IBC
	7439-95-4	Magnesium	1.50E+03	7.55E+04	mg/kg	ARSCH01	12/12	N/A	No	NIBC
	7439-96-5	Manganese	1.47E+02 J	1.29E+03 J	mg/kg	ARSCH09	12/12	N/A	No	NIBC
	7439-97-6	Mercury	2.95E-02 J	9.00E-02 J	mg/kg	ARSCH05	12/12	N/A	Yes	IBC
	7440-02-0	Nickel	4.05E+00 J	2.04E+01 J	mg/kg	ARSCH04	12/12	N/A	Yes	IBC
	7440-09-7	Potassium	5.92E+02	1.76E+03	mg/kg	ARSCH11	12/12	N/A	No	NIBC
	7782-49-2	Selenium	3.40E-01 L	1.20E+00 L	mg/kg	ARSCH03	5/12	8.80E-02 - 9.40E-02	Yes	IBC
	7440-22-4	Silver	3.90E-02 J	1.00E-01	mg/kg	ARSCH07	9/12	2.15E-02 - 2.30E-02	Yes	IBC
	7440-23-5	Sodium	8.30E+00 J	2.55E+02 K	mg/kg	ARSCH12	12/12	N/A	No	NIBC
	7440-28-0	Thallium	4.50E-01 L	1.40E+00 L	mg/kg	ARSCH10	8/9	5.20E-02 - 5.20E-02	No	NIBC
	7440-62-2	Vanadium	1.21E+01 L	4.91E+01 L	mg/kg	ARSCH05	12/12	N/A	No	NIBC
	7440-66-6	Zinc	3.22E+01 J	3.37E+02 L	mg/kg	ARSCH02	12/12	N/A	Yes	IBC

COPEC Selection Rationale Codes

Selection Reason: Important Bioaccumulative Compounds (IBC) [as defined in Table 4-2, of USEPA 823-R-00-001, February 2000]

Deletion Reason: Not Important Bioaccumulative Compound (NIBC)

Notes/Definitions

N/A = Not Applicable or Not Available

COPEC = Chemical of Potential Ecological Concern

J = Estimated Value

L = Estimated Value

mg/kg = milligrams per kilogram

Fifty-five COPECs (**Table 7-20**) were selected in surface soil for the evaluation of direct contact exposure (*Section 7.3.4*) and 39 COPECs (**Table 7-21**) were selected for the evaluation of food chain exposure (*Section 7.3.3*).

EPCs based on the statistical procedures discussed in *Section 7.1.3.3* are presented in **Table 7-22**. Arithmetic mean concentrations are presented for informational purposes.

7.3.3 Risk Characterization

Tier 1 and Tier 2 individual COPEC EEQs and HIs (summed EEQs) for terrestrial receptors at the Southeast Hillside Area are presented in risk characterization tables (**Appendix F-2, Tables F-17 through F-26**).

These summed EEQs are presented in **Table 7-23** (generally rounded to two significant figures), along with the hazard driver [COPEC(s) contributing the majority of the total estimated EEQ] and the exposure pathway of concern (the pathway contributing the most to the total estimated EEQ).

As shown in **Table 7-23**, Tier 1 total EEQs ranged from 21 to 525 for the five receptor species, using TRVs based on either NOAEL or LOAEL values. The short-tailed shrew was predicted to be the most impacted, followed by the American robin, the meadow vole, the red fox, and the red-tailed hawk. The inorganic constituents lead, nickel, and selenium contributed the most to the total EEQs for these receptors. Exposure pathways of most concern, based on the results of the Tier 1 food chain modeling were: plant, terrestrial invertebrate, small mammal, and incidental soil ingestion.

More realistic Tier 2 total EEQs were also elevated, especially values based on NOAEL TRVs, which ranged from 0.004 to 151. However, Tier 2 total EEQs were much lower than Tier 1 total EEQs, and both the NOAEL and LOAEL Tier 2 total EEQs for the red-tailed hawk and red fox, were below one (**Table 7-23**). Lead and selenium were identified as the main hazard drivers for the wildlife receptors, based on soil and terrestrial invertebrate ingestion for the short-tailed shrew and the American robin, and soil and plant ingestion for the meadow vole.

The specific results of the Tier 2 risk estimation for the meadow vole, short-tailed shrew, and American robin are discussed below. The specific results for the red-tailed hawk and red fox are not discussed because the summed EEQs are below one.

Meadow Vole. The total EEQs for both NOAEL and LOAEL TRVs exceeded 1 (27 and 19, respectively). Five COPECs had individual NOAEL-based EEQs that exceeded 1 (EEQ in parenthesis): lead (9.7), selenium (6.1), arsenic (3.6), copper (3.5), and zinc (1.8). Five COPECs had individual LOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (9.1), selenium (3.0), arsenic (2.3), zinc (1.8), and copper (1.7). The primary exposure pathway was the ingestion of soil and plants. The results of the Tier 2 risk evaluation for meadow voles are presented in **Appendix F-2, Table F-18**.

Short-tailed Shrew. The total EEQs for both NOAEL and LOAEL TRVs exceeded 1 (151 and 133, respectively). Nine COPECs had individual NOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (100), nickel (11), selenium (7.2), copper (6.8), arsenic (6.7), zinc (6.3), cadmium (4.9), chromium (2.3), and dieldrin (1.4). Seven COPECs had individual LOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (94), selenium (7.1), nickel (7.1), copper (6.6), zinc (6.3), cadmium (4.5), and arsenic (4.2). The primary exposure

Table 7-22
Medium-Specific Exposure Point Concentration Summary for the Southeast Hillside Area - Surface Soil
Page 1 of 2

Scenario Timeframe: Current/Future
Medium: Soil
Exposure Medium: Surface Soil

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Surface Soil	2-Methylnaphthalene	mg/kg	6.30E-03	N/A	N/A	7.00E-03	7.00E-03	mg/kg	Max	Test (7)
	4,4'-DDE	mg/kg	1.25E-03	N/A	N/A	1.25E-03	1.25E-03	mg/kg	Max	Test (7)
	4,4'-DDT	mg/kg	2.96E-03	N/A	N/A	5.70E-03	5.70E-03	mg/kg	Max	Test (7)
	Acenaphthylene	mg/kg	1.85E-03	N/A	N/A	2.10E-03	2.10E-03	mg/kg	Max	Test (7)
	alpha-BHC	mg/kg	1.80E-03	N/A	N/A	1.80E-03	1.80E-03	mg/kg	Max	Test (7)
	Aroclor 1254	mg/kg	3.70E-02	N/A	N/A	3.70E-02	3.70E-02	mg/kg	Max	Test (7)
	Benzo(a)anthracene	mg/kg	5.34E-03	N/A	N/A	7.60E-03	7.60E-03	mg/kg	Max	Test (7)
	Benzo(a)pyrene	mg/kg	2.47E-03	N/A	N/A	3.30E-03	3.30E-03	mg/kg	Max	Test (7)
	Benzo(b)fluoranthene	mg/kg	8.15E-03	N/A	N/A	1.20E-02	1.20E-02	mg/kg	Max	Test (7)
	Benzo(ghi)perylene	mg/kg	4.58E-03	N/A	N/A	7.10E-03	7.10E-03	mg/kg	Max	Test (7)
	Benzo(k)fluoranthene	mg/kg	2.28E-03	N/A	N/A	3.30E-03	3.30E-03	mg/kg	Max	Test (7)
	Benzoic Acid	mg/kg	4.65E-01	N/A	N/A	4.80E-01	4.80E-01	mg/kg	Max	Test (7)
	beta-BHC	mg/kg	2.10E-02	N/A	N/A	2.10E-02	2.10E-02	mg/kg	Max	Test (7)
	Chrysene	mg/kg	6.63E-03	N/A	N/A	1.10E-02	1.10E-02	mg/kg	Max	Test (7)
	Dieldrin	mg/kg	1.24E-03	N/A	N/A	1.33E-03	1.33E-03	mg/kg	Max	Test (7)
	Endosulfan I	mg/kg	1.50E-03	N/A	N/A	2.00E-03	2.00E-03	mg/kg	Max	Test (7)
	Endosulfan II	mg/kg	6.50E-04	N/A	N/A	6.50E-04	6.50E-04	mg/kg	Max	Test (7)
	Endosulfan sulfate	mg/kg	1.70E-03	N/A	N/A	1.70E-03	1.70E-03	mg/kg	Max	Test (7)
	Endrin	mg/kg	1.66E-03	N/A	N/A	2.55E-03	2.55E-03	mg/kg	Max	Test (7)
	Endrin aldehyde	mg/kg	1.90E-03	N/A	N/A	1.90E-03	1.90E-03	mg/kg	Max	Test (7)
	Endrin ketone	mg/kg	2.70E-03	N/A	N/A	2.70E-03	2.70E-03	mg/kg	Max	Test (7)
	Fluoranthene	mg/kg	1.32E-02	N/A	N/A	1.80E-02	1.80E-02	mg/kg	Max	Test (7)
	Fluorene	mg/kg	1.85E-03	N/A	N/A	2.00E-03	2.00E-03	mg/kg	Max	Test (7)
	gamma-BHC (Lindane)	mg/kg	1.53E-03	N/A	N/A	1.53E-03	1.53E-03	mg/kg	Max	Test (7)
	gamma-Chlordane	mg/kg	1.14E-03	N/A	N/A	1.28E-03	1.28E-03	mg/kg	Max	Test (7)
	Heptachlor epoxide	mg/kg	1.30E-03	N/A	N/A	1.30E-03	1.30E-03	mg/kg	Max	Test (7)
	Indeno(1,2,3-cd)pyrene	mg/kg	5.04E-03	N/A	N/A	6.90E-03	6.90E-03	mg/kg	Max	Test (7)
	Methoxychlor	mg/kg	3.57E-03	N/A	N/A	5.70E-03	5.70E-03	mg/kg	Max	Test (7)
	Naphthalene	mg/kg	7.70E-03	N/A	N/A	8.80E-03	8.80E-03	mg/kg	Max	Test (7)
	Pentachlorophenol	mg/kg	3.20E-01	N/A	N/A	3.20E-01	3.20E-01	mg/kg	Max	Test (7)
	Phenanthrene	mg/kg	1.47E-02	N/A	N/A	1.80E-02	1.80E-02	mg/kg	Max	Test (7)
	Pyrene	mg/kg	9.49E-03	N/A	N/A	1.40E-02	1.40E-02	mg/kg	Max	Test (7)
	Aluminum	mg/kg	1.26E+04	No	1.52E+04 (N)	1.84E+04	1.52E+04	mg/kg	95% Student's-t	Test (4)

