
RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA

**Solid Waste Management Units
40 (RAAP-009) and 71 (RAAP-002)
RCRA Facility Investigation /
Corrective Measures Study Report**

VOLUME I

**FINAL
APRIL 2009**

PREPARED BY:



**5540 Falmouth Street, Suite 201
Richmond, Virginia 23230
(804) 965-9000 main
(804) 965-9764 fax
CONTRACT DACA31-00-D-0011
DELIVERY ORDER NO. 0023**



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

June 30, 2009

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

P.W. Holt
Environmental Manager
Alliant Techsystems, Inc.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24141-0100

Re: Radford Army Ammunition Plant, Va.
Review of Army's Final RCRA Facility Investigation/Corrective Measures Study (RFI/CMS)
Report for Solid Waste Management Units (SWMUs) 40 and 71

Dear Mr. McKenna and Ms. Holt:

The U.S. Environmental Protection Agency (EPA) and Virginia Department of Environmental Quality (VDEQ) have reviewed the U.S. Army's (Army's) April 2009 Final RFI/CMS Report for SWMUs 40 and 71, located at the Radford Army Ammunition Plant (RFAAP) in Radford, Virginia. Based upon our review, the report is approved, and in accordance with Part II. (E) (5) of RFAAP's Corrective Action Permit, it can now be considered final.

If you have any questions, please call me at 215-814-3413. Thanks.

Sincerely,

A handwritten signature in black ink, appearing to read "William Geiger", is written over a horizontal line.

William Geiger
RCRA Project Manager
Office of Remediation (3LC20)

cc: James Cutler, VDEQ





ATK Ammunition Systems
Energetic Systems
Radford Army Ammunition Plant
Route 114, P.O. Box 1
Radford, VA 24143-0100

www.atk.com

May 5, 2009

Mr. William Geiger
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 24143-0100

Subject: With Certification, Solid Waste Management Units 40 (RAAP-009) and 71 (RAAP-002) RCRA
Facility Investigation/Corrective Measures Study Report, Volumes I and II, Final, April 2009
EPA ID# VA1 210020730

Dear Mr. Geiger and Mr. Cutler:

Enclosed is the certification for the subject document that was sent to you on April 29, 2009. Also enclosed are the 29 April 2009 transmittal email and our responses to comments on the draft report that were submitted via email on February 13, 2009. As this is a final document we anticipate receiving a letter of approval from your office.

Please coordinate with and provide any questions or comments to myself at (540) 639-8658, Jerry Redder
ATK staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 731-5782.

Sincerely,

P.W. Holt, Environmental Manager
Alliant Techsystems Inc.

c: Karen Sismour
Virginia Department of Environmental Quality
P. O. Box 10009
Richmond, VA 23240-0009

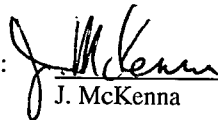
E. A. Lohman
Virginia Department of Environmental Quality
Blue Ridge Regional Office
3019 Peters Creek Road
Roanoke, VA 24019

Rich Mendoza
U.S. Army Environmental Command
1 Rock Island Arsenal
Bldg 90, 3rd Floor, Room 30A
IMAE-CDN
Rock Island, Illinois 61299

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
P.W. Holt
J. J. Redder
Env. File

Coordination:


J. McKenna


M. A. Miano

Concerning the following:

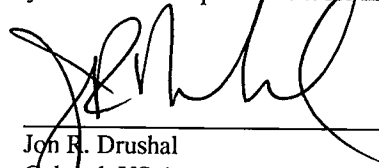
Radford Army Ammunition Plant
Solid Waste Management Units 40 (RAAP-009) and 71 (RAAP-002)
RCRA Facility Investigation/Corrective Measures Study Report
Volumes I and II, Final, April 2009

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:


Jon R. Drushal
Colonel, US Army
Commanding

SIGNATURE:

PRINTED NAME:

TITLE:


Kent Holiday
Vice President and General Manager
ATK Energetics Systems

Greene, Anne

From: McKenna, Jim
Sent: Wednesday, April 29, 2009 10:31 AM
To: Greene, Anne; ealohman@deq.virginia.gov; Druck, Dennis E Mr CIV USA MEDCOM CHPPM; diane.wisbeck@arcadis-us.com; durwood willis2; Geiger.William@epamail.epa.gov; Redder, Jerome; jim spencer; jlcutler@deq.virginia.gov; kjsismour@deq.virginia.gov; Llewellyn, Tim; Mendoza, Richard R Mr CIV USA IMCOM; Meyer, Tom NAB02; Parks, Jeffrey N; Timothy.Leahy@shawgrp.com; Tina_Devine@URSCorp.com
Subject: Final SWMUs 40 and 71 RFI/CMS Report FedEx Tracking Numbers (UNCLASSIFIED)
Importance: High

Classification: UNCLASSIFIED
Caveats: FOUO

All:

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

A certification letter will follow.

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

Jim McKenna

POCs and tracking numbers:

James McKenna 7965 6082 8098 2 Paper copies

Will Geiger 7975 4856 5376 1 Paper copy/1 CD

Jim Cutler 7965 6083 8765 1 Paper copy/1 CD

Tom Meyer 7975 4857 2275 1 Paper copy/1 CD

Richard Mendoza 7975 4857 9854 1 Paper copy/1 CD

Dennis Druck 7975 4857 6671 1 CD

Elizabeth Lohman 7975 4858 6319 1 CD

Susan Ryan 7965 6085 3905 1 CD

Classification: UNCLASSIFIED
Caveats: FOUO

Greene, Anne

From: McKenna, Jim
Sent: Friday, February 13, 2009 7:05 AM
To: diane.wisbeck@arcadis-us.com; jim spencer; Parks, Jeffrey N; Flint, Jeremy; Redder, Jerome; jlcutler@deq.virginia.gov; Mendoza, Richard R Mr CIV USA IMCOM; Timothy.Leahy@shawgrp.com; Llewellyn, Tim; Tina_Devine@URSCorp.com; Meyer, Tom NAB02; Geiger.William@epamail.epa.gov
Subject: FW: SWMU 40/71 RFI/CMS RTC (UNCLASSIFIED)
Importance: High
Attachments: SWMU 40_71_RFI_CMS_RTC Complete.pdf

Classification: UNCLASSIFIED

Caveats: FOUO

All: Resending this as I forgot to include Will Geiger on the original distribution. Please pass on to others in your organization. Jim

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

From: McKenna, Jim J Mr CIV USA AMC
Sent: Thursday, February 12, 2009 4:10 PM
To: diane.wisbeck@arcadis-us.com; jim spencer; Parks, Jeffrey N; jeremy.flint@atk.com; jerome.redder@atk.com; jlcutler@deq.virginia.gov; Mendoza, Richard R Mr CIV USA IMCOM; Timothy.Leahy@shawgrp.com; Llewellyn, Tim; Tina_Devine@URSCorp.com; Meyer, Tom NAB02

Subject: FW: SWMU 40/71 RFI/CMS RTC (UNCLASSIFIED)

Importance: High

Classification: UNCLASSIFIED

Caveats: FOUO

All:

Our response to comments (RTCs) in re the draft SWMU 40/71 RFI/CMS report for discussion at next week's meeting. Please pass on to others in your organization.

Thanks,
Jim

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

From: Tina_Devine@URSCorp.com [mailto:Tina_Devine@URSCorp.com]
Sent: Thursday, February 12, 2009 3:59 PM
To: McKenna, Jim J Mr CIV USA AMC
Subject: SWMU 40/71 RFI/CMS RTC

Here is the final RTCs. Have a great day.

(See attached file: SWMU 40_71_RFI_CMS_RTC Complete.pdf)

Tina DeVine, P.E.
Project Engineer
URS Corporation
(804)474-5448

5/4/2009

This e-mail and any attachments are confidential. If you receive this message in error or are not the intended recipient, you should not retain, distribute, disclose or use any of this information and you should destroy the e-mail and any attachments or copies.

Classification: UNCLASSIFIED

Caveats: FOUO

Classification: UNCLASSIFIED

Caveats: FOUO

Response to Comments (2/2/2009)

Presented below are EPA/VDEQ comments (minus risk assessment) on the *Draft Solid Waste Management Units 40 and 71 RCRA Facility Investigation / Corrective Measures Study Report*, Radford Army Ammunition Plant (RAAP), Virginia, dated April 2008 (RFI/CMS Report). Received 8/27/2008.

GENERAL COMMENTS

1. Based on the information provided in Figures 2-15 through 2-18, site characterization of ground water should continue in the direction of ground water flow, in the vicinity of geophysical resistivity station 2-30 (favorable drilling target 1-20) on Figure 2-17. The Long-Term Groundwater Monitoring Table, included in Section 10.2.3, Long Term Monitoring and Maintenance, only identifies three wells proposed for the long-term groundwater monitoring program at Solid Waste Management Unit (SWMU) 40, the Nitro Landfill. For consistency and clarity, a discussion within the RFI/CMS needs to be presented which further evaluates the geophysical survey information to select an additional downgradient monitoring point for the long-term groundwater monitoring program being proposed. This would also be consistent with the RCRA minimum requirement of three downgradient wells for long term monitoring of a regulated unit (see specific comment #4).

Response: Paragraph one of page 10-2 will be revised to include the following discussion beginning with the third sentence:

The anticipated LTM program is summarized in the following table and would include existing upgradient monitoring well FLMW01 and existing downgradient monitoring wells 40MW5 and 40MW6. A third downgradient monitoring well 40MW7 would be installed at the site to comply with the RCRA minimum monitoring requirements of three downgradient monitoring for long-term monitoring. In Section 10.2.3, the long term monitoring table will be updated to reflect the changes detailed above. Also, related remedial cost estimates will be updated to incorporate costs for the installation of the additional well and sampling, etc. The proposed location of 40MW7 would correspond with the favorable drilling target for a monitoring well located approximately 135 ft west/northwest of the landfill area (see attached Figure 10-2), as indicated by the ATS geophysical study. The proposed location of 40MW7 is identified on Figure 2-17 along geophysical Line 1 at electrode location 1-19 as a blue circle and as labeled on the pseudo-section for Line 1 on Figure 2-15 as a "possible karst feature or fracture zone" at an approximate elevation of 1850 ft mean sea level and lower. When projected out from near the center of the landfill area, this location is also along the predominant average strike of bedrock bedding planes (110°) in the site area as discussed in Section 2.7.1.1 and in the approximate direction of preferential groundwater flow indicated by the dye trace from SWMU 17 to spring SP3. As shown on Figure 2-18, potentiometric data from the landfill area identified an apparent west and northwest component of groundwater flow from the landfill area.

2. There is no discernible rationale for the presentation of unnumbered tables in the main body of Section 6.0, Human Health Risk Assessment; numbered tables at the end of the section; and tables in Appendix E, Human Health Risk Assessment. For ease of comprehension, please reorganize the tables by presenting ones that summarize key HHRA components – for example, chemicals of potential concern (COPCs), exposure point concentrations (EPCs), receptors and exposure pathways, toxicity criteria, and risk summaries – at the end of Section 6.0. Appendix E should contain the more detailed tables. All tables should be numbered, titled, and listed in a table of contents.

Response: Section 6, the human health risk assessment will be revised per human health risk comments received from Betty Anne Quinn.

SPECIFIC COMMENTS

3. **Executive Summary, Page ES-2:** The first full paragraph on this page summarizes the HHRA conclusions for SWMU 71, stating that “No further action is needed at the site on the basis of human health.” However, the same paragraph reports elevated cancer risk estimates associated with the hypothetical future lifetime resident; and elevated non-cancer hazard estimates derived for the hypothetical future construction worker and hypothetical future child resident. The conclusion of “No further action” is not supported by the stated results and is misleading. Furthermore, the presentation of the SWMU 71 results in the Executive Summary differs from that presented in Section 6.6.2.1, SWMU 71 HHRA Summary. Please remove the statement regarding “No further action” from the Executive Summary (or perhaps change it to read “no further remediation”) unless additional information is presented to support the statement. Additionally, please assure that the results of the HHRA are presented consistently throughout the RFI/CMS Report.

Response: The executive summary will be revised as necessary per revisions to the HHRA to address additional risk assessment comments. The executive summary will be revised to be consistent with the results of the HHRA.

4. **Section 2.7.1.2, ATS Geophysical Survey for Monitoring Well Location, Page 2-7:** The location for monitoring well 40MW5 was selected based on the identification of a very low resistivity anomaly at this location during the geophysical survey. This anomaly was identified at approximately 75 feet below ground surface (bgs). It was suggested that this anomaly was likely a karst feature or fracture zone (Figure 2-15, Psuedo-Sections, ATS L-1 and L-2). However, based on drilling at this location, groundwater was not encountered at 40MW5 until 143 ft bgs (Section 2.7.1.3, Monitoring Well Installation). The actual cause of the anomaly at 40MW5 was not explained in the RFI/CMS Report. Please revise the RFI/CMS Report to further address the anomaly encountered at 40MW5, based on the results of drilling at this location. Additionally, please address whether this location is still considered an ‘optimal’ downgradient monitoring location for the landfill, considering the west/northwest groundwater flow direction at the site and the identification of a preferential pathway of groundwater flow to the west, primarily through karst conduits. For long-term monitoring purposes, it may be beneficial to consider installation of a well in a location

west of the landfill (perhaps intercepting an additional anomaly/likely karst feature identified during the geophysical survey).

Response: The boring for 40MW5 did confirm the presence of a fracture zone or karst feature at the anomaly depths indicated by the geophysical survey. As shown on the boring log of 40MW5 in Appendix C.3, a zone of apparent clayey rock fragments was encountered in this boring between a depth of 74 and 90 ft with competent bedrock present above and below this zone. As noted on the boring log this zone corresponds to the depth interval of the geophysical anomaly identified on Figure 2-15 on pseudo-section ATS L-1 as "likely karst features or fracture zone." As discussed in the report, groundwater was not encountered in this zone but was encountered in a discrete fracture at a depth of 143 ft. The depth that groundwater was encountered generally corresponded with the base of the lower resistivity zone (green color) identified by the geophysical survey.

The location of 40MW5 is still considered an optimal location for assessing releases from the landfill area given its positioning immediately adjacent to base of the landfill and its location in the apparent groundwater flow path from north central portions of the landfill area where the landfill material is thickest as shown on Figures 2-15 and 2-18.

The RFI/CMS Report will be revised to include this additional information.

5. **Section 3.4.4, Groundwater Sampling, Page 3-6:** The second paragraph states that both high flow and low flow purging techniques were used to collect the groundwater sample from 40MW5. However, the RFI/CMS Report does not clarify why high flow purging techniques were necessary at this well. If multiple flow zones were encountered or if the well was producing a higher yield than the other wells, this information should be documented to support use of a high flow purging techniques. Please revise the RFI/CMS Report to state why high flow purging techniques were used at monitoring well 40MW5.

Response: As a clarification, well 40MW5 was initial purged at a rate greater than 1,000 milliliters per minute (ml/min) but then was reduced to a low flow purge rate of 500 ml/min or less to minimize excessive drawdown. 40MW5 was screened across a single discrete water-producing zone (fracture) encountered during drilling at 143 ft. Section 3.4.4 will be revised to include this information.

6. **Section 4.1.2, Human Health Nature and Extent Assessment, Page 4-4:** The Summary of COPCs for Soil notes that 2,3,7,8-TCDD TEQ was detected above the residential RBC at surface soil sample location 40SS4. However, with the exception of surface soil sample location 40SS5 located greater than 50 ft southeast of 40SS4, no other surface soil samples in the vicinity of this exceedance were evaluated for 2,3,7,8-TCDD TEQ. Therefore, the extent of 2,3,7,8-TCDD TEQ does not appear to be fully delineated. Please revise the RFI/CMS Report to address this perceived data gap.

Response: Additional sampling for dioxins is not proposed for the RFI/CMS given that the detected concentration at this location is below the industrial RBC and the proposed

corrective measures alternative will include institutional and engineering controls to limit future land use to industrial, maintain containment of the landfill including the cap, and prevent unacceptable human health exposure. Under this future scenario, the calculated risk for the most likely receptor (future maintenance worker) for dioxin in surface soil is de minimus (8E-08).

7. **Section 4.1.2.2, Landfill Material, Dioxins, Page 4-8:** A concentration of 2,3,7,8-TCDD TEQ was detected in sample TESTPIT2F above the soil screening level (SSL) based on a dilution attenuation factor (DAF) of 20. The potential for this contaminant to migrate to groundwater has not been further evaluated. Groundwater samples were not analyzed for dioxins/furans, and a site-specific SSL was not calculated for this constituent, even though it is mentioned in Section 4.1.4. Please revise the RFI/CMS Report to clarify how the potential for 2,3,7,8-TCDD TEQ to migrate to groundwater will be evaluated, given the SSL exceedance at TESTPIT2F.

Response: A site specific SSL has been calculated for the site (1.46E-05 mg/kg). Detected concentrations of 2,3,7,8-TCDD TEQs were below the calculated site specific SSL using site specific physical soil data and a default DAF 20. Dioxins are typically immobile in soil and have a very low solubility in water and therefore are unlikely to migrate to groundwater, particularly with the low permeability clay soil present below the landfill material. One round of confirmatory groundwater samples is proposed during the initial LTM sampling to verify that dioxins have not migrated to groundwater at the site. The remedial cost estimate will be updated to include one round of confirmatory sampling for dioxins in groundwater.

8. **Section 4.1.4.1, Development of Specific Soil-to-Groundwater SSLs, Page 4-10:** It appears that default values were used to calculate site-specific SSLs even though site-specific data are available. For example, default values were used for water-filled soil porosity, air-filled soil porosity, and dry soil bulk density, but Table 2-1, Soil Physical Testing Results, includes the site-specific data from the soil fill and the soil below the landfill for these parameters. Additionally, a default DAF of 20 was used in the SSL equations, but the RFI/CMS Report does not address the applicability of this value. EPA's *Soil Screening Guidance: User's Guide* (July 1996) notes that a default DAF value of 20 is protective for contaminant soil sources up to 0.5 acre in size (Page 30), but Section 1.0, Introduction, states that SWMU 40 is approximately 2 acres in size. The *Soil Screening Guidance* further states that "a DAF of 20 may be protective of larger sources as well; however, this hypothesis should be evaluated on a site-specific basis." Please revise the RFI/CMS Report to use site-specific data wherever possible when calculating site-specific SSLs to obtain SSLs that are more reflective of conditions at the site. Alternatively, please provide further justification for using default values. Additionally, please provide justification for use of a DAF value of 20, or calculate a site-specific DAF for this site as recommended by the *Soil Screening Guidance*.

Response: Site-specific SSLs will be revised to use site physical soil data. The use of the default DAF 20 is considered appropriate for the site given the observed attenuation of constituent concentrations with depth, the lack of appreciable leaching of constituents of potential concern from landfill material to

underlying clay soil, and the lack of leaching of constituents of concern from soil to groundwater approximately 25 years after landfill closure. Factors likely contributing to attenuation include the presence of a low permeability clay cap above the landfill material, the presence of low permeability clay soil below the landfill material (1E-07 to 1E-08 cm/sec), and greater than 90 foot depth to groundwater.

As a clarification, the approximate size of the source area where landfill material is present is approximately 1.3 acres as indicated on Figure 2-11.

It should also be noted that the Site-Specific SSL Calculations, included in Appendix C.8, include the following statement on each page of calculations: "Input Parameters Averaged from All Soil-Sample Physical Text Results." This statement is inaccurate as most of the values used in the calculations are default values. Please clarify this discrepancy.

Response: See previous response. Site-specific SSLs will be revised using available site data.

9. **Section 4.3.2.1, Perchlorate, Page 4-16:** Perchlorate was detected in a well located upgradient of the SWMU 40 landfill. The RFI/CMS Report states that "similar perchlorate concentrations also were detected in groundwater samples collected from the SWMU 17 area upgradient of SWMU 40 during an RFI conducted by Shaw Environment and Infrastructure (Shaw) in August 2007." A complete reference has not been provided to substantiate this information. For defensibility, please revise the RFI/CMS Report to include a complete reference for the SWMU 17 RFI, conducted by Shaw, in this section of the RFI/CMS Report and in Section 14.0, References.

Response: Section 4.3.2.1 will be revised as follows:

"As shown on Figure 4-8, groundwater samples collected from monitoring wells 40MW5 and 40MW6 located immediately adjacent to the landfill area had perchlorate concentrations (0.52 and 0.655 µg/L) below the adjusted T-RBC of 2.56 µg/L. The groundwater sample collected from monitoring well 40MW3 located downgradient of the landfill had a perchlorate concentration (0.52 µg/L) below the adjusted T-RBC of 2.56 µg/L. A higher perchlorate concentration above the adjusted T-RBC was detected in the sample collected from crossgradient well 17MW3 (5.2 µg/L) as shown on Figure 4-8. Similar perchlorate concentrations also were detected in groundwater samples collected from the SWMU 17/Former Lead Furnace Area (FLFA) upgradient of SWMU 40 during an RFI for the FLFA conducted by Shaw Environment and Infrastructure (Shaw) in August 2007 (Shaw 2008). Perchlorate concentrations detected in the Shaw samples were 5.40 µg/L at well 17MW2 and 5.33 µg/L at well LFMW01 (Figure 2-18). Perchlorate is currently being detected at low levels in numerous groundwater samples at RFAAP. The new lab detection method is possibly the reason for consistent low level perchlorate detections throughout the facility such as those detected in the wells located immediately adjacent to SWMUs 40 and 71. The samples located immediately adjacent to and downgradient of the landfill (40MW3, 40MW5, and 40MW6) were below the

unadjusted T-RBC; therefore, perchlorate was not identified as a COPC in groundwater for SWMUs 40 and 71."

The complete reference for the Shaw report (Shaw Environmental, Inc. (Shaw). 2008. *Former Lead Furnace Area RCRA Facility Investigation/Corrective Measures Study: Final Document*. Prepared for U.S. Army Corps of Engineers Baltimore District. November 2008.) will be provided in the references section.

10. **Section 10.2.3, Long Term Monitoring and Maintenance, Page 10-2:** The long-term groundwater monitoring for SWMU 40 does not appear to include analysis for dioxins/furans. Since 2,3,7,8-TCDD TEQ was detected above the SSL in at least one subsurface soil sample (TESTPIT2F), the groundwater monitoring program should include analysis of dioxins/furans to assess the potential migration of this constituent to groundwater. Please revise the RFI/CMS Report to include groundwater sampling for dioxins as part of the long-term monitoring plan, unless additional justification can be provided to exclude this analyte class.

Response: Please see the response to Comment 7. One round of confirmatory groundwater samples is proposed during the initial LTM sampling to verify that dioxins have not migrated to groundwater at the site. The remedial cost estimate will be updated to include one round of confirmatory sampling for dioxins in groundwater.

11. **Section 11.4, Cost, Page 11-5:** In the Summary of Cost for Corrective Measures Alternatives, the Annual Cost Years 6-30 for Alternative 2 is identified as \$17.099. It appears that a comma should have been used in place of the period in this value so that it reads \$17,099. Please revise this table to make the necessary correction.

Response: The summary table will be revised to reflect a value of \$17,099.

Mike's Comments

1. Geophysical examination of the landfill area has indicated the presence of a preferential pathway as shown on Figure 2-15. Figure 2-16 illustrates the structure contours for the top of bedrock. Figure 2-17 illustrates the possible target locations for monitoring wells. Figure 2-18 illustrates the groundwater potentiometric surface. Based on the above, site characterization of ground water should continue in the direction of ground water flow, in the vicinity of geophysical resistivity station 2-30 (favorable drilling target 1-20) on Figure 2-17.

Response: As discussed in the response to Comment 1, the proposed LTM program will be modified to include a third downgradient monitoring well at this location (favorable drilling target identified at electrode 1-19 on Figure 2-17) to comply with the RCRA minimum monitoring requirements of three downgradient monitoring wells.

2. Suggest ground water samples be obtained quarterly for the first four quarters, and then every nine months thereafter for remaining years out to thirty. This will allow for seasonal variations throughout the project.

Response: It is proposed that this schedule be followed for years 1-5 (quarterly year 1 and every nine months for years 2-5), with the opportunity to decrease the monitoring frequency or propose an alternative monitoring schedule after year 5 if long-term monitoring indicates statistical evidence of stable or decreasing concentrations of detected constituents in groundwater and demonstrated long-term effectiveness of the containment remedy. The statistical evaluations and remedy effectiveness evaluations would be performed as part of the requested plan (see Comment 5 below) to evaluate the effectiveness of monitoring at 5 year intervals during the 30 year monitoring period.

3. Add turbidity to the analytical parameters on page 10-2.

Response: Turbidity will be added to the analytical parameter on page 10-2.

4. The alternative chosen sounds very much like Monitored Natural Attenuation. The proposed oversight needs to be expanded to support this alternative.

Response: The proposed LTM program is a release detection program for the landfill and to verify performance of the landfill containment measures rather than a monitored natural attenuation remedy. The monitored natural attenuation remedy would be applicable if remediation of constituent concentrations in groundwater was required to achieve a specific remedial goal. The results of the risk assessment and corrective measures study did not indicate a requirement to undertake remediation of groundwater at this site.

5. Propose a plan to evaluate the effectiveness of monitoring of no more than/no less than five year frequency during the proposed 30 year monitoring.

Response: A plan for evaluating the effectiveness of monitoring will be included in the remedy implementation plan described in Section 10.2.4. Section 10.2.4 will be revised to indicate that effectiveness evaluations will occur at a minimum, five year intervals. Specific details on the evaluations will be included in the remedy implementation work plan. A component of the evaluations is expected to include analysis of groundwater monitoring data for evidence of statistically significant trends and comparisons to applicable risk criteria.

6. Section 4.3.2.1 Please include a figure illustrating the location of 17MW2 and LFMW01, or include them on a figure currently found in this report.

Response: Monitoring well LFMW01 will be added to Figure 2-18. Monitoring well 17MW2 is already illustrated on this figure. A reference to Figure 2-18 will be added to Section 4.3.2.1.

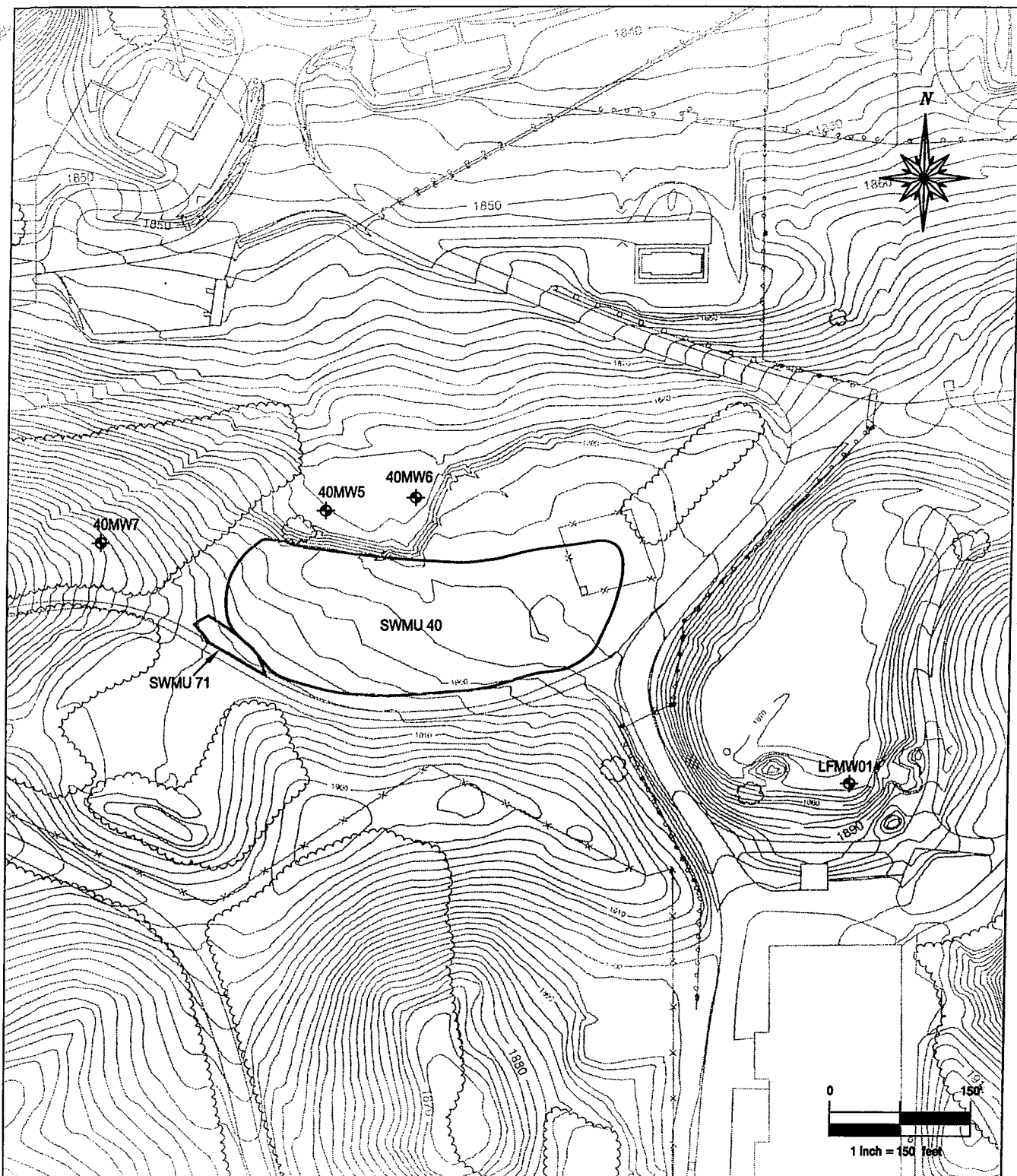
7. If neither SWMU 40 or 71 are the source of Perchlorate results, propose a plan to delineate the Perchlorate source.

Response: Perchlorate is currently being detected at low levels in numerous groundwater samples at RFAAP. The new lab detection method is possibly the reason

for consistent low level perchlorate detections throughout the facility such as those detected in the wells located immediately adjacent to and downgradient of SWMUs 40 and 71. The samples located immediately adjacent to and downgradient of the landfill (40MW3, 40MW5, and 40MW6) were below the unadjusted T-RBC; therefore, perchlorate was not identified as a COPC for SWMUs 40 and 71. (See response to Specific Comment #9). Further assessment of perchlorate is not required based on the lack of identification of the chemical as a COPC for SWMUs 40 and 71.

8. The yield of each well sampled in Section 3.4.4 should be described in the section. Anomalies (such as multiple flow zones) should be explained.

Response: The sustainable yield of the wells with minimal drawdown is generally 500 ml/min or less. Pumping at a higher rate would result in excessive drawdown and likely eventual drying of the wells. As indicated in Section 2.7.2, monitoring wells 40MW5 and 40MW6 are screened across discrete water bearing fractures encountered at depths of 143 and 122 ft bgs, respectively. Monitoring wells 17MW3 and 40MW3 are screened across discrete water bearing zones encountered at depths of approximately 167 ft and 90 ft, respectively. Section 3.4.4 will be revised to include this additional information.



Legend

- Approximate SWMU Boundary
- Topographic Contour
- Vegetation
- Fence
- Monitoring Well Location

FIGURE 10-2
Long Term Monitoring Locations

Date: January 2009	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 150 feet	File Name: Fig.10-2 LTM Wells

SWMUs 40 and 71

RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia

URS

URS Group, Inc.
5540 Falmouth Street
Suite 201
Richmond, Virginia 23230

Response to Comments (1/26/2009)

**Betty Ann's SWMU 40/71 RFI/CMS Risk Assessment Comments received
11/13/2008**

General Comments

1. The text of the human health risk assessment (HHRA) presented in Section 6.0 lacks sufficient detail regarding the methodology used to complete the evaluation. Tables in Appendix E are cited extensively, with limited text descriptions as to what they represent and how calculated values were derived. While tables are useful summaries of information, key components of a HHRA – such as identification of complete exposure pathways for the various receptors, description of the calculation of particulate emission factors (PEFs) used to evaluate inhalation of fugitive dust, and the use of the Johnson and Ettinger model to evaluate vapor intrusion in indoor air – should be elaborated upon in the text. Please incorporate a greater level of detail in the text of the HHRA and reference the tables as supporting documentation.

Response: Agreed. See attached revised text for Section 6. Text has been added to Section 6.2.2 regarding the complete exposure pathways. Text has been added to Section 6.2.3 regarding the use of models to calculate ambient air (fugitive dust and vapor), indoor air, and shower vapor EPCs. Text has been added to Section 6.2.3 regarding the use and calculation of PEFs and VFs.

2. Soil data have been collected at SWMUs 40 and 71 since 1992 (Section 2.8, Previous Investigations), but only data collected from the 2002 and 2006 investigations have been used for estimates of risk and hazard at these sites. The HHRA has not justified exclusion of the earlier site data, even though these data may still be representative of site conditions and applicable to the HHRA. Please revise the HHRA to provide justification for limiting the risk assessment data set to those soil samples collected in 2002 and 2006 only.

Response: Prior to the RFI, historical soil analytical data (1992 and 1994) were limited to SWMU 71 for metals, explosives, and total petroleum hydrocarbons. These data were considered screening level data and excluded from the risk assessment given the age of the data, the use of non SW-846 analytical methods, the lack of available data validation reports/information, and the availability of sufficient newer validated RFI data to more appropriately characterize current conditions in this small area. The HHRA (Section 6.1.1) will be revised to incorporate the rationale provided above.

3. Section 6.5, Uncertainties, and Section 6.6, HHRA Summary and Conclusions, introduce several concepts that were not presented in the preceding sections of the HHRA. For example, Section 6.5 notes that oral toxicity data were used to evaluate dermal exposures. This approach should be described in the Toxicity Assessment (Section 6.3). Furthermore, the HHRA summaries presented in Section 6.6 for SWMUs

40 and 71 are more detailed than the summaries presented in the Risk Characterization (Section 6.4). The uncertainties and conclusions discussed in these sections should be based on the methodology and results presented earlier in Section 6.0. Please reorganize and supplement Section 6.0 to introduce the issues discussed in Sections 6.5 and 6.6.

Response: Agreed. See attached revised text for Section 6. Text has been added to Section 6.3.1 in the toxicity assessment. Section 6 has been reorganized and revised.

4. The HHRA contains several discrepancies that must be addressed. For example, the Executive Summary and Section 6.6, HHRA Summary and Conclusions, identify arsenic and polychlorinated biphenyls (PCBs) as cancer risk drivers for the hypothetical future lifetime resident at SWMU 40, but Section 6.4, Risk Characterization, instead lists aroclors and polynuclear aromatic hydrocarbons (PAHs) as the risk drivers. As detailed in the Specific Comments, there are also discrepancies in the complete exposure pathways identified for the construction worker in Figure 6-2, Conceptual Site Diagram, and various related tables. Please revise the report to ensure accuracy and consistency in the presentation of HHRA results and identification of exposure pathways.

Response: Agreed. See attached revised text for Section 6. The summary table for SWMU 40 in Section 6.4 will be revised to indicate arsenic and PCBs as the risk drivers in soil for the future lifetime resident. As noted for Specific Comment #20, Tables E.1.1 and E.2.1 will be revised to indicate "none" under the "Type of Analysis" column for the construction worker for ingestion and dermal exposure to groundwater. In addition, the report will be revised as necessary for consistency.

Specific Comments

5. **Section 5.3, Fate and Transport Summary, Page 5-10:** "Groundwater samples collected from the landfill area indicated apparent leaching of chloroform from the landfill area to groundwater at levels above its T-RBC. A specific source of chloroform was not identified through sampling of soil and landfill material at the site." This would imply that the chloroform source has not been located. Please revise the RFI/CMS Report to either discuss the hypothesized sources of chloroform at this SWMU and steps that may be implemented to address the repeated occurrence of chloroform contamination at this site.

Response: Extensive source characterization was conducted at SWMU 40 and 71 including the collection of 91 soil samples many of which were collected from landfill material and soil below the landfill. Chloroform was not detected in these samples. The lack of any detections and absence of other volatiles in groundwater samples suggests an alternate source of chloroform in groundwater. The RFI/CMS report will be revised to discuss a potential alternative source of chloroform in groundwater related to leaking water lines at various locations at RFAAP. Studies and groundwater investigations have shown the presence of

chloroform in most groundwater samples collected at the facility regardless of location. The concentrations of chloroform detected in monitoring wells at SWMU 40 and 71 are within the range of chloroform levels present in the water transmitted through water lines at the facility. The landfill area is located downgradient of developed areas containing water lines, which may have been the source of chloroform.

6. **Section 6.0, Human Health Risk Assessment, Page 6-1:** This section states that the HHRA was conducted consistent with EPA's *Interim Final Risk Assessment Guidance for Superfund* (RAGS) and "other current EPA/EPA Region 3 resources and guidance documents." However, specific references for these other resources are not provided in this section. Please provide the appropriate reference citations for these guidance documents.

Response: Agreed. See attached revised text for Section 6.0.

7. **Section 6.1.1, Data Summary, Page 6-2:** This section provides a bulleted list of ways that laboratory-flagged data and duplicate samples were treated in the HHRA. Please add a description of how non-detected values were incorporated into the HHRA.

Response: The following bullet will be added to Section 6.1.1: "Chemicals that were not detected in at least one sample were considered as uncertain analytes in the evaluation of risk;"

8. **Section 6.1.2, Identification of COPCs, Page 6-2:** This section does not address how constituents with no available benchmarks or appropriate surrogates were considered in the risk assessment process. Table E.1-2.1 of Appendix E, SWMU 40 COPC Determination – Surface Soil, appears to show that chemicals without screening benchmarks, such as cobalt and 2-hexanone, were flagged as COPCs. If toxicity data are unavailable for these constituents as well, they need to be discussed qualitatively in the uncertainty analysis. Please revise Section 6.1.2 to address how constituents with no available screening benchmarks were considered in the risk screening process.

Response: The first sentence of the third paragraph states "Analytes detected at a maximum concentration greater than the corresponding adjusted RBC or screening values identified above (or those for which no screening criteria exists) were selected as COPCs." Section 6.5.4 in the uncertainties section will be revised to include a discussion of constituents with no available toxicity data. See attached revised Section 6.

9. **Section 6.2.2, Identification of Exposure Pathways, Page 6-4:** This section lacks sufficient detail regarding the complete exposure pathways evaluated for each receptor. Please provide descriptions of each exposure scenario, including the receptors and complete exposure pathways evaluated. Please also discuss the

different inhalation exposure evaluations (indoor and outdoor air) and associated methodologies, including the use of PEFs, volatilization factors (VFs), and the Johnson and Ettinger vapor intrusion model.

Response: Agreed. See attached revised Section 6.2.2.

- 10. Section 6.2.3, Calculation of EPCs, Page 6-5:** The second paragraph references ProUCL 4.0 as being used to calculate EPCs for the HHRA. Please provide a citation for this software and add it to Section 14.0, References.

Response: A citation and reference will be added for ProUCL 4.0. See attached revised Section 6. The reference added will be "U.S. Environmental Protection Agency (USEPA). 2007c. *ProUCL 4.0, Statistical Software*. April 2007."

This section should also describe the use of PEFs, VFs, and the Johnson and Ettinger model to calculate air EPCs under the various exposure scenarios.

Response: Agreed. See attached revised Sections 6.2.3.

- 11. Section 6.3, Toxicity Assessment, Page 6-5:** This section does not provide sufficient information for this critical step in a HHRA. Please describe in more detail the different types of available toxicity criteria (for example, reference doses [RfDs], reference concentrations [RfCs], and cancer slope factors [CSFs]); and provide the hierarchy of sources for toxicity criteria used in the HHRA, including the Integrated Risk Information System (IRIS) database, Provisional Peer Reviewed Toxicity Values (PPRTV), and other sources (including California Environmental Protection Agency [Cal EPA] toxicity values, the EPA Superfund Health Effects Summary Table [HEAST], and other values) as outlined in OSWER Directive 9285.7-53.

Response: Agreed. See attached revised Section 6.3.

- 12. Section 6.4, Risk Characterization, Page 6-6:** The table on Page 6-6, SWMU 40 – Summary of Risks and Hazards, is supposed to summarize data presented in Tables E.1-9.1 through E.1-9.6 of Appendix E; however, there are numerous inconsistencies among the tables. The hazard index (HI) for the hypothetical future construction worker is 14 on the Page 6-6 table, but Table E.1-9.3 RME, RME Summary of Cancer Risks and Non-Cancer Hazards for COPCs: Construction Worker – SWMU 40, indicates that the total HI across all media and all exposure routes is 2E+01. Furthermore, the HI for the hypothetical future child resident is identified as 26 on the Page 6-6 table, yet a HI of 5E+01 is presented for this same receptor on Table E.1-9.5 RME in Appendix E. An accurate summary of the risks and hazards should be presented on the Page 6-6 table. For defensibility, please revise the HHRA to consistently present the results of the risk characterization throughout the RFI/CMS Report. If any conclusions change as a result of these HIs, please update the HHRA accordingly.

Response: Agreed. See attached revised Section 6. Updated HHRA tables (Appendix E) will be submitted with the complete revised report.

13. Figure 6-2, Conceptual Site Diagram: This figure contains errors and lacks sufficient detail to support the HHRA. Please make the following revisions:

- The column labeled "terrestrial biota" should be removed since this figure has been included to support the human health risk evaluation, and not the ecological risk evaluation.

Response: Agreed. Terrestrial biota column will be removed from Figure 6-2 (see attached).

- Exposure to subsurface soil by a hypothetical future maintenance worker via the inhalation, ingestion, and dermal contact should be considered a complete exposure pathway based on the same rationale used for subsurface soil evaluation for the hypothetical future construction worker, commercial worker, and residents (that is, mixing of potential soil contamination during construction or land development activities may bring subsurface soil to the surface).

Response: Agreed. Future scenario for the hypothetical future maintenance worker for total soil will be added to the HHRA's (which will include both surface and total soil).

- A distinction should be made between each receptor's potential inhalation exposure to vapors in indoor and outdoor air, and particulates in outdoor air.

Response: Agreed. Figure 6-2 (see attached) will be revised to make a distinction between vapors in indoor and outdoor air, shower vapors, and particulates in outdoor air.

14. Table 6-1, Sample Assemblages for Soil COPC Screening: Under the Subsurface Soil heading, sample 40SB2F is listed twice and sample 40SB1F appears to have been inadvertently omitted. According to Table 4-1, SWMU 40 – Summary of Detected Chemicals in Analytical Samples, sample 40SB1F was collected from 4-8 feet below ground surface (bgs), so it should be considered a subsurface soil sample for the risk assessment. Please revise Table 6-1 to address these discrepancies.

Response: Agreed. Table 6-1 will be revised to include 40SB1F and eliminate the double reference of 4SB2F.

15. Table 6-2, Dioxin/Furan 2,3,7,8-TCDD Equivalents Calculation – Soil: This table contains typographical errors (e.g., 1,2,3,4,6,7,8,9-OCDF [OCDD]), does not define all acronyms (e.g., SSL, DAF, MX, MXJ, JB, and M), and does not provide

citations (e.g., soil-to-groundwater SSL, TEF). Please revise Table 6-2 as appropriate.

Response: Agreed. Table 6-2 will be revised to correct typographical errors and provide all acronyms and citations.

16. Table 6-3, RDA-based Screening Criteria Calculations: The number of significant digits in the Soil Screening Criteria columns (Adult Resident, Child Resident, and Selected Criteria) is inconsistent. For consistency, please present the values in the Soil Screening Criteria columns with the same number of significant digits.

Response: Agreed. Table 6-3 will be revised to consistently present the same number of significant digits.

17. Appendix E, Human Health Risk Assessment: For ease of locating specific tables, please include a table of contents after the cover page of this appendix.

Response: Agreed. A table of contents will be provided for Appendix E.

18. Appendix E, Human Health Risk Assessment: Summaries of the indoor air concentrations modeled using the Johnson and Ettinger model are included as Tables E.1-4.5 and E.1-4.7, but the model outputs from these evaluations have not been appended to the RFI/CMS Report. To facilitate a complete review of this RFI/CMS Report, please submit the Johnson and Ettinger model outputs as part of this appendix.

Response: Agreed. The model outputs will be provided in Appendix E.

19. Appendix E, Table E.1-1, Selection of Exposure Pathways - SWMU 40: Exposure to subsurface soil by a hypothetical future maintenance worker via the inhalation, ingestion, and dermal contact should be considered a complete exposure pathway based on the same rationale used for subsurface soil evaluation for the hypothetical future construction worker, commercial worker, and residents (that is, mixing of potential soil contamination during construction or land development activities may bring subsurface soil to the surface). Please provide rationale for the exclusion of this potentially complete exposure pathway or incorporate it into the HHRA as appropriate. This comment also applies to Table E.2-1, Selection of Exposure Pathways - SWMU 71.

Response: . Agreed. Future scenario for the hypothetical future maintenance worker for total soil will be added to the HHRAs.

20. Appendix E, Table E.1-1, Selection of Exposure Pathways - SWMU 40: This table identifies the hypothetical future construction worker as being evaluated quantitatively in the HHRA – as indicated by “Quant” under the heading “Type of

Analysis" – for ingestion and dermal absorption exposure to groundwater. However, the notes in the last column indicate that any contact with groundwater is unlikely for this receptor due to the depth to groundwater (90 to 100 feet bgs). Furthermore, Figure 6-2, Conceptual Site Diagram, does not identify ingestion and dermal contact with groundwater as complete exposure pathways for the construction worker. Please revise the table and subsequent risk evaluation, as appropriate, to resolve this discrepancy. This comment also applies to Table E.2-1.

Response: Tables E.1-1 and E.2-1 will be revised to indicate "none" under the "Type of Analysis" column for the construction worker for ingestion and dermal exposure to groundwater.

21. Appendix E, Table E.1-4.1d, Values used for Daily Intake Equations for Future Scenarios – Total Soil – Exposure Pathway Air: The inhalation rates selected for the adult resident are inconsistent throughout the RFI/CMS Report. Table E.1-4.1d indicates the inhalation rate for an adult resident is 0.63 cubic meters per hour (m^3/hr), which was calculated using a daily long term rate of 15 m^3/day . However, Table E.1-4.2b, Values used for Daily Intake Equations for Future Scenarios - Groundwater - Exposure Pathway Groundwater, specifies an adult resident inhalation rate of 0.83 m^3/hr , calculated using a daily long term rate of 20 m^3/day . Two different sources are cited for the inhalation rates. For consistency, please revise Table E.1-4.1d to use the inhalation rate associated with the most recent guidance (i.e., 0.83 m^3/hr should be used).

Response: The inhalation rate for the adult resident will be revised to 0.83 cubic meters per hour throughout the RFI report. In addition, all references on tables will be updated to indicate the inhalation rate is calculated using a daily rate of 20 m^3/day for 24 hours resulting in an inhalation rate of 0.83 m^3/hour .

22. Appendix E, Table E.1-4.2a, Values used for Daily Intake Equations for Future Scenarios - Groundwater - Exposure Pathway Groundwater: This table presents exposure parameters and daily intake equations associated with ingestion of and dermal contact with groundwater for the hypothetical future construction worker. However, Figure 6-2, Conceptual Site Diagram, does not identify ingestion and dermal contact with groundwater as complete exposure pathways for the construction worker. Please revise the table as appropriate to resolve this discrepancy. This comment also applies to Table E.2-4.2a.

Response: Table E.1-4.2a and Table E.2-4.2a will be revised to eliminate CDI equations for the construction worker for ingestion and dermal exposure to groundwater.

23. Section 8.1.2, SWMU 71, Page 8-1: The last sentence on Page 8-1 states, "When considering background and target organs, calculated hazards for evaluated receptors associated with hypothetical future industrial and residential land uses were below the target hazard of 1E+00." This statement appears incorrect. Page 6-7 of the

HHRA identified vanadium as having a HI greater than 1 for the hypothetical future child resident when segregated by target organ (Kidney, HI = 2). Section 6.4.3 further states that "COPCs identified for SWMU 71 that exceed background include arsenic for surface soil and vanadium for total soil." Since vanadium cannot be attributed to background, hazards associated with this contaminant need to be considered when developing corrective measure objectives (CMOs). Please revise Section 8.1.2 and all other applicable sections of the RFI/CMS Report (including the SWMU 71 Summary and Conclusions, Section 6.6.2) to acknowledge that vanadium is the primary hazard driver for the elevated target organ specific kidney HI for the hypothetical future child resident, and that this chemical exceeded background. CMOs should be developed accordingly.

Response: Based on the ProUCL Technical Guidance Manual (Sections 6.7.1.2 and 6.7.2), since the data sets exhibit unequal variances (see Appendix C, Table C.10-5d) the Satterthwaite's test should be applied. As presented in Appendix C, Table C.10-5d, the Satterthwaite test resulted in the conclusion that the site data was equal to or below background for vanadium. Section 6.3 and Table C.10-1d in Appendix D will be revised to indicate that based on means testing the vanadium in total soil for SWMU 71 not above background. No additional changes to the report are proposed.

6.0 HUMAN HEALTH RISK ASSESSMENT

This HHRA evaluates the probability and magnitude of potential adverse effects on human health associated with exposure to site-related chemicals in soil and groundwater. SWMUs 40 and 71 are evaluated separately given their different disposal histories. Refer to Section 2.0 for additional information regarding the site background. The HHRA's were conducted for the sites consistent with guidance included in EPA's *Interim Final Risk Assessment Guidance for Superfund* (RAGS), as well as other USEPA guidance (USEPA 1989a,b; 1991a; 1997a; 2001; 2002c; and 2004). Guidance documents are also noted on the RAGS Part D tables provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71).

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 screening levels 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 gathered 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 1989b) are discussed; and
- **Section 6.6: Summary and Conclusions:** The results of the HHRA are summarized.

As previously stated, 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 Appendices E.1 (SWMU 40) and E.2 (SWMU 71).

6.1 DATA SUMMARY AND SELECTION OF COPCS

6.1.1 Data Summary

Table 6-1 identifies the samples used in the SWMU 40 and SWMU 71 COPC screening for soil. Note that as presented in Section 2.8 soil data have been collected at SWMUs 40 and 71 since 1992, but only data collected from the 2002 and 2006 investigations have been used for estimates of risk and hazard at these sites. Prior to this RFI, historical soil analytical data (1992 and 1994) were limited to SWMU 71 for metals, explosives, and total petroleum hydrocarbons. These data were considered screening level data and excluded from the risk assessment given the age of the data, the use of non SW-846 analytical methods, the lack of available data validation reports/information, and the availability of sufficient newer validated RFI data to more appropriately characterize current conditions in this small area. Data from the groundwater samples collected from 40MW3, 40MW5, and 40MW6 were used in the COPC screening for groundwater. Refer to Section 4 for complete data tables for detected analytes for each media and disposal area. Additional information regarding the data used in the HHRA's is summarized below:

- Though several dioxins are known to be toxic, toxicity criteria are limited to 2,3,7,8- TCDD. Therefore, the HHRA uses the method outlined in Interim Procedures for Estimating Risks

Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs) (USEPA 1989a and WHO 2005) to assess risks due to exposure to dioxins and/or furans. Each congener is assigned a TEF, which corresponds to its toxicity relative to 2,3,7,8-TCDD. Each congener detection is multiplied by its corresponding TEF; the adjusted concentrations are then summed to derive one total 2,3,7,8-TCDD equivalent concentration for each sample. This concentration is then compared with toxicity criteria for 2,3,7,8-TCDD to calculate risks. TEFs are presented and total 2,3,7,8-TCDD equivalents are calculated for SWMU 40 and SWMU 71 in Table 6-2.

- If a constituent was measured by two methods, results from the more sensitive analytical method were used. For example PAHs were analyzed as part of the SVOC method, as well as, by a PAH specific method. Results from the specific method were used;
- J-flagged data (estimated concentration) and B-flagged data (detected in an associated blank) are considered detections and are used without modification;
- Chemicals that were not detected in at least one sample were considered as uncertain analytes in the evaluation of risk;
- Rejected results (R-flagged) are not used; and
- 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 specific soil and groundwater samples used in the HHRA is provided in Sections 6.1.1.1 and 6.1.1.2.

6.1.1.1 Surface Soil and Total Soil

Soil samples collected during sampling events completed in 2002 and 2006 for the RFI were used for the COPC screenings. As presented in Table 6-1, the soil samples for SWMU 40 and SWMU 71 were segregated and used for the SWMU 40 and SWMU 71 HHRA, respectively. Note that borings 71SB14 and 71SB15 are not located in SWMU 71 but rather located in SWMU 40; therefore, these samples are used in the HHRA for SWMU 40. In Table 6-1, the soil samples for each area have also been divided into surface soil (0 to 1 ft bgs) and subsurface soil (1 to 15 ft bgs). The two soil data groupings used for COPC screening and the HHRA are surface soil (0 to 1 ft bgs) and total soil (0 to 15 ft bgs). Total soil data grouping consists of combining surface and subsurface soil to address mixing of potential soil contamination during construction or land development activities. Soil samples collected a depth of greater than 15 ft bgs were excluded from the HHRA since it is unlikely soil below this depth would be disturbed and mixed with surface soil during excavation. A total of 32 surface soil samples and 32 subsurface soil samples were used for the HHRA for SWMU 40 and a total of 7 surface soil samples and 12 subsurface soil samples were used for the HHRA for SWMU 71.

6.1.1.2 Groundwater

Groundwater samples collected from 40MW3, 40MW5, and 40MW6 during the sampling event completed in 2007 for the RFI were used for the COPC screening.

6.1.2 Identification of COPCs

COPCs were identified for the sites by comparing the maximum detected concentration (MDC) to the following screening levels for each media: USEPA Region III R-RBCs and I-RBCs (surface soil and total soil) and USEPA T-RBCs (groundwater) as presented in the October 2007 USEPA Region III RBC and Alternate RBC Tables (USEPA 2007a). In accordance with USEPA Region III guidance, RBCs for non-carcinogenic chemicals were adjusted downward to a HQ of 0.1 to ensure that chemicals with additive effects were not prematurely eliminated during screening.

For nutrients detected in soil (calcium, potassium, magnesium, and sodium) that have no available RBC, the MDC was compared to the recommended daily allowance (RDA)-derived soil ingestion screening criteria. Table 6-3 presents the equation, exposure parameters, and RDAs used, as well as the calculated screening criteria for the adult resident and child resident receptors. The lowest screening criterion for each nutrient (e.g., the screening criteria for the child resident) was selected as the screening criterion.

In addition, lead ALs of 400 mg/kg for residential receptors and 750 mg/kg for industrial receptors were used in the COPC identification since toxicity criteria were not available for lead (USEPA 1994c).

Analytes detected at a maximum concentration greater than the corresponding adjusted RBC or screening values identified above (or those for which no screening criteria exists) were selected as COPCs. COPC screening tables for each SWMU are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-2.1 (COPC Determination Detects-Surface Soil), E.1-2.2 (COPC Determination Detects-Total Soil), E.1-2.3 (Non-Detect Screening-Soil), E.1-2.4 (COPC Determination Detects-Groundwater), and E.1-2.5 (Non-Detect Screening-Groundwater) for SWMU 40 and Tables E.2-2.1 (COPC Determination Detects-Surface Soil), E.2-2.2 (COPC Determination Detects-Total Soil), E.2-2.3 (Non-Detect Screening-Soil), E.2-2.4 (COPC Determination Detects-Groundwater), and E.2-2.5 (Non-Detect Screening-Groundwater) for SWMU 71. A summary of the results of the human health COPC screenings for the sites are presented in the table below.

Human Health COPCs Identified

Chemical	SWMU 40 Soil		SWMU 71 Soil		Groundwater
	Surface	Total	Surface	Total	
Aluminum	X	X	X	X	
Antimony		X	X	X	
Arsenic	X	X	X	X	
Cadmium		X			
Chromium	X	X	X	X	
Cobalt*	X	X	X	X	
Copper		X			
Iron	X	X	X	X	
Lead		X			
Manganese	X	X	X	X	
Mercury		X			
Thallium	X	X	X	X	
Vanadium	X	X	X	X	
Zinc		X			
Aroclor 1242		X			
Aroclor 1248			X	X	
Aroclor 1254	X	X	X	X	
Aroclor 1260	X	X			
2-Hexanone*	X	X			
4-Methyl-2-Pentanone*	X	X	X	X	
Chloroform					X
Chloromethane*	X	X			
Cyclohexane*	X	X	X	X	

Chemical	SWMU 40		SWMU 71		Groundwater
	Surface	Total	Surface	Total	
Methylcyclohexane*	X	X	X	X	
Di-n-octylphthalate*	X	X		X	
Dimethylphthalate*		X			
Benzo(a)anthracene	X	X			
Benzo(a)pyrene	X	X		X	
Benzo(b)fluoranthene	X	X			
Dibenz(a,h)anthracene	X	X		X	
Indeno(1,2,3-cd)pyrene	X	X			
2,3,7,8-TCDD TEQ	X	X		X	
Nitroglycerin		X			
DRO/GRO		X			

Note: * denotes COPC identified due to no screening value available

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 1989b). 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 conceptual site models (CSMs) for SWMUs 40 and 71 are presented on Figure 6-1. The site is located with a portion of the MMA that is characterized by gently to steeply sloping ridges, the presence of landforms indicative of karst topography (e.g., sinkholes), and a general downward slope toward the northwest. SWMUs 40 and 71 are situated topographically lower than areas to the east, south, and west, and topographically higher than areas to the north. Ground surface topography at the site slopes gently toward the northwest from approximately 1908 ft mean sea level (msl) at SWMU 71 to approximately 1,884 ft msl at the northern edge of the landfill at SWMU 40. At the northern edge of the landfill, the ground surface drops approximately 10 ft along a 1:3 grass covered slope.

Subsurface geology consists of four different strata that were identified, as presented in Section 2.6, including soil fill, landfill material, soil weathered in place from bedrock, and bedrock. Groundwater is present in the underlying bedrock (approximately 90 ft bgs). As previously discussed in Section 2.7.2, monitoring well data indicates that groundwater flow in the site area is to the west toward the New River. Groundwater potentially impacted by the study areas is not currently used as drinking water. Potentially affected media include surface soil, subsurface soil, and groundwater at the sites.

The area surrounding the MMA of RFAAP is not highly developed and land use near the Facility is mostly rural with less rugged areas being used for agriculture. Residential and recreational areas are located adjacent to the RFAAP (IT 2001). It is unlikely, however, that the land use within the MMA will change significantly in the foreseeable future. The MMA contains many buildings and facilities, and is likely to remain industrial in nature.

Neither SWMU is currently active; therefore, maintenance workers are the most likely receptors under current site conditions. Due to installation security, it is unlikely that trespassers could gain access to the SWMUs; however, risks associated with the maintenance worker are considered protective of the limited exposure experienced by the trespasser. Under future site conditions, maintenance workers continue to be receptors and although the development of the areas is unlikely due to the use of the site as a landfill, construction workers and commercial workers may be hypothetical receptors if the area is developed.

RFAAP is likely to remain a military installation; therefore, a residential scenario is considered unlikely. However, the residential scenario was evaluated for both SWMUs to assess clean closure requirements under RCRA.

6.2.2 Identification of Exposure Pathways

The potential receptors identified for the sites include current/future maintenance workers, hypothetical future commercial workers, hypothetical future construction workers, hypothetical future child residents, hypothetical future adult residents, and hypothetical future lifetime residents. Carcinogenic risk is assessed for the hypothetical lifetime resident to account for cumulative lifetime risk. The exposure duration for the lifetime resident scenario is assumed to be 30 years total; therefore, for carcinogens, exposures are combined for hypothetical child resident (6 years) and adult resident (24 years). In Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-1 and E.2-1 summarize the selection of exposure pathways for each SWMU and receptor listing the rationale for the inclusion or exclusion of each pathway. A conceptual site diagram presenting the sources, release mechanisms, pathways, and receptors are presented on Figure 6-2 for SMWU 40 and SWMU 71. The table below summarizes the exposure pathways and media evaluated for each of the potential receptor populations.

Media/Exposure Pathways	Exposure Scenarios			
	Current/Future	Future		
	Maintenance Worker	Commercial Worker	Construction Worker	Resident
Surface Soil				
Ingestion	X			
Dermal Absorption	X			
Inhalation of Fugitive Dust	X			
Inhalation of Outdoor Vapors	X			
Total Soil ⁽¹⁾				
Ingestion	X	X	X	X
Dermal Absorption	X	X	X	X
Inhalation of Fugitive Dust	X	X	X	X
Inhalation of Outdoor Vapors	X	X	X	X
Inhalation of Indoor Vapors		X		X
Groundwater				
Ingestion		X		X
Dermal Absorption		X		X
Inhalation of Outdoor Vapors			X	
Inhalation of Indoor Vapors		X		X
Inhalation of Vapors while Showering ⁽²⁾				X

X = Quantitative Evaluation

⁽¹⁾ The evaluation of total soil assumes that construction, excavation, or other activities "mix" the surface and subsurface soil

⁽²⁾ Inhalation of vapors while showering is evaluated using the adult resident only.

6.2.2.1 Current/Future Land Use Scenario

One receptor, the maintenance worker, was identified under the current land use scenario. The current maintenance worker is assumed to contact surface soil. It is assumed that the maintenance worker scenario is likely to exist in the future; therefore, exposure to total soil is possible if excavation activities occur in the future.

6.2.2.2 Future Land Use Scenario Only

In the event that construction occurs at the sites, soil that was previously found at depth may be brought to the surface and become available to receptors. Therefore, the future hypothetical industrial use scenarios of the construction worker and commercial worker are assumed to come into contact with total soil at the sites. In addition, potential future exposures to groundwater are evaluated in the HHRA. It is assumed that the commercial worker is exposed to groundwater via tap water. The construction worker is only exposed to vapors emanating to ambient air from groundwater beneath excavation trenches.

Although the sites are assumed to remain industrial in nature, the residential scenario is evaluated in this HHRA to meet clean closure requirements under RCRA. Future hypothetical resident is assumed to come into contact with total soil and groundwater.

6.2.3 Calculation of EPCs

To calculate intakes, the mean concentration of each COPC is estimated and is referred to as the EPC. To account for uncertainty when estimating EPCs from sample data, the 95% upper confidence limit of the mean (95% UCL) is used instead of the mean itself (USEPA 1989b). Methods used to calculate 95% UCLs are based on guidance provided in the following documents *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002b) and *On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations* (USEPA 2006).

In general, the method used to calculate a 95% UCL depends on: 1) the number of samples, 2) the prevalence of non-detects, and 3) the data distribution (e.g., normal or lognormal). 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 make for COPCs with a high rate of non-detects. ProUCL 4.0 (USEPA 2007c) is used to calculate EPCs for the sites with the exception of data sets with less than 5% detects for which the MDC was used in the risk assessment. EPCs for soil COPCs are presented in Tables E.1-3.1 and E.1-3.2 of Appendix E.1 (SWMU 40) and Tables E.2-3.1 and E.2-3.2 of Appendix E.2 (SWMU 71). EPC calculations for the sites are included in Appendix C.9. EPCs were not calculated for groundwater; therefore, the MDC for COPCs identified for groundwater were used in the risk assessment.

To address the inhalation of fugitive dust from soil exposure pathway, particulate emission factors (PEFs) were used to derive ambient air EPCs for non-volatile soil COPCs. PEFs were calculated in accordance with the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002c). The PEF calculations are provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.4 and E.2-4.4. To address the inhalation of vapors in outdoor air from soil, a volatilization factor was used to derive ambient air EPC for volatile soil COPCs. The VFs were calculated in accordance with the Supplemental Guidance for Soil Developing Soil Screening Levels for Superfund Sites (USEPA 2002c). The equations used to calculate the volatilization factor to ambient air for VOCs in soil are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.3 and E.2-4.3.

To evaluate inhalation of VOCs from soil and groundwater, EPCs were calculated for VOCs in air using the models as summarized below. The Johnson and Ettinger model (Johnson et al 1991 – updated 2004) was used to estimate indoor air concentrations of volatiles migrating from the soil and into a structure. Spreadsheets for this model were used to estimate air concentrations of VOCs in office buildings and

residences for this HHRA. The spreadsheets are provided in Appendix E.3 and the results provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.5 and E.2-4.5. The Johnson and Ettinger model (Johnson et al 1991 – updated 2004) was also used to estimate indoor air concentrations of volatiles migrating from groundwater through the soil and into a structure. Spreadsheets for this model were used to estimate air concentrations of VOCs in office buildings and residences for this HHRA. The spreadsheet is found in Appendix E.3 and the results provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.7 and E.2-4.7.

EPCs of VOCs in air due to volatilization from groundwater were estimated for a showering scenario, applicable to the adult resident, using the Foster-Chrostowski (1987) shower room model. The model is provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.8 and E.2-4.8.

In the event that excavation work is performed on site, the worker may be exposed to volatile emissions from groundwater below the bottom of the trench. While USEPA does not have a standardized model for estimating concentrations of airborne VOCs in a trench or a pit, the VDEQ provides such a model on their Voluntary Remediation Program (VRP) web site (<http://www.deq.state.va.us/vrprisk/>). The equation and parameters are given in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.9 and E.2-4.9.

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 1989b). 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 1989b).

Intake formulas, exposure parameters, and chemical-specific parameters are provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.1 through E.1-4.9 and Tables E.2-4.1 through E.2-4.9. The results of the CDI calculations are presented for each receptor in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-7.1 through E.1-7.7 and Tables E.2-7.1 through E.2-7.7.

6.3 TOXICITY ASSESSMENT

The methodology used for classifying health effects from exposure to chemicals is recommended by USEPA and considers chronic exposures. The chronic toxicity criteria were obtained from the October 2007 USEPA Region III RBC Table (available at <http://www.epa.gov/reg3hwmd/risk/>), which utilizes the following hierarchy:

- Tier 1 - USEPA's Integrated Risk Information System (IRIS);
- 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;
- Tier 3 - other sources of toxicological reference values that include those from Cal EPA, MRLs from ATSDR, and finally the HEAST toxicity values.

Toxicity criteria used to quantify non-carcinogenic hazards (risk reference doses – RfDs) and carcinogenic risks (e.g., slope factors – CSFs) are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-5.1, E.1-5.2, E.1-6.1, and E.1-6-2 for SWMU 40 and Tables E.2-5.1, E.2-5.2, E.2-6.1, and E.2-6-2 for SWMU 71.

6.3.1 Health Effects Classification and Criteria Development

According to USEPA's science policy, there are two primary approaches to developing toxicity values or health effects criteria. The non-threshold approach is based on USEPA's scientific policy position that a

small number of molecular events can evoke changes in a single cell or a small number of cells. This is described as a non-threshold initiator mechanism because there is essentially no level of exposure (i.e., a threshold) to a constituent that will not result in some finite possibility of causing an adverse effect. Another assumption stemming from USEPA's science policy is that the dose-response curve is linear at low doses. For most carcinogens, toxicity criteria are based on the non-threshold approach.

The threshold approach is based on the assumption that organisms have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before the adverse effect is manifested. For example, an organ can have a large number of cells performing the same or similar functions that must be significantly depleted before the effect on the organ is realized. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable risk of adverse effects. Toxicity criteria for non-carcinogens are based on the threshold approach. Furthermore, as additional information regarding the mechanisms of toxicity becomes available, the threshold approach may also apply to some carcinogens (e.g., chloroform).

6.3.1.1 Cancer Slope Factors

For carcinogens, USEPA estimates the excess lifetime cancer risks associated with various levels of exposure by developing cancer slope factors (CSFs) and unit risks. CSFs are expressed in terms of reciprocal dose, as units of: $(\text{mg chemical/kg body weight} \cdot \text{day})^{-1}$, and describe the upper-bound increase in an individual's risk of developing cancer over a 70-year lifetime per unit of exposure. Unit risks are expressed either as a reciprocal air concentration, in units of micrograms per meter cubed $(\mu\text{g}/\text{m}^3)^{-1}$ or as a reciprocal drinking water concentration, in units of micrograms per liter $(\mu\text{g}/\text{L})^{-1}$. Similarly, they are defined as the probability of an individual developing cancer over a 70-year lifetime from exposure to one unit of concentration in air or water. Because regulatory efforts are geared to be protective of public health, including even the most sensitive members of the population, the CSFs are derived using conservative assumptions.

CSFs and unit risks are derived from the results of human epidemiological studies or chronic animal bioassays. Animal studies usually must be conducted using relatively high doses to detect possible adverse effects. Because humans are expected to be exposed to doses lower than doses used in the animal studies, the potential cancer risks at lower doses are estimated by using mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response relationship. In general, after the data are fit to the dose-response model, the 95% UCL of the slope of the resulting dose-response relationship at low doses is calculated. This upper-bound limit is subjected to various adjustments and an interspecies scaling factor is applied to derive the slope factor or unit risk for humans. Thus, the actual risks associated with a given intake of a potential carcinogen quantitatively evaluated based on animal data are generally regarded as not likely to exceed the risks estimated using these CSFs or unit risks and they may be as low as zero (USEPA 1986b). Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. CSFs and unit risks based on human epidemiological data are derived using conservative assumptions and are unlikely to underestimate risks for a given level of exposure.

Weight-of-evidence categories represent an assessment of the amount and quality of the data, which support the finding that specific chemicals and elements can cause cancer in humans. Although USEPA's guideline for carcinogen risk assessment (USEPA 1996) proposes a weight-of-evidence narrative, IRIS currently uses the original alphanumeric classification. Under the existing guidelines (USEPA 1986a), chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A includes those substances for which high-quality studies have demonstrated a relationship between the exposure to the substance in question and the development of cancer in human populations. Groups B1, B2, and C represent chemicals with limited (B1) or insufficient (B2) human evidence of carcinogenicity, and sufficient (B1, B2) or insufficient (C) animal data. Group D substances are those for which there is

insufficient evidence or not evidence of carcinogenicity in humans or animals and Group E substances are those not having evidence of carcinogenicity available in adequate human or animal studies.

6.3.1.2 Reference Doses and Reference Concentrations

Toxicity criteria for non-carcinogens are generally developed using verified risk reference doses (RfDs) and reference concentrations (RfCs). These are developed by USEPA and listed in IRIS or can be obtained from HEAST (USEPA 1997c) and supplements. RfDs are expressed in units of dose (mg chemical/kg body weight-day) and are usually derived either from human studies involving workplace exposures or from animal studies. In addition, RfDs are estimates (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is used as a reference point for gauging the potential effects of exposures. Usually, exposures (as chemical intakes or doses) that are less than the RfD are not likely to be associated with adverse health effects.

RfDs are developed for both chronic and sub-chronic exposures. Chronic RfDs are presented in IRIS or HEAST and are intended for use in evaluating exposures of durations greater than seven years. Sub-chronic RfDs are developed by USEPA's NCEA and are used to characterize the potential for the occurrence of non-carcinogenic effects associated with short-term exposures [two weeks to seven years as defined by USEPA (1989b)]. The sub-chronic RfDs are developed similarly to chronic RfDs and are typically equal to chronic RfDs or are an order of magnitude greater (less stringent). Sub-chronic RfDs are presented in HEAST but are no longer being reviewed and updated in the same manner as IRIS. Because there is greater uncertainty associated with the sub-chronic RfDs, chronic RfDs have been used in this HHRA.

RfDs are derived using uncertainty factors that reflect scientific judgment regarding the various types of data used to estimate the RfD. RfDs are typically estimated from no observable adverse effect levels (NOAELs) or lowest observable adverse effect levels (LOAELs) in human or animal studies. Uncertainty factors, generally 10-fold factors, are intended to account for:

- The variation in sensitivity among members of the human population;
- The uncertainty in extrapolating animal data to the case of humans;
- The uncertainty in extrapolating from data obtained in a study that is less-than-lifetime exposure;
- The uncertainty in using LOAEL data, when necessary, rather than NOAEL data; and
- The inability of a single study to adequately address every possible adverse outcome in humans.

To derive RfDs, NOAELs or LOAELs are divided by one or more uncertainty factors, as appropriate. When taken together, these uncertainty factors may confer an extra margin of safety of up to a factor of 10,000 below a LOAEL. In some cases, modifying factors are also applied to RfDs to take into account other uncertainties in the toxicity database and reflect the professional judgment of those reviewing the database. The net result is that RfDs are generally considered to provide a conservative estimate of the likelihood of adverse non-carcinogenic effects.

6.3.1.3 Adjustment for Dermal Absorption

Toxicity criteria have not been developed by USEPA specifically for dermal absorption; instead, oral toxicity criteria are adjusted to assess this pathway. In order to have a meaningful comparison between the dermal absorption dose estimates, which represent internal (or absorbed) doses, and oral toxicity criteria, which typically represent potential (or administered) doses, toxicity criteria are modified to represent absorbed doses. The method for modifying toxicity criteria involves calculation of an absolute oral absorption factor for each chemical and use of this value to increase the chemical's CSF or to decrease the chemical's RfD, as shown in the following equations:

- Adjusted Dermal CSF = CSF/Absolute oral absorption factor
- Adjusted Dermal RfD = RfD x Absolute oral absorption factor

The absolute oral absorption factors should reflect the specific conditions under which the toxicological study was conducted (e.g., method of administration such as gavage, water or diet, and vehicle of administration such as solvent or solution). The absolute oral absorption factors and adjusted toxicity criteria for the COPCs used when evaluating dermal absorption are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-5.1 and E.1-6.1 and Tables E.2-5.1 and E.2-6.1, respectively. The adjusted CSFs and RfDs presented in these tables were used to evaluate potential risks associated with dermal absorption.

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 (1989b).

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. In addition, carcinogenic risk for the residential scenario for carcinogens that act via a mutagenic mode of action (i.e., benzo(a)pyrene) as identified in the October 2007 Region III RBC table were evaluated utilizing default age-dependant adjustment factors in accordance with the Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (USEPA 2005a).

Non-carcinogenic adverse health effects are calculated by dividing the CDI of each COPC by its RfD, forming a HQ. HQs greater than one (1) 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 a Hazard Index (HI). As with HQs, HIs that are greater than 1 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 child and adult residents independently.

Excess lifetime cancer risks derived in this report are compared to USEPA's target risk range for Superfund sites of 1E-06 to 1E-04 (USEPA 1989b). 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 1E-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 presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71) in Tables E.1-7.1 – E.1-7.7 and E.2-7.1 – E.2-7.7. A refinement of the HIs based on target organs is conducted. As shown in Appendices E.1 (SWMU 40) and E.2 (SWMU 71) in Tables E.1-9.1 – E.1-9.7 and E.2-9.1 – E.2-9.7, the refinement consists of calculating HIs based on a target organ-specific basis. In addition in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-10.1 – E.1-10.2 and E.2-10.1 – E.2-10.2 summarize risks and hazards for risk/HI drivers (i.e., those COPCs contributing to a total risk greater than 1E-04 or a total target organ hazard greater than 1).

Risks and hazards presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71) in Tables E.1-9.1 – E.1-9.7 and E.2-9.1 – E.2-9.7 are summarized in the tables below.

SWMU 40 – Summary of Risks and Hazards

Timeframe/Receptor	Risk	HI	Risk Drivers	Target Organ Segregation HI>1
Current/Future Maintenance Worker (Surface Soil)	3.E-06	0.08	None	None
Hypothetical Future Maintenance Worker (Total Soil)	4.E-06	0.4	None	None
Hypothetical Future Commercial Worker	1.E-05	1	None	None
Hypothetical Future Construction Worker	9.E-06	15	None	Vascular (HI=5) – Soil (As – Ing (0.2), Nitroglycerin – Ing (4.3)) CNS (HI=9) – Soil (Al – Inh (4), Mn – Inh (5))
Hypothetical Future Adult Resident	See Lifetime Resident	4	NA	Vascular (HI=2) – Soil (Nitroglycerin – Ing (2))
Hypothetical Future Child Resident	See Lifetime Resident	26	NA	GI Tract (HI=4) – Soil (Cr-Ing/Derm (0.5), Cu-Ing (2.5), Fe-Ing (0.7)) Vascular (HI=18) – Soil (As - Ing (1), Nitroglycerin – Ing (17)) Kidney (HI=2) – Soil (V – Ing/Derm (1)) (Methylcyclohexane – Inh (1))
Hypothetical Lifetime Resident	3.E-04	NA	Soil – Arsenic and PCBs Groundwater - Chloroform	NA

Note: NA = Not Applicable

HI = Hazard Index

CNS = Central Nervous System

Bold = Exceeds USEPA Risk or Hazard Range

Al = Aluminum, As = Arsenic, Cr – Chromium, Cu = Copper, Fe = Iron, Mn = Manganese, V = Vanadium,

Ing = Ingestion, Inh = Inhalation, Derm = Dermal

SWMU 71 – Summary of Risks and Hazards

Timeframe/Receptor	Risk	HI	Risk Drivers	Target Organ Segregation HI>1
Current/Future Maintenance Worker (Surface Soil)	2.E-06	0.07	None	None
Hypothetical Future Maintenance Worker (Total Soil)	1.E-06	0.08	None	None
Hypothetical Future Commercial Worker	4.E-06	0.3	None	None
Hypothetical Future Construction Worker	4.E-06	5	None	CNS (HI=4) – Soil (Al – Inh (2), Mn – Inh (2))
Hypothetical Future Adult Resident	See Lifetime Resident	1	NA	None
Hypothetical Future Child Resident	See Lifetime Resident	5	NA	Liver (HI=2) – Soil (Cr – Ing/Derm (0.6), Fe – Ing (0.7), Tl – Ing (0.07)) Groundwater – Chloroform – Ing (0.2)) Kidney (HI=2) – Soil (V – Ing/Derm (2))
Hypothetical Lifetime Resident	2.E-04	NA	Groundwater - Chloroform	NA

Note: NA = Not Applicable

HI = Hazard Index

CNS = Central Nervous System

Bold = Exceeds USEPA Risk or Hazard Range

Al = Aluminum, Cr = Chromium, Fe = Iron, Mn = Manganese, Tl = Thallium, V=Vanadium

Ing = Ingestion, Inh = Inhalation

6.4.1 Lead Exposure Assessment

The MDCs for lead in surface soil and total soil for SWMU 40 were above the lead screening level of 400 mg/kg, and therefore, the potential hazard associated with lead was evaluated using the Integrated Exposure Uptake Biokinetic (IEUBK) model for the child resident scenario (USEPA 2007d) and the EPA Adult Lead Model (USEPA 2005b) for adult workers. Lead concentrations in surface and total soil for SWMU 71 were below the lead screening level of 400 mg/kg; therefore, additional lead modeling was not completed for the site.

Site-specific lead exposures were evaluated for residential exposures at SWMU 40 using the IEUBK model. This calculation was based on the site-specific mean concentration of lead detected in total soil (54.8 mg/kg) and the maximum detected lead concentration in groundwater (0.51 µg/L). The results of the model are presented in Appendix E.1. The corresponding input parameters and distribution probability plot are also provided in the Appendix E.1. The results of the modeling presented in Appendix E.1 predict the probability of children expected to have blood levels of 10 gram per deciliter (g/dL) or greater. The lead risks are considered unacceptable if the child-blood lead level for more than 5% of children is estimated to equal or exceed the Center for Disease Control and Prevention (CDCP) concern threshold of 10 g/dL.

USEPA developed a physiologically-based pharmacokinetic adult lead model (ALM) (version 05/19/2003) that can be applied to adult worker receptors. The ALM is currently the accepted and standard model to assess adult non-residential exposures to lead in soil and indoor dust. The model uses a simplified representation of lead biokinetics to predict quasi steady-state blood level concentrations among adults who have relatively steady patterns of site exposures. The methodology focuses on estimating fetal blood lead concentrations in female workers. All of the equations in the model are used to calculate target concentrations based on the probability of exceeding a blood lead level of 10 g/dL for a fetus. Lead risks are considered unacceptable for a non-residential (worker) receptor if the fetal blood lead level for more than 5% of fetuses of adult female workers is estimated to equal or exceed the CDCP concern threshold of 10 g/dL. The ALM is used to evaluate risks of lead exposure to the fetus of pregnant female industrial workers, construction workers, and other workers that are identified as relevant receptors at a site.

6.4.1.1 Lead Exposure Assessment - SWMU 40

Default parameters were utilized for the ALM model with the following ingestion rates and exposure frequencies: maintenance worker – ingestion rate (100 mg/day) and exposure frequency (219 days), commercial worker – ingestion rate (50 mg/day) and exposure frequency (250 days), and construction worker – ingestion rate (330 mg/day) and exposure frequency (250 days). Default parameters were used for the IEUBK model. The arithmetic means for lead in surface soil (27.5 mg/kg) and total soil (54.8 mg/kg) were used in the models for the maintenance worker and the arithmetic mean for lead in total soil (54.8 mg/kg) was used in the models for the remaining potential receptors. The lead modeling predicts the probability of the receptors to have blood levels of 10 microgram per deciliter or greater. This probability is then compared to an established threshold of 5%. The results of the modeling for SWMU 40 is presented in Appendix E.1 and summarized below:

- Current/Future Maintenance Worker (Surface Soil): 1.4% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Maintenance Worker (Total Soil): 1.6% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Construction Worker: 2.9% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Commercial Worker: 1.4% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Child resident: 0.014% probability that child blood levels would exceed 10 g/dL (<5%).

The results of the lead modeling predicted the probability of the receptors for SWMU 40 expected to have blood levels of 10 microgram per deciliter or greater were below the established threshold of 5%.

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 both SWMU 40 and SWMU 71, a "margin of exposure evaluation" was conducted for the sites. This evaluation consists of a comparison of estimated intake of iron to the RDA and concentrations known to cause adverse health effects in children (USEPA 2001).

For the margin of exposure evaluation, the estimated iron intakes at the sites for a future resident child scenario for surface soil and total soil are calculated using the assumptions and equations provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71). These estimated iron intake levels are then compared to the RDA for children (6 months to 10 years old) of 10 mg/day (NCEA 2006). In addition, using an average child weight of 15 kg (USEPA 1989b), the child intakes for surface soil and total soil are

calculated and compared to the calculated provisional (risk reference dose) RfD of 0.7 mg/kg-day. The results of the margin of exposure evaluation are summarized in the table below.

Results of Iron Margin of Exposure Evaluation

	Iron EPC (mg/kg)	RDA Evaluation			Provisional Risk Reference Dose (RfD) Evaluation		
		Child Daily Intake Estimate (mg/day)	RDA (mg/day)	Result	Child Daily Intake (mg/kg- day)	Calculated Provisional RfD (mg/kg-day)	Result
SWMU 40 - Total Soil	37,114	7.1	10	<RDA	0.48	0.7	<RfD
SWMU 71 -Total Soil	39,796	7.6	10	<RDA	0.51	0.7	<RfD

The iron exposure assessment results for the hypothetical future child resident were below the applicable iron margin of exposure screening criteria for both SWMU 40 and SWMU 71.