Table 7-22
Medium-Specific Exposure Point Concentration Summary for the Southeast Hillside Area - Surface Soil
Page 2 of 2

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean of Detects	Multiple Detection Limits? (Yes/No) ¹	95% UCL (Distribution) ²	Maximum Concentration	Exposure Point Concentration			
							Value	Units	Statistic ³	Rationale ⁴
Surface Soil	Antimony	mg/kg	1.34E+00	No	2.39E+00 (G)	6.10E+00	2.39E+00	mg/kg	95% Approx. Gamma	Test (6)
	Arsenic	mg/kg	2.88E+01	No	3.42E+01 (N)	4.41E+01	3.42E+01	mg/kg	95% Student's-t	Test (4)
	Barium	mg/kg	9.06E+01	No	1.07E+02 (N)	1.34E+02	1.07E+02	mg/kg	95% Student's-t	Test (4)
	Beryllium	mg/kg	1.02E+00	No	1.26E+00 (N)	1.60E+00	1.26E+00	mg/kg	95% Student's-t	Test (4)
	Cadmium	mg/kg	6.07E-01	No	7.66E-01 (N)	1.30E+00	7.66E-01	mg/kg	95% KM-t	Test (4)
	Calcium	mg/kg	5.32E+04	No	7.99E+04 (N)	1.44E+05	7.99E+04	mg/kg	95% Student's-t	Test (4)
	Chromium	mg/kg	1.21E+01	No	1.46E+01 (N)	1.72E+01	1.46E+01	mg/kg	95% Student's-t	Test (4)
	Cobalt	mg/kg	7.80E+00	No	9.85E+00 (N)	1.45E+01	9.85E+00	mg/kg	95% Student's-t	Test (4)
	Copper	mg/kg	4.17E+01	No	5.75E+01 (G)	1.14E+02	5.75E+01	mg/kg	95% Approx. Gamma	Test (6)
	Iron	mg/kg	3.68E+04	No	4.50E+04 (N)	6.00E+04	4.50E+04	mg/kg	95% Student's-t	Test (4)
	Lead	mg/kg	4.75E+02	No	1.46E+03 (L)	2.50E+03	1.46E+03	mg/kg	95% Cheby, Mean, Sd	Test (5)
	Magnesium	mg/kg	2.76E+04	No	5.31E+04 (G)	7.55E+04	5.31E+04	mg/kg	95% Approx. Gamma	Test (6)
	Manganese	mg/kg	7.60E+02	No	9.52E+02 (N)	1.29E+03	9.52E+02	mg/kg	95% Student's-t	Test (4)
	Mercury	mg/kg	5.97E-02	No	7.03E-02 (N)	9.00E-02	7.03E-02	mg/kg	95% Student's-t	Test (4)
	Nickel	mg/kg	1.28E+01	No	1.57E+01 (N)	2.04E+01	1.57E+01	mg/kg	95% Student's-t	Test (4)
	Potassium	mg/kg	1.25E+03	No	1.44E+03 (N)	1.76E+03	1.44E+03	mg/kg	95% Student's-t	Test (4)
	Selenium	mg/kg	8.30E-01	Yes	9.18E-01 (N)	1.20E+00	9.18E-01	mg/kg	95% KM-% Btstrp	Test (1)
	Silver	mg/kg	6.74E-02	Yes	7.28E-02 (N)	1.00E-01	7.28E-02	mg/kg	95% KM-% Btstrp	Test (1)
	Sodium	mg/kg	1.22E+02	No	1.73E+02 (N)	2.55E+02	1.73E+02	mg/kg	95% Student's-t	Test (4)
	Thallium	mg/kg	8.49E-01	No	9.90E-01 (N)	1.40E+00	9.90E-01	mg/kg	95% KM-t	Test (4)
	Vanadium	mg/kg	2.89E+01	No	3.56E+01 (N)	4.91E+01	3.56E+01	mg/kg	95% Student's-t	Test (4)
	Zinc	mg/kg	9.65E+01	No	1.38E+02 (G)	3.37E+02	1.38E+02	mg/kg	95% Approx. Gamma	Test (6)

Notes: N/A = Not applicable

¹ ProUCL software (version 4.1, USEPA, 2011) recommends use of Kaplan-Meier method if there are multiple detection limits.

² Statistical Distribution and 95% UCL as determined by ProUCL (unless otherwise noted): (G) the data were determined to follow gamma distribution; (L) the data were determined to follow lognormal distribution; (NP) the data were determined to be non-parametric; (N) the data were determined to be normally distributed.

³ Statistic: Maximum Detected Value (Max); 95% KM Chebyshev (95% KM-Cheby); 97.5% KM Chebyshev (97.5% KM-Cheby); 99% KM Chebyshev (99% KM-Cheby); 95% KM Percentile Bootstrap (95% KM-% Btstrp); 95% KM-t (95% KM-t); 95% KM-BCA (95% KM-BCA); 95% H-UCL (95% H-UCL); 95% Chebyshev -Mean, SD- UCL (95% Cheby, Mean, SD); 97.5% Chebyshev -Mean, SD- UCL (97.5% Cheby, Mean, SD); 99% Chebyshev -Mean, SD- UCL (99% Cheby, Mean, SD); 95% UCL of Log-transformed Data (95% UCL-T) 95% Student's-t (95% Student's-t); 95% Modified-t (95% Modified-t); 95% UCL based on bootstrap statistic (95% UCL-Bst); 95% Approximate Gamma UCL (95% Approx. Gamma); 95% KM Chebyshev-MVUE (95% KM-Cheby-MVUE).

⁴ Unless otherwise noted (see footnote 5), ProUCL EPC selection rationale based on, detection limit values, distribution, standard deviation, and sample size (see ProUCL output in appendix for further details):

Test (1): Kaplan-Meier method recommended by ProUCL due to multiple detection limits.
Test (2): 95% UCL exceeds or equals the maximum detected concentration, therefore, maximum concentration used for EPC.
Test (3): Shapiro-Wilk W test, Kolmogorov-Smirnov (K-S), and Anderson-Darling (A-D) tests, indicate data follow nonparametric distribution.
Test (4): Shapiro-Wilk W test indicates data are normally distributed.
Test (5): Shapiro-Wilk W test indicates data are log-normally distributed.
Test (6): Kolmogorov-Smirnov (K-S) and/or Anderson-Darling (A-D) tests indicate data follow gamma distribution.
Test (7): Sample size is less than or equal to 5, therefore, maximum concentration used for EPC.
Test (8): Infrequent detection resulted in ProUCL modeling error for this constituent, therefore, maximum concentration used for EPC.

Table 7-23
Wildlife Summed EEQ Hazard Summary for Food Chain Exposure
at the Southeast Hillside Area

Receptor	Tier 1 ^a		Tier 2 ^b	
	NOAEL-Based EEQ	LOAEL-Based EEQ	NOAEL-Based EEQ	LOAEL-Based EEQ
Meadow vole	106	77	27	19
Hazard Driver(s) ^c :	<u>Lead and Selenium</u> - soil and plant ingestion		<u>Lead and Selenium</u> - soil and plant ingestion	
Short-tailed shrew	525	411	151	133
Hazard Driver(s) ^c :	<u>Lead and Nickel</u> - terrestrial invertebrate and soil ingestion		<u>Lead</u> - terrestrial invertebrate ingestion and soil ingestion	
American robin	381	310	139	115
Hazard Driver(s) ^c :	<u>Lead</u> - terrestrial invertebrate and soil ingestion		<u>Lead</u> - terrestrial invertebrate and soil ingestion	
Red-tailed hawk	25	21	0.009	0.007
Hazard Driver(s) ^c :	<u>Lead</u> - small mammal ingestion		--	
Red fox	31	27	0.005	0.004
Hazard Driver(s) ^c :	<u>Lead</u> - small mammal ingestion		--	

^a Tier 1 = Max EEQ using max EPC, max BAF/BCF, max Intake Rates, min BW, and FHR =1.

^b Tier 2 = EEQ using 95% EPC, non-max BAF/BCF, avg Intake Rates, avg BW and calculated FHR less than or equal to 1.

^c Hazard drivers are those chemicals contributing the most to the total estimated EEQ, and the primary route of exposure associated with this driver.

Notes:

"---" = Total EEQ < 1

BAF/BCF = Bioaccumulation Factor/Bioconcentration Factor

BW = Body Weight

EEQ = Ecological Effects Quotient

EPC = Exposure Point Concentration

FHR = Fraction Home Range

LOAEL = Lowest-Observed-Adverse-Effect Level

NOAEL = No-Observed-Adverse-Effect Level

pathway was the ingestion of terrestrial invertebrates and soil. The results of the short-tailed shrew Tier 2 risk evaluation are presented in **Appendix F-2, Table F-20**.

American Robin. The total EEQs for both NOAEL and LOAEL TRVs exceeded 1 (139 and 115, respectively). Eight COPECs had individual NOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (119), copper (5.3), zinc (3.6), selenium (2.5), cadmium (2.3), arsenic (1.6), nickel (1.2), and chromium (1.1). Seven COPECs had individual LOAEL-based EEQs that exceeded or equaled 1 (EEQ in parenthesis): lead (100), copper (4.4), zinc (3.6), selenium (2.0), cadmium (1.4), chromium (1.1), and arsenic (1.0). The primary exposure pathway was the ingestion of terrestrial invertebrates and soil. The results of the Tier 2 risk evaluation for American robins are presented in **Appendix F-2, Table F-22**.

7.3.4 Approach for the Evaluation of Direct Contact Toxicity

To evaluate direct contact exposure, for those organisms that live within an environmental medium, COPEC surface soil concentrations were compared with a variety of direct contact screening values. Intake was not calculated because potential adverse effects are assessed by evaluating the COPEC concentrations. Measured COPEC concentrations were simply compared with direct contact benchmarks appropriate for communities that reside in surface soil. The results are summarized below.

To evaluate direct contact exposure, for those organisms that live within an environmental medium, COPEC media (surface soil, sediment, and surface water) concentrations were compared with a variety of direct contact screening values. Intake was not calculated because potential adverse effects are assessed by evaluating the COPEC concentrations. Measured COPEC concentrations were simply compared with direct contact benchmarks appropriate for communities that reside in these media. The results are summarized in the following subsection.

7.3.4.1 Surface Soil

As there are no promulgated soil screening criteria for organisms potentially exposed to COPECs in surface soil collected from the ARSAR, a two-step process was used to assess direct contact soil toxicity (see *Section 7.1.9.1* for more details). The results are summarized in **Table 7-24**.

Fifty-five surface soil COPECs were compared with the soil screening values and the results are as follows:

- Eight analytes were carried forward for further evaluation because there were no BTAG or EcoSSL screening benchmarks were available (2-methylnaphthalene, benzoic acid, endosulfan I, endosulfan II, endosulfan sulfate, calcium, potassium, and sodium). Of these, 2-methylnaphthalene was detected in all five samples; benzoic acid and endosulfan I were detected in two of five samples; endosulfan II and endosulfan sulfate were detected in one of five samples; and calcium, potassium, and sodium were detected in all 12 surface soil samples.
 - o There were no available soil benchmarks for 2-methylnaphthalene or benzoic acid.
 - o The endosulfan I, endosulfan II, and endosulfan sulfate MDCs all exceeded the one available screening value based on the Dutch target screening value. The target value indicates the level at which there is sustainable soil quality and indicates negligible risks to the ecosystem. Besides the target value, a Dutch intervention value of 4 mg/kg is also published for these three pesticides, representing the concentration

Table 7-24
Direct Toxicity Evaluation for Surface Soil at the Southeast Hillside Area
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Chemical (1)	Detection Frequency	MDC (mg/kg)	EPC (mg/kg)	BTAG or USEPA EcoSSL Screening Toxicity Value (2)	Retain COPEC as Max Conc > BTAG or EcoSSL Value?	If Retained as COPEC, Comment on BTAG or EcoSSL Value	NOAA SQuiRT Value (3)	CCME Value (4)	USEPA EcoSSL Direct Contact Value (5)	ORNL Screening Benchmark for Plants (6)	ORNL Screening Benchmark for Invertebrates (7)	COPEC Weight of Evidence Summary - Number of Direct Contact Benchmarks Exceeded Using MDC	COPEC Weight of Evidence Summary - Number of Direct Contact Benchmarks Exceeded Using EPC	Comment
Cadmium	11/12	1.30E+00	7.66E-01	3.60E-01	Yes	Mammal tox	1.20E+01	1.40E+00	3.20E+01	4.00E+00	2.00E+01	0/5	0/5	No exceedences
Calcium	12/12	1.44E+05	7.99E+04	NVA	Yes	---	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening value
Chromium (Cr III tox)	12/12	1.72E+01	1.46E+01	2.60E+01	No	Bird tox	2.20E+02	NVA	NVA	1.00E+00	4.00E-01	2/3		ORNL-plant for total Cr, EcoSSL says data insufficient to derive direct contact SSL
Chromium (Cr VI tox)	12/12	1.72E+01	1.46E+01	1.30E+02	No									
Cobalt	12/12	1.45E+01	9.85E+00	1.30E+01	Yes	Plant tox	1.80E+02	4.00E+01	1.30E+01	2.00E+01	NVA	1/4	0/4	EcoSSL and ORNL plant tox, EcoSSL says data insufficient to derive direct contact invertebrate SSL
Copper	12/12	1.14E+02	5.75E+01	2.80E+01	Yes	Bird tox	9.60E+01	6.30E+01	7.00E+01	1.00E+02	5.00E+01	5/5	1/5	EcoSSL and ORNL plant tox
Iron	12/12	6.00E+04	4.50E+04	5 ≤ pH ≤ 8	No (pH is between 5 and 8)									pH = 5.92
Lead	12/12	2.50E+03	1.46E+03	1.10E+01		Bird tox	5.30E+02	7.00E+01	1.20E+02	5.00E+01	5.00E+02	5/5	5/5	EcoSSL and ORNL plant tox
Magnesium	12/12	7.55E+04	5.31E+04	4.40E+03	Yes	No reference	NVA	NVA	NVA	NVA	NVA	NVA	NVA	
Manganese	12/12	1.29E+03	9.52E+02	2.20E+02	Yes	Plant tox	NVA	NVA	2.20E+02	5.00E+02	NVA	2/2	2/2	EcoSSL and ORNL plant tox
Mercury	12/12	9.00E-02	7.03E-02	5.80E-02	Yes	No reference	1.00E+01	6.60E+00	NVA	3.00E-01	1.00E-01	0/4	0/4	No reference for BTAG
Nickel	12/12	2.04E+01	1.57E+01	3.80E+01	No									
Potassium	12/12	1.76E+03	1.44E+03	NVA	Yes	---	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening value
Selenium	5/12	1.20E+00	9.18E-01	5.20E-01	Yes	Plant tox	1.00E+02	1.00E+00	5.20E-01	1.00E+00	7.00E+01	3/5	1/5	EcoSSL and ORNL plant tox
Silver	9/12	1.00E-01	7.28E-02	4.20E+00	No									
Sodium	12/12	2.55E+02	1.73E+02	NVA	Yes	---	NVA	NVA	NVA	NVA	NVA	NVA	NVA	No screening value
Thallium	8/9	1.40E+00	9.90E-01	1.00E-03	Yes	Plant tox (no ref)	1.50E+01	1.00E+00	NVA	1.00E+00	NVA	2/3	0/3	ORNL plant tox, no reference for BTAG plant tox, no EcoSSL
Vanadium	12/12	4.91E+01	3.56E+01	7.80E+00	Yes	Bird tox	2.50E+02	1.30E+02	NVA	2.00E+00	NVA	1/3	1/3	ORNL plant tox
Zinc	12/12	3.37E+02	1.38E+02	4.60E+01	Yes	Plant tox (OHMTADS)	3.50E+02	2.00E+02	1.20E+02	5.00E+01	2.00E+02	4/5	2/5	ORNL plant tox

All values presented in mg/kg.
MDC = Maximum detected concentration.
EPC = Exposure Point Concentration. The 95% UCL was selected as the EPC unless it exceeded the maximum detected concentration, in which case the MDC was chosen as the EPC.
NVA = No Value Available
LMW = Low Molecular Weight PAH
HMW = High Molecular Weight PAH
IFD = Infrequently Detected (≤5%)
Surface soil pH of 5.92 based geometric mean of surface soil samples from MMA.