6.4.3 Background

Statistical evaluations were conducted to compare metals concentrations in soil at SWMUs 40 and 71 to 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 2002a) and included distribution testing and comparisons of site data to background using ProUCL 4.0. At SWMUs 40 and 71, if the distribution testing showed that either site data sets and background data sets in each case were not normal, consistent with Section 4.1 of the above referenced USEPA guidance, comparisons of site to background were conducted using non-parametric testing to evaluate whether site concentrations were consistently higher or lower than the background data set. If the distribution of the site and background data sets were both distributed normally, a paired t-test was conducted to evaluate whether site concentrations were consistently higher or lower than the background data set. Appendix C.10 presents results of the statistical evaluations.

Based on the background evaluations presented in Appendix C.10, COPCs identified for SWMU 40 that exceed background include aluminum for surface soil and aluminum, arsenic, cadmium, and zinc for total soil. The COPC identified for SWMU 71 that exceeds background is arsenic for surface soil. Note that background comparisons could not be conducted for antimony, mercury, and thallium due to the number of detections in the background data set.

6.4.4 SWMUs 40 and 71 HHRA Summary

6.4.4.1 SWMU 40 HHRA Summary

The total risk for each receptor is below or within USEPA's target risk range for Superfund sites (1E-06 to 1E-04, USEPA 1989b) with the exception of the hypothetical future lifetime resident due primarily to arsenic and PCBs in soil and chloroform in groundwater. The iron exposure assessment results for the hypothetical future child resident were below the applicable iron margin of exposure screening criteria for SWMU 40. The results of the lead modeling predicted the probability of the receptors for SWMU 40 expected to have blood levels of 10 microgram per deciliter or greater were below the established threshold of 5%. The total HIs after target organ segregation for all receptors are equal to or below the USEPA reference HI of 1E+00 with the exception of the hypothetical future construction worker (Central Nervous System (CNS) and vascular), the hypothetical future adult resident (vascular), and the

hypothetical future child resident (GI tract, vascular, and kidney). The site-related hazards are further characterized as follows:

Hypothetical Future Construction Worker

The vascular HI of 5 for the hypothetical future construction worker is primarily due to nitroglycerin ($HQ=4.3$) in soil which was detected 1 of 53 samples. Due to the frequency of detection of nitroglycerin ($<2\%$ detects) and the concentration of the detection 130 mg/kg, nitroglycerin is not considered a COC for the site.

The site-related CNS HI for the hypothetical future construction worker, when excluding metal hazard drivers below background (manganese), is $4E+00$ with aluminum as the remaining hazard driver for this target organ.

Hypothetical Future Adult Resident

The vascular HI of 2 for the hypothetical future adult resident is primarily due to nitroglycerin ($HQ=2$) in soil which was detected 1 of 53 samples. Due to the frequency of detection of nitroglycerin ($<2\%$ detects) and the concentration of the detection 130 mg/kg, nitroglycerin is not considered a COC for the site.

Hypothetical Future Child Resident

The primary hazard drivers for the elevated target organ specific GI tract HI for the hypothetical future child resident are chromium, copper, and iron in total soil, but these chemicals are below background; therefore, the hazard is not considered site-related.

The vascular HI of 18 for the hypothetical future child resident is primarily due to nitroglycerin ($HQ=17$) in soil which was detected 1 of 53 samples. Due to the frequency of detection of nitroglycerin ($<2\%$ detects) and the concentration of the detection 130 mg/kg, nitroglycerin is not considered a COC for the site. The site-related vascular HI, when excluding nitroglycerin, is $1E+00$ which is equal to the USEPA reference HI of $1E+00$.

The site-related kidney HI for child resident, when excluding metals hazard drivers detected below background (vanadium), is $1E+00$ primarily due to methylcyclohexane in soil which is equal to the USEPA reference HI of $1E+00$.

6.4.4.2 SWMU 71 HHRA Summary

As presented in Section 6.4, the total risk for each receptor is below or within USEPA's target risk range for Superfund sites ($1E-06$ to $1E-04$, USEPA 1989b) with the exception of the hypothetical future lifetime resident due primarily to chloroform in groundwater. The iron exposure assessment results for the hypothetical future child resident were below the applicable iron margin of exposure screening criteria for SWMU 71. Lead concentrations in surface and total soil for SWMU 71 were below the lead screening level of 400 mg/kg; therefore, additional lead modeling was not completed for the site. The total HIs after target organ segregation for all receptors except for the hypothetical future construction worker (CNS) and hypothetical future child resident (liver and kidney) are equal to or below the USEPA reference HI of $1E+00$. The site-related hazards are further characterized as follows:

Hypothetical Future Construction Worker

The primary hazard drivers for the elevated target organ specific CNS HI for the hypothetical future construction worker were aluminum and manganese in total soil, but both these chemicals were below background; therefore, the hazard is not considered site-related.

Hypothetical Future Child Resident

The site-related liver HI for hypothetical future child resident, when excluding metals hazard drivers detected below background (chromium and iron), is $3E-01$, which is below the USEPA reference HI of $1E+00$.

The primary hazard drivers for the elevated target organ specific kidney HI for the hypothetical future child resident was vanadium in total soil, but this chemical was below background; therefore, the hazard is not considered site-related.

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 SWMU 40 and SWMU 71, 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 at the SWMUs. 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. These data were retained in the HHRA without modification. The inclusion of "B" qualified data in the risk assessment may overestimate risk.

Another uncertainty associated with sampling and analysis concerns the inclusion of chemicals that are potentially present in the environment due to anthropogenic sources. For example, PAHs are considered ubiquitous in soil from anthropogenic sources, such as the burning of fossil fuels, forest fires, and airborne particulates eroded from roadways and automobile tires. If such chemicals are not site-related, the risks associated with the site may be overestimated. This uncertainty may have a low-to-moderate effect on overestimating risks.

6.5.2 Selection of Chemicals for Evaluation

A comparison of maximum detected chemical concentrations to USEPA Region III RBCs was conducted for both surface and total soil. Chemicals whose maximum concentrations were below their respective RBCs 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 RBCs. 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 exceed their respective RBCs) and the cumulative risk estimates would not be expected to be significantly greater. As presented on the non-detect MDL screening tables in Appendices E.1 (SWMU 40), Tables E.1-2.3 and E.1-2.5, and E.2 (SWMU 71), Tables E.2-2.3 and E.2-2.5 (SWMU 71), the maximum MDL exceeded the adjusted RBCs for several chemical in soil and groundwater; therefore, the site-related risks and hazards could be underestimated for the risk assessments due to inadequate detection limits.

Background concentrations of metals in soil at RFAAP have been characterized and are used in statistical comparisons to site soil to evaluate whether concentrations of metals detected at SWMU 40 and SWMU 71 are consistently higher or lower than background. Uncertainties associated with the use of these data may lead to a low-to-moderate overestimation or underestimation of surface and total soil risks due to metals.

Screening criteria are derived from RDAs for essential human dietary minerals, trace elements, and electrolytes that are toxic at very high doses (i.e., calcium, magnesium, potassium, and sodium). 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 exposure point concentrations, 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.

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 over estimate risks, depending 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, one half of the MDL was sometimes used for non-detect samples in the calculation of the 95% UCL of the mean. Approaches which substitutes 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. The uncertainty of the exposure point concentration will increase as the number of non-detects in a data set increases and the uncertainty could result in either the overestimation or underestimation of EPCs.

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 (e.g., exposures were assumed to occur for 25 years for workers). In addition, many USEPA (1991a) 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% bioavailable; this assumes that ingested chemicals present in a soil matrix are absorbed through the gastrointestinal (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 *Risk Assessment Guidance for Superfund (RAGS): Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA 2004). 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 1999b) indicates cadmium is not known to result in human health effects by dermal absorption because virtually zero cadmium 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 (ATSDR 1999a). Therefore, using the dermal absorption factors to evaluate dermal absorption exposures to soil may result in an overestimation of risks.

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 1986a), 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% 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. More refined modeling in the area of dose response calculation (e.g., using maximum likelihood dose response values rather than the 95% 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. This HHRA does not use oral-based toxicity criteria to estimate risks from inhalation exposure because of the following uncertainties 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). For example, orally administered benzo(a)pyrene is associated with benign and malignant tumors in the gut mucosa (Neal and Rigdon 1967), but inhaled benzo(a)pyrene produces an increased incidence of upper respiratory tract tumors (Thyssen et al. 1981). Therefore, quantitative risk estimates based on these two administration routes are dissimilar;
- 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 (μm) 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;
- Because highly soluble gases (e.g., chloroform) are more rapidly absorbed into the blood than poorly soluble gases (e.g., ethylene), they take much longer to reach equilibrium. Thus, the inhalation absorption rate of a gas is more dependent on blood solubility than the oral absorption rate of the same substance administered as a liquid; and
- 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 fore 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.

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; and
- 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 Integrated Risk Information System (IRIS) toxicity criteria, provisional toxicity criteria were used where available (Appendices E.1 and E.2 - Tables E.1-5.1 through E.1-6.2 and Tables E.2-5.1 through E.2-6.2). Provisional toxicity criteria present a source of uncertainty, since USEPA has evaluated the compound, but consensus has not been established on the toxicity criteria. Provisional oral toxicity values were used for aluminum, antimony, arsenic, chromium, cobalt, copper, iron, thallium, vanadium, zinc, Aroclor 1254, chloroform, 2-hexanone, di-n-octylphthalate, nitroglycerin, and 2,3,7,8-TCDD equivalents. For this assessment, use of provisional toxicity criteria was preferable to not evaluating the chemical in order to limit data gaps. However, because these toxicity criteria have not been formally accepted by USEPA, there is uncertainty with these values and, therefore, with the risks calculated using these toxicity criteria.

Some detected constituents (cobalt, 2-hexanone, 4-methyl-2-pentanone, chloromethane, cyclohexane, methylcyclohexane, di-n-octylphthalate, and dimethylphthalate) do not have USEPA Region III RBCs and were therefore carried forward as COPCs into the HHRA. Provisional/surrogate toxicity values were researched for these COPCs and cancer risk/non-cancer hazard calculations were derived. It is undetermined if the uncertainty is biased high or low for these COPCs because of the provisional nature of the toxicity data used. However, these COPCs are addressed quantitatively in the HHRA using what little toxicity data are available to reduce the level of uncertainty associated with the risk assessment results.

For some chemicals, toxicity criteria were unavailable (Appendices E.1 and E.2 - Tables E.1-5.1 through E.1-6.2 and Tables E.2-5.1 through E.2-6.2).

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 causes minor differences between summed risk and hazard values, depending on how the summing is performed. For example, RAGS Table 7s in Appendix E presents risks and hazards that are summed for exposure route, exposure point, exposure medium, and medium total. Only for the first (exposure route) are the individual chemical-specific risks and hazards summed to derive 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 minor rounding-related differences between the 'same' values presented in RAGS Table 9s and 10s in Appendix E.

6.6 HHRA CONCLUSIONS

This HHRA was performed to evaluate the potential human health effects associated with previous activities at the SWMUs. Receptors evaluated for both areas included: current/future maintenance worker, hypothetical future construction worker, hypothetical future commercial worker, hypothetical future adult resident, hypothetical future child resident, and hypothetical future lifetime resident.

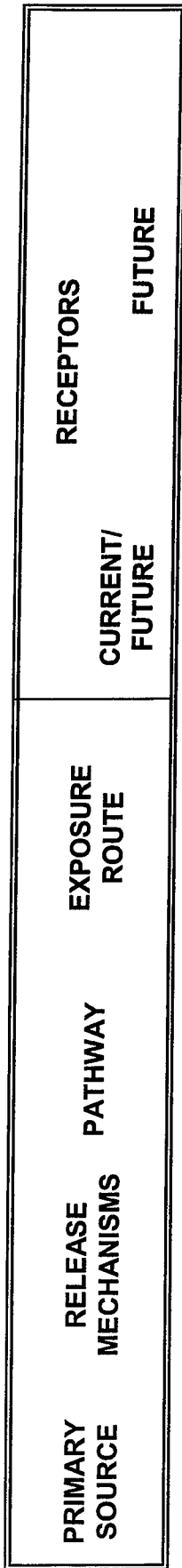
6.6.1 SWMU 40 HHRA Conclusions

In summary for SWMU 40, the results of the risk assessment indicate that the calculated site-related cancer risks and hazards (when taking target organs and background into consideration) are within USEPA target ranges for each of the receptors evaluated with the exception of cumulative risk for the

hypothetical future lifetime resident primarily due to chloroform in groundwater and hazard for the hypothetical future construction worker (CNS due to aluminum in soil via the inhalation pathway).

6.6.2 SWMU 71 HHRA Conclusions

In summary for SWMU 71, the results of the risk assessment indicate that the calculated site-related cancer risks and hazards (when taking target organs and background into consideration) are within USEPA target ranges for each of the receptors evaluated with the exception of the hypothetical future lifetime resident due primarily to chloroform in groundwater.



PRIMARY SOURCE		RELEASE MECHANISMS		PATHWAY		EXPOSURE ROUTE		RECEPTORS					
								MAINTENANCE WORKER	COMMERCIAL/ INDUSTRIAL WORKER	CONSTRUCTION WORKER	CHILD RESIDENT	ADULT RESIDENT	LIFETIME RESIDENT
DISPOSAL ACTIVITIES	DIRECT DEPOSITION	SURFICIAL SOIL	Ingestion	●	●	●	●	●	●	●	●	●	●
			Dermal Contact	●	●	●	●	●	●	●	●	●	
			Inhalation (Particulates)	●	●	●	●	●	●	●	●	●	
			Inhalation (Indoor Vapor)										
			Inhalation (Outdoor Vapor)	●	●	●	●	●	●	●	●	●	
	SUBSURFACE SOIL	Ingestion	●	●	●	●	●	●	●	●	●	●	
		Dermal Contact	●	●	●	●	●	●	●	●	●	●	
		Inhalation (Particulates)	●	●	●	●	●	●	●	●	●	●	
		Inhalation (Indoor Vapor)*											
		Inhalation (Outdoor Vapor)*	●	●	●	●	●	●	●	●	●	●	
LEACHING	GROUNDWATER	Ingestion											
		Dermal Contact											
		Inhalation (Indoor Vapor)											
		Inhalation (Outdoor Vapor)											
		Inhalation (Shower Air)											

● Potentially complete pathway assessed quantitatively

FIGURE 6-2
Conceptual Site Diagram

Date: January 2009	URS Project#: 11656351
Prepared by: CLD	Approved by: JCS
Scale: Not to Scale	File Name: Fig. 6-2 CSD

SWMUs 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia

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Table E-1-1
Selection of Exposure Pathways - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Surface Soil	Surface Soil	Surface Soil	Maintenance Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
	Subsurface Soil	Subsurface Soil	Subsurface Soil	Maintenance Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil.
		Air	Ambient Air Above Subsurface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Ingestion	None	Receptor is not likely to ingest subsurface soil from the site since maintenance does not include excavation.
	Groundwater ¹	Groundwater	Groundwater	Maintenance Worker	Adult	Dermal Absorption	None	Receptor is not likely to come in contact with subsurface soil from the site since maintenance does not include excavation.
		Air	Ambient Air Above Subsurface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Inhalation	None	Receptor is not likely to inhale particulates and vapors from ambient air above the subsurface soil since maintenance activities do not include excavation.
		Groundwater	Groundwater	Maintenance Worker	Adult	Ingestion	None	Receptor is not likely to ingest groundwater from the site during maintenance activities.
		Air	Upward Migration of Vapors from Groundwater (Outdoors)	Maintenance Worker	Adult	Dermal Absorption	None	Receptor is not likely to contact groundwater from the site during maintenance activities.
	Surface Soil	Surface Soil	Upward Migration of Vapors from Groundwater (Indoors)	Maintenance Worker	Adult	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
		Surface Soil	Vapors while Showering	Maintenance Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
Future	Surface Soil	Surface Soil	Surface Soil	Maintenance Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
		Surface Soil	Surface Soil	Maintenance Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
		Surface Soil	Surface Soil	Commercial/Industrial Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil while working on site.
		Surface Soil	Surface Soil	Commercial/Industrial Worker	Adult	Dermal Absorption	Quant	Receptor could contact surface soil while working on site.
		Surface Soil	Surface Soil	Construction Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil from the site during construction activities.
		Surface Soil	Surface Soil	Construction Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site during construction activities.
		Surface Soil	Surface Soil	Resident	Child	Ingestion	Quant	Receptor could ingest surface soil while living on site.
		Surface Soil	Surface Soil	Resident	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil while living on site.
		Surface Soil	Surface Soil	Resident	Child/Adult	Ingestion	Quant	Receptor could ingest surface soil while living on site.
		Surface Soil	Surface Soil	Resident	Child/Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil while living on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Dermal Absorption	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while working on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while working on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Commercial/Industrial Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil while living on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Construction Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while working on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Construction Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site during construction activities.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Resident	Child	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while living on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Resident	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil while living on site.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Child/Adult	Child/Adult	Ingestion	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Child/Adult	Child/Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil while living on site.

Table E.1-1
Selection of Exposure Pathways - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future Cont.	Surface Soil Cont.	Air Cont.	Upward Migration of Vapors from Soil (Indoors)	Maintenance Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into building.
				Construction Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Adult	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into residence.
				Child	Child	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident. 1
	Subsurface Soil	Subsurface Soil	Subsurface Soil	Child/Adult	Child/Adult	Inhalation	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
				Adult	Adult	Ingestion	Quant	Receptor could come in contact with subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
						Dermal Absorption	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a commercial/industrial facility.
				Adult	Adult	Ingestion	Quant	Receptor could contact subsurface soil when mixed with surface soil from construction of a commercial/industrial facility.
						Dermal Absorption	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence.
				Adult	Adult	Ingestion	Quant	Receptor could come into contact with subsurface soil from the site during construction activities.
						Dermal Absorption	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence.
				Child	Child	Ingestion	Quant	Receptor could come in contact with subsurface soil when mixed with surface soil from construction of a residence.
						Dermal Absorption	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence.
				Adult	Adult	Ingestion	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence.
						Dermal Absorption	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
	Air	Air	Ambient Air Above Subsurface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil when mixed with surface soil from construction of a commercial/industrial facility.
				Construction Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil during construction activities.
				Resident	Child	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil when mixed with surface soil from construction of a residence.
				Adult	Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.

Table E.1-1
Selection of Exposure Pathways - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future Cont.	Subsurface Soil Cont.	Air Cont.	Upward Migration of Vapors from Soil (Indoors)	Maintenance Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into building.
				Construction Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Resident	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into residence.
				Child	Child	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into residence.
	Groundwater ¹	Groundwater	Groundwater	Child/Adult	Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
				Adult	Adult	Ingestion	None	Receptor is not likely to ingest groundwater from the site during maintenance activities.
						Dermal Absorption	None	Receptor is not likely to contact groundwater from the site during maintenance activities.
				Adult	Adult	Ingestion	Quant	Receptor could ingest groundwater used as a water supply.
						Dermal Absorption	Quant	Receptor could come into contact with groundwater used as a water supply for industrial process.
				Construction Worker	Adult	Ingestion	None	Due to the depth to groundwater (approximately 90-100 ft bgs), the receptor is not likely to ingest groundwater during excavation activities.
						Dermal Absorption	None	Due to the depth to groundwater (approximately 90-100 ft bgs), the receptor is not likely to contact groundwater during excavation activities.
				Resident	Adult	Ingestion	Quant	Receptor could ingest groundwater used as a water supply.
				Child	Child	Ingestion	Quant	Receptor could come into contact with groundwater used as a water supply.
				Child/Adult	Child/Adult	Ingestion	Quant	Receptor could ingest groundwater used as a water supply.
	Air	Upward Migration of Vapors from Groundwater (Outdoors)		Maintenance Worker	Adult	Inhalation	None	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident.
				Commercial/Industrial Worker	Adult	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Construction Worker	Adult	Inhalation	Quant	Receptor could inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Resident	Adult	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Child	Child	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Child/Adult	Child/Adult	Inhalation	None	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. ^[2]
				Adult	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale VOCs from groundwater via vapor intrusion into building.
				Construction Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Resident	Adult	Inhalation	Quant	Receptor could inhale VOCs from groundwater via vapor intrusion into residence.
				Child	Child	Inhalation	Quant	Receptor could inhale VOCs from groundwater via vapor intrusion into residence.

Table E.1-1
Selection of Exposure Pathways - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium Groundwater Cont.	Exposure Medium Air Cont.	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future Cont.			Upward Migration of Vapors from Groundwater (Indoors) Cont. Vapors while Showering	Resident Cont.	Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. ^[a]
				Maintenance Worker	Adult	Inhalation	None	Receptor is assumed not to shower on-site.
				Commercial/Industrial Worker	Adult	Inhalation	None	Receptor is assumed not to shower on-site.
				Construction Worker	Adult	Inhalation	None	Receptor could inhale vapors from groundwater while showering.
				Resident	Adult	Inhalation	Quant	Receptor is assumed not to shower.
					Child	Inhalation	None	Receptor is assumed not to shower.
					Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. Since the shower scenario applies only to the adult resident, the lifetime resident exposure will be equivalent to that of the adult resident. ^[a]

Notes:

^a Groundwater from the surface aquifer is not currently used at the sites for potable or non-potable water supply.

Table E-2-1
Selection of Exposure Pathways - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Surface Soil	Surface Soil	Surface Soil	Maintenance Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
		Air	Ambient Air Above Surface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
	Subsurface Soil	Subsurface Soil	Subsurface Soil	Maintenance Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil.
		Air	Ambient Air Above Subsurface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Ingestion	None	Receptor is not likely to ingest subsurface soil from the site since maintenance does not include excavation.
	Groundwater ¹	Air	Ambient Air Above Subsurface Soil (Particulates and Vapors)	Maintenance Worker	Adult	Dermal Absorption	None	Receptor is not likely to come in contact with subsurface soil from the site since maintenance does not include excavation.
		Groundwater	Groundwater	Maintenance Worker	Adult	Inhalation	None	Receptor is not likely to inhale particulates and vapors from ambient air above the subsurface soil since maintenance activities do not include excavation.
			Upward Migration of Vapors from Groundwater (Outdoors)	Maintenance Worker	Adult	Ingestion	None	Receptor is not likely to ingest groundwater from the site during maintenance activities.
		Air	Upward Migration of Vapors from Groundwater (Indoors)	Maintenance Worker	Adult	Dermal Absorption	None	Receptor is not likely to contact groundwater from the site during maintenance activities.
	Surface Soil		Vapors while Showering	Maintenance Worker	Adult	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
		Surface Soil	Surface Soil	Maintenance Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
Future	Surface Soil	Surface Soil	Surface Soil	Maintenance Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
				Maintenance Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns).
				Commercial/Industrial Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil while working on site.
				Construction Worker	Adult	Dermal Absorption	Quant	Receptor could contact surface soil while working on site.
				Construction Worker	Adult	Ingestion	Quant	Receptor could ingest surface soil from the site during construction activities.
				Construction Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil from the site during construction activities.
				Resident	Child	Ingestion	Quant	Receptor could ingest surface soil while living on site.
				Resident	Adult	Dermal Absorption	Quant	Receptor could come into contact with surface soil while living on site.
				Resident	Adult	Ingestion	Quant	Receptor could ingest surface soil while living on site.
				Resident	Child/Adult	Dermal Absorption	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
				Maintenance Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while working on site.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while working on site.
				Construction Worker	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while working on site.
				Resident	Child	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while living on site.
				Resident	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the surface soil while living on site.
				Child/Adult	Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.

Table E.2-1
Selection of Exposure Pathways - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future Cont.	Surface Soil Cont.	Air Cont.	Upward Migration of Vapors from Soil (Indoors)	Maintenance Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into building.
				Construction Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Resident	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into residence.
				Child	Child	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident. ¹
	Subsurface Soil	Subsurface Soil	Subsurface Soil	Child/Adult	Child/Adult	Inhalation	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
				Adult	Adult	Ingestion	Quant	Receptor could come in contact with subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
						Dermal Absorption	Quant	Receptor could come in contact with subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
				Adult	Adult	Ingestion	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a commercial/industrial facility.
						Dermal Absorption	Quant	Receptor could contact subsurface soil when mixed with surface soil from construction of a commercial/industrial facility.
				Adult	Adult	Ingestion	Quant	Receptor could ingest subsurface soil from the site while during construction activities.
						Dermal Absorption	Quant	Receptor could come into contact with subsurface soil from the site during construction activities.
				Child	Child	Ingestion	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence.
						Dermal Absorption	Quant	Receptor could come in contact with subsurface soil when mixed with surface soil from construction of a residence.
				Adult	Adult	Ingestion	Quant	Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence.
						Dermal Absorption	Quant	Receptor could come in contact with subsurface soil when mixed with surface soil from construction of a residence.
	Air	Air	Ambient Air Above Subsurface Soil (Particulates and Vapors)	Child/Adult	Child/Adult	Ingestion	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
				Adult	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil when mixed with surface soil from construction activities while conducting routine maintenance activities.
						Dermal Absorption	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil when mixed with surface soil from construction of a residence.
				Adult	Adult	Inhalation	Quant	Receptor could inhale particulates and vapors from ambient air above the subsurface soil when mixed with surface soil from construction of a residence.
				Child/Adult	Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.

Table E-2-1
Selection of Exposure Pathways - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future Cont.	Subsurface Soil Cont.	Air Cont.	Upward Migration of Vapors from Soil (Indoors)	Maintenance Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into building.
				Construction Worker	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Resident	Adult	Inhalation	Quant	Receptor could inhale VOCs from soil via vapor intrusion into residence.
				Child	Child	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non-cancer hazard evaluations are treated separately for child and adult resident.
	Groundwater ¹	Groundwater	Groundwater	Child/Adult	Child/Adult	Inhalation	Quant	Receptor is not likely to ingest groundwater from the site during maintenance activities.
				Adult	Adult	Ingestion	None	Receptor is not likely to ingest groundwater from the site during maintenance activities.
				Commercial/Industrial Worker	Adult	Dermal Absorption	None	Receptor could ingest groundwater used as a water supply.
				Adult	Adult	Ingestion	Quant	Receptor could come into contact with groundwater used as a water supply for industrial process.
				Construction Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with groundwater used as a water supply for industrial process.
				Resident	Adult	Ingestion	None	Due to the depth to groundwater (approximately 90-100 ft bgs), the receptor is not likely to ingest groundwater during excavation activities.
				Child	Child	Dermal Absorption	None	Due to the depth to groundwater (approximately 90-100 ft bgs), the receptor is not likely to contact groundwater during excavation activities.
				Child/Adult	Child/Adult	Ingestion	Quant	Receptor could ingest groundwater used as a water supply.
	Air	Air	Upward Migration of Vapors from Groundwater (Outdoors)	Maintenance Worker	Adult	Inhalation	Quant	Receptor could come into contact with groundwater used as a water supply.
				Commercial/Industrial Worker	Adult	Inhalation	Quant	Receptor could ingest groundwater used as a water supply.
				Construction Worker	Adult	Dermal Absorption	Quant	Receptor could come into contact with groundwater used as a water supply.
				Resident	Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident.
				Child	Child	Dermal Absorption	Quant	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Adult	Adult	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Child	Child	Inhalation	None	Receptor could inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Child/Adult	Child/Adult	Inhalation	Quant	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Adult	Adult	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Child	Child	Inhalation	None	Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities.
				Child/Adult	Child/Adult	Inhalation	None	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. ²⁾
				Adult	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Child	Child	Inhalation	Quant	Receptor could inhale VOCs from groundwater via vapor intrusion into building.
				Adult	Adult	Inhalation	None	Receptor is assumed to be outdoors.
				Child	Child	Inhalation	Quant	Receptor could inhale VOCs from groundwater via vapor intrusion into residence.
				Adult	Adult	Inhalation	Quant	Receptor could inhale VOCs from groundwater via vapor intrusion into residence.

Table E.2-1
Selection of Exposure Pathways - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future Cont.	Groundwater Cont.	Air Cont.	Upward Migration of Vapors from Groundwater (Indoors) Cont. Vapors while Showering	Resident Cont.	Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. ^[1]
				Maintenance Worker	Adult	Inhalation	None	Receptor is assumed not to shower on-site.
				Commercial/Industrial Worker	Adult	Inhalation	None	Receptor is assumed not to shower on-site.
				Construction Worker	Adult	Inhalation	None	Receptor is assumed not to shower on-site.
				Resident	Child	Inhalation	None	Receptor could inhale vapors from groundwater while showering.
					Child/Adult	Inhalation	Quant	The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. Since the shower scenario applies only to the adult resident, the lifetime resident exposure will be equivalent to that of the adult resident. ^[2]

Notes:

¹ Groundwater from the surface aquifer is not currently used at the sites for potable or non-potable water supply.



Geiger.William@epamail.epa.gov
04/10/2009 03:09 PM

To "McKenna, Jim J Mr CIV USA AMC"
<jim.mckenna@us.army.mil>
cc diane.wisbeck@arcadis-us.com, "jim spencer"
<james_o_spencer@urscorp.com>, "Parks, Jeffrey N"
<Jeffrey.Parks@shawgrp.com>, jeremy.flint@atk.com,
bcc
Subject SWMU 40/71 RFI/CMS RTC (UNCLASSIFIED)

Jim, for the most part, EPA/VDEQ approve of Radford's responses to our comments on the SWMU 40/71 RFI CMS. We can discuss future monitoring in the implementation work plan. We are still concerned with the repeated occurrences of perchlorate and chloroform across the site, and would recommend monitoring for these constituents at any LTM areas. We may want to consider some sort of action at SWMU 17 if there is a potential source of perchlorate at that location. Also, Betty Ann noted that your response to her specific comment #5 should be added to the final report. It wasn't clear if that was the intention.

William A. Geiger
USEPA Region III
1650 Arch Street, 3LC20
Philadelphia, PA 19103
(215)814-3413

"McKenna, Jim J
Mr CIV USA AMC"
<jim.mckenna@us.
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02/13/2009 07:04
AM

To
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<Tina_Devine@URSCorp.com>,
"Meyer, Tom NAB02"
<Tom.Meyer@nab02.usace.army.mil>,
William Geiger/R3/USEPA/US@EPA
cc

Subject
FW: SWMU 40/71 RFI/CMS RTC
(UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

All: Resending this as I forgot to include Will Geiger on the original distribution. Please pass on to others in your organization. Jim

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

From: McKenna, Jim J Mr CIV USA AMC
Sent: Thursday, February 12, 2009 4:10 PM
To: diane.wisbeck@arcadis-us.com; jim.spencer; Parks, Jeffrey N;
jeremy.flint@atk.com; jerome.redder@atk.com; jlcutler@deq.virginia.gov;
Mendoza, Richard R Mr CIV USA IMCOM; Timothy.Leahy@shawgrp.com;
Llewellyn, Tim; Tina_Devine@URSCorp.com; Meyer, Tom NAB02
Subject: FW: SWMU 40/71 RFI/CMS RTC (UNCLASSIFIED)
Importance: High

Classification: UNCLASSIFIED
Caveats: FOUO

All:

Our response to comments (RTCs) in re the draft SWMU 40/71 RFI/CMS report for discussion at next week's meeting. Please pass on to others in your organization.

Thanks,
Jim

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

From: Tina_Devine@URSCorp.com [mailto:Tina_Devine@URSCorp.com]
Sent: Thursday, February 12, 2009 3:59 PM
To: McKenna, Jim J Mr CIV USA AMC
Subject: SWMU 40/71 RFI/CMS RTC

Here is the final RTCs. Have a great day.

(See attached file: SWMU 40_71_RFI_CMS_RTC Complete.pdf)

Tina DeVine, P.E.
Project Engineer
URS Corporation
(804)474-5448

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Classification: UNCLASSIFIED
Caveats: FOUO

Classification: UNCLASSIFIED
Caveats: FOUO



Geiger.William@epamail.epa.gov

11/13/08 10:30 AM

To "McKenna, Jim J Mr CIV USA AMC"

<jim.mckenna@us.army.mil>

cc dennis.druck@us.army.mil, diane.wisbeck@arcadis-us.com,
"jim spencer" <james_o_spencer@urscorp.com>, "Parks,
Jeffrey N" <Jeffrey.Parks@shawgrp.com>,
bcc

Subject SWMUs 40/71 RFI/CMS Risk Comments

History:

 This message has been forwarded.

Jim, Ruth had no comments on the SWMUs 40/71 RFI/CMS. Here are Betty Ann's.

(See attached file: Betty Ann SWMU 40-71 RFI-CMS.doc)

William A. Geiger
USEPA Region III
1650 Arch Street
Philadelphia, PA 19103



(215) 814-3413 [Betty Ann SWMU 40-71 RFI-CMS.doc](#)

Betty Ann's SWMU 40/71 RFI/CMS Risk Assessment Comments

General Comments

1. The text of the human health risk assessment (HHRA) presented in Section 6.0 lacks sufficient detail regarding the methodology used to complete the evaluation. Tables in Appendix E are cited extensively, with limited text descriptions as to what they represent and how calculated values were derived. While tables are useful summaries of information, key components of a HHRA – such as identification of complete exposure pathways for the various receptors, description of the calculation of particulate emission factors (PEFs) used to evaluate inhalation of fugitive dust, and the use of the Johnson and Ettinger model to evaluate vapor intrusion in indoor air – should be elaborated upon in the text. Please incorporate a greater level of detail in the text of the HHRA and reference the tables as supporting documentation.
2. Soil data have been collected at SWMUs 40 and 71 since 1992 (Section 2.8, Previous Investigations), but only data collected from the 2002 and 2006 investigations have been used for estimates of risk and hazard at these sites. The HHRA has not justified exclusion of the earlier site data, even though these data may still be representative of site conditions and applicable to the HHRA. Please revise the HHRA to provide justification for limiting the risk assessment data set to those soil samples collected in 2002 and 2006 only.
3. Section 6.5, Uncertainties, and Section 6.6, HHRA Summary and Conclusions, introduce several concepts that were not presented in the preceding sections of the HHRA. For example, Section 6.5 notes that oral toxicity data were used to evaluate dermal exposures. This approach should be described in the Toxicity Assessment (Section 6.3). Furthermore, the HHRA summaries presented in Section 6.6 for SWMUs 40 and 71 are more detailed than the summaries presented in the Risk Characterization (Section 6.4). The uncertainties and conclusions discussed in these sections should be based on the methodology and results presented earlier in Section 6.0. Please reorganize and supplement Section 6.0 to introduce the issues discussed in Sections 6.5 and 6.6.
4. The HHRA contains several discrepancies that must be addressed. For example, the Executive Summary and Section 6.6, HHRA Summary and Conclusions, identify arsenic and polychlorinated biphenyls (PCBs) as cancer risk drivers for the hypothetical future lifetime resident at SWMU 40, but Section 6.4, Risk Characterization, instead lists aroclors and polynuclear aromatic hydrocarbons (PAHs) as the risk drivers. As detailed in the Specific Comments, there are also discrepancies in the complete exposure pathways identified for the construction worker in Figure 6-2, Conceptual Site Diagram, and various related tables. Please revise the report to ensure accuracy and consistency in the presentation of HHRA results and identification of exposure pathways.

Specific Comments

5. Section 5.3, Fate and Transport Summary, Page 5-10: “Groundwater samples collected from the landfill area indicated apparent leaching of chloroform from the landfill area to groundwater at levels above its T-RBC. A specific source of chloroform was not identified through sampling of soil and landfill material at the site.” This would imply that the chloroform source has not been located. Please revise the RFI/CMS Report to either discuss the hypothesized sources of chloroform at this SWMU and steps that may be implemented to address the repeated occurrence of chloroform contamination at this site.

6. Section 6.0, Human Health Risk Assessment, Page 6-1: This section states that the HHRA was conducted consistent with EPA’s *Interim Final Risk Assessment Guidance for Superfund* (RAGS) and “other current EPA/EPA Region 3 resources and guidance documents.” However, specific references for these other resources are not provided in this section. Please provide the appropriate reference citations for these guidance documents.

7. Section 6.1.1, Data Summary, Page 6-2: This section provides a bulleted list of ways that laboratory-flagged data and duplicate samples were treated in the HHRA. Please add a description of how non-detected values were incorporated into the HHRA.

8. Section 6.1.2, Identification of COPCs, Page 6-2: This section does not address how constituents with no available benchmarks or appropriate surrogates were considered in the risk assessment process. Table E.1-2.1 of Appendix E, SWMU 40 COPC Determination – Surface Soil, appears to show that chemicals without screening benchmarks, such as cobalt and 2-hexanone, were flagged as COPCs. If toxicity data are unavailable for these constituents as well, they need to be discussed qualitatively in the uncertainty analysis. Please revise Section 6.1.2 to address how constituents with no available screening benchmarks were considered in the risk screening process.

9. Section 6.2.2, Identification of Exposure Pathways, Page 6-4: This section lacks sufficient detail regarding the complete exposure pathways evaluated for each receptor. Please provide descriptions of each exposure scenario, including the receptors and complete exposure pathways evaluated. Please also discuss the different inhalation exposure evaluations (indoor and outdoor air) and associated methodologies, including the use of PEFs, volatilization factors (VFs), and the Johnson and Ettinger vapor intrusion model.

10. Section 6.2.3, Calculation of EPCs, Page 6-5: The second paragraph references ProUCL 4.0 as being used to calculate EPCs for the HHRA. Please provide a citation for this software and add it to Section 14.0, References.

This section should also describe the use of PEFs, VFs, and the Johnson and Ettinger model to calculate air EPCs under the various exposure scenarios.

11. Section 6.3, Toxicity Assessment, Page 6-5: This section does not provide sufficient information for this critical step in a HHRA. Please describe in more detail the different types of available toxicity criteria (for example, reference doses [RfDs], reference concentrations [RfCs], and cancer slope factors [CSFs]); and provide the hierarchy of sources for toxicity criteria used in the HHRA, including the Integrated Risk Information System (IRIS) database, Provisional Peer Reviewed Toxicity Values (PPRTV), and other sources (including California Environmental Protection Agency [Cal EPA] toxicity values, the EPA Superfund Health Effects Summary Table [HEAST], and other values) as outlined in OSWER Directive 9285.7-53.

12. Section 6.4, Risk Characterization, Page 6-6: The table on Page 6-6, SWMU 40 – Summary of Risks and Hazards, is supposed to summarize data presented in Tables E.1-9.1 through E.1-9.6 of Appendix E; however, there are numerous inconsistencies among the tables. The hazard index (HI) for the hypothetical future construction worker is 14 on the Page 6-6 table, but Table E.1-9.3 RME, RME Summary of Cancer Risks and Non-Cancer Hazards for COPCs: Construction Worker – SWMU 40, indicates that the total HI across all media and all exposure routes is 2E+01. Furthermore, the HI for the hypothetical future child resident is identified as 26 on the Page 6-6 table, yet a HI of 5E+01 is presented for this same receptor on Table E.1-9.5 RME in Appendix E. An accurate summary of the risks and hazards should be presented on the Page 6-6 table. For defensibility, please revise the HHRA to consistently present the results of the risk characterization throughout the RFI/CMS Report. If any conclusions change as a result of these HIs, please update the HHRA accordingly.

13. Figure 6-2, Conceptual Site Diagram: This figure contains errors and lacks sufficient detail to support the HHRA. Please make the following revisions:

- The column labeled “terrestrial biota” should be removed since this figure has been included to support the human health risk evaluation, and not the ecological risk evaluation.
- Exposure to subsurface soil by a hypothetical future maintenance worker via the inhalation, ingestion, and dermal contact should be considered a complete exposure pathway based on the same rationale used for subsurface soil evaluation for the hypothetical future construction worker, commercial worker, and residents (that is, mixing of potential soil contamination during construction or land development activities may bring subsurface soil to the surface).
- A distinction should be made between each receptor’s potential inhalation exposure to vapors in indoor and outdoor air, and particulates in outdoor air.

14. Table 6-1, Sample Assemblages for Soil COPC Screening: Under the Subsurface Soil heading, sample 40SB2F is listed twice and sample 40SB1F appears to have been inadvertently omitted. According to Table 4-1, SWMU 40 – Summary of Detected Chemicals in Analytical Samples, sample 40SB1F was collected from 4-8 feet below ground surface (bgs), so it should be considered a subsurface soil sample for the risk assessment. Please revise Table 6-1 to address these discrepancies.

15. Table 6-2, Dioxin/Furan 2,3,7,8-TCDD Equivalents Calculation – Soil: This table contains typographical errors (e.g., 1,2,3,4,6,7,8,9-OCDF [OCDD]), does not define all acronyms (e.g., SSL, DAF, MX, MXJ, JB, and M), and does not provide citations (e.g., soil-to-groundwater SSL, TEF). Please revise Table 6-2 as appropriate.

16. Table 6-3, RDA-based Screening Criteria Calculations: The number of significant digits in the Soil Screening Criteria columns (Adult Resident, Child Resident, and Selected Criteria) is inconsistent. For consistency, please present the values in the Soil Screening Criteria columns with the same number of significant digits.

17. Appendix E, Human Health Risk Assessment: For ease of locating specific tables, please include a table of contents after the cover page of this appendix.

18. Appendix E, Human Health Risk Assessment: Summaries of the indoor air concentrations modeled using the Johnson and Ettinger model are included as Tables E.1-4.5 and E.1-4.7, but the model outputs from these evaluations have not been appended to the RFI/CMS Report. To facilitate a complete review of this RFI/CMS Report, please submit the Johnson and Ettinger model outputs as part of this appendix.

19. Appendix E, Table E.1-1, Selection of Exposure Pathways - SWMU 40: Exposure to subsurface soil by a hypothetical future maintenance worker via the inhalation, ingestion, and dermal contact should be considered a complete exposure pathway based on the same rationale used for subsurface soil evaluation for the hypothetical future construction worker, commercial worker, and residents (that is, mixing of potential soil contamination during construction or land development activities may bring subsurface soil to the surface). Please provide rationale for the exclusion of this potentially complete exposure pathway or incorporate it into the HHRA as appropriate. This comment also applies to Table E.2-1, Selection of Exposure Pathways - SWMU 71.

20. Appendix E, Table E.1-1, Selection of Exposure Pathways - SWMU 40: This table identifies the hypothetical future construction worker as being evaluated quantitatively in the HHRA – as indicated by “Quant” under the heading “Type of Analysis” – for ingestion and dermal absorption exposure to groundwater. However, the notes in the last column indicate that any contact with groundwater is unlikely for this receptor due to the depth to groundwater (90 to 100 feet bgs). Furthermore,

Figure 6-2, Conceptual Site Diagram, does not identify ingestion and dermal contact with groundwater as complete exposure pathways for the construction worker. Please revise the table and subsequent risk evaluation, as appropriate, to resolve this discrepancy. This comment also applies to Table E.2-1.

21. Appendix E, Table E.1-4.1d, Values used for Daily Intake Equations for Future Scenarios – Total Soil – Exposure Pathway Air: The inhalation rates selected for the adult resident are inconsistent throughout the RFI/CMS Report. Table E.1-4.1d indicates the inhalation rate for an adult resident is 0.63 cubic meters per hour (m^3/hr), which was calculated using a daily long term rate of $15 \text{ m}^3/\text{day}$. However, Table E.1-4.2b, Values used for Daily Intake Equations for Future Scenarios - Groundwater - Exposure Pathway Groundwater, specifies an adult resident inhalation rate of $0.83 \text{ m}^3/\text{hr}$, calculated using a daily long term rate of $20 \text{ m}^3/\text{day}$. Two different sources are cited for the inhalation rates. For consistency, please revise Table E.1-4.1d to use the inhalation rate associated with the most recent guidance (i.e., $0.83 \text{ m}^3/\text{hr}$ should be used).

22. Appendix E, Table E.1-4.2a, Values used for Daily Intake Equations for Future Scenarios - Groundwater - Exposure Pathway Groundwater: This table presents exposure parameters and daily intake equations associated with ingestion of and dermal contact with groundwater for the hypothetical future construction worker. However, Figure 6-2, Conceptual Site Diagram, does not identify ingestion and dermal contact with groundwater as complete exposure pathways for the construction worker. Please revise the table as appropriate to resolve this discrepancy. This comment also applies to Table E.2-4.2a.

23. Section 8.1.2, SWMU 71, Page 8-1: The last sentence on Page 8-1 states, “When considering background and target organs, calculated hazards for evaluated receptors associated with hypothetical future industrial and residential land uses were below the target hazard of $1\text{E}+00$.” This statement appears incorrect. Page 6-7 of the HHRA identified vanadium as having a HI greater than 1 for the hypothetical future child resident when segregated by target organ (Kidney, $\text{HI} = 2$). Section 6.4.3 further states that “COPCs identified for SWMU 71 that exceed background include arsenic for surface soil and vanadium for total soil.” Since vanadium cannot be attributed to background, hazards associated with this contaminant need to be considered when developing corrective measure objectives (CMOs). Please revise Section 8.1.2 and all other applicable sections of the RFI/CMS Report (including the SWMU 71 Summary and Conclusions, Section 6.6.2) to acknowledge that vanadium is the primary hazard driver for the elevated target organ specific kidney HI for the hypothetical future child resident, and that this chemical exceeded background. CMOs should be developed accordingly.



Geiger.William@epamail.epa.gov

08/27/08 09:04 AM

To "McKenna, Jim J Mr CIV USA AMC"

<jim.mckenna@us.army.mil>

cc dennis.druck@us.army.mil, diane.wisbeck@arcadis-us.com,
"jim spencer" <james_o_spencer@urscorp.com>, "Parks,
Jeffrey N" <Jeffrey.Parks@shawgrp.com>,

bcc

Subject SWMU 40/71 Comments

Jim, here are EPA/VDEQ comments on the SWMUs 40 and 71 RFI/CMS. These do not include Ruth or Betty Ann's comments. Thanks.

(See attached file: SWMUs 40 and 71 RFI_CMS Comments.doc)

William A. Geiger
USEPA Region III
1650 Arch Street
Philadelphia, PA 19103



(215) 814-3413 [SWMUs 40 and 71 RFI_CMS Comments.doc](#)

Presented below are EPA/VDEQ comments (minus risk assessment) on the *Draft Solid Waste Management Units 40 and 71 RCRA Facility Investigation / Corrective Measures Study Report*, Radford Army Ammunition Plant (RAAP), Virginia, dated April 2008 (RFI/CMS Report).

GENERAL COMMENTS

1. Based on the information provided in Figures 2-15 through 2-18, site characterization of ground water should continue in the direction of ground water flow, in the vicinity of geophysical resistivity station 2-30 (favorable drilling target 1-20) on Figure 2-17. The Long-Term Groundwater Monitoring Table, included in Section 10.2.3, Long Term Monitoring and Maintenance, only identifies three wells proposed for the long-term groundwater monitoring program at Solid Waste Management Unit (SWMU) 40, the Nitro Landfill. For consistency and clarity, a discussion within the RFI/CMS needs to be presented which further evaluates the geophysical survey information to select an additional downgradient monitoring point for the long-term groundwater monitoring program being proposed. This would also be consistent with the RCRA minimum requirement of three downgradient wells for long term monitoring of a regulated unit (see specific comment #4).
2. There is no discernible rationale for the presentation of unnumbered tables in the main body of Section 6.0, Human Health Risk Assessment; numbered tables at the end of the section; and tables in Appendix E, Human Health Risk Assessment. For ease of comprehension, please reorganize the tables by presenting ones that summarize key HHRA components – for example, chemicals of potential concern (COPCs), exposure point concentrations (EPCs), receptors and exposure pathways, toxicity criteria, and risk summaries – at the end of Section 6.0. Appendix E should contain the more detailed tables. All tables should be numbered, titled, and listed in a table of contents.

SPECIFIC COMMENTS

3. **Executive Summary, Page ES-2:** The first full paragraph on this page summarizes the HHRA conclusions for SWMU 71, stating that “No further action is needed at the site on the basis of human health.” However, the same paragraph reports elevated cancer risk estimates associated with the hypothetical future lifetime resident; and elevated non-cancer hazard estimates derived for the hypothetical future construction worker and hypothetical future child resident. The conclusion of “No further action” is not supported by the stated results and is misleading. Furthermore, the presentation of the SWMU 71 results in the Executive Summary differs from that presented in Section 6.6.2.1, SWMU 71 HHRA Summary. Please remove the statement regarding “No further action” from the Executive Summary (or perhaps change it to read “no further remediation”) unless additional information is presented to support the statement. Additionally, please assure that the results of the HHRA are presented consistently throughout the RFI/CMS Report.
4. **Section 2.7.1.2, ATS Geophysical Survey for Monitoring Well Location, Page 2-7:** The location for monitoring well 40MW5 was selected based on the identification of a very low resistivity anomaly at this location during the geophysical survey. This

anomaly was identified at approximately 75 feet below ground surface (bgs). It was suggested that this anomaly was likely a karst feature or fracture zone (Figure 2-15, Psuedo-Sections, ATS L-1 and L-2). However, based on drilling at this location, groundwater was not encountered at 40MW5 until 143 ft bgs (Section 2.7.1.3, Monitoring Well Installation). The actual cause of the anomaly at 40MW5 was not explained in the RFI/CMS Report. Please revise the RFI/CMS Report to further address the anomaly encountered at 40MW5, based on the results of drilling at this location. Additionally, please address whether this location is still considered an 'optimal' downgradient monitoring location for the landfill, considering the west/northwest groundwater flow direction at the site and the identification of a preferential pathway of groundwater flow to the west, primarily through karst conduits. For long-term monitoring purposes, it may be beneficial to consider installation of a well in a location west of the landfill (perhaps intercepting an additional anomaly/likely karst feature identified during the geophysical survey).

5. **Section 3.4.4, Groundwater Sampling, Page 3-6:** The second paragraph states that both high flow and low flow purging techniques were used to collect the groundwater sample from 40MW5. However, the RFI/CMS Report does not clarify why high flow purging techniques were necessary at this well. If multiple flow zones were encountered or if the well was producing a higher yield than the other wells, this information should be documented to support use of a high flow purging techniques. Please revise the RFI/CMS Report to state why high flow purging techniques were used at monitoring well 40MW5.
6. **Section 4.1.2, Human Health Nature and Extent Assessment, Page 4-4:** The Summary of COPCs for Soil notes that 2,3,7,8-TCDD TEQ was detected above the residential RBC at surface soil sample location 40SS4. However, with the exception of surface soil sample location 40SS5 located greater than 50 ft southeast of 40SS4, no other surface soil samples in the vicinity of this exceedance were evaluated for 2,3,7,8-TCDD TEQ. Therefore, the extent of 2,3,7,8-TCDD TEQ does not appear to be fully delineated. Please revise the RFI/CMS Report to address this perceived data gap.
7. **Section 4.1.2.2, Landfill Material, Dioxins, Page 4-8:** A concentration of 2,3,7,8-TCDD TEQ was detected in sample TESTPIT2F above the soil screening level (SSL) based on a dilution attenuation factor (DAF) of 20. The potential for this contaminant to migrate to groundwater has not been further evaluated. Groundwater samples were not analyzed for dioxins/furans, and a site-specific SSL was not calculated for this constituent, even though it is mentioned in Section 4.1.4. Please revise the RFI/CMS Report to clarify how the potential for 2,3,7,8-TCDD TEQ to migrate to groundwater will be evaluated, given the SSL exceedance at TESTPIT2F.
8. **Section 4.1.4.1, Development of Specific Soil-to-Groundwater SSLs, Page 4-10:** It appears that default values were used to calculate site-specific SSLs even though site-specific data are available. For example, default values were used for water-filled soil porosity, air-filled soil porosity, and dry soil bulk density, but Table 2-1, Soil Physical Testing Results, includes the site-specific data from the soil fill and the soil below the landfill for these parameters. Additionally, a default DAF of 20 was used in the SSL

equations, but the RFI/CMS Report does not address the applicability of this value. EPA's *Soil Screening Guidance: User's Guide* (July 1996) notes that a default DAF value of 20 is protective for contaminant soil sources up to 0.5 acre in size (Page 30), but Section 1.0, Introduction, states that SWMU 40 is approximately 2 acres in size. The *Soil Screening Guidance* further states that "a DAF of 20 may be protective of larger sources as well; however, this hypothesis should be evaluated on a site-specific basis." Please revise the RFI/CMS Report to use site-specific data wherever possible when calculating site-specific SSLs to obtain SSLs that are more reflective of conditions at the site. Alternatively, please provide further justification for using default values. Additionally, please provide justification for use of a DAF value of 20, or calculate a site-specific DAF for this site as recommended by the *Soil Screening Guidance*.

It should also be noted that the Site-Specific SSL Calculations, included in Appendix C.8, include the following statement on each page of calculations: "Input Parameters Averaged from All Soil-Sample Physical Text Results." This statement is inaccurate as most of the values used in the calculations are default values. Please clarify this discrepancy.

9. **Section 4.3.2.1, Perchlorate, Page 4-16:** Perchlorate was detected in a well located upgradient of the SWMU 40 landfill. The RFI/CMS Report states that "similar perchlorate concentrations also were detected in groundwater samples collected from the SWMU 17 area upgradient of SWMU 40 during an RFI conducted by Shaw Environment and Infrastructure (Shaw) in August 2007." A complete reference has not been provided to substantiate this information. For defensibility, please revise the RFI/CMS Report to include a complete reference for the SWMU 17 RFI, conducted by Shaw, in this section of the RFI/CMS Report and in Section 14.0, References.
10. **Section 10.2.3, Long Term Monitoring and Maintenance, Page 10-2:** The long-term groundwater monitoring for SWMU 40 does not appear to include analysis for dioxins/furans. Since 2,3,7,8-TCDD TEQ was detected above the SSL in at least one subsurface soil sample (TESTPIT2F), the groundwater monitoring program should include analysis of dioxins/furans to assess the potential migration of this constituent to groundwater. Please revise the RFI/CMS Report to include groundwater sampling for dioxins as part of the long-term monitoring plan, unless additional justification can be provided to exclude this analyte class.
11. **Section 11.4, Cost, Page 11-5:** In the Summary of Cost for Corrective Measures Alternatives, the Annual Cost Years 6-30 for Alternative 2 is identified as \$17.099. It appears that a comma should have been used in place of the period in this value so that it reads \$17,099. Please revise this table to make the necessary correction.

Mike's Comments

1. Geophysical examination of the landfill area has indicated the presence of a preferential pathway as shown on Figure 2-15. Figure 2-16 illustrates the structure contours for the top of bedrock. Figure 2-17 illustrates the possible target locations for monitoring wells. Figure 2-18

illustrates the groundwater potentiometric surface. Based on the above, site characterization of ground water should continue in the direction of ground water flow, in the vicinity of geophysical resistivity station 2-30 (favorable drilling target 1-20) on Figure 2-17.

2. Suggest ground water samples be obtained quarterly for the first four quarters, and then every nine months thereafter for remaining years out to thirty. This will allow for seasonal variations throughout the project.
3. Add turbidity to the analytical parameters on page 10-2.
4. The alternative chosen sounds very much like Monitored Natural Attenuation. The proposed oversight needs to be expanded to support this alternative.
5. Propose a plan to evaluate the effectiveness of monitoring of no more than/no less than five year frequency during the proposed 30 year monitoring.
6. Section 4.3.2.1 Please include a figure illustrating the location of 17MW2 and LFMW01, or include them on a figure currently found in this report.
7. If neither SWMU 40 or 71 are the source of Perchlorate results, propose a plan to delineate the Perchlorate source.
8. The yield of each well sampled in Section 3.4.4 should be described in the section. Anomalies (such as multiple flow zones) should be explained.



DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MD 21010-5403

8 MAY 2008

MCHB-TS-REH

MEMORANDUM FOR Office of Environmental Quality, Radford Army Ammunition Plant
(SJMRF-OP-EQ/Mr. Jim McKenna), P.O. Box 2, Radford, VA 24143-0002

SUBJECT: Review of Document Titled: "Draft RCRA Facility Investigation/ Corrective Measures Study Report for SWMUs 40 (RAAP-009) and 71 (RAAP-002), Radford Army Ammunition Plant, Virginia, April 2008"

1. The U.S. Army Center for Health Promotion and Preventive Medicine reviewed the subject document on behalf of the Office of The Surgeon General pursuant to Army Regulation 200-1 (Environmental Protection and Enhancement). We appreciate the opportunity to review this report and concur with the selected corrective measures alternative as being protective of human health and the environment.
2. The document was reviewed by Mr. Dennis Druck, Environmental Health Risk Assessment Program. He can be reached at DSN 584-2953, commercial (410) 436-2953 or electronic mail "dennis.druck@us.army.mil".

FOR THE COMMANDER:

JEFFREY S. KIRKPATRICK
Director, Health Risk Management

CF:
HQDA (DASG-PPM-NC)
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April 24, 2008

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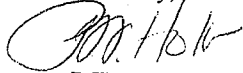
Subject: With Certification, Radford Army Ammunition Plant,
Solid Waste Management Units 40 (RAAP-009) and 71 (RAAP-002) RCRA Facility
Investigation/Corrective Measures Study Report, Volumes I and II, Draft April 2008
EPA ID# VA1 210020730

Dear Mr. Geiger and Mr. Cutler:

Enclosed is the certification for the subject document that was sent to you on April 21, 2008. Also enclosed is a copy of the transmittal email message.

Please coordinate with and provide any questions or comments to myself at (540) 639-8658, Jerry Redder of my staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 639-8641.

Sincerely,



P.W. Holt, Environmental Manager
Alliant Techsystems Inc.

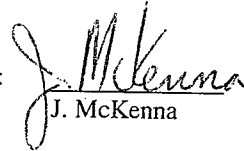
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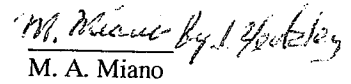
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Coordination:


J. McKenna


M. A. Miano

Concerning the following:

Radford Army Ammunition Plant

Solid Waste Management Units 40 (RAAP-009) and 71 (RAAP-002)

RCRA Facility Investigation/Corrective Measures Study Report

Volumes I and II

Draft April 2008

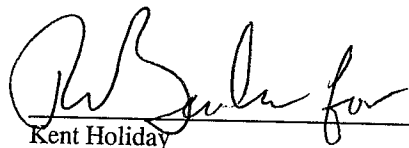
I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage 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:  for Jon R. Drushal

TITLE: Lieutenant Colonel, US Army
Commanding

SIGNATURE:

PRINTED NAME:  for Kent Holiday

TITLE: Vice President and General Manager
ATK Energetics Systems

Greene, Anne

From: McKenna, Jim
Sent: Monday, April 21, 2008 2:46 PM
To: McKenna, Jim; Greene, Anne; beth lohman; dennis.druck@us.army.mil; diane.wisbeck@arcadis-us.com; durwood willis2; Geiger.William@epamail.epa.gov; Redder, Jerome; jim spencer; jlcutler@deq.virginia.gov; Llewellyn, Tim; Mendoza, Richard R Mr CIV USA IMCOM; Meyer, Tom NAB02; Parks, Jeffrey N; Timothy.Leahy@shawgrp.com; Tina_Devine@URSCorp.com
Subject: Radford AAP - Draft SWMU 40/71 RFI/CMS Report (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

All:

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

Certification letter will follow from Radford AAP under separate cover.

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

Jim McKenna
Classification: UNCLASSIFIED
Caveats: NONE

EXECUTIVE SUMMARY

URS Group, Inc. (URS) conducted a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and Corrective Measures Study (CMS) at Radford Army Ammunition Plant (RFAAP) Solid Waste Management Unit (SWMU) 40, the Nitro Landfill, and SWMU 71, Flash Burn Area. SWMU 40 is an approximate 2 acre landfill area and SWMU 71 comprises an approximate 2,250 square foot (ft²) area conterminous with the southwestern corner of the landfill.

The work was conducted to fulfill the requirements set forth in the 2000 RCRA Corrective Action permit as tasked by the United States Army Corps of Engineers, Baltimore District. URS performed the RFI/CMS in accordance with the Master Work Plan (URS 2003), Work Plan Addendum 014 (URS 2002), Geophysical Investigation Plan for SWMU 40 (March 2006), and Geophysical Investigation Report – SWMU 40 (March 2007) approved by the U.S. Environmental Protection Agency (USEPA) Region III and the Virginia Department of Environmental Quality.

Nature and Extent Assessment

Metals and polychlorinated biphenyls (PCBs) are the primary chemicals of potential concern (COPCs) in soil at SWMU 40. COPCs in soil are primarily limited to the landfill material itself with the exception of a surficial area of soil containing PCBs located adjacent to the northern escarpment of the landfill. An approximate 1.2 acre area of landfill material has been delineated within the SWMU 40 area. The estimated in place volume of the landfill material is 18,700 bank cubic yards (BCY). Landfill material is capped by low-permeability clay with geotextile material and underlain by low permeability clay. Metals are the primary site-related COPCs in soil at SWMU 71.

Low-level concentrations of organic and inorganic constituents were detected in the two monitoring wells installed adjacent to the landfill area. Chloroform was the only constituent identified as a COPC with detected concentrations above the USEPA tap water risk-based screening concentration (T-RBC) but below the USEPA maximum contaminant level (MCL) for total halomethanes. Extensive source characterization was conducted at SWMUs 40 and 71 including the collection of 91 soil samples many of which were collected from landfill material and soil below the landfill material at SWMU 40. Chloroform was not detected in these samples. The lack of any detections and absence of other volatiles in groundwater samples suggests a potential alternate source for chloroform in groundwater. Studies and groundwater investigations have shown the presence of chloroform in most groundwater samples collected at the facility regardless of location. The concentrations of chloroform detected in monitoring wells at SWMUs 40 and 71 are within the range of chloroform levels present in the water transmitted through water lines at the facility. The landfill area is located downgradient of developed areas containing water lines that could be leaking, which may have been the source of chloroform. Based on the historical use of SWMU 40 (i.e., sanitary landfill), chloroform could be a potential site-related groundwater COPC, but it should be noted that no source of chloroform has been identified within the landfill material or soil beneath the landfill material at SWMU 40. Also it should be noted that based on the historical use of SWMU 71 (i.e., flash and burn area), the site-related soil COPCs identified (metals), and the small size of the site, chloroform is not considered a site-related COPC in groundwater for SWMU 71.

Fate and Transport Assessment

The fate and transport assessment identified mass transport and erosion from the northern edge/slope of the landfill area at SWMU 40 due to the detection of PCBs in surface soil deposited at the base of the landfill slope. Surface water runoff has several distinct gullies and swales into the northern edge/slope of the landfill in this area.

Groundwater samples collected from the landfill area indicated apparent leaching of chloroform from the landfill area to groundwater at levels above its T-RBC but below the EPA MCL. A specific source of chloroform was not identified through sampling of soil and landfill material at the site. Significant

leaching of other constituents to clay soil present below the landfill material or to groundwater at the site was not apparent from the data collected.

Human Health Risk Assessment (HHRA)

A HHRA was performed to evaluate the potential human health effects associated with previous activities at the site. Soil was evaluated separately in the HHRA for SWMUs 40 and 71. Groundwater was evaluated on a site-wide basis. Receptors evaluated for both areas included: current/future maintenance worker, future construction worker, future commercial worker, future adult resident, future child resident, and lifetime resident. The HHRA included the calculated estimates of upper bound excess lifetime cancer risks for carcinogenic chemicals, and calculated estimates of hazard quotients (HQs) and hazard indices (HI) for noncarcinogenic chemicals. HHRA methodology was consistent with guidance included in EPA's *Interim Final Risk Assessment Guidance for Superfund* (RAGS) and other current USEPA/USEPA Region III resources and guidance documents as noted in the report.

SWMU 40: The current land use of the site (closed landfill) is unlikely to change in the future due to the presence of a closed landfill with approximately 18,700 BCY of landfill material contained in place by a surface cap and cover. The results of the risk assessment for SWMU 40 indicated that the total calculated risk for each receptor is below or within USEPA's target risk range for Superfund sites (1E-06 to 1E-04, USEPA 1989b) with the exception of the hypothetical future lifetime resident due primarily to arsenic and PCBs in soil and chloroform in groundwater at concentrations below the USEPA MCL. Calculated site-related hazards (when taking target organs and background into consideration) are equal to or below the USEPA reference HI of 1E+00 for each of the receptors evaluated with the exception of the hypothetical future construction worker (CNS due to aluminum in soil via the inhalation pathway).

SWMU 71: The current land use of the site (gravel covered undeveloped area) is unlikely to change in the future due to its small size (2,250 square feet) and location directly adjacent to the landfill. The total calculated site-related risk for each receptor is below or within USEPA's target risk range for Superfund sites (1E-06 to 1E-04, USEPA 1989b). Calculated site-related hazards (when taking target organs and background into consideration) for all receptors are equal to or below the USEPA reference HI of 1E+00. No further action is needed at the site on the basis of human health.

Screening Level Ecological Risk Assessment (SLERA)

A SLERA was performed to evaluate potential ecological risks associated with previous activities at the site. SWMUs 40 and 71 were evaluated separately in the SLERA given that these areas have different waste disposal histories and characteristics. Direct contact and wildlife ingestion pathways were evaluated for soil. Terrestrial receptors that were evaluated included: plant communities, soil invertebrate/ microbial communities, American Robin, Red-tailed Hawk, Meadow Vole, Red Fox, and Short-tailed Shrew. The SLERA assessed risk by comparing various exposure estimates for chemicals to available toxicity reference values (TRVs) for each receptor. The relative risk was expressed as an HQ. An HQ of less than 1 indicates no or negligible risk. The potential for risk increases as the HQ increases above unity. HQs were calculated for no effects range observable adverse effect levels (NOAELs) and lowest observable adverse effect levels (LOAELs). Preliminary and refined risk characterizations were conducted, with refined characterizations considering 95% upper confidence limits (UCLs) concentrations, background evaluations, and other more environmentally realistic assumptions than conservative preliminary estimates.

SWMU 40: The refined risk characterization for plants indicated calculated HQs below 1 when considering background, with the exception of mercury (3.1) and selenium (1.7) for which background comparisons cannot be conducted. The refined risk characterizations for soil invertebrates and microbial communities indicated calculated HQs below 1 when considering background, with the exception of mercury, which had a HQ of 9.3. The refined risk characterization for wildlife resulted in the identification of no chemicals with a LOAEL-based HQ greater than 1. After consideration of spatial distribution of data at the site, the results of the SLERA, background concentrations, and the isolated

nature of the landfill material in place at the site, the SMDP is the following: *There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site on the basis of ecological risk.*

SWMU 71: The refined risk characterization for plants indicated calculated HQs below 1 when considering background, with the exception of antimony (2.4) for which background comparisons cannot be conducted. The refined risk characterization for soil invertebrates and microbial indicated calculated HQs below 1 when considering background, with the exception of mercury, which had a HQ of 2.9. The refined risk characterization for wildlife resulted in the identification of no chemicals with a LOAEL-based HQ greater than 1. After consideration of spatial distribution of data at the site, the results of the SLERA, background concentrations, and site characteristics, the SMDP is the following: *There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site on the basis of ecological risk.*

Corrective Measures Study (CMS)

The RFI fate and transport assessment and risk assessments identified a requirement to evaluate corrective measures for SWMU 40 but did not indicate a requirement to evaluate corrective measures at SWMU 71 based on the current and future scenarios evaluated. Corrective measures objectives (CMOs) identified for SWMU 40 included: 1) maintain containment of the landfill material at the site and implement necessary controls to prevent future uncontrolled human exposure to this landfill material, and 2) implement any necessary measures to stabilize and repair the landfill cover at the northern edge of the landfill area to prevent any further mass transport of soil material in this area.

Three corrective measures technologies were selected in the CMS for development of two corrective measures alternatives for SWMU 40 in addition to a baseline no further action alternative including:

- Alternative No. 1: No Further Action;
- Alternative No. 2: Institutional Controls, Engineering Controls, and Long-Term Monitoring and Maintenance;
- Alternative No. 3: Excavation of Soil/Landfill Material and Offsite Disposal for Clean Closure and Unrestricted Land Use.

The three alternatives were evaluated with respect to criteria specified in Attachment D of the RFAAP RCRA Permit (EPA 2000) and criteria for evaluating corrective measures alternatives in Section IV Part E of the RCRA Corrective Plan guidance document (EPA 1994a). Alternative Two was selected as the final alternative for SWMU 40 because it will: 1) effectively achieve each of the CMOs by providing for continued containment of landfill material at the site, preventing future uncontrolled human health exposure to the waste material, and repairing the small areas of the cap that have eroded, and achieve the required CMOs at one eighth the total cost of Alternative 3 expressed as total dollars and at one eighteenth the total cost of Alternative 3 when costs are expressed as net present value. Implementation of Alternative Three would exceed the established CMOs but would require transferring waste material from landfill to another at significant cost without reduction of volume or toxicity.

Implementation of Alternative Two, including implementation of ICs, is expected to be completed in less than six months, with cap repairs requiring less than 30 days to complete after site mobilization. This time frame is considered an estimate and the actual time to complete the corrective measures will be subject to site-specific conditions.

Implementation of Alternative Two will include the following:

- Repairs to the landfill cap;
- Implementation of ICs;
- Installation of a third downgradient monitoring well; and

- LTM for 30 years including: inspection and maintenance of the landfill cap, periodic sampling of four groundwater monitoring wells for five years followed by annual sampling for 25 years, and preparation of annual LTM reports.

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LIST OF ABBREVIATIONS AND ACRONYMS

2ADNT	2-amino-4,6-dinitrotoluene
4ADNT	4-amino-2,6-dinitrotoluene
°C	Degrees Celsius
%	Percent
AL	Action Level
ALM	Adult Lead Model
ATSDR	Agency for Toxic Substance Disease Registry
AF	Area Use Factor
BCY	Bank Cubic Yards
bgs	Below Ground Surface
BOD	Biochemical Oxygen Demand
CDCP	Center for Disease Control and Prevention
CDD	Chlorinated Dibenzo-p-dioxin
CDF	Chlorinated Dibenzofuran
CDI	Chronic Daily Intake
cfs	Cubic Feet Per Second
cm/sec	Centimeters Per Second
CMO	Corrective Measure Objective
CMS	Corrective Measures Study
CNS	Central Nervous System
COD	Chemical Oxygen Demand
COI	Chemical of Interest
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DQO	Data Quality Objective
DNT	Dinitrotoluene
ECSM	Ecological Conceptual Site Model
EPC	Exposure Point Concentration
EPIC	Environmental Photographic Interpretation Center
ERAGS	Ecological Risk Assessment Guidance for Superfund
ft	Feet
ft/ft	Feet per Foot
g/dL	Grams Per Deciliter
GI	Gastrointestinal
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMX	Cyclo-1,3,5,7-tetramethylene 2,4,6,8-tetranitramine; Octogen
HSA	Horseshoe Area
HQ	Hazard Quotient
I-RBC	Industrial Risk-Based Concentration
IDM	Investigation-Derived Material
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

LOAEL	Lowest Observable Adverse Effect Level
MCL	Maximum Contaminant Level
MDC	Maximum Detected Concentration
MNA	Monitored Natural Attenuation
µg/L	Micrograms per Liter
µm	Micrometer
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
MHSP	Master Health and Safety Plan
MQAP	Master Quality Assurance Plan
MSE	Millennium Science and Engineering
msl	Mean Sea Level
MWP	Master Work Plan
NOAEL	No Observable Adverse Effect Level
ORP	Oxidation-Reduction Potential
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PEF	Particulate Emission Factor
PETN	Pentaerythritol tetranitrate
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
R-RBC	Residential Risk-Based Concentration
RACM	Regulated Asbestos Containing Material
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowance
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RFA	RCRA Facility Assessment
RfD	Risk Reference Dose
RFAAP	Radford Army Ammunition Plant
RFI	RCRA Facility Investigation
RG	Remedial Goal
SC	Clayey Sand
SLERA	Screening Level Ecological Risk Assessment
SM	Silty Sand
SMDP	Scientific/Management Decision Point
SOP	Standard Operating Procedure
SSL	Soil Screening Level
SVOC	Semi-volatile Organic Compound
SWMU	Solid Waste Management Unit
T-RBC	Tap Water Risk-Based Concentration
TAL	Target Analyte List
TCDD	Tetrachlorodibenzo-p-dioxin

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

TCL.....	Target Compound List
TCLP.....	Toxicity Characteristic Leaching Procedure
TEF	Toxicity Equivalent Factor
TEQ.....	Toxicity Equivalent Concentration
TIC.....	Tentatively Identified Compound
TOC	Total Organic Carbon
TOX	Total Organic Halogen
TNT.....	Trinitrotoluene
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
URS.....	URS Group, Inc.
USACE	United States Army Corps of Engineers
USEPA.....	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VI	Verification Investigation
VOC	Volatile Organic Compound
WPA.....	Work Plan Addendum

1.0 INTRODUCTION

This Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI)/Corrective Measures Study (CMS) report presents the results and findings of the investigations conducted at the Radford Army Ammunition Plant (RFAAP) Solid Waste Management Unit (SWMU) 40, the Nitro Landfill (RAAP-009), and SWMU 71, Flash Burn Area (RAAP-002). SWMU 40 is an approximate 2 acre landfill area and SWMU 71 comprises an approximate 2,250 square foot (ft²) area conterminous with the southwestern corner of the landfill

The work was conducted by URS Group, Inc. (URS) to fulfill the requirements set forth in the 2000 RCRA Corrective Action permit as tasked by the United States Army Corps of Engineers (USACE), Baltimore District. URS performed the RFI in accordance with the Master Work Plan (MWP) developed for RFAAP, Work Plan Addendum (WPA) 014 to the MWP (URS 2002), Geophysical Investigation Plan for SWMU 40 (March 2006), and Geophysical Investigation Report – SWMU 40 (March 2007). These documents, approved by the United States Environmental Protection Agency (USEPA) Region III and the Virginia Department of Environmental Quality (VDEQ), contain the Master Quality Assurance Plan (MQAP), the Master Health and Safety Plan (MHSP), and associated project-specific addenda.

This RFI was completed in multiple phases of investigation and included: completion of geophysical investigations, direct push soil borings, test pits, installation of monitoring wells, geotechnical characterization, physical soil testing, chemical sampling of soil and groundwater, and aquifer characterization. The RFI was designed to:

- Fill data gaps from previous site investigations;
- Assess the nature and extent of the landfill area at SWMU 40 including cap material, landfill material, and soil underlying landfill material;
- Evaluate potential releases to groundwater;
- Evaluate the nature and extent of chemicals present in soil at SWMU 71;
- Evaluate potential releases to groundwater at the site;
- Evaluate potential risks to human health and the environment using the physical and chemical data collected at the site; and
- Collect data to support completion of a CMS.

Section 2.0 of this report presents site background information including: site history, physical setting, and previous investigation results. The RFI field investigation program is described in Section 3.0. Sufficient data was collected for the RFI to complete a Nature and Extent of Chemicals Assessment (Section 4.0), Fate and Transport Evaluation (Section 5.0), Human Health Risk Assessment (HHRA) (Section 6.0), and a Screening Level Ecological Risk Assessment (SLERA) (Section 7.0).

The results of the risk assessments and fate and transport assessment indicated a requirement to complete a CMS for soil at SWMU 40. The purpose of the CMS is to develop and evaluate remedial alternatives and to recommend the remedy to be implemented. The CMS portion of this report includes the following sections: Establishment of Corrective Measures Objectives (Section 8.0), Identification and Screening of Corrective Measure Technologies (Section 9.0), Development of Corrective Measure Alternatives (Section 10.0), Evaluation of Corrective Measure Alternatives (Section 11.0), Ranking of Corrective Measure Alternatives (Section 12.0), and Substantiation/Justification of Final Remedy (Section 13.0).

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2.0 SITE BACKGROUND

2.1 SITE DESCRIPTION

SWMUs 40 and 71 are located within the south-central portion of the Main Manufacturing Area (MMA) at RFAAP (Figure 2-1). Figure 2-2 shows the site layout, which includes the approximate 2-acre landfill area (SWMU 40) and the approximate 2,250 ft² flash burn area (SWMU 71), which is conterminous with the southwest corner of the landfill.

SWMU 40 is an undeveloped open grass-covered area, with the exception of a gravel covered area used for temporary storage of asbestos located at the eastern edge of the site (Figure 2-2). A paved road is located immediately south of the landfill area and undeveloped land borders the landfill area to the north (field) and west (wooded area).

SWMU 71 is a gravel covered area between a paved road and the SWMU 40 landfill area.

Tanks and structures are not located on the site. In 1991, an asbestos accumulation area was constructed at the eastern edge of the landfill area. The approximate 80 foot (ft) by 80 ft area is covered with gravel and surrounded by a fence and locked enclosure. A commercial, covered roll off box is staged within the storage area. The roll off box is an active unit to handle Regulated Asbestos Containing Material (RACM) that complies with 40 CFR 61.145 (a) (4). Planned renovations or demolitions involving asbestos are not handled in this box. Each non-scheduled event is documented and the material placed in the box with the appropriate containment. Compliance with 40 CFR 61.145 (a) (4) does not require a permit or sampling at the accumulation area. It requires control of the RACM from the point of generation to this accumulation area, where it is placed in the roll off box located in a fenced and locked enclosure, through final offsite disposal. These procedures are intended to prevent a release to the environment. Given the above information, and the fact this controlled accumulation area is active and is physically separate from the SWMUs 40 and 71 project area (i.e. the inactive RCRA corrective action permit site under investigation), the accumulation area is not considered of interest to SWMUs 40 and 71 RFI, and therefore, has not been included as part of the investigation.



SWMUs 40 and 71

2.2 SITE HISTORY

The RCRA Facility Assessment (RFA) conducted by the USEPA in 1987 identified SWMUs 40 and 71 as having the potential to release contaminants into the environment. Both of these SWMUs are included in the RFAAP RCRA Permit for Corrective Action (USEPA 2000b).

SWMU 40 was used in the 1970s and early 1980s for the burial of paper, office trash, concrete, and rubber tires. The unit was not permitted as a solid waste landfill by the Commonwealth of Virginia. Operations ceased and the unit was closed with a clay cap and grass cover. Subsequently, areas located northeast of the unit were used to stockpile soil derived from construction-related activities. In approximately 1991, a fenced enclosure was constructed in the northeastern corner of the SWMU 40 area for use as temporary asbestos accumulation area (Figure 2-2).

Metal process pipes potentially contaminated with propellant were flash-burned from approximately 1962 to 1982 at SWMU 71. Oil-soaked straw was used as a fuel source. The pipes were reused or sold for recycling after flash burning (Dames & Moore 1992).

2.3 PHYSIOGRAPHY

General physiography of RFAAP and the MMA is discussed in Section 3.2 of the MWP. The site is located with a portion of the MMA that is characterized by gently to steeply sloping ridges, the presence of landforms indicative of karst topography (e.g., sinkholes), and a general downward slope toward the northwest. SWMUs 40 and 71 are situated topographically lower than areas to the east, south, and west, and topographically higher than areas to the north (Figures 2-1 and 2-2).

Ground surface topography at the site slopes gently toward the northwest from approximately 1908 ft mean sea level (msl) at SWMU 71 to approximately 1,894 ft msl at the northern edge of the landfill at SWMU 40. At the northern edge of the landfill, the ground surface drops approximately 10 ft along a 1:3 grass covered slope.

Local erosion features, which consist of small swales and gullies, are present at the north central edge of the landfill and cut into the northern edge/slope of the landfill (Figure 2-2 and photo in Appendix A). Topography indicates small scale depositional features present at the base of the landfill slope. Occasional pieces of metal debris are scattered on the surface and are visible along the landfill slope.

2.4 SURFACE WATER

Figure 2-3 shows surface-water drainage patterns in the site area. Few surface water bodies are present in the south-central portion of the MMA and storm water drainage primarily occurs via infiltration and overland flow in ditches along engineered roadways. Runoff from the landfill area flows toward the north along several distinct gullies and swales, which cut into the northern edge/slope of the landfill. Overland flow has deposited material at the base of the landfill slope (Figure 2-3).

2.5 SITE SOIL

Generally information on the soil types found in the MMA of RFAAP is included in Section 3.5.1 of the MWP. SWMU 40 and SWMU 70 soil is mapped locally as Unison-Urban Land Complex (URS 2003). In undisturbed areas, this soil type typically consists of a 14-inch thick surface layer of dark brown loam and a 43-inch thick subsoil of yellowish-red, sticky plastic clay underlain by a red sandy clay loam to a depth of 58 inches. Permeability of this soil is moderate, natural fertility is low, and organic matter content is low to moderate. It is typically medium to strongly acidic with a pH of 4.5 to 5.5 (USDA 1995). Land-surface disturbances have removed or obliterated the surface loam and parts of the underlying soil horizons.

Specific physical properties of site soil have been evaluated for the RFI by submitting four soil samples to URS' laboratory in Totowa New Jersey for physical testing for various parameters as summarized in Table 2-1 and in the table below.

Summary of Physical Soil Test Data for RFI

Test Parameter	Range of Parameter Values
Sample Depths (ft bgs)	0 to 4 (2 samples) 3-5 (1 sample) 30-32 (1 sample)
Unified Soil Classification Symbol	CL (lean clay) - 2 samples CH (fat clay) – 2 samples
Sieve Analysis - % fines (minus 200 Sieve)=	60.9 to 95.1%
Sieve Analysis - hydrometer percent minus 2 μ m	27 to 53%
Organic Content	2.8 to 5.5%
pH – distilled water	6.5 to 8.8
pH – 0.01 M CaCl Solution	6.4 to 7.5
Soil particle density (pounds per cubic foot)	2.685 – 2.692
Soil bulk density (pounds per cubic foot)	114.9 to 131.9
Soil dry density (pounds per cubic foot)	81.4 to 110.5
Coefficient of permeability (centimeters per second)	2.7E-09 to 1.1E-07
Total Porosity	0.34 to 0.52
Air Filled Porosity	0.00 to 0.02
Water Filled Porosity	0.33 to 0.52
Water Content (%)	18.1 to 41.0%

Soil physical test results indicate that the primary soil type at the site is lean to fat clay (CL and CH). A complete report of the RFI physical test results is included in Appendix C.1

2.6 SITE GEOLOGY

Regional geology and general geology at RFAAP are discussed in Sections 3.6 and 3.7 of the MWP, respectively. Geologic and subsurface conditions at SWMU 40 and SWMU 71 were assessed by completing three geophysical surveys, drilling of 24 soil borings and four rock borings, excavation of two test pits, installation of two groundwater monitoring wells, inspection of six bedrock outcrops in the site area, and completion of a geological site reconnaissance. Specific information on the field investigation program is presented in Section 3.0. Geophysical reports for surveys conducted by Geophex Services Ltd (Geophex) in 2001, Argonne National Laboratories (ANL) in 2002, and ATS International in 2006 are included in Appendices D.1, D.2, and D.3, respectively. Geophysical survey areas are shown on Figure 2-4. Boring, test pit, monitoring well, and bedrock outcrop locations are shown on Figure 2-5. Table 2-2 summarizes boring, test pit, and bedrock outcrop data. Monitoring well construction data are summarized in Table 2-3. Complete lithologic logs of monitoring wells and soil borings are included in Appendices C.2 (Verification Investigation [VI]) and C.3 (RFI).