- (1) Direct contact COPECs are for all detected constituents.
(2) Screening toxicity values from BTAG (1995) or EcoSSL (USEPA, 2007). EcoSSLs given highest priority as they are more definitive.
(3) NOAA SQuiRT 2008 (non-EcoSSL and non-microbe values used).
(4) Canadian Council of Ministers of the Environment (CCME), Canadian Environmental Quality Guidelines, December 2003.
(5) Lowest EcoSSL value for direct contact toxicity for either plants or terrestrial invertebrates (USEPA, 2007).
(6) Screening benchmarks for plants from ORNL (1997, ES/ER/TM-85/R3).
(7) Screening benchmarks for earthworms from ORNL (1997, ES/ER/TM-126/R2).
(8) The 95% UCL EPC was not calculated because the sample size was less than or equal to five.

where functional properties of soil for humans, plants, and animal life are seriously impaired or threatened. As the endosulfan I, endosulfan II, and endosulfan sulfate MDCs of 0.002, 0.000064, and 0.0017 mg/kg are only 0.05, 0.02, and 0.04 percent of the intervention value, respectively, concerns for these three COPECs are deemed minimal.

- o Calcium, potassium, and sodium are essential nutrients and not considered direct contact COPECs in surface soil at the Southeast Hillside Area.
- Although magnesium was detected in all 12 samples and the MDC exceeded the BTAG benchmark (the only available benchmark), the value is not based on direct contact toxicity. In addition, magnesium is an essential nutrient and not considered a direct contact COPEC. Therefore, magnesium is not considered a direct contact hazard in surface soil at the Southeast Hillside Area.
- Aluminum was detected in all 12 surface soil samples. However, aluminum in soil is not considered readily bioavailable in soils with a pH above 5.5 (USEPA, 2007b). As the geometric mean surface soil pH at the MMA was 5.92, aluminum is not considered a significant direct contact hazard at the Southeast Hillside Area.
- Iron was also detected in all 12 surface soil samples. However, iron in soil is not considered readily bioavailable in soils with a pH between 5.0 and 8.0 (USEPA, 2007b). As the geometric mean surface soil pH at the MMA was 5.92, iron is not considered a significant direct contact hazard at the Southeast Hillside Area.
- The following 32 analytes: silver, nickel, chromium (Cr VI and Cr III), beryllium, barium, pyrene, phenanthrene, pentachlorophenol, naphthalene, methoxychlor, indeno(1,2,3-cd)pyrene, heptachlor epoxide, gamma-chlordane, gamma-BHC, fluorene, fluoranthene, endrin ketone, endrin aldehyde, endrin, dieldrin, chrysene, beta-BHC, benzo(k)fluoranthene, benzo(ghi)perylene, benzo(b)fluoranthene, benzo(a)pyrene, benzo(a)anthracene, Aroclor 1254, alpha-BHC, acenaphthylene, 4,4'-DDT, and 4,4'-DDE, had MDCs and EPCs (if calculated) that did not exceed the EcoSSL or BTAG soil screening benchmarks. Therefore, no further action is required for these constituents in surface soil at the Southeast Hillside Area.
- Cadmium and mercury had MDCs that exceeded the initial EcoSSL or BTAG soil screening benchmarks, but none of the additional direct contact screening benchmarks were exceeded by their respective MDCs. Therefore, no further action is required for cadmium or mercury in surface soil at the Southeast Hillside Area.
- Antimony, cobalt, and vanadium had MDCs that exceeded the initial EcoSSL or BTAG soil screening benchmarks, but the MDC did not exceed more than half of the additional soil benchmarks. In addition, all of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. Therefore, no further action is required for cobalt, mercury, or vanadium in surface soil at the Southeast Hillside Area.
- The following seven analytes: arsenic, copper, lead, manganese, selenium, thallium, and zinc, had MDCs that exceeded the initial EcoSSL or BTAG soil screening benchmarks and more than half of the additional soil benchmarks and are discussed below:

- o Arsenic was detected in all 12 surface soil samples and the MDC and EPC exceeded three of the five additional soil benchmarks. However, two of the exceeded benchmarks (ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the EcoSSL guidance indicates there is insufficient data to derive a direct contact SSL. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for arsenic in surface soil at the Southeast Hillside Area.
- o Copper was detected in all 12 surface soil samples and the MDC exceeded all five additional soil benchmarks. However, the soil EPC only exceeded one of the five additional benchmarks. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for copper in surface soil at the Southeast Hillside Area.
- o Lead was detected in all 12 surface soil samples and the MDC and EPC exceeded all five additional soil benchmarks. Two of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the direct contact SSL for invertebrates is 1,700 mg/kg, and the EPC of 1,458 mg/kg does not exceed the invertebrate SSL for lead. Therefore, the potential for direct contact toxicity may not be significant enough to recommend further action for lead in surface soil at the site. However, as the MDC (2,500 mg/kg) exceeded the SSL for invertebrates, and invertebrates are not overly mobile, and lead is already a concern for wildlife based on foodchain modeling, lead is retained as a concern for direct contact and may or may not result in the reduction of terrestrial invertebrates as a food source at the Southeast Hillside Area.
- o Manganese was detected in all 12 surface soil samples and the MDC and EPC exceeded both additional soil benchmarks. However, both of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. It should be noted that the MDC and EPC exceed the EcoSSL direct contact value for invertebrates (450 mg/kg), therefore, there is potential for direct contact toxicity for manganese at the site. This may or may not result in the reduction of terrestrial invertebrates as a food source at the Southeast Hillside Area.
- o Selenium was detected in five of 12 surface soil samples and the MDC exceeded three of five additional soil benchmarks. However, two of the exceeded benchmarks (EcoSSL and ORNL) were for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. Furthermore, the soil EPC only exceeded one of the five additional benchmarks (which was for plant toxicity). Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for selenium in surface soil at the Southeast Hillside Area.
- o Thallium was detected in eight of nine surface soil samples and the MDC exceeded two of the three additional soil benchmarks. However, one of the exceeded benchmarks (ORNL) was for plant toxicity, and as discussed in *Section 7.1.8.1*, plant toxicity is not an overriding concern for the site. In addition, the soil EPC did not exceed any of the additional benchmarks, and the EcoSSL guidance indicates there is

insufficient data to derive a direct contact SSL. Therefore, the potential for direct contact toxicity is not significant enough to recommend further action for thallium in surface soil at the Southeast Hillside Area.

These results suggest that direct contact toxicity for COPECs in surface soil may be a concern for lead and manganese. It should also be noted that toxicity to terrestrial invertebrates is assessed indirectly, as terrestrial invertebrates such as earthworms are included in the food chain models used in the assessments.

7.3.5 Background Metals Considerations

From the Tier 2 LOAEL assessment, there were eight inorganic COPEC drivers (arsenic, cadmium, chromium, copper, lead, nickel, selenium, and zinc) with EEQs greater than one for the food chain assessment. The COPEC hazard drivers for the surface soil direct contact assessment were manganese and lead. Inorganic COPECs that were not statistically different based on appropriate statistical tests are considered background related (see *Section 6.4.3* for additional details of background evaluation). Based on information presented in **Table 7-25**, arsenic, cadmium, copper, lead, nickel, selenium, and zinc COPECs in surface soil considered to be potentially site related and not attributed to background at the Southeast Hillside Area. However, it should be noted that for cadmium, the mean and median of the detected site values were below the mean and median of the detected background values, and the failure of the statistical test may have been due to the unequal detection frequency of the site compared with the background data set (92 percent vs. 7 percent, respectively) and differing detection limits.

Table 7-25
Background Comparison for Surface Soil at the Southeast Hillside Area

Soil COPEC	Gehan Test ^{a, b} Site > Background?	Considered to be Background?
Arsenic	Yes	No
Cadmium	Yes	No
Chromium	No	Yes
Copper	Yes	No
Lead	Yes	No
Manganese	No	Yes
Nickel	Yes	No
Selenium	Yes	No
Zinc	Yes	No

^a Gehan test used unless otherwise noted. See Appendix for backup statistics.

^b If both site and background data sets had normal distribution with 100% detects, the t-test was used (Note: None of the COPECs listed above met this condition).

7.3.6 Uncertainty Analysis

There were 122 chemical constituents not detected in surface soil analytical samples.

Appendix F-2, Table F-39 (surface soil) evaluated the uncertainty associated with these constituents' detection limits by presenting a comparison of the maximum detection limit for each non-detect constituent with a conservative ecological toxicity screening value. Region III BTAG soil SLs are antiquated (last published in 1995 and no longer readily available) relative to Region III BTAG surface water and sediment values (updated in 2006); therefore, non-detect soil

values were compared to BTAG soil levels as well as additional soil screening values presented in **Appendix F-2, Table F-38**.

Thirty-six of the non-detect surface soil constituents had maximum detection limits that exceeded the screening criteria. These findings are not unexpected, given the conservative and numerically low screening values.

7.3.6.1 Uncertainties with Surface Soil EEQs

The inorganic COPECs arsenic, cadmium, copper, lead, nickel, selenium, and zinc had Tier 2 LOAEL-based EEQs that exceeded 1 when round to one significant figure, and were determined not to be related to background. Given the uncertainties associated with the SLERA process, the key parameters associated with these elevated EEQs (exceeded 1 when round to one significant figure) were examined in more detail.

Arsenic. For arsenic, the mammalian-LOAEL TRV of 1.66 mg/kg-day was based on a laboratory dog study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew and vole (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the arsenic shrew EEQ of 4.2 dropping to 1 when rounded to one significant figure. The use of an alternative UF of approximately 4 would result in the arsenic vole EEQ of 2.3 dropping to 1 when rounded to one significant figure. In addition, a geologic and geochemical analysis of the arsenic concentrations and distribution strongly suggests a natural source for the elevated arsenic concentrations in the Southeast Hillside Area (see *Section 4.7.3*).

Cadmium. For cadmium, the mammalian-LOAEL TRV of 1.6 mg/kg-day was based on a laboratory rat study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the cadmium shrew EEQ of 4.5 dropping to 1 when rounded to one significant figure.

Copper. For copper, the mammalian-LOAEL TRV of 5.78 mg/kg-day was based on a laboratory rat study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew and 4 for the vole (**Appendix F-2, Table F-34**). The use of these UFs is quite conservative, and the use of an alternative UF of 1 would result in the copper shrew EEQ of 6.6 dropping to less than 1 for the shrew. The use an alternative UF of approximately 2 would result in the copper vole EEQ of 1.7 dropping to less than 1. The avian-LOAEL TRV of 4.88 mg/kg-day was based on a laboratory turkey study, as cited in USEPA (2007b), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the robin (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the copper robin EEQ of 4.4 dropping to 1 when rounded to one significant figure.

Lead. For lead, the mammalian-LOAEL TRV of 5 mg/kg-day was based on a rat study cited in EcoSSL (2005), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew and 4 for the vole (**Appendix F-2, Table F-34**). The use of these UFs are quite conservative; however, the use of an alternative UF of 1 would only result in the lead EEQ of 94 dropping to 12 for the shrew, while the vole lead EEQ would only drop from 9.1 to 2.3.

For lead, the avian-LOAEL TRV of 1.94 mg/kg-day was based on a quail study cited in EcoSSL (2005), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the robin

(**Appendix F-2, Table F-34**). The use of this UF is quite conservative; however, the use of an alternative UF of 1 would only result in the lead EEQ of 100 dropping to 13.

Uncertainties Related to Lead TRVs. There is some uncertainty associated with the TRVs selected for lead, in that the LOAELs are very close to the NOAELs. For mammals the NOAEL is 4.7 mg/kg-day and the LOAEL is 5 mg/kg-day. For birds the NOAEL is 1.63 mg/kg-day and the LOAEL is 1.94 mg/kg-day. These TRVs are taken from the EcoSSL (2005). In the EcoSSL guidance, NOAEL results for growth and reproduction from various studies are used to calculate a geometric mean NOAEL. This mean NOAEL is then examined in relationship to the lowest bounded LOAEL for reproduction, growth, and survival to derive the TRV.

For mammals, a geometric mean was calculated for lead at 40.7 mg/kg-day; however, this value is higher than the lowest bounded LOAEL for reproduction, growth, or survival results (5 mg/kg-day). Therefore, the NOAEL is equal to the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, and is equal to 4.7 mg/kg-day. If the LOAEL associated with the same study from which the NOAEL was taken was used (8.9 mg/kg-day), the Tier 2 LOAEL-based EEQs would be 6.6 for the shrew and less than 1 for the vole using an UF of 1.

For birds, a geometric mean NOAEL was calculated for lead at 10.9 mg/kg-day; however, this value is higher than the lowest bounded LOAEL for reproduction, growth, or survival results (1.94 mg/kg-day). Therefore, the NOAEL is equal to the highest bounded NOAEL below the lowest bounded LOAEL for reproduction, growth, or survival, and is equal to 1.63 mg/kg-day. If the LOAEL associated with the same study from which the NOAEL was taken were used (3.26 mg/kg/d), the Tier 2 LOAEL-based EEQs for the robin would be 7.5 for a UF 1. While the use of alternate LOAELs is not recommended for decision making, this illustrates the potential range of EEQs that could result from using different TRVs.

Nickel. For nickel, the mammalian-LOAEL TRV of 2.71 mg/kg-day was based on a laboratory rat study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 (**Appendix F-2, Table F-34**). The use of this UF is quite conservative and the use of an alternative UF of 1 would result in the nickel shrew EEQ of 7.1 dropping to less than 1.

Selenium. For selenium, the mammalian-LOAEL TRV of 0.145 mg/kg-day was based on a laboratory mouse study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the shrew and 4 for the vole (**Appendix F-2, Table F-34**). The use of these UFs is quite conservative, and the use of an alternative UF of 1 would result in the selenium shrew EEQ of 7.1 dropping to less than 1. The use of an alternative UF of 1 would result in the selenium vole EEQ of 3.0 dropping to less than 1. The avian-LOAEL TRV of 0.368 mg/kg-day was based on a laboratory chicken study, as cited in USEPA (2007b); therefore, the EEQ calculation used a TRV extrapolation UF of 8 for the robin (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of 4 would result in the selenium robin EEQ of 2.0 dropping to 1.0.

Zinc. For zinc, the mammalian-LOAEL TRV of 75.7 mg/kg-day was based on a laboratory sheep study, as cited in EcoSSL (2007), therefore, the EEQ calculation used a TRV extrapolation UF of 8 (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UFs of 1 for the shrew and 4 for the vole, would result in both the zinc shrew EEQ of 6.3 and the vole EEQ of 1.8 dropping to less than 1. The avian-LOAEL TRV of 66.5 mg/kg-day was based on a laboratory chicken study, as cited in USEPA (2007b); therefore, the EEQ

calculation used a TRV extrapolation UF of 8 for the robin (**Appendix F-2, Table F-34**). The use of this UF is quite conservative, and the use of an alternative UF of approximately 2 would result in the zinc robin EEQ of 3.6 dropping to less than 1.

Based on this evaluation for the LOAEL-based risk drivers arsenic, cadmium, copper, nickel, selenium, and zinc, the use of alternative UFs (e.g., alternative UFs for TRV species extrapolations), would reduce the estimated LOAEL-based EEQs to 1 (when rounded to one significant figure) or less than one for all receptors.

However, use of an alternative UF for lead would not reduce the LOAEL-based EEQ to 1 (when rounded to one significant figure) for the short-tailed shrew, meadow vole, or American robin. In addition, use of alternative LOAEL-TRVs (based on different toxicity studies) would not reduce the estimated LOAEL-based EEQs to 1 for the shrew or robin.

7.3.7 SLERA Results and Conclusions

The SLERA evaluated risks to ecological populations inhabiting terrestrial habitats at the Southeast Hillside Area. Conclusions are derived from the risk assessment and are based on the responses to the assessment hypotheses and assessment endpoints. The assessment results for food chain exposure are summarized in **Table 7-23**, and direct contact exposure results for terrestrial invertebrates, which may serve as a food source for wildlife, are summarized in **Table 7-24** and discussed in *Sections 7.3.3 and 7.3.4*.