Two geological cross-sections (A-A' and B) have been prepared to show the interpreted geologic conditions in the area of SWMUs 40 and 71. Cross-section A-A' is orientated along ANL geophysical profile ANL-2 (ANL 2003), which runs north south across SWMU 40 between screening boreholes 40MW2 and 40MW4 (Figure 2-6). Cross-section B-B' is orientated along Geophex geophysical profile L-1, which runs east west across the center of SWMU 40 (Figure 2-7).

Four different strata are identified on the geologic cross-sections including soil fill, landfill material, soil weathered in place from bedrock, and bedrock. Descriptions of these strata are provided in the following sections.

2.6.1 Landfill Cover

Landfill cover is present at the surface across SWMU 40. No distinct landfill material was present in the borings advanced in SWMU 71. As presented in Table 2-2 and on Figure 2-8, the thickness of landfill cover encountered at boring and test pit locations within SWMU 40 ranged from 1 ft to 6.5 ft bgs. The landfill cover generally consists of dark brown to yellowish brown lean clay (CL) and sandy lean clay (CL) with variable gravel at the surface or near surface.

2.6.2 Landfill Material

Landfill material underlies the landfill cover within the SWMU 40 boundary. In general, this material consists of gray to black clay, sand, gravel, and cinders mixed with abundant paper, glass, plastic, metal, wood chips, rubber, and bagged garbage. Landfill material was described as moist to wet with an odor ranging from sulfurous to strongly acrid and bitter. In some areas, such as boring 40SB6, the landfill material sequence was composed primarily of soil fill with only a minor amount of other types of material. Fluid seepage from landfill material occurred within Test Pit 1, with an accumulation of 2 to 3 ft of water observed in the bottom of the test pit after three hours. Landfill material was described as wet at soil borings 40SB6, 40SB7, 40SB8, and 40SB9 completed near of the center of the landfill area.

EM surveys conducted by Geophex Services, Ltd (Geophex) in 2001 were initially used to assess the lateral extent of landfill material at the site. Figures 2-9 and 2-10 show the results of these EM surveys. Subsequent borings and test pits conducted in 2002 and 2006 refined these estimates and indicated that the EM surveys overestimated the lateral extent of landfill material at the eastern and northern periphery of SWMU 40. The vertical extent of landfill material was directly assessed by completing borings and test pits across the site area (Figure 2-11). Supporting data from the ANL geophysical surveys including two-dimensional electrical resistivity imaging (2D-ERI) and seismic profiles were also used in the evaluations. Figure 2-11 shows the approximately lateral extent and thickness of landfill material as defined by borings, test pits, and geophysical surveys completed at the site.

The observed thickness of landfill material ranged from 3 ft (boring 71SB14) to 14.5 ft (boring 40SB4). In general, the thickness of landfill material increased from the western, southern, and eastern periphery of SWMU 40 toward the central and northern part of SWMU 40 (Figure 2-11). Soil boring and test pit investigations confirm that earlier interpretations of 2D-ERI data by Geophex had significantly overestimated the thickness of landfill material; thereby supporting the ANL hypothesis that the presence of broad zones of low-resistivity (< 20 ohm/m) in the 2D-ERI survey was likely related to features in weathered bedrock, such as clay zones (ANL 2003).

As presented on Figure 2-11, based on the landfill thickness data collected from the borings and test pits, approximately 18,700 bank cubic yards (BCY) of landfill material (in place volume measured in cubic yards) may be present at SWMU 40.

2.6.3 Soil Below Landfill Material

Soil that has weathered in place from argillaceous carbonate bedrock underlies landfill material at SWMU 40. Soil below landfill material generally consists of brown to yellowish red clay (CL or CH) with variable sand content and occasional gravel. Four physical samples of soil (VI and RFI) were laboratory classified as CL or CH (Table 2-1). Both RFI physical samples (40SB4 and 71SB11) had low vertical hydraulic conductivities in the range of $1\text{E-}7$ to $1\text{E-}8$ centimeters per second (cm/sec).

As presented on Figure 2-12, the observed thickness of soil underlying landfill material ranged from 1 to 26.8 ft (Figure 2-12). The data is considered to represent the minimum thickness of soil present at the boring locations investigated; since it is assumed that boring refusal by the direct-push unit represents the top of bedrock. Bedrock outcrops occur south of SWMU 40. The top surface of the soil below landfill material/subsurface soil generally slopes northward across SWMU 40 toward the north central boundary

of SWMU 40 (Figure 2-12). This pattern suggests that a single excavation or fill area existed over the majority of the SWMU rather than separate trenches into natural soil as originally thought.

2.6.4 Bedrock

The site is underlain by the Cambrian age Elbrook Formation, which is comprised of laminated to thick-bedded dolomite, thin- to medium-bedded limestone, and dolomitic platy shale and siltstone. Strike and dip measurements obtained at six outcrops in the site area indicate bedrock strikes in the range of 110 to 115° with bedrock dips ranging from 12 to 16° (Table 2-2).

2.6.4.1 Photogeologic Analysis

The Environmental Photographic Interpretation Center (EPIC), under the direction of the USEPA, performed a photogeologic interpretation of RFAAP, with a particular study in the SWMU 40 and SWMU 17 area. EPIC identified a large field of sinkholes in the south and southeast portion of the MMA where SWMU 40 is located and depicted the SWMU 40 area as being located within a sinkhole within the northern portion of the sinkhole field (Figure 2-13). EPIC concluded that “Units 17 and 40...are physically contained within sinkholes that are part of a group of comparatively large sinkholes.” This sinkhole in the area of SWMU 40 is also apparent on the Radford North USGS 7.5-Minute Topographic Quadrangle.

2.6.4.2 Bedrock Borings

Rock coring that was completed at the site in VI borings 40MW1A, 40MW2, 40MW3, and 40MW4 penetrated 43 to 160 ft of light gray to bluish gray limestone and dolomite bedrock with some interbedded brown siltstone. The consistency of bedrock that was encountered in the VI borings ranged from soft to hard with numerous zones of intense weathering and fracturing. Clay filled weathered zones and voids were encountered in each of the VI borings, with notable voids and/or weathering at the completion depth of borings 40MW2, 40MW3A, and 40MW4. Zones of more competent bedrock were encountered in boring 40MW1A at depths below the completion depths of the other borings. Air rotary rock borings completed for the RFI (40MW5 and 40MW6) to a maximum depth of 157 ft bgs encountered similar conditions.

2.6.4.3 ANL Geophysical Survey

ANL completed geophysical surveys at the site to evaluate subsurface and bedrock conditions to depths up to 120 ft bgs. 2D-ERI and seismic refraction profiling/tomography were used to evaluate changes in the electrical (2D-ERI) and acoustic (seismic) characteristics of subsurface materials. Borehole velocity surveys were conducted in screened borings 40MW2 to 57 ft bgs and 40MW4 to 64 ft bgs to provide confirming/baseline information concerning the subsurface geologic material for the seismic refraction models. Interpreted results for the seismic tomography survey are shown on geologic cross-sections A-A' and B-B' (Figures 2-6 and 2-7) completed along ANL profile L-2 and Geophex profile L-1 reoccupied by ANL. Detailed discussions of profile-specific results are presented in ANL Geophysical Report included in Appendix D.2.

2.6.4.4 ATS Geophysical Survey

ATS completed two 2D-ERI profiles north and east of the landfill area at SWMU 40 to evaluate local bedrock structures influencing groundwater flow and potential leachate migration from the landfill area. These profiles were also used to identify optimal monitoring well locations and depths as discussed in Section 2.7. 2D-ERI surveys were performed to evaluate subsurface and bedrock conditions at depths up to 250 ft bgs in the landfill area, which corresponded to the approximate elevation of the New River. Figures 2-14a, 14b, and 14c shows pseudo-section results with interpreted features.

The resistivity data collected to the north and to the west of SWMU 40 showed bedrock beneath the site was characterized by numerous low-resistivity anomalies which are consistent with bedrock fracture or fault zones and karst-related dissolution features (Figure 2-15). Seven resistivity anomalies were

identified and interpreted by ATS as fracture zones and/or karst features. Two zones of very low resistivity values are observed in the central portion of Line 1 and are interpreted as karst features or fracture zones. Numerous anomalies were also observed in the section for Line 2, with ATS interpreting possible fracture zones beneath electrodes 2-13, 2-23, and 2-48 and possible karst features identified beneath electrodes 2-13, 2-38, and 2-48.

2.6.4.5 Top of Bedrock

Figure 2-16 is a structural contour map of the top of bedrock in the site area based on boring, test pit, outcrop, and geophysical data. Geologic cross-sections on Figures 2-6 and 2-7 also present the same data in selected profiles across the site area. Observed depths to bedrock in the SWMU 40 area ranged from approximately 6 to 45 ft bgs, with depths to bedrock in the SWMU 71 area less than 12 ft bgs. In general, the bedrock surface slopes from the western, south, and eastern edges of the site toward the north central part of SWMU 40. An apparent depression in the bedrock occurs in the area of boring 40SB4, where the depth to bedrock is approximately 45 ft (Figure 2-16). The contact between soil and bedrock may be abrupt or gradational over several feet, depending on the degree of weathering.

In general, variably weathered bedrock underlies soil at the site. The contact between soil and bedrock may be abrupt or gradational over several feet, depending on the degree of weathering. For purposes of the RFI intrusive investigation, direct-push boring or test pit refusal was assumed to represent the top of weathered bedrock. However, the upper surface of weathered bedrock may be identified at deeper depths with other drilling techniques or by geophysical resistivity and seismic surveys.

2.7 SITE HYDROGEOLOGY

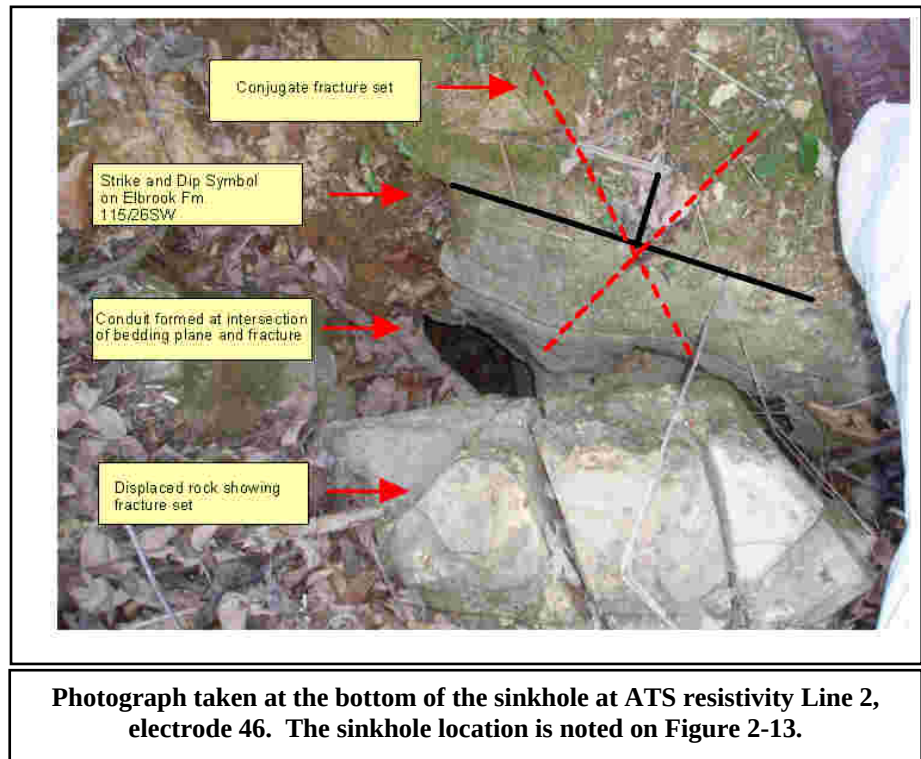
Regional hydrogeology and general hydrogeology information for RFAAP is included in Section 3.8 of the MWP. Site-specific hydrogeologic conditions are discussed in the following sections.

2.7.1.1 Karst Hydrogeology

The positive dye trace conducted at SWMU 17 by Parsons Engineering Science (Parsons) in 1993 and 1994 (Parsons 1996) indicates the presence of an open-flow karst conduit beneath or in close proximity to SWMU 40 as shown on Figure 2-13, which is a close-up of Figure 3-7 included in the 2005 Draft Current Conditions Report for RFAAP (Shaw 2005). Dye injection locations and dye travel path along with various photo-lineament, structural features, and sinkhole location interpretations are shown on this figure relative to the location of the site. The direction of travel for the dye trace to spring SPG 3 appears to be along the predominant average strike of bedrock bedding planes (110°) in the site area. This information combined with the understanding that SWMU 40 has been constructed above a sinkhole suggests groundwater migration from the vicinity of the site is likely to be primarily to the west, generally along strike, and primarily through relatively well-developed karst conduits. The resistivity data collected to the north and to the west of SWMU 40 during the ATS geophysical survey shows bedrock beneath the site is characterized by numerous low-resistivity anomalies which are consistent with bedrock fracture or fault zones and karst-related dissolution features (Figure 2-13).

Results of studies in the Shenandoah Valley indicate caves in the Cambro-Ordovician limestones and dolomites form along the intersections of bedding planes and joints (Harlow et al., 2005; Orndorff and Harlow, 2002). Cave conduits in general form along bedding planes, joints, and faults or at the intersection of any two of these (Worthington 2001). Additionally, sinkholes (and conduits) may preferentially develop along bedding strike with more rapid dissolution of lithologically less resistant rock. This preferential development is more readily expressed as bedding is folded and exposed to weathering. The annotated photograph below illustrates some of these features of sinkhole and conduit formation in the site area.

Conduits typically organize into a structurally controlled dendritic network feeding larger second and third order conduits that outfall to large springs (Worthington 2001). As the distance from the spring to the perimeter of the recharge area increases, the deeper the groundwater flow, and the larger the spring. Studies in Virginia have shown that even at depths of 100 meters or more, large scale thrust faults in Virginia can be high transmissivity fault-zone aquifers (Seaton and Burbey 2005). These and the other considerations noted above suggest that the groundwater flow underneath SMWU 40 feeding the Parsons 3 Spring area is relatively deep and fed by a conduit(s) developed within or in close proximity to the Pulaski Thrust Fault at the base of the Elbrook Formation. The larger conduit(s) is fed by smaller structurally controlled conduits formed along the intersections of bedding planes and fractures or joints. It was within this context that the results of the ATS resistivity survey were evaluated and the suitability of low resistivity anomalies assessed as optimal target locations for monitoring wells.



2.7.1.2 ATS Geophysical Survey for Monitoring Well Location

Seven resistivity anomalies were identified and interpreted by ATS as fracture zones and/or karst features (Figure 2-17). Two zones of very low resistivity values were identified in the central portion of Line 1 and were interpreted as karst features or fracture zones. Numerous anomalies were also identified in the section for Line 2, with ATS interpreting possible fracture zones beneath electrodes 2-13, 2-23, and 2-48 and possible karst features identified beneath electrodes 2-13, 2-38, and 2-48. Each of these areas was identified as possible target locations for installation of monitoring wells (Figure 2-17). A number of factors were considered to select optimal monitoring well locations including:

- The highly variable nature of subsurface conditions and the difficulty in placing wells to intercept preferential groundwater flowpaths developed in karst terrain;
- Dye from injection point INJ1 at SWMU 17 traveled a minimum straight line distance of 4,800 feet in a day to S136 (Parsons 3 Spring), thus demonstrating the existence of a groundwater conduit(s) beneath the site area (Figure 2-13);
- The Parsons 3 Spring and other springs are located within or in close proximity to the Max Meadows Tectonic Breccia, which outcrops at this location along the New River. The breccia occurs within the fault zone at the base of the Elbrook Formation. The fault in this area is a refolded splay fault structurally above the main décollement for the Pulaski Fault (Schultz 1986); and

- Low resistivity zones and resistivity contrasts identified at depth at the site can reasonably be assumed to be water saturated karst features indicative of preferential pathways for groundwater flow.

Two optimal monitoring well locations (40MW5 and 40MW6) were identified at the site immediately north of the landfill based on the geophysical investigation results and the information presented in Sections 2.7.1.1 and 2.7.1.2. Locations 40MW5 and 40MW6 were identified at electrodes 1-34 and 1-41, respectively, (Figures 2-17), where two very low resistivity anomalies were identified beneath the north edge of the landfill area; these areas likely intercept karst drainage from the probable sinkhole buried beneath SWMU 40 and are appropriate locations to measure potential releases to groundwater from the landfill. Based on the resistivity profile and depth intervals of the anomalies, minimal completion depths of 75 and 130 ft were targeted for 40MW5 and 40MW6, respectively.

The boring for 40MW5 did confirm the presence of a fracture zone or karst feature at the anomaly depths indicated by the geophysical survey. As shown on the boring log of 40MW5 in Appendix C.3, a zone of apparent clayey rock fragments was encountered in this boring between a depth of 74 and 90 ft with competent bedrock present above and below this zone. As noted on the boring log this zone corresponds to the depth interval of the geophysical anomaly identified on Figure 2-15 on pseudo-section ATS L-1 as “likely karst features or fracture zone.” As discussed in the report, groundwater was not encountered in this zone but was encountered in a discrete fracture at a depth of 143 ft. The depth that groundwater was encountered generally corresponded with the base of the lower resistivity zone (green color) identified by the geophysical survey. The location of 40MW5 is still considered an optimal location for assessing releases from the landfill area given its positioning immediately adjacent to base of the landfill and its location in the apparent groundwater flow path from north central portions of the landfill area where the landfill material is thickest as shown on Figures 2-15 and 2-18.

2.7.1.3 Monitoring Well Installation

Groundwater conditions at the site were investigated by installing two monitoring wells 40MW5 and 40MW6 at locations immediately north of the landfill area in areas identified as likely locations to intercept karst drainage from the landfill area at SWMU 40 (Figure 2-17). During drilling of 40MW5 and 40MW6, the first zones of encountered water in bedrock were within fracture zones at 143 and 122 ft bgs, respectively. Monitoring wells 40MW5 and 40MW6 were completed with 20 ft long screens across the water bearing fracture zones to total depths of 157 and 135 ft bgs, respectively. Boring logs and construction diagrams for the monitoring wells are included in Appendix C.3. Monitoring well construction data for 40MW5 and 40MW6 and existing wells 17MW3 and 40MW3 sampled for the RFI are summarized in Table 2-3.

2.7.2 Groundwater Potentiometric Elevations and Groundwater Flow Direction

Groundwater in the site area occurs within bedrock in fractures and water saturated karst features. The first zone of groundwater encountered in bedrock during drilling of 40MW5 and 40MW6 occurred at depths of 143 and 122 ft bgs, respectively. Stabilized potentiometric levels in these wells after drilling and during RFI groundwater sampling were approximately 100 to 106 ft bgs.

Groundwater elevation data were collected from site area wells 17MW3, 40MW3, 40MW5, and 40MW6 prior to the groundwater sampling event conducted for the RFI in August 2007. A second round of measurements was collected from these monitoring wells in December 2007 along with other monitoring wells and piezometers at adjacent SWMU 17 including 17PZ1 and 17MW2. Groundwater measurement data and elevations are summarized in Table 2-4. The data provided in Table 2-4 have been used to prepare a groundwater potentiometric map for December 2007 (Figure 2-18).

The overall groundwater flow direction shown on Figure 2-18 is west and northwest toward the New River. Dye test results at SWMU 17 identified a preferential pathway of groundwater flow from the

vicinity of SWMUs 17 and 40 toward the west, generally along bedrock strike, and primarily through relatively well-developed karst conduits.

The average hydraulic gradient has been calculated for groundwater flow paths across the site area using the potentiometric contour data on Figure 2-18. The following table presents the results of the calculations.

Hydraulic Gradient for Lateral Groundwater Flow at Area A

Date	Flow Path Contour Lines	Elevation Difference (ft)	Flow Path Distance (ft)	Calculated Hydraulic Gradient (ft/ft)
12/10/2007	1790-1770 ft	20	435	0.046

An average hydraulic gradient of 0.046 feet per foot (ft/ft) was calculated for the site. Groundwater flow velocities within bedrock in the site area are expected to vary by several orders of magnitude (from less than 0.1 ft per day to more than 1,000 ft per day) depending on the degree of weathering, fracturing, and development of karst conduits.

2.8 PREVIOUS INVESTIGATIONS

Previous investigations conducted at the site are summarized in the following sections including an Installation Assessment and RCRA Verification Investigations.

2.8.1 Installation Assessment (Air Photo Interpretation) – 1992

The Environmental Photographic Interpretation Center (EPIC), under the direction of USEPA, performed an assessment of multiple SWMUs at RFAAP using selected aerial photographs from 1937 to 1986. The objective was to “concentrate upon tracking 42 known SWMUs located in the [RFAAP], and to identify other features which may represent potential groundwater or surface water contamination sources” (USEPA 1992).

Activity was first noted at SWMU 40 in a 1971 photograph and indicated significant filling with three fill faces interpreted in the SWMU 40 area (USEPA 1992). The 1986 photograph indicated most of the site was re-vegetated with the exception of the northeast corner where evidence of recent filling was visible (USEPA 1992). SWMU 71 activity was first noted on the 1986 photograph. EPIC performed a photogeologic interpretation of the RFAAP to identify solution features such as fractures and sinkholes with particular study near SWMU 40 and SWMU 17. EPIC identified a field of large sinkholes south of the south central MMA as shown on Figure 2-13. The SWMUs 40 and 71 area is depicted as being located within a sinkhole in the northern portion of the sinkhole field. The EPIC study concluded, “Units 17 and 40....are physically contained within sinkholes that are part of a group of comparatively large sinkholes.”

2.8.2 RCRA Verification Investigation – Dames & Moore 1992

A RCRA Verification Investigation (VI) was conducted at SWMUs 40 and 71 in 1992 by Dames & Moore (Dames & Moore 1992). Four borings, 40MW1A, 40MW2, 40MW3A, and 40MW4, were completed around SWMU 40 to a depth of 49 to 162 ft bgs for planned monitoring well installations (Figure 2-19). Groundwater was not encountered during drilling. Borings 40MW2 and 40MW4 were completed as screened points but have been dry since installation. Bedrock encountered in the borings consisted of argillaceous (i.e., clay rich) limestone and dolomite with abundant clayey zones. Numerous zones of intense weathering and fracturing were encountered and a mud filled void was present at 49 ft bgs in 40MW3A. Depth to bedrock at the boring locations ranged from 2 to 17 ft bgs (Dames & Moore 1992).

Three surface soil samples, 71SS1, 71SS2, and 71SS3, were collected from SWMU 71 as part of the VI (Dames & Moore 1992). Figure 2-19 shows the locations of the samples, which were collected to assess whether surface soil had been impacted through the release of hazardous constituents during flash burn operations. Samples were collected from 0 to 6 inches bgs, beneath gravel or organic layers and analyzed for TAL metals, explosives, and total petroleum hydrocarbons (TPH). Soil sample results are summarized in Table 2-5. Metals were identified as a potential concern in surface soil primary due to detections of arsenic and thallium at concentrations above their RFAAP background point estimate and industrial risk-based screening criteria. Explosives were not detected in these samples and TPH was detected at concentrations below the VDEQ action level of 100 milligrams per kilogram (mg/kg).

2.8.3 RCRA Verification Investigation: Phase II – Dames & Moore 1994

Based on the results of the 1992 VI, 12 additional soil samples were collected from SWMU 71 to define the horizontal and vertical distribution of detected analytes (Dames & Moore 1994). Seven samples of surface soil (0 to 6 inches bgs) and five samples of subsurface soil (4 ft bgs) were collected and analyzed for TAL metals, Toxicity Characteristic Leaching Procedure (TCLP) metals, and TPH. Figure 2-20 shows the locations of samples 71SS4 through 71SS10. Sample results are summarized in Table 2-6. Metals were identified as a potential concern in subsurface soil primarily due to arsenic detected at a concentration above its RFAAP background point estimate and industrial risk-based screening criteria. TPH was detected in three soil samples at concentrations above the VDEQ action level of 100 mg/kg.

2.8.4 SWMU 17 Dye Trace Study and RFI – Parsons Engineering Science (1996)

Parsons Engineering Science (Parsons) conducted a dye-tracing study at SWMU 17 in 1993 (Fall – low flow conditions) and 1994 (Spring – high flow conditions). SWMU 17 is located less than 200 ft east of the landfill area at SWMU 40 (Figure 2-13). Parsons installed three bedrock monitoring wells (17MW2, 17MW3, and 40MW3) and two temporary dye-injection wells (INJ 1 and INJ 2) as part of the study. These wells are approximately 400 to 500 ft north, south, and east of SWMU 40 as shown on Figure 2-13. Monitoring wells were installed to depths ranging from 120 to 190 ft bgs and were designed to intercept the regional water table associated with the New River. The two injection points (INJ1 and INJ2) were installed to a maximum depth of 23.5 ft within the two sinkholes associated with SWMU 17. A successful dye test was conducted at the Stage and Burn Area of SWMU 17, which was located within a sinkhole located closest to the SWMU 40 landfill.

The Parsons dye trace study indicated that a spring (SPG3), which discharges directly to the New River, is hydraulically connected to the sinkhole associated with the SWMU 17 Stage and Burn Area (SWMU 17A). Dye placed in the injection point (INJ1) within this sinkhole traveled 4,800 ft to the spring in less than 24 hours. The flow path identified by the dye trace closely parallels a west-northwest to east-southeast trending fracture trace. This fracture can be extended to connect both the dye injection point and the dye resurgence point. Parsons concluded that these conditions suggested that a direct conduit exists between SWMU 17 and SPG 3, which was likely caused by solution opening along a subsurface fracture. Under low flow conditions, Parsons calculated an estimated travel time of 2,905 to 3,716 ft/day for groundwater flow through this direct conduit. Under high flow conditions, the travel time was estimated as 4,800 ft/day. As indicated in Section 2.7, the open-flow karst conduit identified by Parsons is likely present beneath or in close proximity to the site as shown on Figure 2-13.

As part of an RFI conducted at SWMU 17, Parsons collected groundwater samples from monitoring wells 17MW1, 17MW2, 17MW3, and 40MW4 in 1995 for analysis of explosives, total metals, dissolved metals, total organic carbon (TOC), and total organic halogens (TOX). Explosives were not detected in these samples. Dissolved metals that were detected in the samples included barium, beryllium, and lead. The concentration of dissolved beryllium detected in 17MW2 (4.26 micrograms per liter (µg/L)) was above the EPA maximum contaminant level of 4 µg/L. Dissolved levels of other metals were below their EPA Region III risk-based screening concentrations (RBCs) for tap water (T-RBCs). Parsons also obtained one round of static water levels from the four monitoring wells prior to sampling. A

potentiometric surface map prepared by Parsons indicated groundwater flow toward the west from the Stage and Burn Area of SWMU 17 toward SWMU 40 and west from the other sinkhole southeast of the Stage and Burn Area toward 17MW3 located south and crossgradient of SWMU 40.

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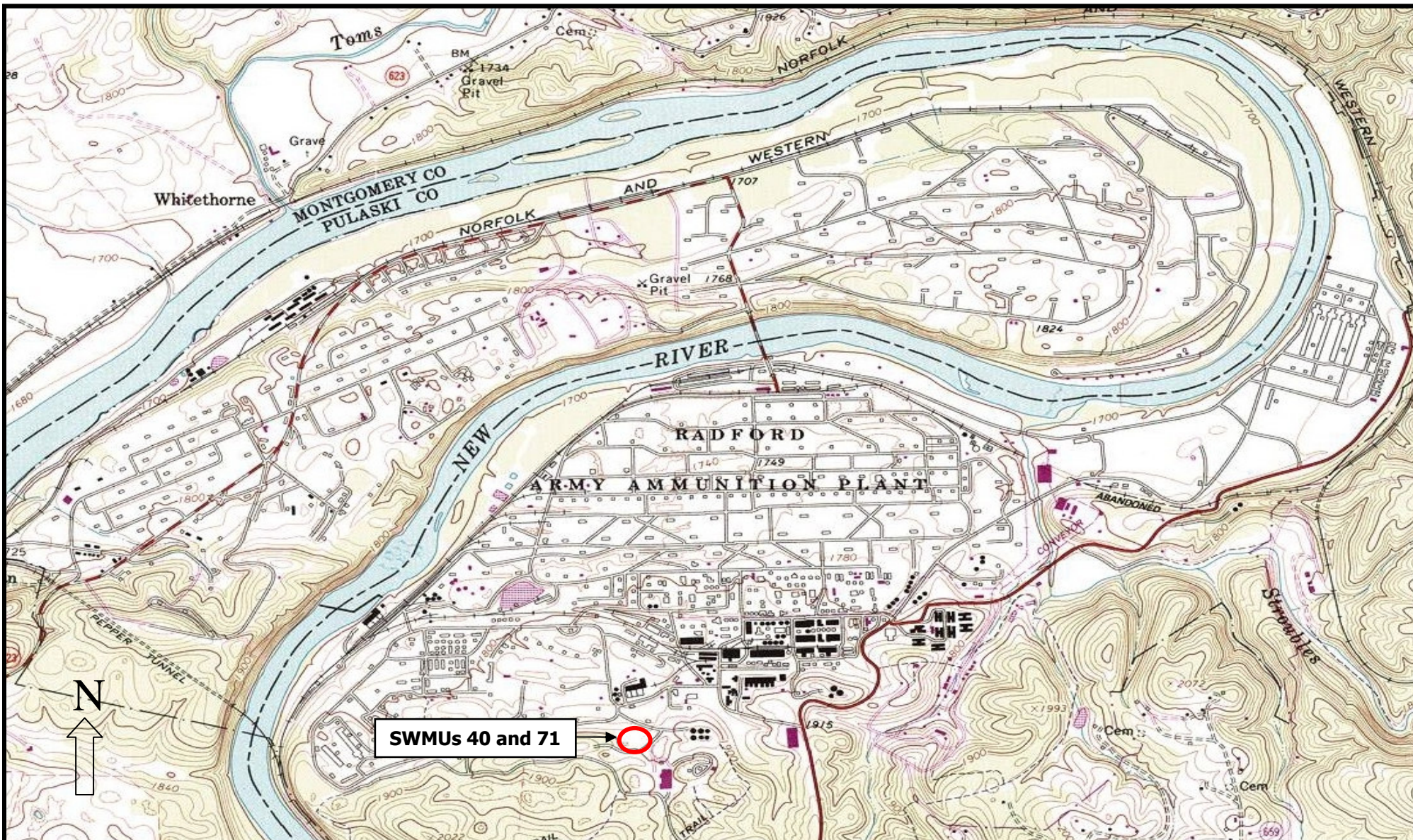


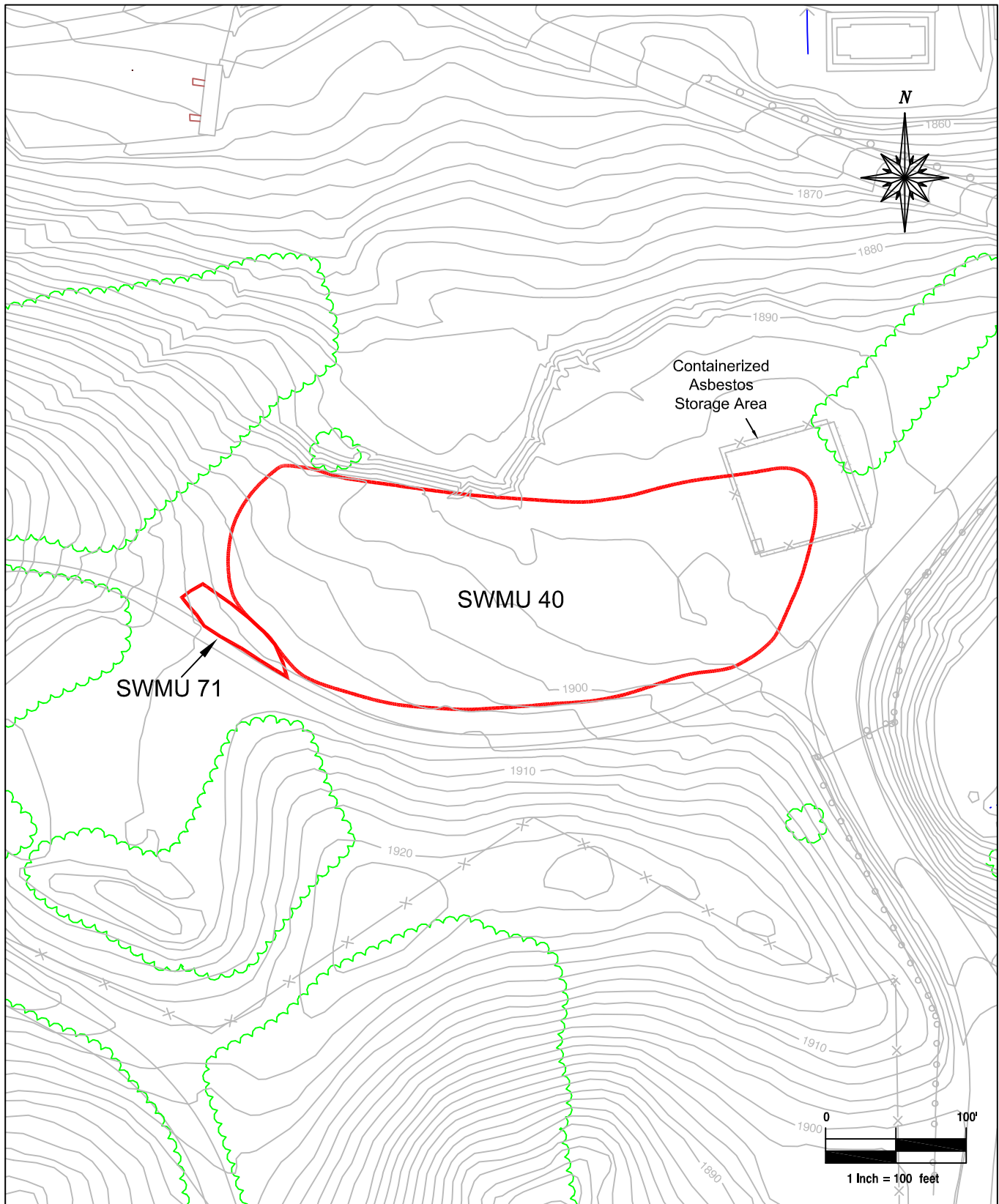
FIGURE 2-1
Site Location Map

Date: November 2007	URS Project#: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1" = 2000'	File Name: Fig.2-1 Site Loc

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Legend

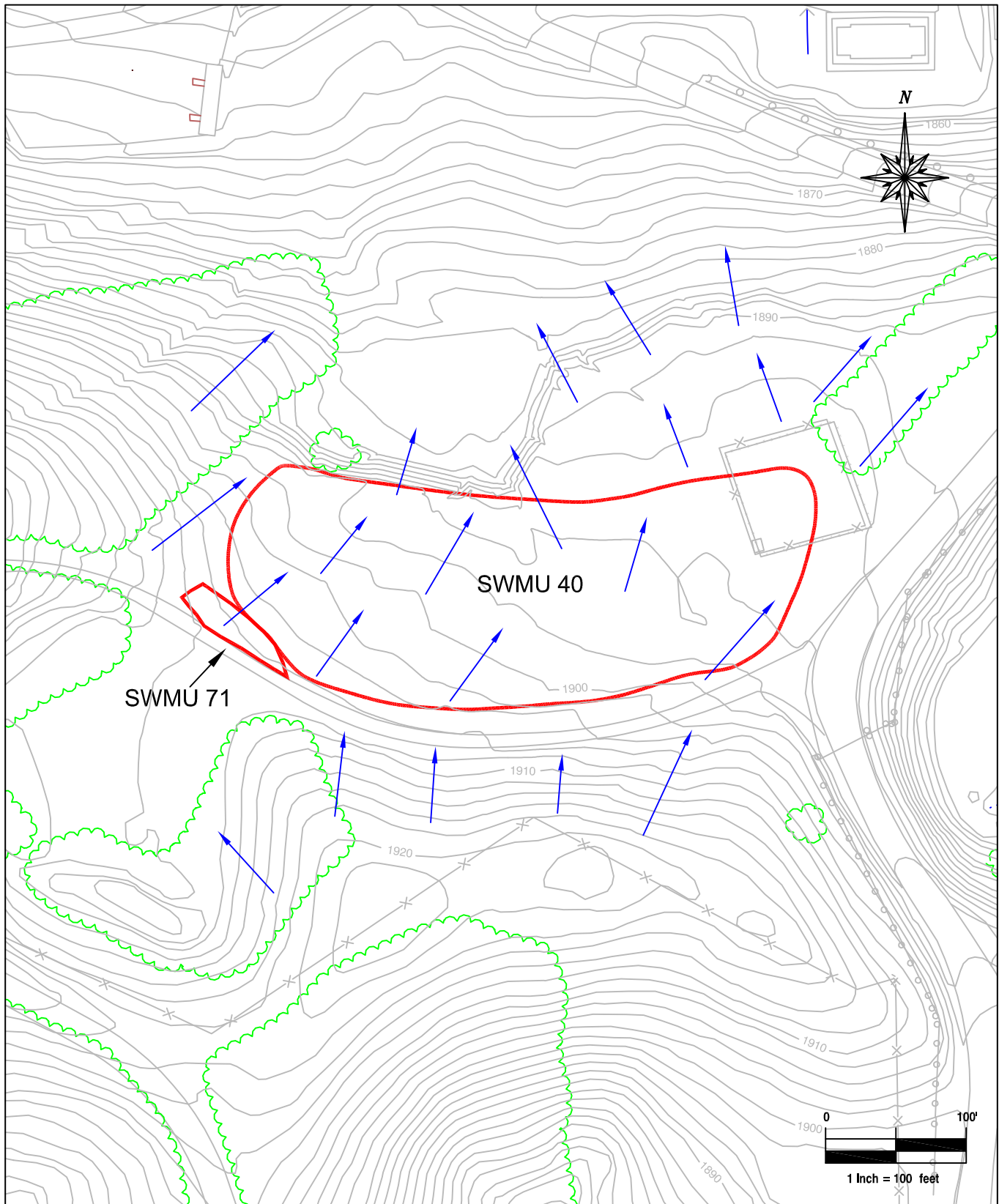
- Approximate SWMU Boundary
- Topographic Contour
- ~ Vegetation
- x—x— Fence

FIGURE 2-2
Site Layout

Date: January 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 100 feet	File Name: Fig.2-2 SiteLayout

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Legend

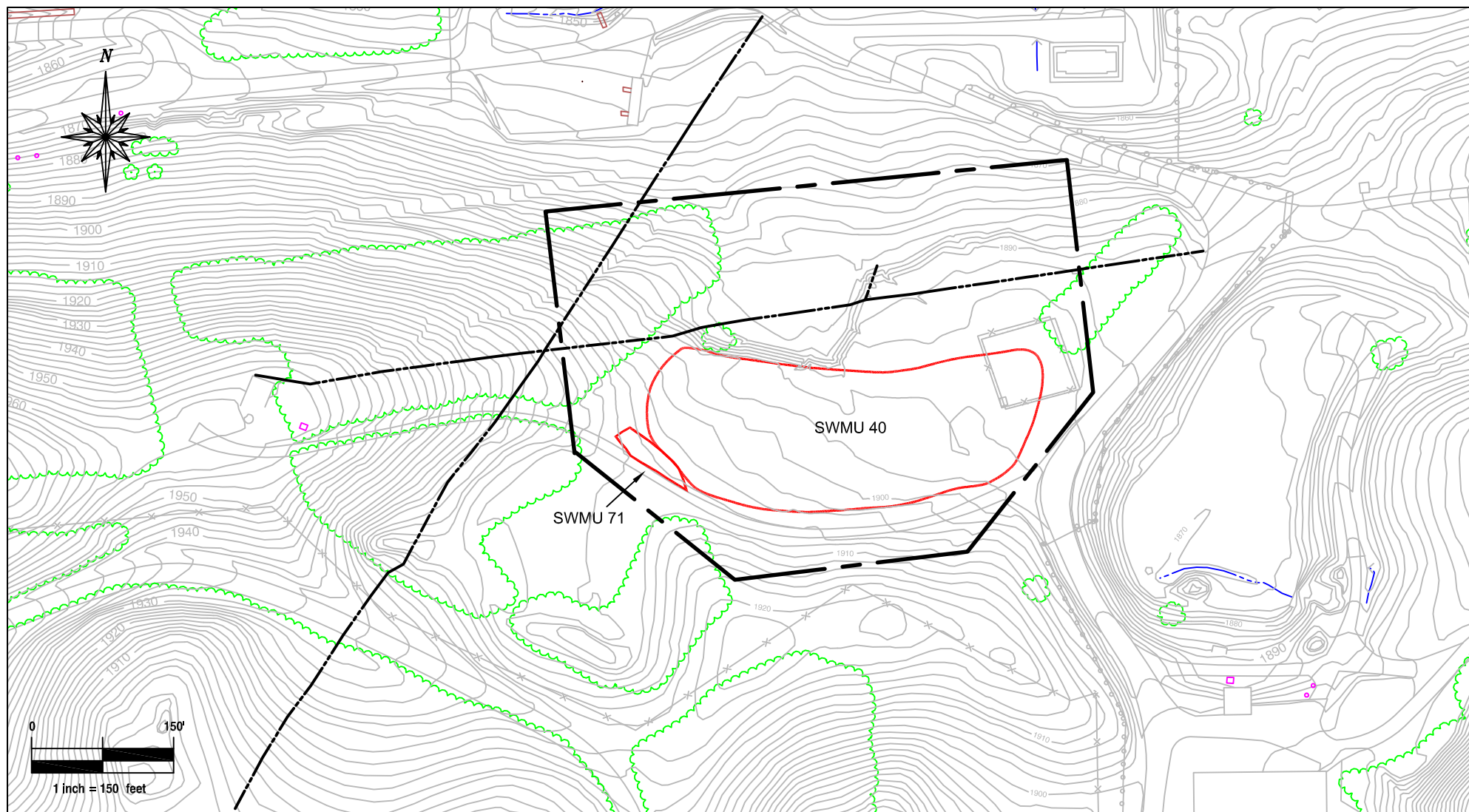
- Approximate SWMU Boundary
- Topographic Contour
- ~ Vegetation
- X X Fence
- ➔ Surface Water Flow Direction