The food chain assessment suggests potential adverse impacts to terrestrial wildlife, especially shrews, robins, and voles for modeled contact with the hazard driver (lead) in surface soil. Based on the Tier 2 LOAEL-based approach, lead for the short-tailed shrew, American robin, and meadow vole had estimated EEQs greater than 1 when rounded to one significant figure even when alternative UFs were used in the SLERA EEQ calculations. These findings suggest that wildlife food chain impacts related to lead are a potential concern for surface soil at the Southeast Hillside Area. However, given the relatively small size of the site (1.1 acres), it is unlikely populations of wildlife such as American robins, short-tailed shrews, and/or meadow voles would be adversely impacted by concentrations of lead in soil. While a few individuals may suffer deleterious effects based on modeled exposure, these are conservative modeled estimations, not results of ecological field studies. In addition, no threatened or endangered species are known to occur at the site; therefore, losses of individuals that are common species of wildlife are not an overriding concern.

Another line of evidence to support a conclusion of no significant ecological risk comes from Oregon Department of Environmental Quality (DEQ) *Final Guidance for Ecological Risk Assessment: Levels I, II, III, IV* (Oregon DEQ Waste Management and Clean-up Division, 1998, updated 12/2001) that discusses an approach they recommend to estimate the size of a population area, for evaluating potential population-level impacts. This guidance gives a relatively simple approach for estimating the “size” of a wildlife population (basically: $100 \times \text{Home Range}/\pi$). The shrew receptor has a home range of about 1 acre, so the population size for this species would be about 32 acres, and for the vole (with a home range of about 0.09 acres), the population size for this species would be about 2.9 acres. The robin has a home range of 1.2 acres, so a population size for this species would be about 38 acres. Given that the Southeast Hillside Area is only 1.1 acres, this suggests that the impacted area would likely not adversely impact local populations. It should be noted that the vole is predicted to be much less impacted than either the shrew or the robin, so even though approximately 38 percent of the Southeast

Hillside Area is within the vole's population area (1.1/2.9), this receptor had a much lower HQ. Therefore, shrews, robins, and voles should not be adversely impacted at the local population level.

The direct contact assessment results suggest a potential reduction in wildlife food supply (i.e., plants and soil invertebrates) due to manganese and lead in surface soil. However, manganese in surface soil is background related (*Section 7.3.5*) and is not considered further. Potential reductions in food supply (due to modeled earthworm and plant toxicity from lead) are not an overriding concern to area wildlife, as they would be expected to forage in unimpacted area proximate to the site where soil invertebrates and plants are expected to be abundant.

It is important to note that the location of the hillside is behind the target berm and across the stream from an access point for equipment required for soil removal, if soil removal was to be considered to address potential ecological concerns. Access to this area would require removal of portions of the berm, clearing the trees on the near side of the stream, and clearing portions of the hillside itself. These actions would degrade the quality of the stream through the removal of the trees stabilizing the banks and providing shade. Excavation of the hillside to remove lead-containing soil would de-stabilize the soil above that point, creating an ongoing erosion issue. These actions would collectively lead to a greater loss of habitat and potential receptors populations than taking no action on the hillside.

These SLERA assessment results may serve as the foci of discussions with risk managers and regulatory agencies. It is very important to note that many conservative assumptions and modeling approaches were used in the assessment, and actual hazards to wildlife may be orders of magnitude lower than predicted herein.

8.0 SUMMARY AND CONCLUSIONS

8.1 Nature and Extent Conclusions

8.1.1 Target Berm

The soil at the ARSAR target berm was investigated during the 2009 SSP and then again in 2011 in support of this RFI/IM. The data set 2009 SSP indicated that lead and antimony were the constituents of concern in the target berm. The IM was performed to address these constituents detected at elevated concentrations in the berm soil. Following the removal of the top 1-2 ft of soil from the firing range berm, surface soil samples were collected from 0-0.5 ft bgs and screened for lead and antimony using an XRF. All samples screened by XRF for lead and antimony were also sent to an off-site lab and tested for TAL metals. In addition to TAL metals, 50 percent of the collected samples were also analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives. Analytical results from the laboratory confirmation samples demonstrated that: 1) the IM successfully addressed the elevated concentrations of lead and antimony in the berm; 2) no analytes were detected above SLs in the berm soil; and, 3) no further action is recommended for the target berm.

8.1.1.1 Building Debris Removal

The building debris located behind the target berm was investigated in 2010 during the initial site reconnaissance. Prior to removal activities, the soil beneath the building debris area was investigated during the 2011 sampling event to determine if the building debris had negatively impacted the underlying soil. Data from the samples indicated that there were no TCLP metal exceedances below the building debris area. Chrysotile was encountered within the sample at a level of 1.3 percent and was determined to be not friable. As previously discussed, 5.21 tons of building debris was removed and disposed of as nonhazardous waste at an offsite landfill.

8.1.2 Firing Range Floor and Potential Firing Point Area

The soil at the ARSAR firing range floor and potential firing points was not sampled during previous investigations. Analytical data was collected in 2011 to support this RFI/IM. Ninety-three surface soil samples were collected from 0-0.5 ft bgs for XRF lead screening from the firing range floor and potential firing points to determine the extent and depth of potential soil contamination and determine if remediation was warranted for the firing range floor. XRF screening indicated that lead concentrations in the firing range floor were below the 400 mg/kg RG designated for the site. Laboratory confirmation samples from nine XRF screening samples analyzed for TAL metals, TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives, verified that: 1) XRF screening results for lead were all below the r-RG; 2) although three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene], one PCB (PCB-1254), and two metals (arsenic and iron) were detected at concentrations above soil SLs, these detections were isolated and not considered to be related to past site use; and, 3) no further action is recommended for the firing range floor and potential firing points.

8.1.3 Southeast Hillside Area

The soil at the Southeast Hillside Area was investigated during the 2009 SSP and then again in 2011 in support of the 2011 RFI. A total of 33 surface soil samples were collected from 0-0.5 ft bgs in a grid pattern for XRF screening to delineate the elevated arsenic concentrations detected during the SSP and assess lead concentrations. Twelve samples were sent to an off-site

laboratory to confirm the XRF screening results, to assess the extent of elevated arsenic and determine whether there was a correlation between elevated lead and elevated arsenic, and characterize the soil at five locations for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, and explosives.

As shown on **Figure 8-1**, the XRF and laboratory confirmation data indicates that arsenic was detected at levels above the accepted background concentration and soil SLs over much of the southeast hillside, including areas where lead concentrations were minimal. As samples were collected in the 6- to 8-inch soil layer directly overlying the bedrock, elevated arsenic concentrations appear to be naturally occurring. The Southeast Hillside Area is situated in a tectonic fault window of an undifferentiated Devonian, Silurian, and Ordovician unit, a unique geologic setting at RFAAP. This tectonic window exposes the Martinsburg Formation and the Millboro Shale. Soils developed from these units contain higher amounts of arsenopyrite (a sulfide mineral). Elevated concentrations in soil along the hillside are attributed to the higher amounts of arsenopyrite naturally occurring in these soils (Schultz and Bartholomew, 2009). Based on the lack of detections in surface water and concentrations well below SLs in sediment in Stroubles Creek samples, elevated concentrations of arsenic detected in the Southeast Hillside Area do not appear to be mobile or migrating from the hillside.

As shown on **Figure 8-2**, the XRF and laboratory confirmation data indicates that elevated concentrations of lead were predominantly encountered in a focused area approximately 10 ft above Stroubles Creek. Although no bullet fragments were discovered along the hillside during sampling activities, the distribution of lead at this height and area along the hillside indicates that errant shots from the firing range most likely flew just over the top of the target berm and lodged into the surface of the hillside. Similar to arsenic, the lack of lead detections in surface water and concentrations well below SLs in sediment in Stroubles Creek samples, elevated concentrations of lead detected in the southeast hillside do not appear to be mobile or migrating from the hillside.

8.1.4 Surface Water and Sediment

Five surface water and sediment sample pairs (one upgradient, two behind the berm, and two downgradient) were collected from Stroubles Creek to assess whether previous activities at the ARSAR have impacted the stream and whether constituents were being transported off site by the stream.

Data from the surface water samples indicated that although three VOCs (acetone, chloromethane, and toluene), one SVOC (di-n-butylphthalate), one pesticide (methoxychlor), and perchlorate were detected in the samples, detected concentrations were well below applicable SLs and are not a concern in surface water at the site. PCBs, explosives, and herbicides were not detected in any of the samples and, therefore, are not a concern in surface water at the site. Three metals (aluminum, iron, and manganese) were detected at concentrations exceeding applicable SLs. Aluminum, iron, and manganese are ubiquitous in surface water samples collected throughout RFAAP. In addition, the main constituents of concern (antimony, arsenic, and lead) in soil at the site were not detected in any surface water samples collected at the site.