FIGURE 2-3
Surface Water Drainage

Date: January 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 100 feet	File Name: Fig.2-3 SWDrainage

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Legend

— Approximate SWMU Boundary	- - - ATS Survey Lines
— Topographic Contour	. . . ANL and Geoplex Area
~~~~~ Vegetation	
X X Fence	

FIGURE 2-4
Geophysical Survey Areas

Date:
January 2008

Prepared By:
DBC

Scale:
1" = 150'

Job Number:
21354880

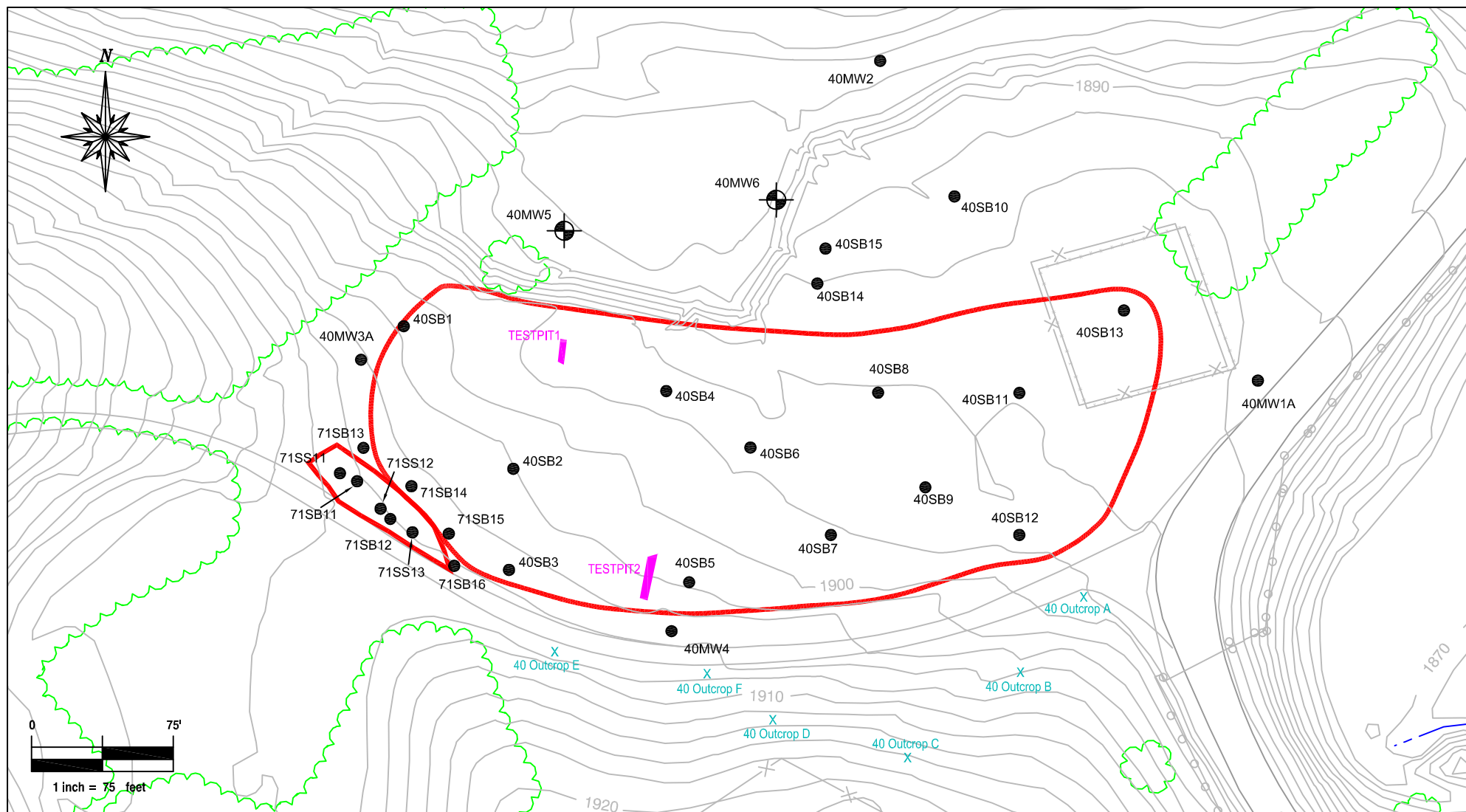
Reviewed By:
JOS

File Name:
Fig.2-4 Geo. Areas

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Legend

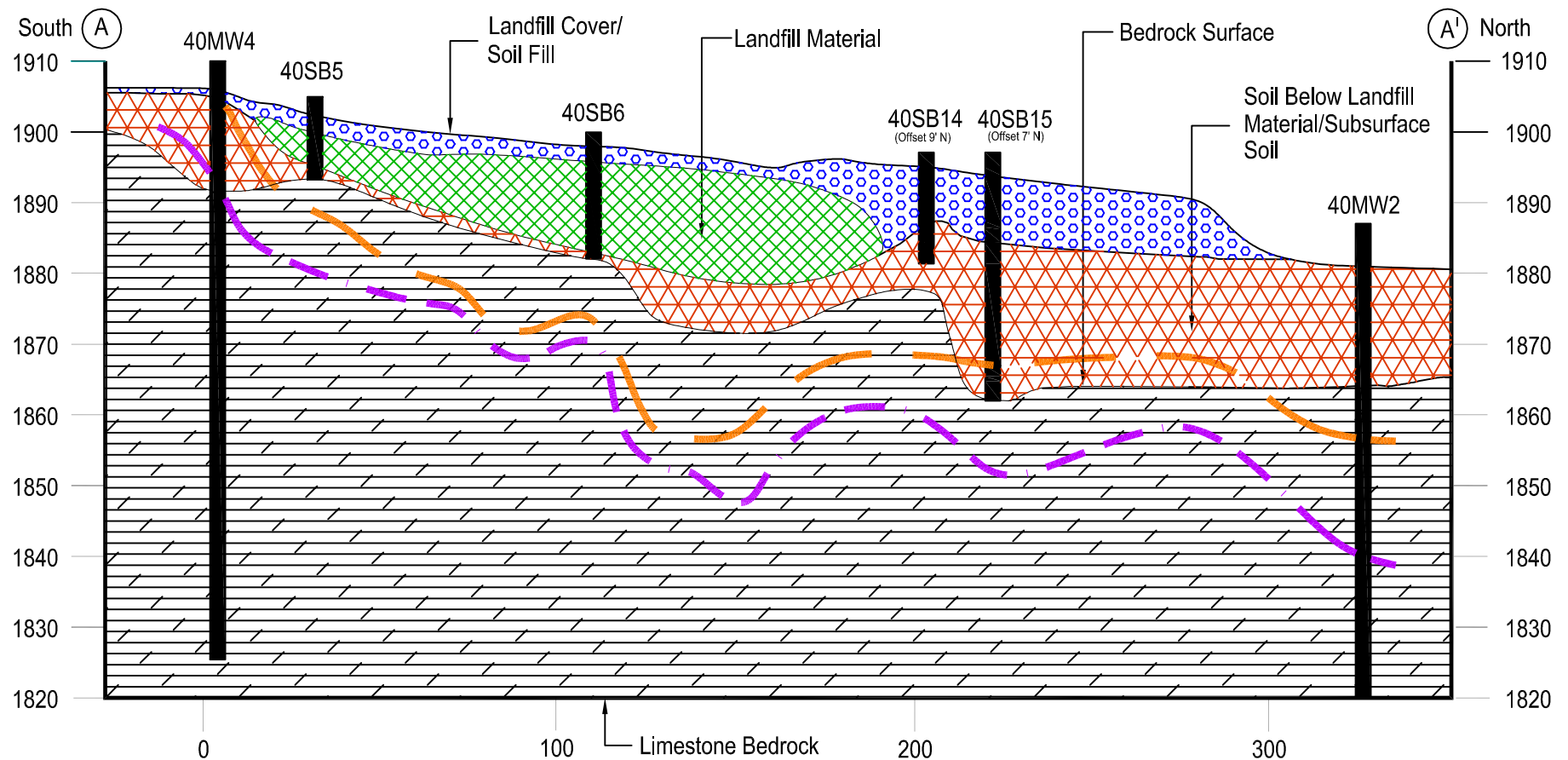
- SWMU Boundary
- Test Pit Location
- Soil Boring Location
- X Bedrock Outcrop Location

FIGURE 2-5
RFI Soil Boring, Test Pit,
and Bedrock Outcrop Locations

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.2-5 SB,TP,OCLocs

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Legend

- Top of Weathered Bedrock - Seismic Tomography Survey - ANL L-2 Profile (ANL 2003)
- - - Top of Bedrock - Seismic Tomography Survey - ANL L-2 Profile (ANL 2003)
- Monitoring Well/Soil Boring Location

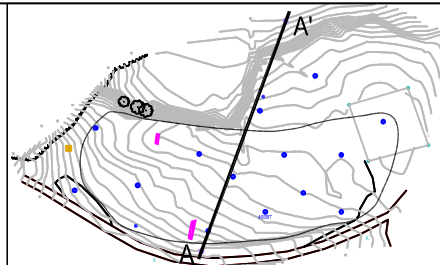
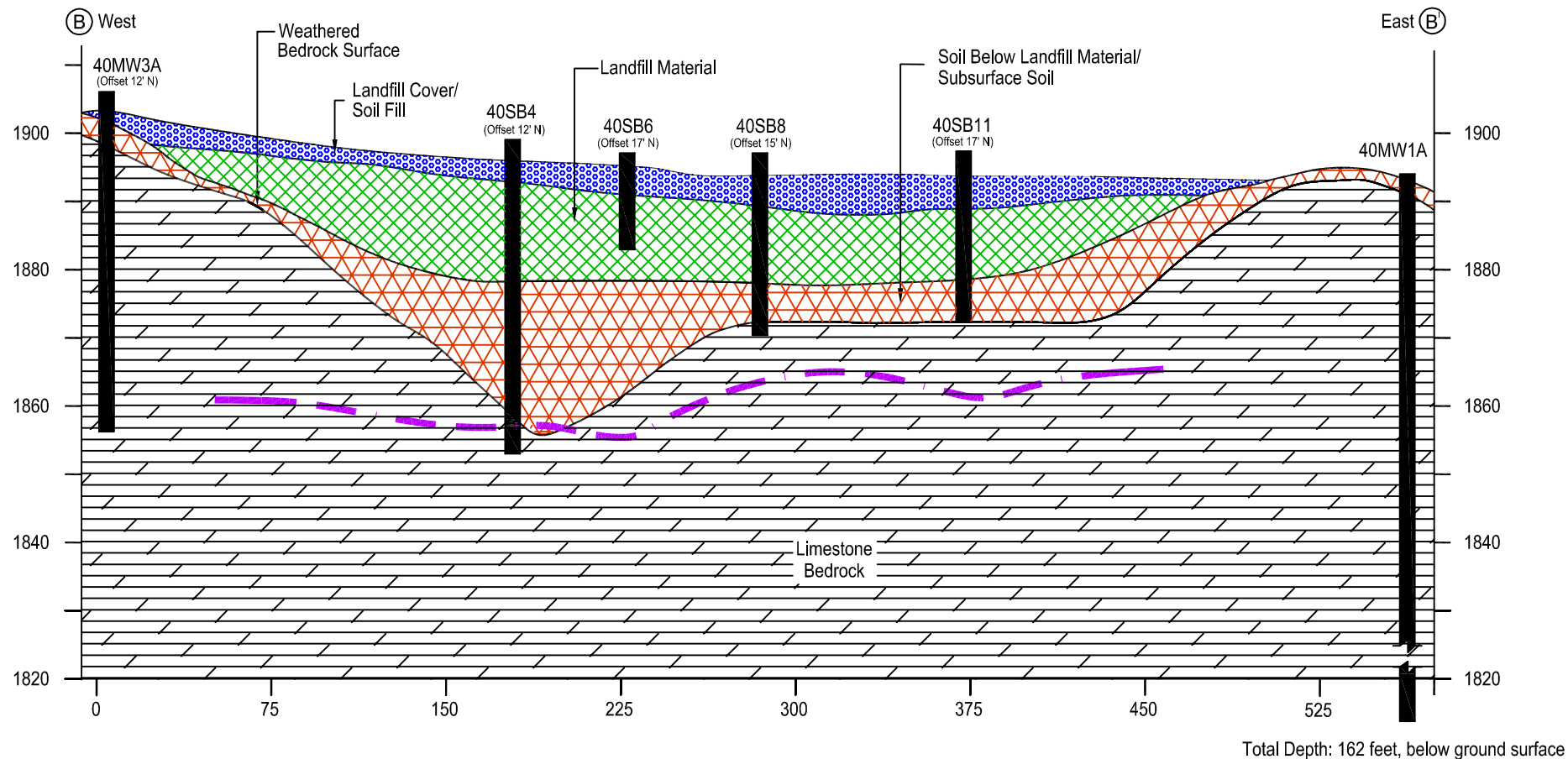


FIGURE 2-6
Geologic Cross-section
A-A'

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-6 X-Sec A-A'

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Legend

- Top of Bedrock - Tomography Survey - Geophex L-1 Profile (ANL 2003) (Line Inferred From Discreet Survey Points East of 40SB4)
- Monitoring Well/Soil Boring Location

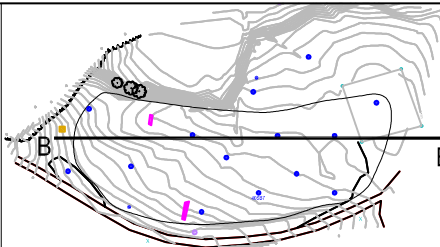
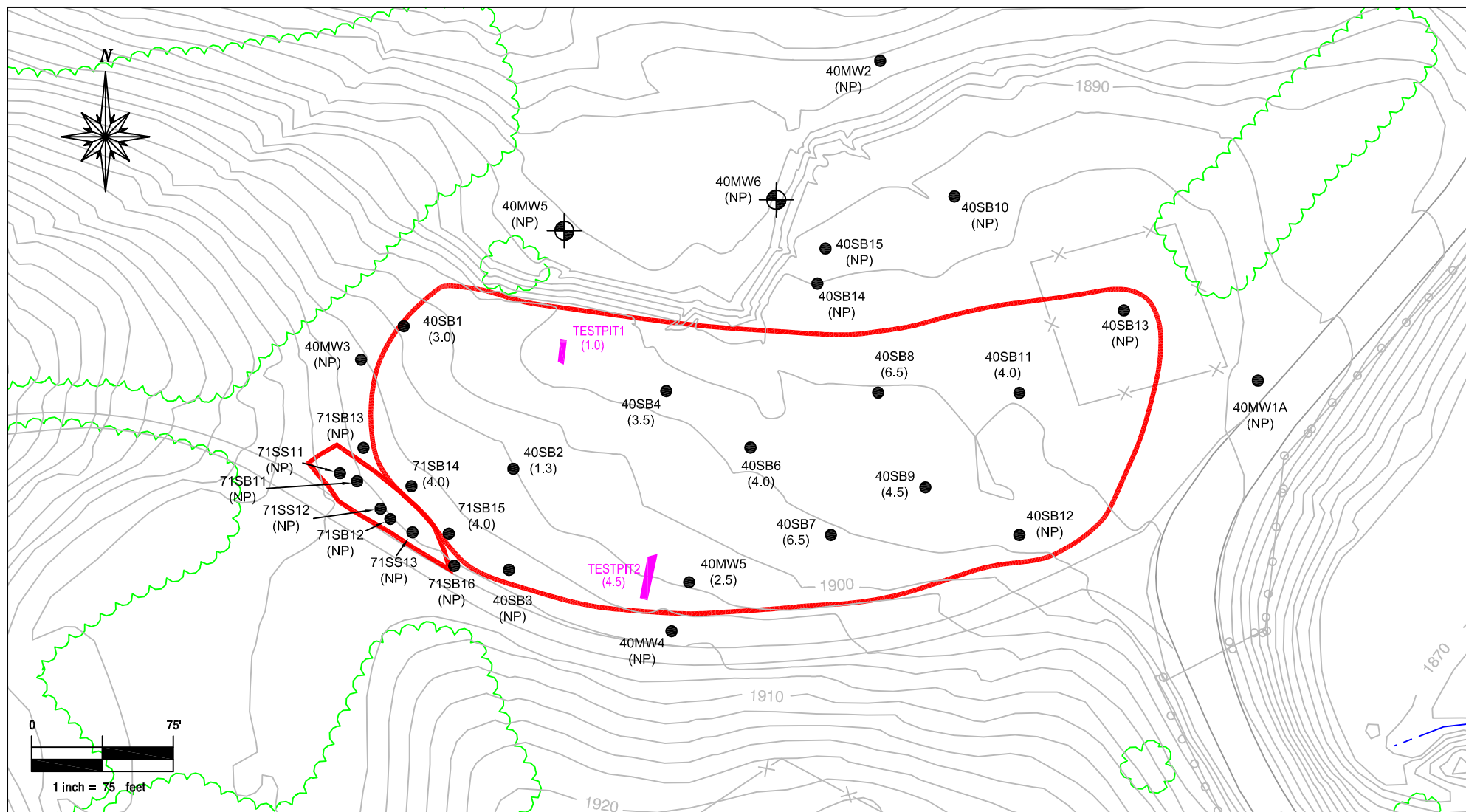


FIGURE 2-7
Geologic Cross-section
B-B'

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-7 X-Sec B-B'

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Legend

- Topographic Contour (feet mean sea level)
- SWMU Boundary / Limit of Landfill Material
- Soil Boring Location
- (NP) Landfill Material Not Present
- (4.0) Thickness of Landfill Cover
- Test Pit Location

FIGURE 2-8

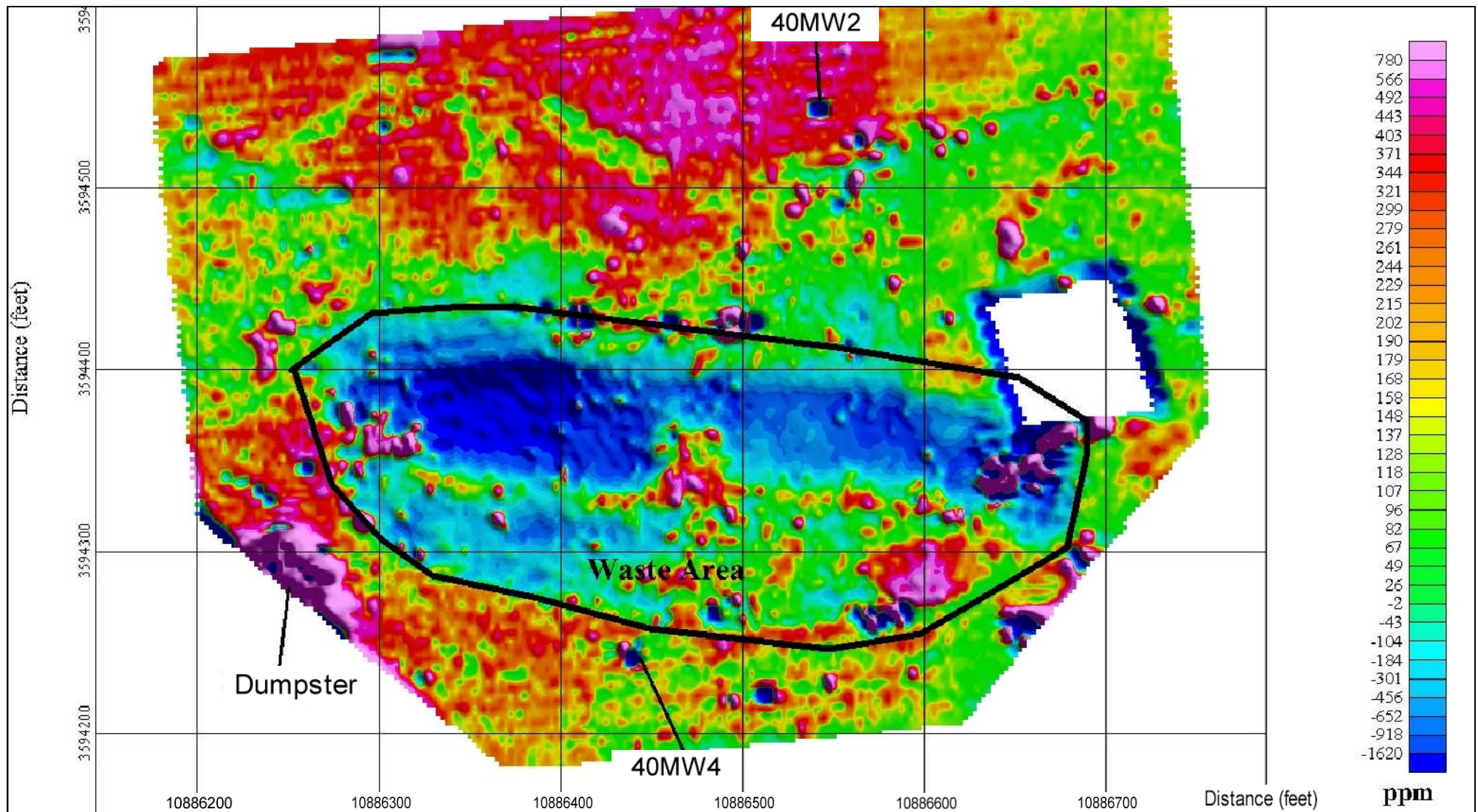
Thickness of Landfill Cover

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.2-8 Cover Thick

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Legend

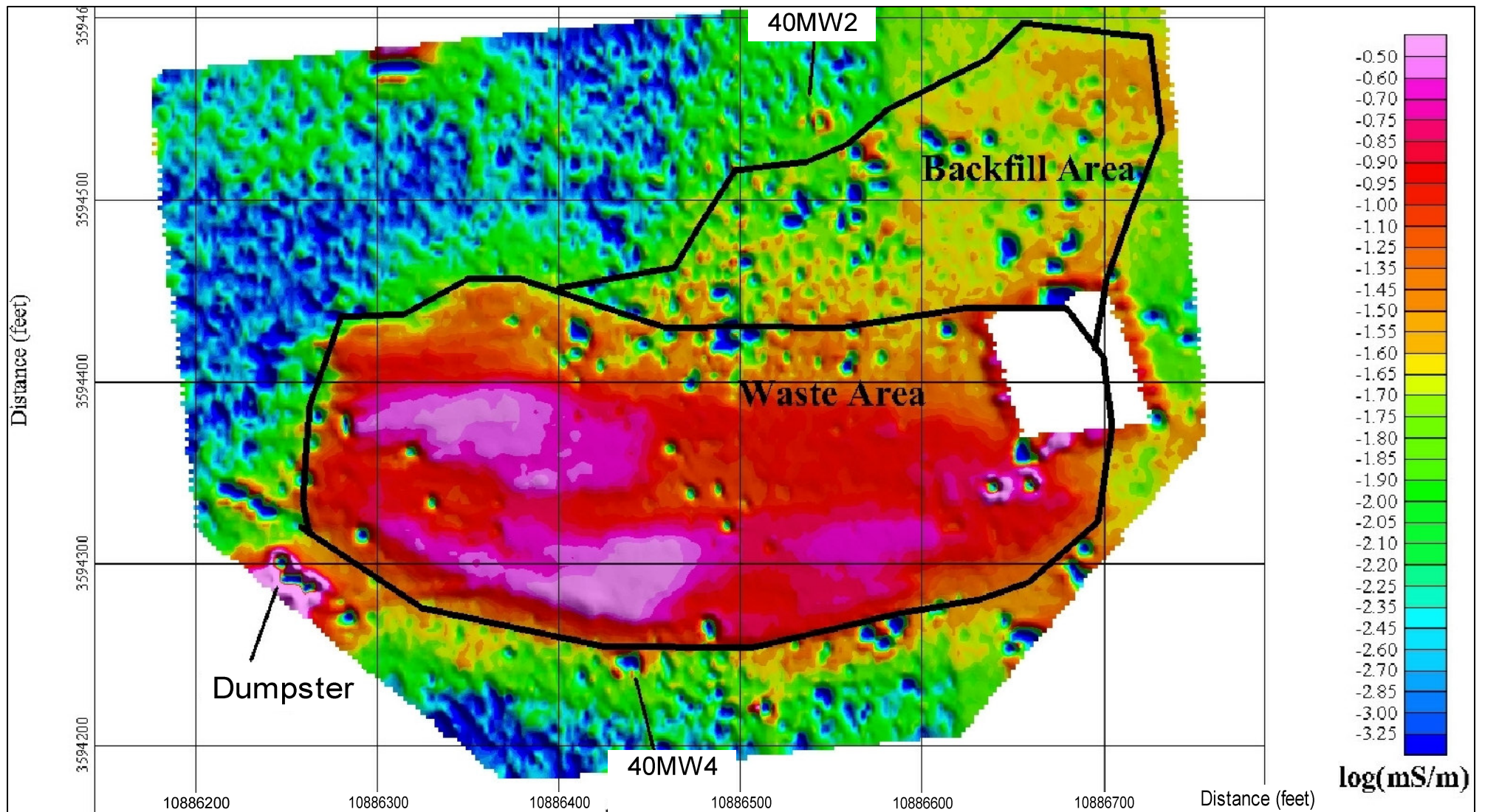
 Approximate Waste Area Boundary

FIGURE 2-9
Geophex EM
1,050 Hz Inphase Survey

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-9 Geo. 1050

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Legend

— Approximate Waste and Backfill Area Boundaries

FIGURE 2-10

Geophex EM
4,170 Hz Apparent Conductivity

Date: January 2008

Job Number: 21354880

Prepared By: DBC

Reviewed By: JOS

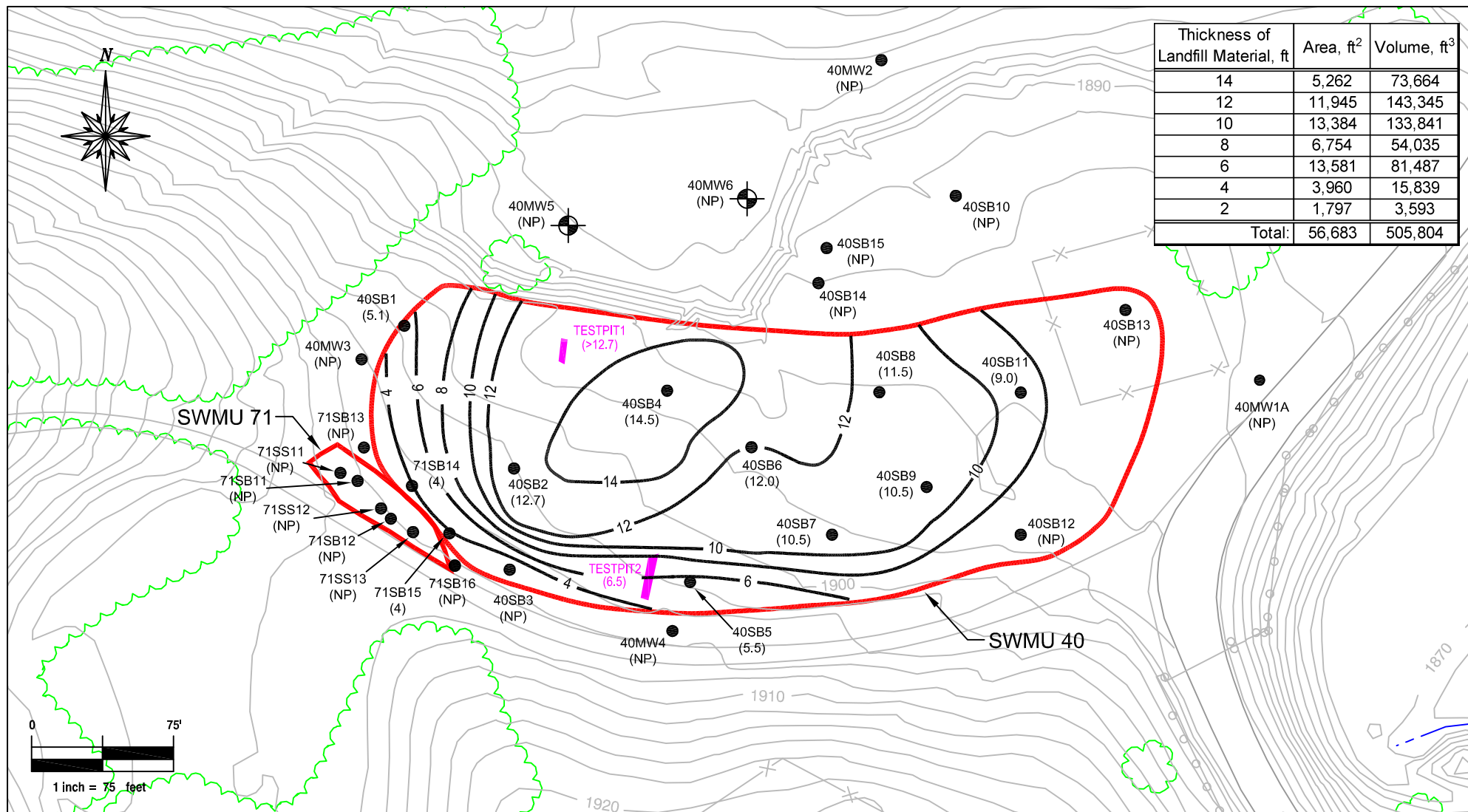
Scale: As Shown

File Name: Fig.2-10 Geo. 4170

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Legend

- Topographic Contour (feet mean sea level)
- SWMU Boundary
- Test Pit Location
- Soil Boring Location
- Isopach Contour Line (feet, mean sea level)

- (14.5) Thickness of Landfill Material (feet)
- (NP) Landfill Material Not Present

FIGURE 2-11

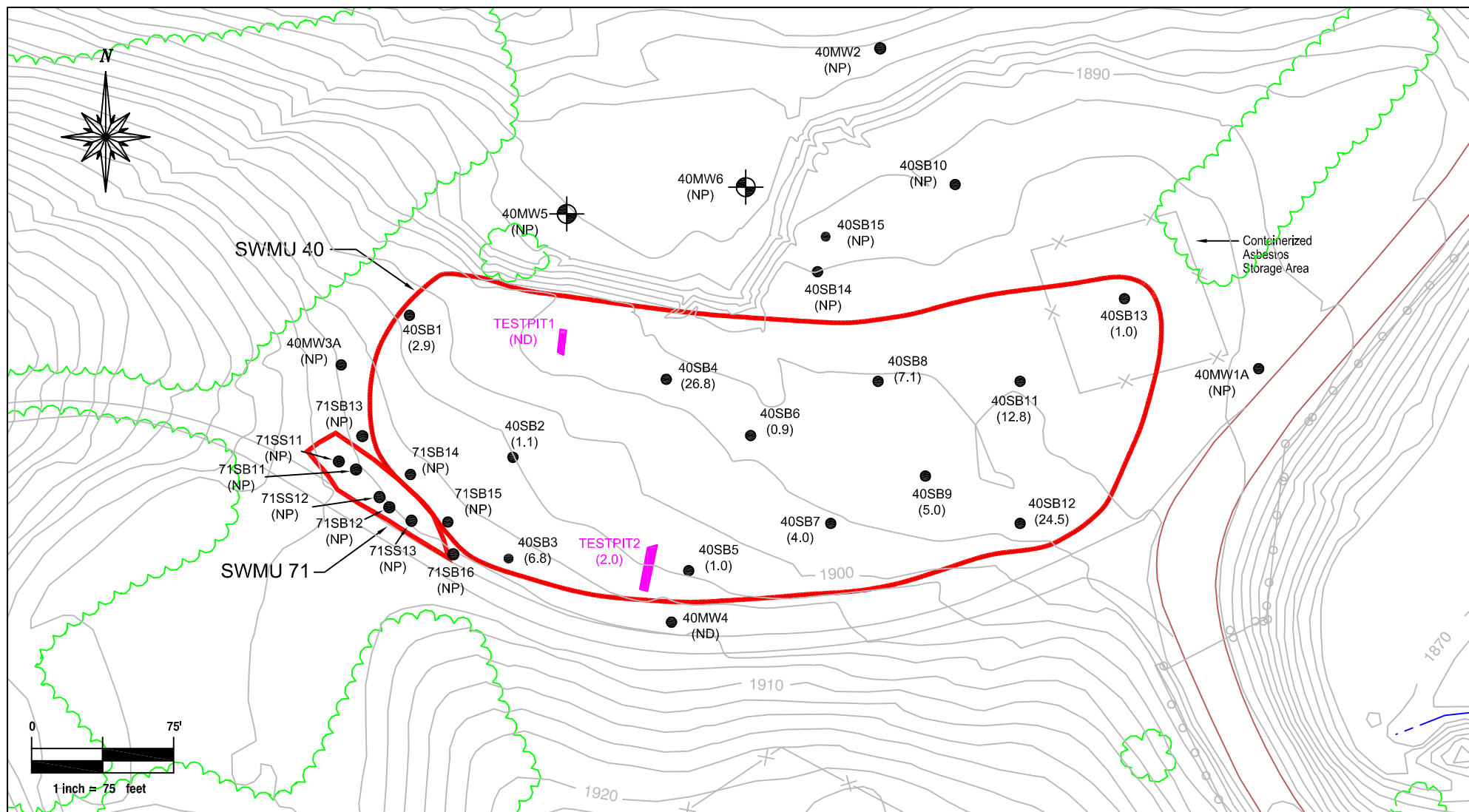
Thickness of Landfill Material

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.2-11 LF Mat,Thick

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Legend

- Topographic Contour (feet mean sea level)
- SWMU Boundary / Limit of Landfill Material
- Soil Boring Location
- (NP) Landfill Material Not Present
- (4.0) Thickness of Soil Below Landfill Material

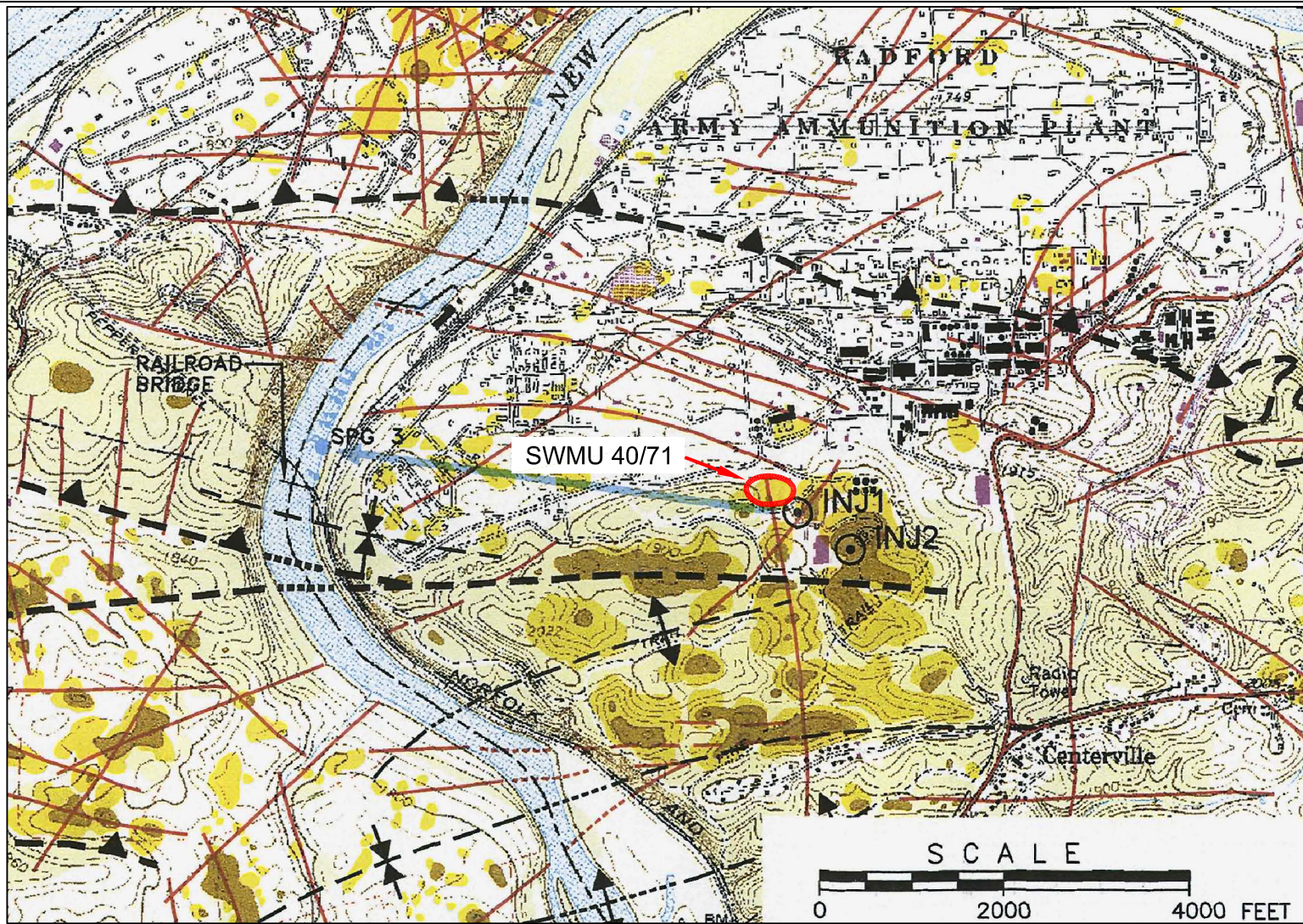
- Test Pit Location
- (ND) Not Determined

FIGURE 2-12
Thickness of Soil
Below Landfill Material

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.2-12 Cover Thick

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LEGEND:

- PHOTOLINEAMENTS
- USGS SINKHOLES
- ENGINEERING SCIENCE INC. SINKHOLES
- INJ2 ⊙ DYE INJECTIONS
- SPG 3 ● SPRING
- DYE TRACE FLOW DIRECTION

STRUCTURES:

- ▲— PULASKI THRUST FAULT SPLAY
- ↕— ANTIFORM
- ∩— SYNFORM

Source: Current Conditions Report, Shaw, 2005



FIGURE 2-13

Interpreted Photo - Lineaments,
Sinkholes and Dye Trace Results

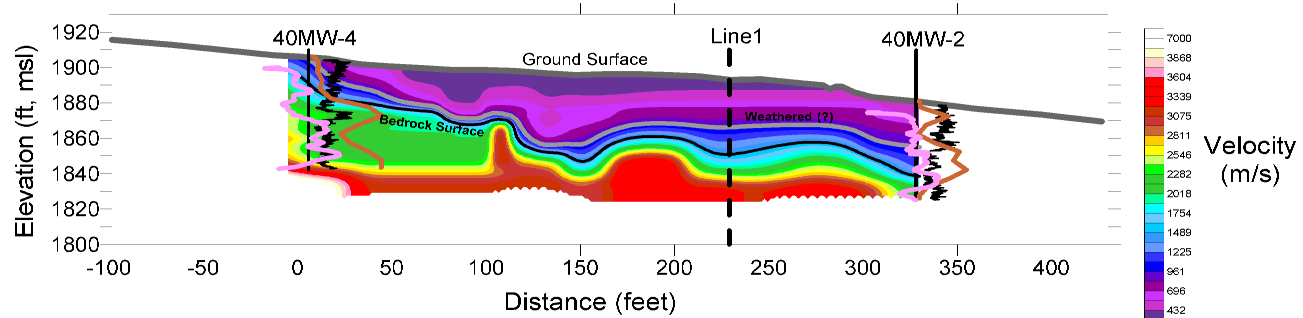
Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-13 Inter.Photo

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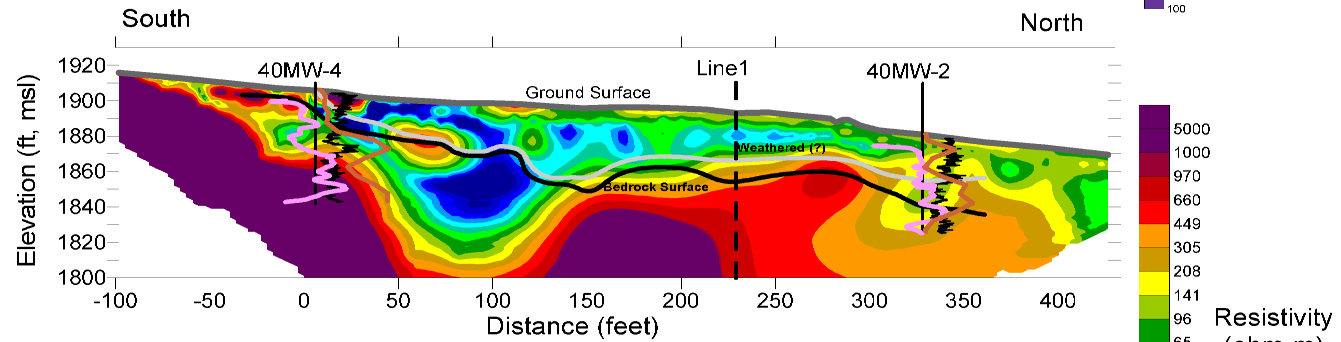
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SWMU 40/71 ANL Profile L-2

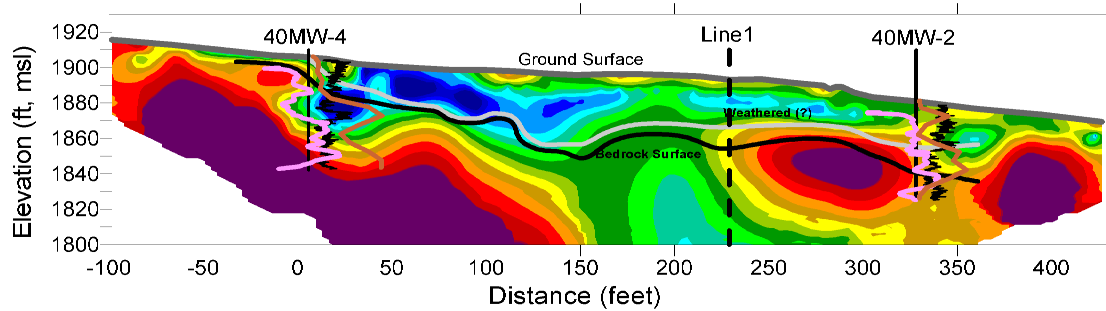
Seismic Tomography Model



2D-ERI Dipole-Dipole Model



2D-ERI Schlumberger Model



Legend

- VI Monitoring Well
- ANL Profile Line 1

*Note: Source: Argonne National Laboratories (ANL) (2003)

FIGURE 2-14a

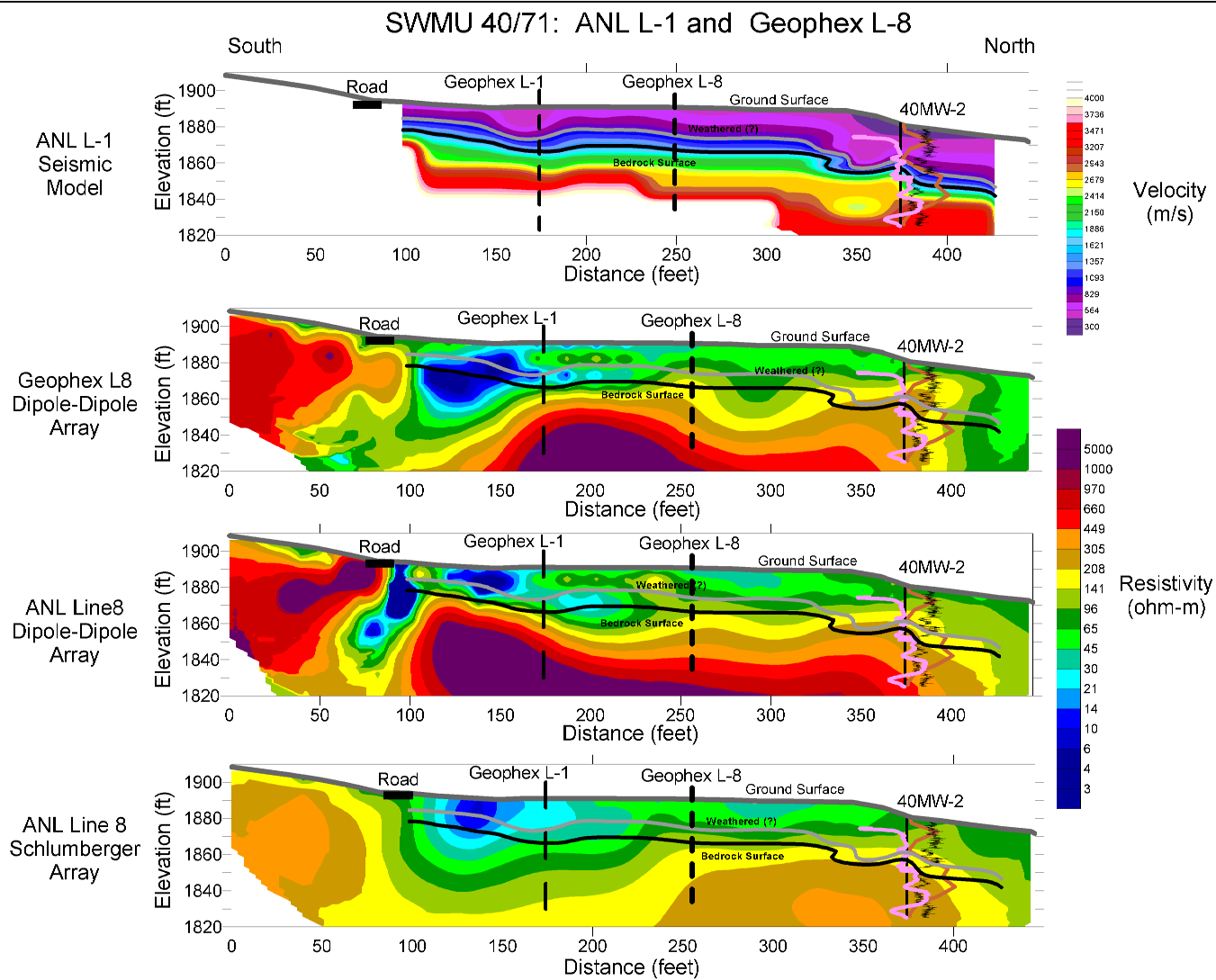
Pseudo Sections -
ANL L-2

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-14a ANL L2

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Legend

- VI Monitoring Well
- ANL Profile Line 1

***Note:** Source: Argonne National Laboratories (ANL) (2003)

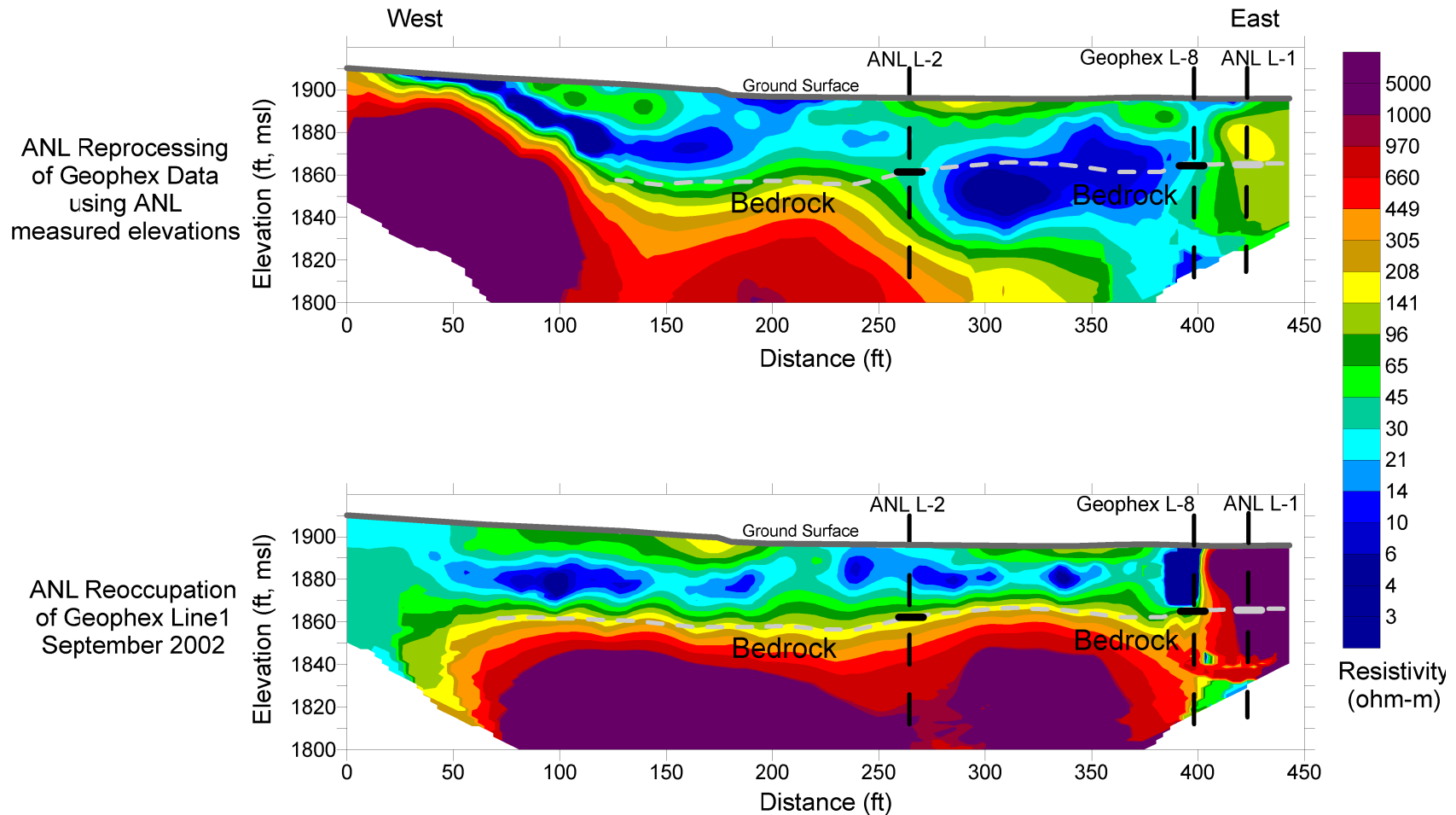
FIGURE 2-14b
Pseudo Sections -
ANL L-1 and Geophex L-8

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-14b ANL L1& Geo L8

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SWMU-40/71 Geophex Line-1



Legend

- | VI Monitoring Well
- ANL Profile Line 1

*Note: Source: Argonne National Laboratories (ANL) (2003)

FIGURE 2-14c Pseudo Sections - Geophex L-1

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: As Shown	File Name: Fig.2-14c Geo L1

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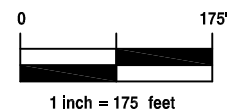
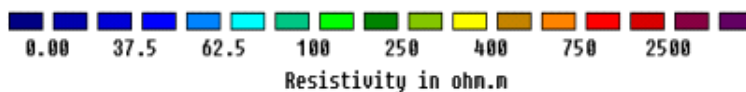
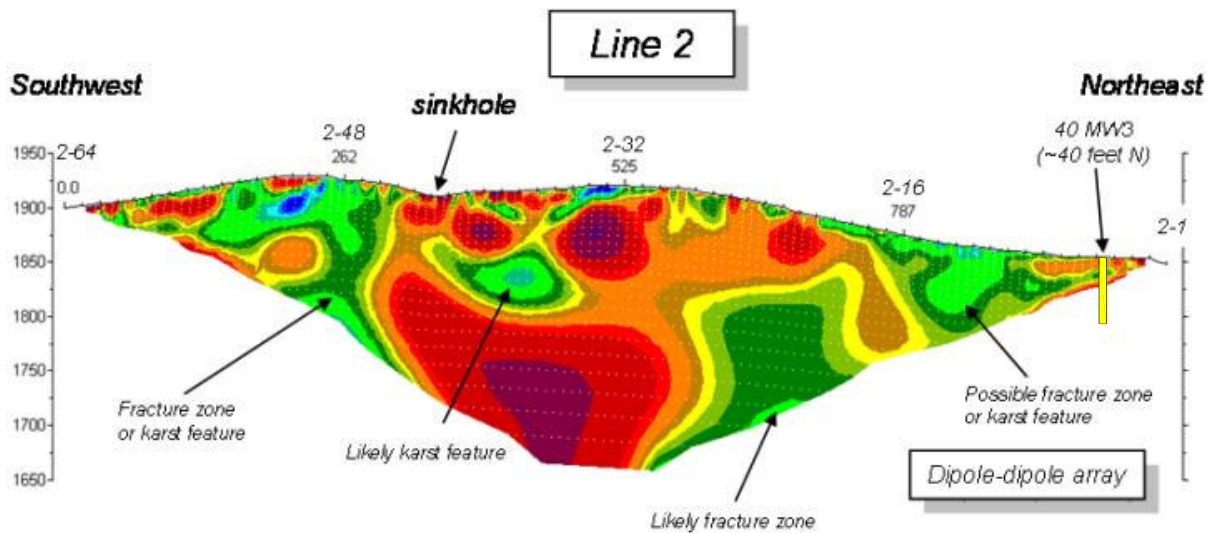
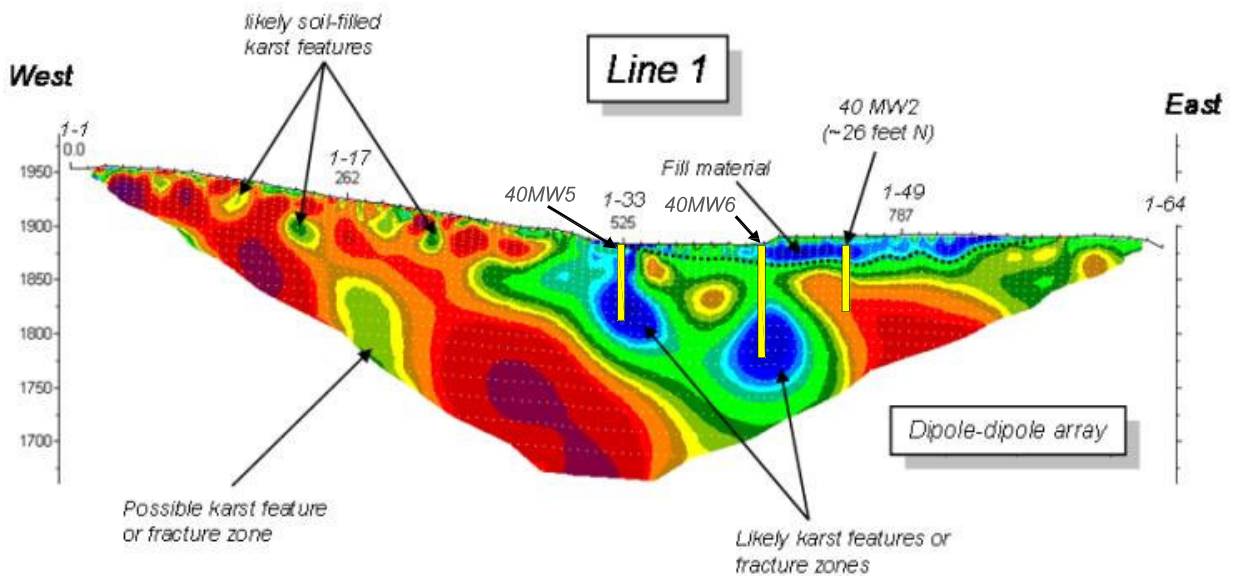


FIGURE 2-15

Pseudo-Sections -
ATS L-1 and L-2

Date:
November 2007

Prepared by:
DBC

Scale:
1 inch = 175 feet

URS Project #:
21354880

Approved by:
JOS

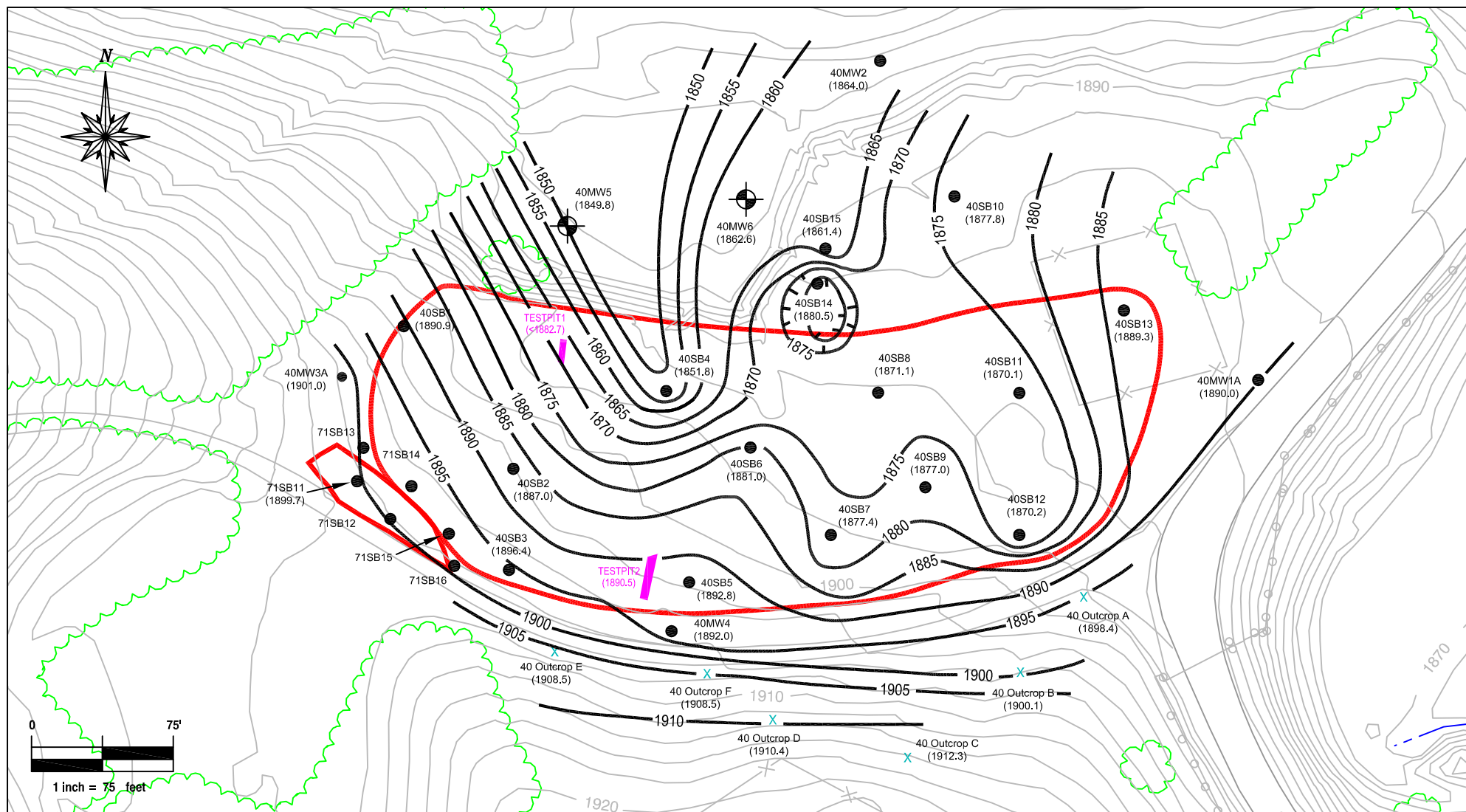
File Name:
Fig.2-15 ATS-Pseudo

SWMUs 40 and 71

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Legend

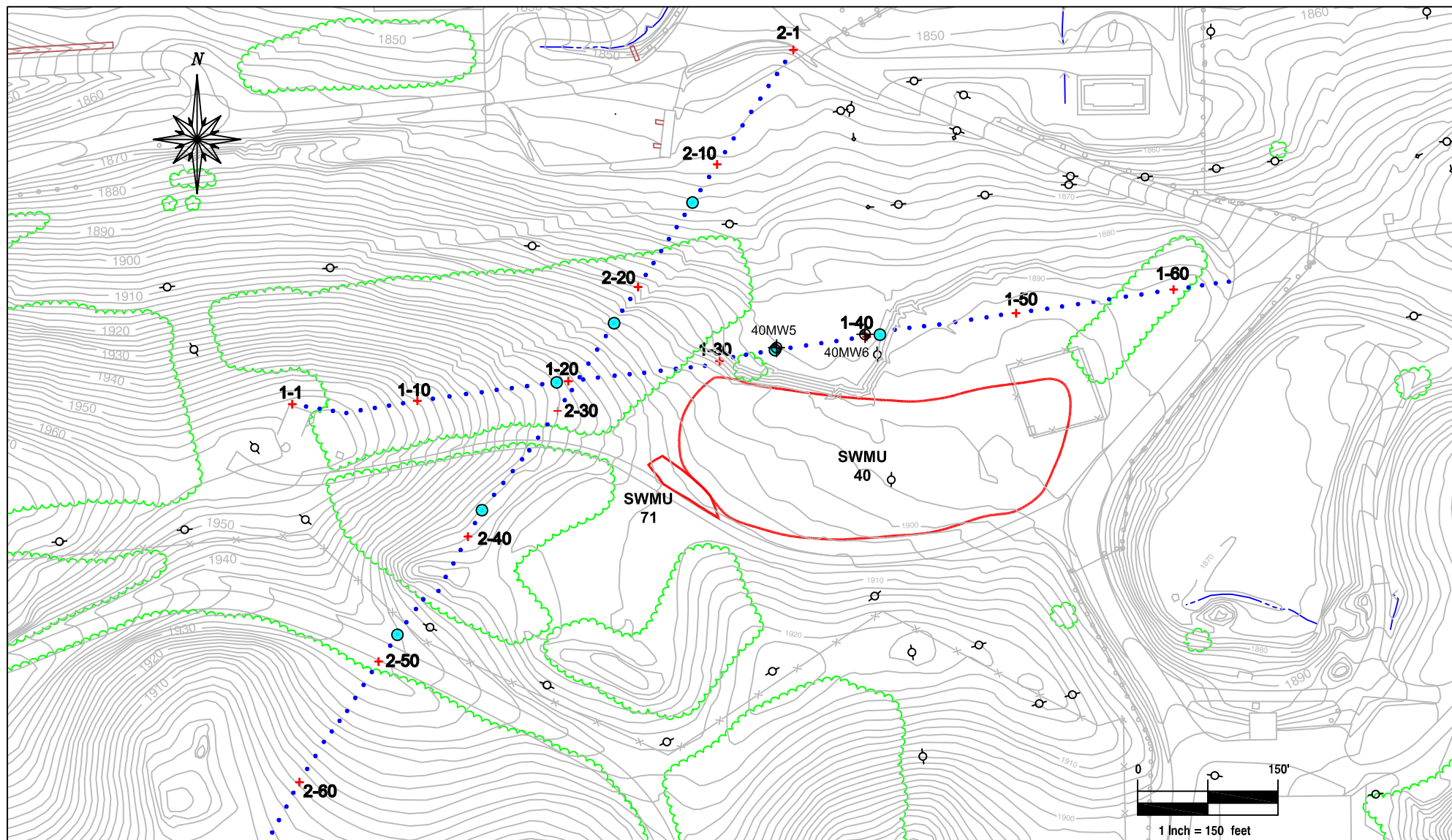
- Topographic Contour (feet mean sea level)
- SWMU Boundary
- Test Pit Location
- Soil Boring Location
- Contour Line (feet, mean sea level)
- Bedrock Outcrop Location

FIGURE 2-16
Structural Contour Map -
Top of Bedrock

Date: November 2007	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.2-16 TopOBed

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Legend

- SWMU Boundary
-  Monitoring Well Location (Installed 2007 based on Geophysics)
- + Geophysical Resistivity Stations
- Topographic Contour
-  Favorable Drilling Target for Proposed Monitoring Well
-  Overhead Electric Pole

FIGURE 2-17

ATS Geophysical Survey - Identified
Possible Target Locations for Monitoring Wells

Date:
November 2007

Job Number:
21354880

Prepared By:
DBC

Reviewed By:
JOS

Scale:
1" = 150'

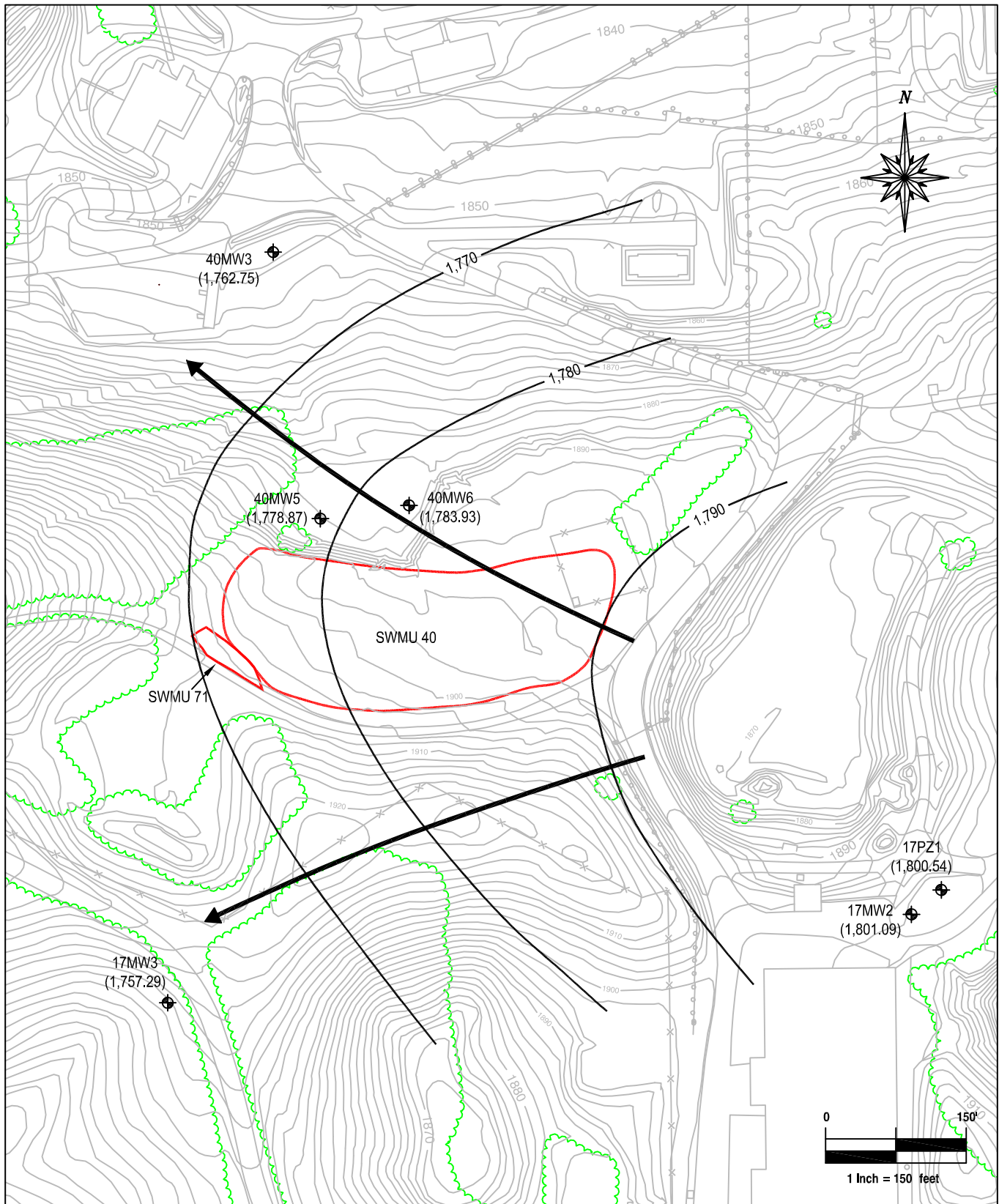
File Name:
Fig.2-17 PossWellLocs

SWMUs 40 and 71

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Legend

- Approximate SWMU Boundary
- Topographic Contour
- ~ Vegetation
- x x Fence
- Groundwater Potentiometric Contour
- ← Inferred Groundwater Path
- (1,752.54) Groundwater Elevation (feet, mean sea level)

FIGURE 2-18
Groundwater Potentiometric Map

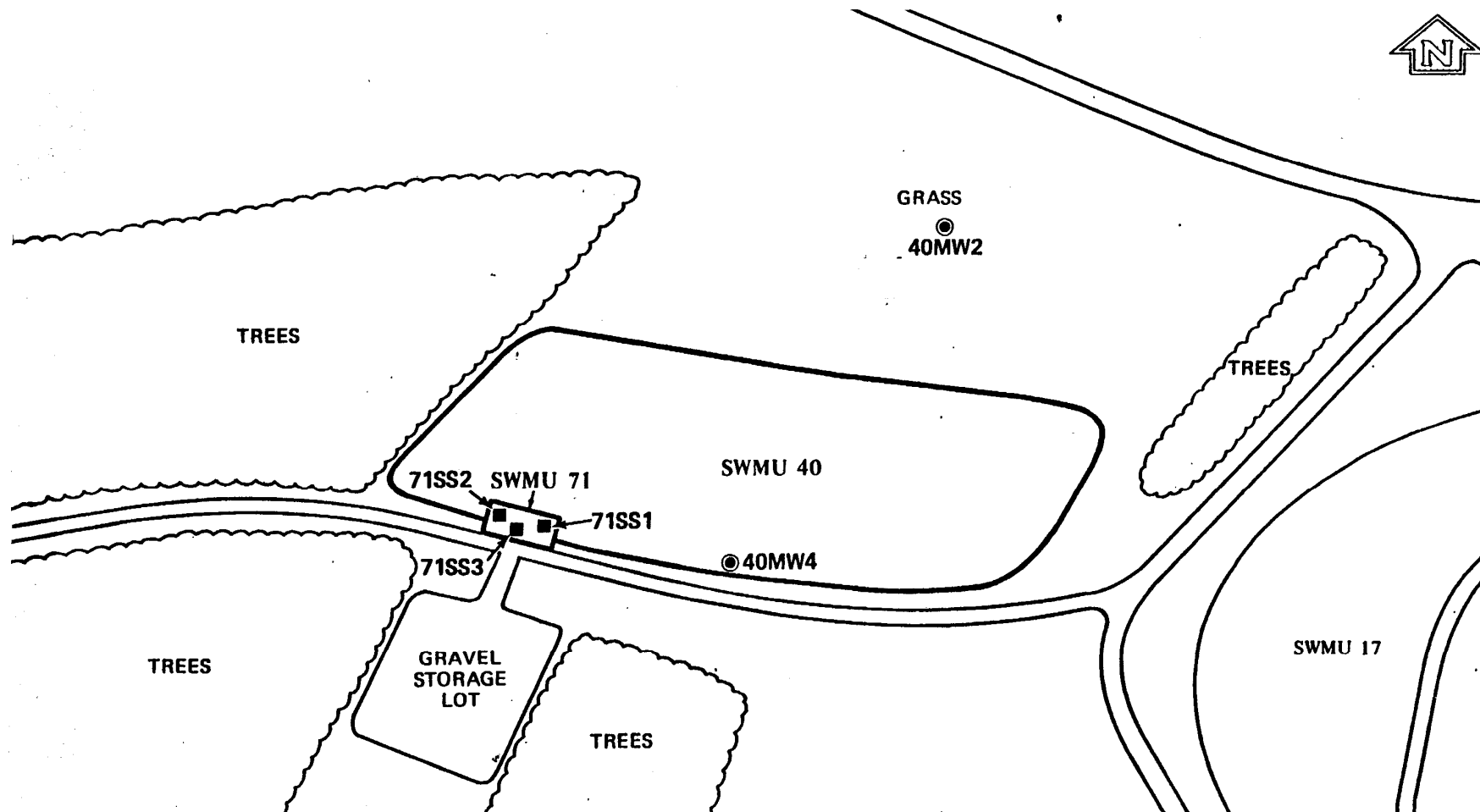
Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 150 feet	File Name: Fig.2-18 PotMap

SWMUs 40 and 71

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Richmond, Virginia 23230



LEGEND:

- Soil Sample
- Monitoring Well

Source: Modified from Dames and Moore 1992

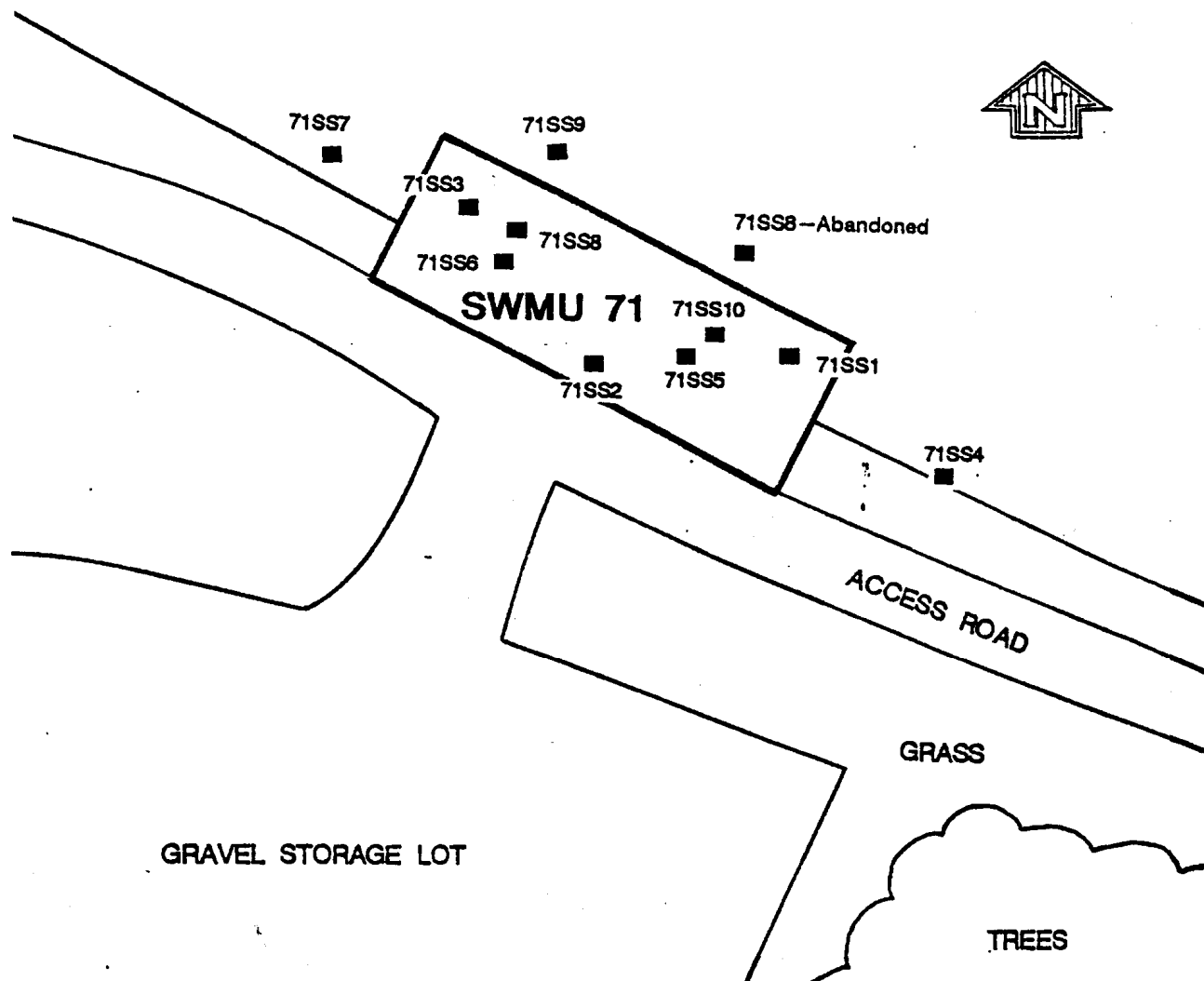
FIGURE 2-19
Sample Locations (Dames and Moore 1992)

Date: November 2007	URS Project#: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1" = 100'	File Name: 21354880

SWMUs 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia



URS Group, Inc.
5540 Falmouth Street,
Suite 201
Richmond, VA 23230



LEGEND:

- Soil Sample
- Monitoring Well

Source: Modified from Dames and Moore 1994

FIGURE 2-20
Sample Locations (Dames and Moore 1994)

Date: November 2007	URS Project#: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1" = 20'	File Name: 21354880

SWMUs 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia



URS Group, Inc.
5540 Falmouth Street,
Suite 201
Richmond, VA 23230

Table 2-1
Soil Physical Testing Results
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Soil Sample				Physical Analyses															
Location	Depth (feet bgs)	Type	USCS Soil Type	Water Content (D2216)	Liquid Limit (D4318)	Plastic Limit (D4318)	Plastic Ind. (D4318)	Sieve Minus No. 200 (D422)	Hydrometer % Minus 2 μ m (D422)	pH Distilled Water (D4972)	pH 0.01 M CaCl Solution (D4972)	Organic Content (D2974)	Soil Particle Density (D854)	Total Bulk Density (D2937)	Dry Bulk Density (D2937)	Hydraulic Conductivity (D5084)	Total Soil Porosity (Calculated)	Air-Filled Soil Porosity (Calculated)	Water-Filled Soil Porosity (Calculated)
				%	-	-	-	%	%	--	--	%	--	pcf	pcf	cm/sec	-	-	-
40SB4	0 - 4	Soil Fill	CL	18.1	35	13	22	60.9	27	6.8	6.6	5.5	2.687	129.0	109.2	6.6E-08	0.35	0.02	0.33
40SB4	30 - 32	Soil Below Landfill Material	CH	41.0	50	23	27	79.9	33	6.5	6.4	3.0	2.691	114.9	81.4	8.5E-08	0.52	0.00	0.52
40SB9	0 - 4	Soil Fill	CL	19.4	30	14	16	NT	NT	8.8	7.5	2.8	2.692	131.9	110.5	2.7E-09	0.34	0.00	0.34
71SB11	3 - 5	Residual Soil	CH	32.1	55	23	32	95.1	53	6.6	6.4	4.1	2.685	117.2	88.7	1.1E-07	0.47	0.01	0.46

Notes:

NT = Not tested because of insufficient sample quantity

bgs = Below ground surface

pcf = Pounds per cubic foot

cm/s = centimeters per second

USCS = Unified Soil Classification System

CL = Low Plasticity Clay

CH = High Plasticity Clay

(D2216) = ASTM Test Method

Unconsol = Unconsolidated

-- = Unitless

Table 2-2
Soil Boring, Test Pit, and Bedrock Outcrop Data
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Data Point ID No.	Date	Elevation		Depth to Bottom (ft bgs)			Thickness (ft)			Comments
		Ground Surface	Refusal (Top of Bedrock)	Landfill Cover	Landfill Material	Boring Refusal	Landfill Cover	Landfill Material	Soil Below Landfill Material	
SWMU 40 - Landfill										
40SB1	15-Nov-02	1901.9	1890.9	3.0	8.1	11.0	3.0	5.1	2.9	Landfill Material
40SB2	15-Nov-02	1902.1	1887.0	1.3	14.0	15.1	1.3	12.7	1.1	Landfill Material
40SB3	14-Nov-02	1905.3	1896.4			8.9				No Landfill Material
40SB4	14-Nov-02	1896.6	1851.8	3.5	18.0	44.8	3.5	14.5	26.8	Landfill Material
40SB5	14-Nov-02	1901.8	1892.8	2.5	8.0	9.0	2.5	5.5	1.0	Landfill Material
40SB6	13-Nov-02	1897.9	1881.0	4.0	15.9	16.9	4.0	11.9	1.0	Landfill Material
40SB7	13-Nov-02	1898.4	1877.4	6.5	17.0	21.0	6.5	10.5	4.0	Landfill Material
40SB8	13-Nov-02	1896.2	1871.1	6.5	18.0	25.1	6.5	11.5	7.1	Landfill Material
40SB9	13-Nov-02	1897.0	1877.0	4.5	15.0	20.0	4.5	10.5	5.0	Landfill Material
40SB10	13-Nov-02	1892.7	1877.8			14.9				No Landfill Material
40SB11	12-Nov-02	1895.9	1870.1	4.0	13.0	25.8	4.0	9.0	12.8	Landfill Material
40SB12	11-Nov-02	1897.2	1870.2			27.0				No Landfill Material
40SB13	19-Nov-02	1895.5	1889.3			6.2				No Landfill Material
40SB14	18-Nov-02	1893.9	1880.5			13.4				No Landfill Material
40SB15	18-Nov-02	1892.9	1861.4			31.5				No Landfill Material
71SB14	20-Apr-06	--	--	4.0	7.0	7.0	4.0	3.0		Landfill Material, Refusal at 7 ft bgs
71SB15	20-Apr-06	--	--	4.0	8.0	8.0	4.0	4.0		Landfill Material, Refusal at 8 ft bgs
40MW1A	21-Oct-91	1892	1890			2.0				No Landfill Material
40MW2	20-Oct-91	1881	1864			17.0				No Landfill Material
40MW3A	18-Oct-91	1905	1901			4.5				No Landfill Material
40MW4	28-Oct-91	1906	1892			14.0				No Landfill Material
40MW5	17-Jul-07	1883.8	1849.8							No Landfill Material
40MW6	16-Jul-07	1882.6	1863							No Landfill Material
TEST PIT 40TP-1	20-Nov-02	1897.3		1.0	<13.7		1.0	> 12.7		Refusal not reached *
TEST PIT 40TP-2	20-Nov-02	1903.5	1890.5	4.5	11.0	13.0	4.5	6.5	2.0	Refusal south edge
40 OUTCROP A		1898.4	1898.4							Strike 110.0 Dip 15.0
40 OUTCROP B		1900.1	1900.1							Strike 111.0 Dip 16.0
40 OUTCROP C		1912.3	1912.3							Strike 112.0 Dip 12.0
40 OUTCROP D		1910.4	1910.4							Strike 114.0 to Dip 12.0
40 OUTCROP E		1908.5	1908.5							Strike 115.0 to Dip 15.0
40 OUTCROP F		1907.3	1907.3							Strike 111.0 to Dip 16.0

Table 2-2
Soil Boring, Test Pit, and Bedrock Outcrop Data
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Data Point ID No.	Date	Elevation		Depth to Bottom (ft bgs)			Thickness (ft)			Comments
		Ground Surface	Refusal (Top of Bedrock)	Landfill Cover	Landfill Material	Boring Refusal	Landfill Cover	Landfill Material	Soil Below Landfill Material	
SWMU 71 - Flash-Burn Area										
71SB11	18-Nov-02	1906.6	1899.7			6.9				No Landfill Material
71SB12	20-Apr-06	--	--			6.0				No Landfill Material
71SB13	20-Apr-06	--	--			9.0				No Landfill Material
71SB16	20-Apr-06	--	--			5.0				No Landfill Material
71SS11	18-Nov-02	1907.3	1900.4			7.0				No Landfill Material
71SS12	18-Nov-02	1906.3	1899.4			11.2				No Landfill Material
71SS13	18-Nov-02	1906.1	1899.2			7.2				No Landfill Material

Notes:

ft = feet

bgs = below ground surface

-- = Not Available

Table 2-3
Monitoring Well Construction Data
SWMU 40s and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Well Identification	Date Installed	Screened Zone	Well Diameter (In)	Total Well Depth (ft bgs)	Elevation Ground Surface (ft msl)	Elevation TOC (ft msl)	Screened Interval (ft bgs)	Depth to Bedrock (ft bgs)	Bedrock Elevation (ft msl)
40MW3	5/25/2003	Bedrock	4	117.0	1855.28	1857.29	97.0-117.0	51.0	1804.28
40MW5	7/17/2007	Bedrock	2	157.0	1883.84	1885.62	137.0-157.0	34.0	1849.84
40MW6	7/16/2007	Bedrock	2	135.0	1882.61	1884.48	115.0-135.0	20.0	1862.61
17MW3	5/24/1993	Bedrock	4	181.5	1903.43	1905.42	161.5-181.5	1.5	1901.93

Notes:

TOC = Top of Casing

BTOC = Below Top of Casing

DTW = Depth to Water

ft = feet

msl = mean sea level

bgs = below ground surface

Table 2-4
Groundwater Elevation Data
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Well Identification	Elevation TOC (ft msl)	DTW (ft BTOC) 8/13/07	Groundwater Elevation 8/13/07 (ft msl)	DTW (ft BTOC) 12/10/07	Groundwater Elevation 12/10/07 (ft msl)
40MW3	1857.50	94.02	1763.48	94.75	1762.75
40MW5	1885.62	102.77	1782.85	106.75	1778.87
40MW6	1884.25	94.59	1789.66	100.32	1783.93
17PZ1	1906.09	--	--	105.55	1800.54
17MW2	1905.88	--	--	104.79	1801.09
17MW3	1905.42	147.99	1757.43	148.13	1757.29

Notes:

TOC = Top of Casing

BTOC = Below Top of Casing

DTW = Depth to Water

ft = feet

msl = mean sea level

bgs = below ground surface

Table 2-5
Summary of Detected Analytes for Soil Samples Collected at SWMU 71
Modified from Dames and Moore Verification Investigation Report (1992)
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	Facility-Wide Background Point Estimate ^[A]	Adjusted Soil RBC (Residential)	Adjusted Soil RBC (Industrial)	Draft BTAG Screening Level	71SS1 2/5/1992 0.5		71SS2 2/5/1992 0.5		71SS3 2/5/1992 0.5	
					Result	Q	Result	Q	Result	Q
TAL Inorganics (mg/kg)										
ALUMINUM	40,041	7,821	102,200	1	15,200		4,040		4,880	
ARSENIC	15.8	0.426	1.91	328	13		27		190	
BARIUM	209	1,564	20,440	440	166		155		161	
BERYLLIUM	1.02	15.64	204.4	0.02	<u>3</u>		<u>1.63</u>		<u>1.73</u>	
CALCIUM	--	--	--	--	9,130		3,130	B	10,100	
CHROMIUM ^[1]	65.3	23.46	306.6	0.0075	40.8		19.1		14	
COBALT	72.3	--	--	100	13.1		5.48		2.29	
COPPER	53.5	312.9	4,088	15	53.5		40.9		46.5	
IRON	50,962	5,475	71,540	12	27,600		9,720		32,700	
LEAD ^[2]	26.8	400	750	0.01	<u>97.2</u>		<u>76.6</u>		<u>147</u>	
MAGNESIUM	--	--	--	4,400	7,610		1,860		1,240	
MANGANESE	2,543	156.4	2,044	330	<u>463</u>		127		44.7	
MERCURY ^[3]	0.13	2.35	30.66	0.058	<u>0.23</u>		<u>0.372</u>		<u>2.7</u>	
NICKEL	62.8	156.4	2,044	2	18.3		11.1		7.11	
POTASSIUM	--	--	--	--	1,620		640		1,560	
SELENIUM	--	39.11	511	1.8	<0.25		0.449		6.69	
SILVER	--	39.11	511	0.0000098	1.2		0.97		1.76	
SODIUM	--	--	--	--	457	B	289	B	377	B
THALLIUM	2.11	0.548	7.154	0.001	25.2		13.9		32.7	
VANADIUM	108	7.821	102.2	0.5	<u>50.9</u>		<u>17</u>		<u>22.7</u>	
ZINC	202	2,346	30,660	10	160		80.5		43.5	
Other (mg/kg)										
TPH	--	--	--	--	61.2		55.2		79.5	

Notes:

ft bgs = Feet Below Ground Surface

mg/kg = Milligram Per Kilogram

TAL = Target Analyte List

^[A] = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)

RBC = Risk-Based Concentration

USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007 RBC Tables

Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

BTAG = USEPA Region III Draft Biological Technical Assistance Group Screening Levels

-- = No Risk Criteria Available

Q = Qualifier

B = Analyte was detected in associated method blank

 = Concentration Above Soil Residential RBC