Data from the sediment samples indicated that three VOCs (acetone, benzene, and toluene), 14 SVOCs/PAHs, six pesticides (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, endrin, heptachlor, and methoxychlor), and 22 metals were detected in sediment samples at concentrations below

ArcGIS File: RFAAP_Fig8-1_ARSAAR_SEHill_Arsenic_Soil_Results_IM_RFI.mxd (3/7/2013 12:00:28 PM)



LEGEND

Lab Confirmation Location Arsenic Results

- < Background UTL (15.8 mg/kg)
- >= Background UTL (15.8 mg/kg)

XRF Sample Location Arsenic Results

- < Background UTL (15.8 mg/kg)
- > Background UTL (15.8 mg/kg)

- Water Feature
- Surface Water Flow Direction
- Fence Line
- XRF Sample Grid
- Historic Feature
- MRS Boundary

- Notes:
- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
 - 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
 - 3) Soil results are from 2011.
 - 4) UTL = Upper Threshold Limit.
 - 5) Background UTLs were obtained from the RFAAP Facility-Wide Background Study Report (IT, 2001).



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FIGURE 8-1
Army Reserve Small Arms Range
Southeast Hillside Area
Arsenic Concentrations in Surface Soil
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: RFAAP_Fig8-2_ARSAR_SEHill_Lead_Soil_Results_IM_RFI.mxd (3/5/2013 5:20:48 PM)



LEGEND

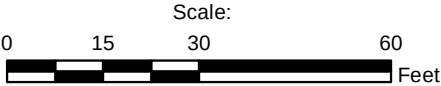
Lab Confirmation Location Lead Results

- Soil Sample Location Result < r-SL
- Soil Sample Location Result >= r-SL, but <= i-SL
- Soil Sample Location Result >= i-SL

XRF Sample Location Lead Results

- < 400 mkg/kg
- > 400 mkg/kg
- Water Feature
- Surface Water Flow Direction
- Fence Line
- XRF Sample Grid
- Historic Feature
- MRS Boundary

- Notes:
- 1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
 - 2) Historic features and MRS boundary were obtained from Final Site Screening Process Report (URS, 2009).
 - 3) Soil results are from 2011.
 - 4) Soil SLs were obtained from the USEPA Mid-Atlantic Region Regional Screening Level Summary Table, November 2012.



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FIGURE 8-2
Army Reserve Small Arms Range
Southeast Hillside Area
Lead Concentrations in Surface Soil
Radford Army Ammunition Plant,
Radford, VA

applicable SLs and, therefore, are not a concern in sediment at the site. Three PAHs [benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene] were the only analytes detected in sediment samples above applicable SLs. In most cases, detected concentrations of benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene were marginally greater than their respective r-SLs and all were well below i-SLs. The presence of these PAHs is not considered to be related to past site use, rather, their presence is attributable to the deteriorating asphalt roads and parking lots immediately adjacent to the site.

8.1.5 Groundwater

Two direct-push downgradient groundwater samples were collected from temporary wells installed in the southwestern portion of the site. Groundwater sample data indicated that five VOCs (acetone, chloroform, chloromethane, ethylbenzene, and toluene), five SVOCs/PAHs [benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, di-n-butylphthalate, and naphthalene], nine total metals, and nine dissolved metals were detected in groundwater samples at concentrations below applicable SLs and, therefore, are not a concern in groundwater at the site. Pesticides, PCBs, explosives, and herbicides were not detected in any of the samples and, therefore, are not a concern in groundwater at the site. Analytes detected at concentrations exceeding groundwater SLs included three PAHs [bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene], one total metal (antimony), and perchlorate. These isolated exceedances at concentrations marginally exceeding groundwater SLs are not a concern in groundwater at the site. None of the analytes exceeding groundwater SLs are related to past site use. In addition, these samples were collected from direct-push temporary wells without a sand-pack, which increases the amount of sediment in the sample. It is likely that the elevated concentrations are due to sediment entrained in the samples or potential drag down from the surface during boring advancement.

8.2 Human Health Risk Assessment Conclusions

An HHRA was performed to evaluate the potential human health effects associated with previous activities at the ARSAR. Receptors evaluated for both areas included current/future maintenance worker, future industrial worker, future excavation worker, future adult resident, future child resident, and lifetime resident.

Firing Point/Berm Area Summary

As presented in *Section 6.4* for the Firing Point/Berm Area, the total cancer risk for current/future maintenance worker exposures to surface soil (1E-06) was equal to the lower limit of the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (1E-06) was equal to the lower limit of the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For future industrial worker exposures to surface soil, the total cancer risk for exposures to surface soil (5E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (4E-06) was within the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the future excavation worker, the total cancer risk for exposures to surface soil (3E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to cobalt. Based on the background

comparison, cobalt was found to be background-related. The total HI for surface soil (16) was above 1 due to aluminum, cobalt, and manganese. Based on background comparisons, however, these COPCs were found to be background-related. The total cancer risk for exposures to sediment (5E-07) was below the acceptable risk range. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the future hypothetical lifetime resident, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic and benzo(a)pyrene. The total HI for surface soil was less than 1. The total cancer risk for exposures to sediment (2E-06) was within the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

For the hypothetical child resident, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic and benzo(a)pyrene. The total HI for surface soil (HI = 4) is above an acceptable HI of 1 primarily due to iron and thallium with individual HIs that were each equal to 1. The margin of exposure evaluation for iron indicated that concentrations of iron were within the allowable range. While the HI for thallium did not exceed 1, it was equal to 1 and contributed to the exceedance of the target organ HI for skin. The results from ProUCL concluded that thallium was above background; however, it is noted that the mean, median, and maximum concentrations of thallium for the site data set were all below the corresponding statistics for the background data set. The total cancer risk for exposures to sediment (1E-06) was equal to the lower limit of the acceptable risk range due to arsenic. The total HI for sediment was less than 1. No COPCs were identified in surface water or groundwater.

Southeast Hillside Area Summary

As presented in *Section 6.4* for the Southeast Hillside Area, the total cancer risk for current/future maintenance worker exposures to surface soil (4E-06) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. However, as noted in *Section 4.7.3*, a geologic and geochemical analysis strongly suggests a natural source for the elevated arsenic in the Southeast Hillside Area. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For future industrial worker exposures to surface soil, the total cancer risk for exposures to surface soil (2E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. However, as noted in *Section 4.7.3*, a geologic and geochemical analysis strongly suggests a natural source for the elevated arsenic in the Southeast Hillside Area. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For the future excavation worker, the total cancer risk for exposures to surface soil (1E-06) was equal to the lower limit of the acceptable risk range of 1E-06 to 1E-04. The total HI for surface soil was equal to 1. Site concentrations of lead in surface soil are below the health protective criterion for lead.

For the future hypothetical lifetime resident, the total cancer risk for exposures to surface soil (9E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. However, as noted in *Section 4.7.3*, a geologic and geochemical analysis strongly suggests a natural source for

the elevated arsenic in the Southeast Hillside Area. The total HI for surface soil was less than 1. Site concentrations of lead in surface soil are above the health protective criterion for lead.

For the hypothetical child resident, the total cancer risk for exposures to surface soil (6E-05) was within the acceptable risk range of 1E-06 to 1E-04 due to arsenic. The total HI for surface soil (HI = 5) is above an acceptable HI of 1 due to arsenic and thallium. Although ProUCL concluded that thallium was above background, it is noted that the mean, median, and maximum concentrations of thallium for the site data set were all below the corresponding statistics for the background data set. However, as noted in *Section 4.7.3*, a geologic and geochemical analysis strongly suggests a natural source for the elevated arsenic in the Southeast Hillside Area. Site concentrations of lead in surface soil are above the health protective criterion for lead.

8.3 Screening Level Ecological Risk Assessment Conclusions

8.3.1 Firing Point/Berm Area

The data, results, and conclusions of the SLERA evaluated risks to ecological populations inhabiting terrestrial and aquatic habitats at the Firing Point/Berm Area. Conclusions are derived from the risk assessment and are based on the responses to the assessment hypotheses and assessment endpoints. The assessment results for food chain exposure are summarized in **Table 7-15**, and direct contact exposure results for terrestrial and aquatic invertebrates, which may serve as a food source for wildlife, are summarized in **Tables 7-16, 7-17, and 7-18**, and discussed in *Section 7.2.7*.

The food chain assessment suggests potential adverse impacts to terrestrial wildlife, especially shrews, robins, and voles for modeled contact with cadmium, chromium, copper, lead, nickel, selenium, and zinc in surface soil. However, the use of alternative UFs (e.g., alternative UFs for TRV species extrapolation), would reduce the estimated LOAEL-based EEQs to 1 (when rounded to one significant figure) or less than one for all receptors at the Firing Point/Berm Area.