bold = Concentration Above Soil Industrial RBC

 = Concentration Exceeds BTAG Screening Level

underline = Concentration Exceeds Site Background Values

^[1] = Chromium VI RBC value was used

^[2] = Lead criteria are Action Levels; see USEPA Region III guidance

^[3] = Mercuric chloride soil RBC value used

Table 2-6
Summary of Detected Analytes for Soil Samples Collected at SWMU 71
Modified from Dames and Moore Verification Investigation Report (1994)
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	Facility-Wide Background Point Estimate ^[A]	Adjusted Soil RBC (Residential)	Adjusted Soil RBC (Industrial)	Draft BTAG Screening Level	71SS4 7/15/1993 0.0	71SS4 7/15/1993 4.0	71SS5 7/15/1993 0.0	71SS5(dup) 7/15/1993 0.0	71SS5 7/15/1993 4.0	71SS6 7/15/1993 0.0	71SS6 7/15/1993 4.0
TAL Metals (mg/kg)											
ALUMINUM	40,041	7,821	102,200	1	23,300	26,900	17,400	24,300	33,100	13,600	48,300
ARSENIC	15.8	0.426	1.91	328	5.3	7.4	8.3	5.7	6.9	17	8.6
BARIUM	209	1,564	20,440	440	264	87.1	80.3	99.9	56	151	111
BERYLLIUM	1.02	15.64	204.4	0.02	1.27	1.75	<0.5	1.43	2.37	1.06	3.19
CADMIUM	0.69	3.911	51.1	2.5	<0.7	<0.7	3.36	<0.7	<0.7	<0.7	<0.7
CALCIUM	--	--	--	--	6,280	1,360	42,800	1,860	1,730	4,700	2,000
CHROMIUM ^[1]	65.3	23.46	306.6	0.0075	35.7	51.1	23.5	36.6	47.6	33.4	63.5
COBALT	72.3	--	--	100	15	14.3	4.27	5.68	15.9	12.1	14.9
COPPER	54	312.9	4,088	15	27.4	26.1	11.8	15.6	38.4	197	32.3
IRON	50,962	5,475	71,540	12	32,000	46,800	24,600	38,200	33,700	26,000	50,500
LEAD ^[2]	26.8	400	750	0.01	38.2	18	61.2	25.9	<10.5	51.4	21.9
MAGNESIUM	--	--	--	4,400	6,720	7,800	26,000	2,470	47,300	5,600	26,900
MANGANESE	2,543	156.4	2,044	330	355	351	164	131	341	381	438
MERCURY ^[3]	0.13	2.35	30.66	0.058	0.124	<0.05	0.133	0.179	<0.05	0.272	0.088
NICKEL	62.8	156.4	2,044	2	22.1	31.1	7.7	11.1	41.2	323	46.2
POTASSIUM	--	--	--	--	1,810	1,970	707	1,020	7,000	1,370	4,070
SELENIUM	--	39.11	511	1.8	<0.25	<0.25	<0.25	<0.25	<0.25	0.587	<0.25
SILVER	--	39.11	511	0.0000098	<0.589	<0.589	<0.589	<0.589	<0.589	1.16	<0.589
SODIUM	--	--	--	--	734	740	378	401	348	403	457
VANADIUM	108	7.821	102.2	0.5	58.7	80.7	55.1	80.2	67.3	41.1	103
ZINC	202	2,346	30,660	10	79.5	59.2	23.9	34.2	56.3	95.9	76.1
Other (mg/kg)											
TPH	--	--	--	--	553	<28.7	36.7	36.1	<28.7	723	40.8

Table 2-6 (Continued)
Summary of Detected Analytes for Soil Samples Collected at SWMU 71
Modified from Dames and Moore Verification Investigation Report (1994)
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	Facility-Wide Background Point Estimate ^[A]	Adjusted Soil RBC (Residential)	Adjusted Soil RBC (Industrial)	Draft BTAG Screening Level	71SS7 7/15/1993 0.0	71SS7 7/15/1993 4.0	71SS8 7/15/1993 0.0	71SS9 7/15/1993 0.0	71SS9 7/15/1993 4.0	71SS10 7/15/1993 0.0
TAL Metals (mg/kg)										
ALUMINUM	40,041	7,821	102,200	1	26,300	48,700	22,200	13,800	14,400	23,300
ARSENIC	15.8	0.426	1.91	328	7.4	9.3	7.5	8.6	530	12
BARIUM	209	1,564	20,440	440	126	109	282	120	107	380
BERYLLIUM	1.02	15.64	204.4	0.02	1.61	4.7	1.61	0.951	1.29	2.12
CADMIUM	0.69	3.911	51.1	2.5	<0.7	<0.7	<0.7	<0.7	0.977	<0.7
CALCIUM	--	--	--	--	2,180	1,780	3,650	16,000	14,700	6,590
CHROMIUM ^[1]	65.3	23.46	306.6	0.0075	46.2	65.7	34.9	39.8	41.7	37.4
COBALT	72.3	--	--	100	18.5	13.8	16.1	7.91	25.4	14.6
COPPER	54	312.9	4,088	15	22.1	40	21.4	123	116	27
IRON	50,962	5,475	71,540	12	28,200	62,400	33,400	21,900	48,100	35,700
LEAD ^[2]	26.8	400	750	0.01	<10.5	16.8	22	78.2	133	21.7
MAGNESIUM	--	--	--	4,400	27,000	13,900	7,540	3,050	4,840	9,520
MANGANESE	2,543	156.4	2,044	330	1,330	670	644	495	375	1,300
MERCURY ^[3]	0.13	2.35	30.66	0.058	<0.05	0.13	<0.05	17	6.4	0.068
NICKEL	62.8	156.4	2,044	2	28.5	57.5	22.5	11.7	52.2	26.2
POTASSIUM	--	--	--	--	2,630	2,900	1,810	1,210	1,140	1,770
SELENIUM	--	39.11	511	1.8	<0.25	<0.25	<0.25	<0.25	2.16	<0.25
SILVER	--	39.11	511	0.0000098	<0.589	<0.589	<0.589	<0.589	<0.589	<0.589
SODIUM	--	--	--	--	416	433	629	639	1,080	805
VANADIUM	108	7,821	102.2	0.5	66.2	117	55.3	77.5	92.1	60.1
ZINC	202	2,346	30,660	10	63.8	72.9	64.7	170	223	72.6
Other (mg/kg)										
TPH	--	--	--	--	38.4	<28.7	<28.7	1,330	1,090	<28.8

Notes:

ft bgs = Feet Below Ground Surface

mg/kg = Milligram Per Kilogram

TAL = Target Analyte List

^[A] = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)

RBC = Risk-Based Concentration

USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007 RBC Tables

Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

BTAG = USEPA Region III Draft Biological Technical Assistance Group Screening Levels

-- = No Risk Criteria Available

 = Concentration Above Soil Residential RBC

= Concentration Above Soil Industrial RBC

 = Concentration Exceeds BTAG Screening Level

 = Concentration Exceeds Site Background Values

^[1] = Chromium VI RBC value was used

^[2] = Lead criteria are Action Levels; see USEPA Region III guidance

^[3] = Mercuric chloride soil RBC value used

3.0 FIELD INVESTIGATION PROGRAM

The field investigation program for the RFI conducted at SWMUs 40 and 71 included geophysical investigations, soil investigations, and groundwater investigations as outlined in the following sections.

3.1 GEOPHYSICAL INVESTIGATIONS

Three geophysical surveys were conducted for the RFI conducted at SWMUs 40 and 71 including an initial survey by Geophex in May 2001, a follow-up survey by Argonne National Laboratories (ANL) in 2002, and a third survey by ATS International, Inc. in 2006 for RFI groundwater investigations.

3.1.1 Geophex Geophysical Survey – 2001

Geophex conducted geophysical investigations at the site in 2001 for URS, as part of the RFI work plan development. Magnetic and electromagnetic (EM) induction surveys were completed within an approximate 5.4 acre area to assess the lateral extent of the landfill area at the site. Based on interpretations of the magnetic and EM data, eight 2D-ERI profiles were completed at various orientations to evaluate the vertical extent of landfill areas and subsurface conditions. Natural gamma and EM induction logging was performed in 40MW2 and 40MW4 to assist with 2D-ERI profile interpretations. Geophysical results and interpretations are discussed in Section 2.6 and the report prepared by Geophex in May 2001 is provided in Appendix D.1.

3.1.2 Argonne National Laboratory Geophysical Survey – 2002

In August and September 2002, ANL completed follow-up geophysical surveys at the site to evaluate and refine geophysical models and interpretations presented in the 2001 Geophex Report; in particular with respect to probable thickness of landfill material and depth to bedrock. The ANL survey consisted of 2D-ERI, seismic refraction profiling (tomographic and earth-layer solutions), and vertical profiling (check shots). Additional borehole velocity measurements were collected in screened boreholes 40MW2 and 40MW4 to assist in guiding the seismic interpretations, and downhole electrical and natural-gamma logging surveying was collected by USACE staff to help constrain the resistivity models.

Both seismic and resistivity data were collected along Profile ANL L-2, which connected screened boreholes 40MW2 and 40MW4 and used the well log information as a basis for interpreting the geophysical data collected at the site. Seismic data were also collected along profile ANL L-1, which was tied to screened borehole 40MW2; these data were used as a tie line for Geophex profiles L-1 and L-8. 2D-ERI data were collected for profiles Geophex L-1 and Geophex L-8 to verify the geophysical models constructed by Geophex (2001). Interpretation of the resistivity models for reoccupied profiles L-1 and L-8 was based on results for lines ANL L-1 and L-2. Geophysical results and interpretations are discussed in Section 2.6 and the report prepared by ANL in April 2003 is provided in Appendix D.2.

3.1.3 ATS International Inc. Geophysical Survey – 2006

A 2D-ERI survey was conducted at the site for URS by ATS on December 11 and 12, 2006 as outlined in the geophysical investigation plan prepared by URS in 2006, with modifications for field conditions. The objectives of this geophysical investigation were to use 2D-ERI to: 1) evaluate local bedrock structures influencing groundwater flow and potential leachate migration from the landfill area, and 2) to identify optimal monitoring well locations and depth intervals for monitoring to intercept any potential leachate plume and to detect releases of hazardous constituents to groundwater.

Data from two resistivity lines were collected at the site. Line 1 was placed trending east to west on the north side of SMWU 40. Line 2 was placed trending north to south on the west side of the landfill area. These orientations were intended to provide optimum imaging of karst features and geologic structures at depth in the site vicinity, and to intercept the anticipated hydraulic gradient to the north and/or west towards the New River. Both dipole-dipole and pole-dipole electrode arrangements were used for both lines. Geophysical results and interpretations are discussed in Sections 2.6 and 2.7. A copy of the URS

Geophysical Report, which details the geophysical survey results, observed site conditions, and provides recommendations for monitoring well placement, is included in Appendix D.3. The ATS survey report is provided in Appendix D.3 – URS Geophysical Report (Appendix B).

3.2 SAMPLING AND ANALYSIS

The RFI sampling and analysis program is summarized in Table 3-1; this table identifies the boring locations, test pit locations, chemical and physical sample locations and depths, and analytical methods and parameters. Figure 3-1 shows the soil sample locations for the RFI. Figure 3-2 shows the groundwater monitoring wells sampled for the RFI.

3.2.1 Soil Borings, Test Pits, and Soil Sampling

A combination of surface soil sampling (21 locations), test pits (2 locations), and direct push borings (24 locations) were used to characterize soil and landfill conditions at SWMUs 40 and 71. Surface sample, soil boring, and test pit locations are shown on Figure 3-1 and summarized in Table 3-1. RFI soil investigations and associated samples for SWMU 40 are summarized in the following table.

Soil Sampling and Analysis for SWMU 40

Date	Type and Locations	Analytical Parameters	Comments
November 2002	Surface Soil Samples: 40SS1, 40SS2, and 40SS3 through 40SS5	TCL VOCs, TCL SVOCs, PAHs, TAL metals, explosives, TCL pesticides/PCBs	Evaluate surface soil conditions and overland runoff and mass transport to base of landfill where erosion gullies exist.
	Surface Soil Samples: 40SS4, 40SS5	TCL VOCs, TCL SVOCs, PAHs, TAL metals, explosives, TCL pesticides/PCBs, TCL dioxin furans	Evaluate surface soil conditions in area covered with cinder material.
	Direct Push Borings: 40SB1 through 40SB13	TCL VOCs, TCL SVOCs, PAHs, TAL metals, explosives, TCL pesticides/PCBs (selected samples), TCL dioxin furans (selected samples)	Characterize nature and extent of constituents in soil cover, landfill material, and subsurface soil.
	Direct Push Stratigraphic Borings: 40SB14, 40SB15	Stratigraphic borings, no chemical testing	Performed north of landfill area to obtain additional data on subsurface conditions and depth to bedrock

Date	Type and Locations	Analytical Parameters	Comments
	Test Pits: Test Pit 1 Test Pit 2	TCL VOCs, TCL SVOCs, PAHs, explosives, TCL pesticides/PCBs, TAL metals, TCL dioxin/furans (selected samples)	Evaluate characteristics of cover material over landfill material, landfill material, and soil below landfill material. Test Pit 1 – excavated to 13.7 ft depth Test Pit 2 – excavated to 4.5 to 13 ft depth
April 2006	Surface Soil Samples: 40SS6 through 40SS18	TCL PCBs, PCB congener (one sample)	Further evaluate the nature and extent of PCBs at base of landfill and overland migration.

Soil samples for chemical analysis were generally collected from four intervals, when landfill material was present in a boring, including: a surface sample (“A” sample), landfill material sample where present (“F” sample), intermediate depth sample (“B” sample), and terminal depth sample (“C” sample). Note that some “B” and “C” samples were also identified as landfill material. Surface samples were collected from 0 to 1 ft bgs. Landfill material samples were collected from discrete intervals ranging from 2 to 14 ft bgs, where landfill material was identified. Intermediate depth samples were collected from discrete intervals at depths ranging from 2 to 20 ft bgs. Terminal depth samples were collected from discrete intervals at depths ranging from 6 to 44 ft bgs. RFI soil investigations and associated samples for SWMU 71 are summarized in the following table.

Soil Sampling and Analysis for SWMU 71

Date	Type and Locations	Analytical Parameters	Comments
November 2002	Surface Soil Samples: 71SS11 through 71SS13	TCL VOCs, TCL SVOCs, PAHs, TAL metals, explosives, TCL pesticides/PCBs, TCL dioxin furans (selected samples)	Characterize nature and extent of chemicals in surface soil at SWMU 71.
November 2002	Direct Push Boring: 71SB11	TCL VOCs, TCL SVOCs, PAHs, TAL metals, explosives, TCL pesticides/PCBs, TCL dioxin furans (selected samples)	Further delineation of the nature and extent of chemicals in surface soil and subsurface soil.
April 2006	Direct Push Borings: 71SS11 through 71SS13 71SB13 through 71SB17	TCL PCBs, TAL metals, TPH, PCB congeners (one sample)	Further delineation of the nature and extent of PCBs, and metals in surface and subsurface soil at SWMU 71. Evaluate TPH concentrations in soil from previous flash burning.

For the initial RFI phase conducted in 2002, soil samples were analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), TCL semi-volatile organic compounds (SVOCs), polynuclear aromatic hydrocarbons (PAHs), explosives including nitroglycerin and pentaerythritol tetranitrate (PETN), and TAL metals. Selected samples were also analyzed for TCL pesticides, TCL polychlorinated biphenyls (PCBs), and TCL dioxin/furans. For the second phase of the RFI conducted in 2006, soil samples were analyzed for TCL PCBs at SWMUs 40 and 71, with samples at SWMU 71 also analyzed for TAL metals and total petroleum hydrocarbons (TPH) to further define the nature and extent of these chemicals in soil. PCB congener testing was also conducted on two of the PCB samples using EPA Method 1668 for the VDEQ list of 52 congeners. Refer to Table 3-1 for RFI boring and analyses information.

During the 2002 investigation, four soil samples were collected for physical testing of moisture content, pH, porosity, bulk density, total organic content, grain size analysis, Atterberg limits, and hydraulic conductivity (Table 2-1).

3.2.2 Monitoring Well Installation and Groundwater Sampling

In July 2007, monitoring wells 40MW5 and 40MW6 were installed at the site immediately north of the landfill area at SWMU 40 to evaluate potential releases to groundwater (Figure 3-2). As discussed in Section 2.7, these wells were placed at locations identified by the 2006 ATS geophysical survey as very low resistivity anomalies that would likely intercept karst drainage from the probable sinkhole buried beneath SWMU 40. Monitoring well construction data are summarized in Table 2-3.

One round of groundwater sampling was completed for the RFI in August 2007. Groundwater samples were collected from newly installed monitoring wells 40MW5 and 40MW6 and existing monitoring wells 17MW3 and 40MW3 located topographically upgradient and downgradient of the site, respectively. The groundwater sampling and analysis program is summarized in Table 3-1 and in the table below. Figure 3-2 shows the monitoring well locations that were sampled.

Monitoring Well Sampling and Analysis

Sampling Date	Monitoring Wells Sampled	Analytical Parameters
August 2007	17MW3 (U) 40MW3 (D) 40MW5 (LD) 40MW6 (LD)	TCL VOCs, TCL SVOCs, explosives with nitroglycerin and PETN, TCL pesticides/PCBs, perchlorate, and TAL metals (total and dissolved). Field water quality parameters: pH, temperature, specific conductance, dissolved oxygen, ORP, and turbidity.

Note: (U) = Upgradient, (LD) = Immediately Downgradient of Landfill, (D) = Downgradient.

3.3 QUALITY ASSURANCE

Quality Assurance (QA) planning defined the overall system of activities for assuring the reliability of data produced. The system integrated the quality planning, assessment, and corrective actions of various groups in the organization to provide the independent QA program necessary to establish and maintain an effective system for collection and analysis of environmental samples and related activities. The program encompasses the generation of complete data with its subsequent review, validation, and documentation.