The direct contact assessment results suggest a potential reduction in wildlife food supply (i.e., plants, soil invertebrates, surface water biota, and sediment biota) due to manganese in surface soil; copper, iron, and benzo(b)fluoranthene in sediment; and aluminum and barium in surface water. However, manganese in surface soil is background related (*Section 7.2.5*) and is not considered further. Although some aluminum concentrations in surface water exceed the promulgated chronic criterion for the protection of aquatic life, aluminum toxicity is expected to be minimal due to the expected presence of moderately hard water at the site and associated reduced bioavailability (*Section 7.2.4.3*).

8.3.2 Southeast Hillside Area

The data, results, and conclusions of the SLERA evaluated risks to ecological populations inhabiting terrestrial and aquatic habitats at the Southeast Hillside Area. Conclusions are derived from the risk assessment and are based on the responses to the assessment hypotheses and assessment endpoints. The assessment results for food chain exposure are summarized in **Table 7-23**, and direct contact exposure results for terrestrial invertebrates, which may serve as a food source for wildlife, are summarized in **Table 7-24** and discussed in *Section 7.3.7*.

The food chain assessment suggests potential adverse impacts to terrestrial wildlife, especially shrews, robins, and voles for modeled contact with the hazard driver (lead) in surface soil. Based on the Tier 2 LOAEL-based approach, lead for the short-tailed shrew, American robin, and meadow vole had estimated EEQs greater than 1 when rounded to one significant figure

even when alternative UFs were used in the SLERA EEQ calculations. These findings suggest that wildlife food chain impacts related to lead are a potential concern for surface soil at the Southeast Hillside Area. However, given the relatively small size of the site (1.1 acres), it is unlikely populations of wildlife such as American robins, short-tailed shrews, and/or meadow voles would be adversely impacted by concentrations of some metals in soil, such as lead. While a few individuals may suffer deleterious effects based on modeled exposure, these are conservative modeled estimations, not results of ecological field studies. Also, no threatened or endangered species are known to occur at the site; therefore, losses of individuals that are common species of wildlife are not an overriding concern. Potential reductions in food supply (due to modeled earthworm and plant toxicity) are not an overriding concern to area wildlife, as they would be expected to forage in non-impacted area proximate to the site where soil invertebrates and plants are expected to be abundant.

Another line of evidence to support these conclusions comes from Oregon DEQ Final Guidance for Ecological Risk Assessment: Levels I, II, III, IV (Oregon DEQ Waste Management and Clean-up Division, 1998, updated 12/2001) that discusses an approach they recommend to estimate the size of a population area, for evaluating potential population-level impacts (see the discussion that starts on pdf page 65 of **Appendix H**). This guidance gives a relatively simple approach for estimating the “size” of a wildlife population (basically: $100 \times \text{Home Range}/\pi$). Our shrew receptor has an HR of about 1 acre, so the population size for this species would be about 32 acres, and for the vole (with an HR of about 0.09 acres), population size for this species would be about 2.9 acres. The robin has an HR of 1.2 acres, so population size would be about 38 acres. Given that the Southeast Hillside Area is only 1.1 acres, this suggests that impacted area would likely not adversely impact local populations.

Note that the vole is much less impacted than either the shrew or the robin, so even though about 38 percent of the site is within the vole’s population area ($1.1/2.9$), this receptor had a much lower HQ. Shrews and robins should not be adversely impacted at the local population level.

The direct contact assessment results suggest a potential reduction in wildlife food supply (i.e., plants and soil invertebrates) due to manganese and lead in surface soil. However, manganese in surface soil is background related (*Section 7.3.5*) and is not considered further. Potential reductions in food supply (due to modeled earthworm and plant toxicity from lead) are not an overriding concern to area wildlife, as they would be expected to forage in unimpacted area proximate to the site where soil invertebrates and plants are expected to be abundant.

Finally, the location of the hillside is behind the berm and across the stream from an access point for equipment required for soil removal. Access to this area would require removal of portions of the berm, clearing the trees on the near side of the stream and clearing portions of the hillside itself. These actions would degrade the quality of the stream through the removal of the trees stabilizing the banks and providing shade. Excavation of the hillside to remove lead-containing soil would de-stabilize the soil above that point, creating an ongoing erosion issue. These actions would collectively lead to a greater loss of habitat and potential receptors populations than taking no action on the hillside.

8.4 Interim Measures Conclusions

Interim Measures were performed in conjunction with the RFI investigation to address the elevated lead and antimony previously reported in surface soil of the berm. Prior to the commencement of excavation activities, trees growing on top and in the face of the berm were

removed. After the trees were removed, three series of exploratory trenches were cut within the berm to determine how the berm was constructed. The exploratory trenches showed that the berm was constructed of a lean well graded, clayey material that was free of debris.

Following tree removal activities, several piles of debris, located behind and adjacent to the berm, were removed. The debris consisted of various types of wastes including concrete, brick, fence posts, wood, and wire. These items were removed with an excavator and stored in a central location until after completion of the target berm soil excavation and load out. The debris, totaling 5.21 tons, was loaded into a dump truck and hauled off-site to an approved local landfill.

A composite soil sample was collected from the berm to characterize the soil for proper disposal; composite soil results indicated that the berm soil was non-hazardous. Approximately 1-2 ft of soil was removed from the berm face and direct loaded into dump trucks for off-site disposal. During soil excavation activities, an XRF was used to measure real time lead and antimony concentrations in the excavated surface of the berm and guide the excavation. Soil was excavated from the berm face until XRF results demonstrated that lead and antimony concentrations were below the pre-established RGs. Once XRF screening results indicated that the RGs for lead and antimony had been achieved, samples from the XRF screening locations were sent to an off-site laboratory to confirm the XRF screening results. Laboratory confirmation samples indicated the XRF screening results and demonstrated that the RGs for lead and antimony had been achieved for the target berm. Upon completion of the berm excavation, it was determined that a total of 147 tons, or approximately 105 CY, of impacted soil was removed from the firing range berm.

Once it was determined that the RGs had been achieved, the berm excavation was graded for proper drainage and a seed mat was applied. A site inspection performed approximately 60 days following restoration activities confirmed that the site was properly restored.

8.5 Recommendations

Based on past use of the site and the previous investigation conducted at the site, lead and antimony were constituents identified as the main constituents of concern for the Firing Point/Berm Area of the ARSAR. Media samples collected during from the Firing Point/Berm Area during 2011 RFI/IM activities indicated that lead and antimony were not detected in soil, surface water, sediment, or groundwater at concentrations exceeding applicable SLs/RGs. Isolated occurrences of benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene, PCB-1254, perchlorate, and other naturally-occurring metals at concentrations marginally above SLs in media samples are not related to past site use and not considered to be a concern at the Firing Point/Berm Area. Therefore, No Further Action is recommended for the Firing Point/Berm Area of the ARSAR. The Firing Point/Berm Area of the ARSAR is suitable for unrestricted use because there are no unacceptable risks to site receptors.

Arsenic was reported at elevated levels in soil samples collected along the Southeast Hillside Area during the previous investigation and during the 2011 RFI. No source related to past site use has been identified for arsenic. Elevated concentrations of arsenic detected in the southeast hillside soil are considered to be naturally occurring. The geology of the Southeast Hillside Area is different than the geology in the rest of RFAAP, as documented on the Radford North geologic quadrangle map (Schultz and Bartholomew, 2009). A tectonic window exposes an undivided Devonian, Silurian, and Ordovician unit that only outcrops in one other location

within the Radford North Quadrangle (not within RFAAP) (Schultz and Bartholomew, 2009). This unit consists, in part, of the Millsboro Shale and the Martinsburg Formation, both of which are rich in arsenopyrites, giving them their dark grey color. These arsenopyrites are the likely source of the elevated arsenic in the Southeast Hillside Area.

Concentrations of lead are above the health protective criterion for hypothetical future residents in surface soil at the Southeast Hillside Area. Although residential development of the Southeast Hillside Area is highly unlikely, the results of the lead evaluation indicate a need for future land use controls.

Institutional Controls (ICs) are being implemented at the site within the boundary of Southeast Hillside Area as shown on **Figure 2-2**. The objective of the ICs is to prevent any future residential use. In the event the property is transferred or leased, equivalent ICs will be put into terms and conditions of the deed or lease, which are no less restrictive than the IC objectives described above. Furthermore, the transferee or lessee will be responsible for ensuring IC compliance by any future users. However, the Army acknowledges the responsibility for all original liability under the Comprehensive Environmental Response, Compensation, and Liability Act and its right and responsibility to enforce ICs unless otherwise transferred to the new property recipient.

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