The accuracy and integrity of RFI data were ensured through the implementation of internal quality control (QC) measures consistent with MWP Addendum 014 (URS 2002). QA and QC procedures, including field QC, laboratory QC, data management, and data validation, were integrated into the investigation program to meet data quality objectives (DQOs) established and approved for the RFI. The

data were evaluated for each of the DQO indicators and the results of this evaluation are presented in Appendix G.1. DQOs for the RFI were met.

3.4 INVESTIGATION METHODOLOGY

3.4.1 Geophysical Surveys

Geophysical investigation methods used for geophysical surveys conducted by Geophex, ANL, and ATS are discussed in detail in the investigation reports included in Appendices D.1, D.2, and D.3, respectively. 2D-ERI and magnetic geophysical surveys were also conducted with reference to the procedures outlined in SOPs 20.7 and 20.8, respectively.

3.4.2 Soil Sampling for Chemical Analysis

Surface and subsurface soil samples were collected for chemical analysis following the procedures outlined in standard operating procedure (SOP) 30.1 included in Appendix B and as described in Section 5.2 of the MWP (URS 2003).

The soil core interval was examined and classified by the site geologist and recorded in the field logbook and on the boring log consistent with SOPs 10.1 and 10.3, respectively (Appendix B). Soil was then extracted from the appropriate interval; sample containers were filled, labeled, and placed into coolers with ice and maintained at 4 degrees Celsius (°C).

Soil samples were collected from the borings using a tractor-mounted direct push rig (Geoprobe®). This rig was equipped with 1.25-inch diameter push rods, 4-ft long, 2-inch diameter, stainless steel closed solid barrel sampler (Macro-Core®) with a disposable liner and stainless steel cutting shoes. A percussion hammer was used to advance the sampling assembly. Following withdrawal of the Macro-Core® and removal of the liner, a cutting device was used to open the liner before inspection and processing of the sample cores.

Once the termination depth of the boring was reached and sample collection was completed, the borehole was backfilled with hydrated bentonite chips. Excess soil cuttings were temporarily accumulated in 55-gallon drums at the Installation-approved area for disposal as discussed in Section 3.4.7. Soil boring logs for the RFI are included in Appendix C.3.

3.4.3 Monitoring Well Installation and Development

Monitoring wells 40MW5 and 40MW6 were installed following the procedures outlined in SOP 20.1 (Appendix B) and as described in Section 5.2 of the MWP (URS 2003) for installation of multi-cased wells. These monitoring wells were installed using a truck mounted, air rotary drill rig. A 10-inch diameter roller bit was used to drill in overburden to the depth of bedrock. A 10-inch diameter air-hammer bit was then used to drill in bedrock to the target depth for installation of outer steel casing into competent bedrock. After the borehole was advanced to the target depth, a 6-inch steel diameter steel casing was lowered to the bottom of the boring (61 ft bgs in 40MW5 and 79 ft bgs in 40MW6). The casing was then grouted in-place by using a tremie pipe to inject grout into the annulus between the outer casing and borehole wall until undiluted grout reached the surface. The grout was then allowed to cure a minimum of 24 hours before further drilling inside the casing with a 5-5/8-inch air-hammer bit to the termination depth of the well boring. Boring logs were completed for each boring as described in SOP 10.3 (Appendix B) and drilling activities were documented in the field notebook as described in SOP 10.1 (Appendix B). Downhole drill rig tools and equipment were decontaminated before use at each location following SOP 80.1 (Appendix B).

Monitoring wells were constructed with 2-inch diameter, Schedule 40 polyvinyl chloride (PVC) 0.01-inch factory slotted screen and riser pipe with threaded joints. Twenty foot long screens were used for each well, with the screened positioned to intercept the depth and fracture zone where the first significant water was encountered during drilling. At 40MW5 and 40MW6, the first significant zones of encountered water in bedrock were 143 and 122 ft bgs, respectively. Monitoring wells 40MW5 and 40MW6 were

completed to a total depth of 157 and 135 ft bgs, respectively. Boring logs and construction diagrams for the monitoring wells are included in Appendix C.3. Monitoring well construction data are summarized in Table 2-3.

Prior to sampling, each of the monitoring wells was developed consistent with SOP 20.2 (Appendix B) and as described in Section 5.2 of the MWP (URS 2003). Initially, predevelopment of the wells was performed by airlifting techniques before final grouting and completion of the wells to remove accumulated fines and sediments. Three equivalent well volumes were removed from each monitoring well during predevelopment. Final development was completed after well completion and stabilization using a surge block, disposable bailer, and stainless steel, adjustable flow rate submersible pump with new disposable tubing. Development was continued at each monitoring well until a minimum of three equivalent well volumes were purged, water quality indicator parameters had stabilized, development water was clear to the unaided eye, and any remaining sediment had been removed from the well. Well development records are included in Appendix C.4.

3.4.4 Groundwater Sampling

Groundwater samples were collected for chemical analysis in accordance with SOP 30.2 (Appendix B) and as described in Section 5.2.10 of the MWP (URS 2003). Groundwater sampling information was recorded in the field logbooks as described in SOPs 10.1 and 10.2 (Appendix B). Groundwater sampling field data sheets are included in Appendix C.5.

Low flow purging and sampling techniques were used to collect the groundwater samples from monitoring wells 17MW3, 40MW3, and 40MW6. Initial purging in these monitoring wells was at a rate greater than 1,000 milliliters per minute (ml/minute) but was reduced to low flow purging (500 ml/min) or less to minimize excessive drawdown. Well 40MW5 was initially purged at a rate greater than 1,000 milliliters per minute (ml/min) but then was reduced to a low flow purge rate of 500 ml/min or less to minimize excessive drawdown. 40MW5 was screened across a single discrete water-producing zone (fracture) encountered during drilling at 143 ft. The sustainable yield of the wells with minimal drawdown is generally 500 ml/min or less. Pumping at a higher rate would result in excessive drawdown and likely eventual drying of the wells. As indicated in Section 2.7.2, monitoring wells 40MW5 and 40MW6 are screened across discrete water bearing fractures encountered at depths of 143 and 122 ft bgs, respectively. Monitoring wells 17MW3 and 40MW3 are screened across discrete water bearing zones encountered at depths of approximately 167 ft and 90 ft, respectively.

Groundwater sampling followed the procedures outlined in Section 3.3 of SOP 30.2 (Appendix B). Equipment used to purge and sample wells was thoroughly decontaminated before and after use following SOP 80.1 (Appendix B). All equipment used for monitoring water quality parameters was calibrated before use according to the manufacture's instructions and SOP 40.1 (Appendix B). Prior to the sampling round, the depth to water was measured at each well to the nearest 0.01 ft using an electronic water level indicator in accordance with SOP 40.2. Calibration and measurement data were recorded in the field logbook.

A stainless steel, adjustable flow rate submersible pump, and new disposable tubing were used to collect the groundwater samples. The pump tubing was connected to an in-line flow-through cell and the multi-parameter meter probe was connected to the flow cell to monitor water quality parameters during purging. Pumping was started and the pump rate was adjusted to cause minimal drawdown (less than 0.2 ft if possible). A Horiba Model U-22 multi-parameter water quality meter was used to monitor pH, specific conductance, temperature, ORP, dissolved oxygen, and turbidity during purging. Purging was continued until parameter stabilization was achieved. Once purging was complete, the pumping rate was reduced to its lowest steady rate and the in-line flow cell was disconnected from the tubing to allow for sampling from the tubing directly into sample containers provided the laboratory.

Groundwater samples were collected and containerized in the order of volatilization sensitivity of the parameters. Filtered and unfiltered samples were collected for metals analysis. Metals samples were filtered with an in-line high capacity 0.45-micron disposable filter. The appropriate sample containers were filled, labeled, and placed into coolers with ice and maintained at 4 °C.

3.4.5 Water Quality Measurements

Field water quality measurements were collected consistent with SOP 40.1(Appendix B) using a Horiba Model U-22 multi-parameter water quality meter. Prior to its use each day, the meter was calibrated according to the manufacturer's instructions.

3.4.6 Site Surveying

Anderson and Associates, Inc. completed a topographic survey of the site as part of the RFI. Planned sampling locations and other site features were surveyed prior to completion of the field investigation. At the conclusion of the field investigations, the locations and elevations of samples, borings, and test pits were also obtained using a Trimble Pathfinder Pro XRS® global positioning system (GPS). Offsets of planned boring and test pit locations (40SB13, 40SB14, 40SB15, and Test Pit 2) related to previous surveyed locations were located with the GPS unit. The GPS unit was also used for the geophysical surveys conducted at the site. In 2007, Draper Aden completed a survey of new monitoring wells 40MW5 and 40MW6 and existing wells 17PZ1, 17MW2, 17MW3, and 40MW3.

Surveying was conducted using the U.S. State [Virginia (South Zone)] Plane Coordinate System (measured in U.S. survey ft) using the North American Datum 1983. Vertical elevations at the site were surveyed to the nearest 0.01 ft using the National Vertical Datum of 1988. Sample location coordinates, elevations, and survey data are included in Appendix C.6.

3.4.7 Investigation-Derived Material (IDM) Management

IDM management activities were conducted consistent with the procedures outlined in WPA 013 (URS 2003) and documented in the field logbook, and conducted as described below.

3.4.7.1 Accumulation

IDM accumulated during field sampling activities conducted in 2002 included the following materials and containers:

- Soil cuttings – two 55-gallon drums;
- Personal protective equipment (PPE), probe liners, and plastic sheeting – eight 55-gallon drums;
- Decontamination and purge water – Fifteen 55-gallon drums; and
- Test pit material – two 30 cubic yard roll off containers (Containers No. 1 and No. 2).

IDM accumulated during monitoring well installation and groundwater sampling activities conducted in 2007 including the following materials and containers:

- Soil cuttings – twenty one 55-gallon drums;
- Personal protective equipment (PPE), plastic sheeting, and miscellaneous disposable supplies – four 55-gallon drums; and
- Decontamination, drilling water, development water, and purge water – twenty three 55-gallon drums.

IDM accumulation and labeling was conducted as outlined in MWP SOP 70.1 (Appendix B). Drums were transferred to the Installation's approved container accumulation area at SWMU 17. The roll off containers were covered and staged at the site while this IDM was on hold pending analysis for characterization and disposal.

3.4.7.2 Material Characterization

IDM characterization samples were collected for each set of containerized soil cuttings and PPE generated during the 2002 and 2007 investigations. One characterization sample was also collected from each roll off container holding test pit material. IDM was characterized to evaluate whether it was a RCRA characteristic hazardous waste as described in Part 40 of the Code of Federal Regulations (CFR) Part 261, Subpart C (as referenced in the Virginia Hazardous Waste Management Regulations).

The analytical results for the IDM characterization samples indicated the soil cuttings, water, and the materials in roll off container No. 2 were non-hazardous material. Analyses indicated material in roll off container No. 1 exhibited the RCRA hazardous waste characteristic of toxicity for lead; therefore, Facility personnel classified this material as a hazardous waste (hazardous waste code D008, lead). IDM sample results are presented in Appendix C.7.

3.4.7.3 Transportation and Disposal

Before disposal, waste analytical results were provided to the Installation, IDM management subcontractor, and the disposal facilities for review and approval. Manifests were reviewed and signed by Installation personnel prior to loading and transport of the IDM. The Installation maintains a record of the manifests and related information including analytical testing results and waste profiles.

First Piedmont transported the non hazardous soil drums and the non hazardous material in roll off container No. 2 to the First Piedmont Landfill in Chatham, Virginia. Freehold Cartage, Inc. transported the 20.5 tons of hazardous waste in roll-off container No. 1 to Perma Fix of Michigan, Inc. in Brownsville, Michigan.

3.4.7.4 Decontamination Water

Following the waste characterization sample analysis, the Installation and RFAAP Process Water Treatment Plant engineers were provided a copy of the water IDM sample results and groundwater sample results. After receiving Plant approval, decontamination water and purge water were discharged into the collection system of the Process Water Treatment Plant.

3.5 WORK PLAN FIELD CHANGES

In some cases, deviations to the Work Plan were necessary to adjust for field conditions as they occurred during field sampling.

3.5.1 Soil and Test Pit Investigations

Specific deviations to the Work Plan for soil and test pit investigations included the following:

- One additional test pit (Test Pit No. 2) was completed near the southern periphery of SWMU 40 to further evaluate the southern extent of buried material and its nature. Two samples for chemical analysis were collected from Test Pit No. 2; and
- Two additional soil borings (40SB14 and 40SB15) were completed northeast of SWMU 40 to obtain additional geologic data on the nature of subsurface conditions in this area including the depth to bedrock.
- The number of samples specified in the WPA for chemical analysis at boring and test pit locations was conditional based on the whether fill material was present in the boring, depth to bedrock refusal, and nature of material encountered. Thus, depending on conditions encountered at a soil boring, the number of soil samples collected at each location varied from 2 to 4 samples.

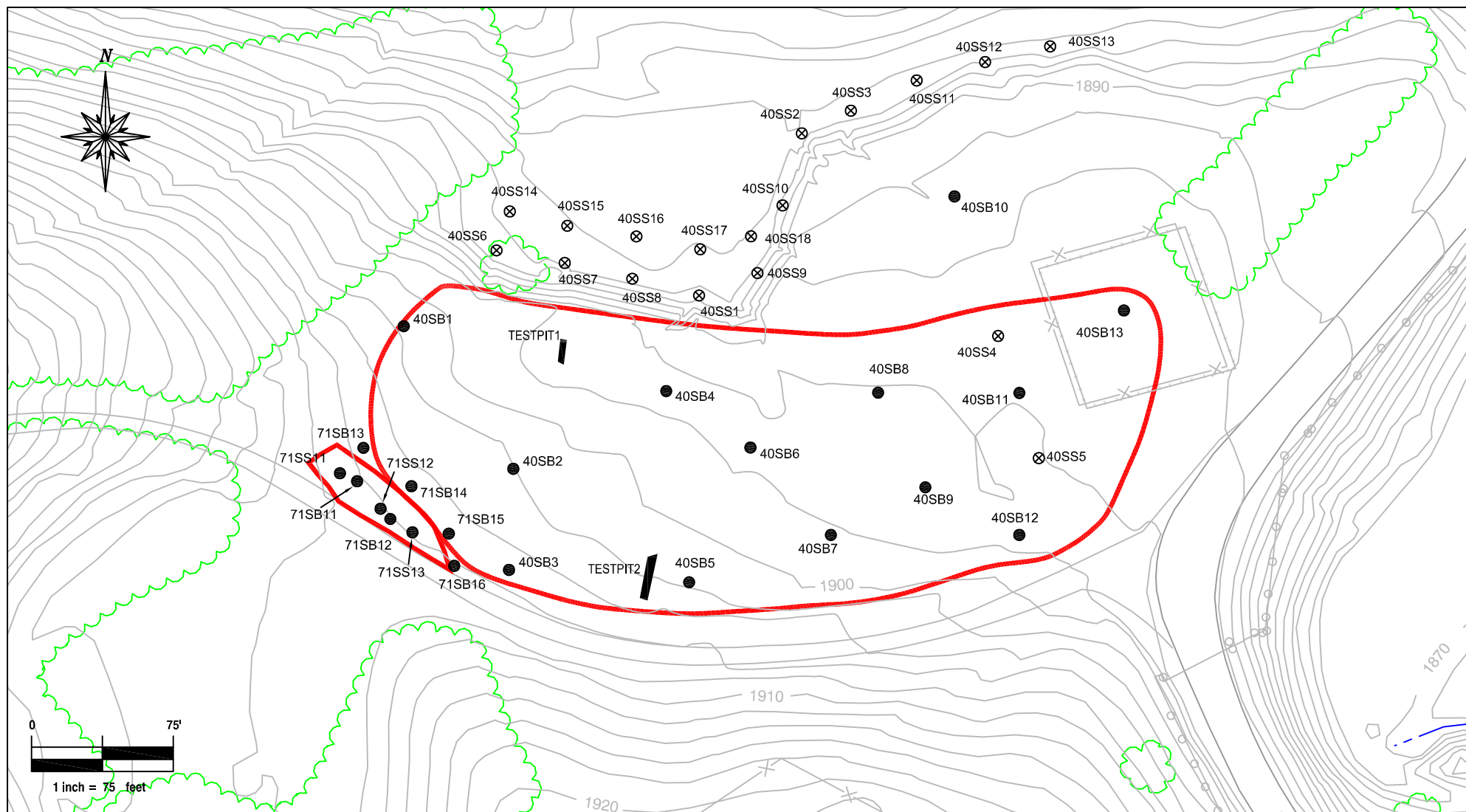
3.5.2 ATS Geophysical Investigation - 2006

The ATS geophysical survey conducted in 2006 was modified from the URS Geophysical Investigation Plan (URS 2006) due to encountered field conditions. A two-phased approach was originally to be used

for the survey, varying the electrode spacing and length of lines. However, this approach had to be modified due to limited space at the site, and therefore, a single set of high resolution lines was used with electrodes spaced at 5 meters; the lines were also extended to the maximum length the site would reasonably allow. This also had the advantage of reducing the survey time by removing the step of removal and repositioning electrodes from the low to high resolution configuration. The additional desired depth imaging was then acquired with a second pole-dipole array. Task objectives were met using both dipole-dipole and pole-dipole electrode arrangements for both lines placed at maximum length.

The planned location of Line 2 also had to be moved just west from the proposed location to maintain a straight line orientation around the fenced metals and drum storage area.

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Legend

- SWMU Boundary
- Test Pit Location
- Soil Boring Location
- ⊗ Surface Soil Sample Location

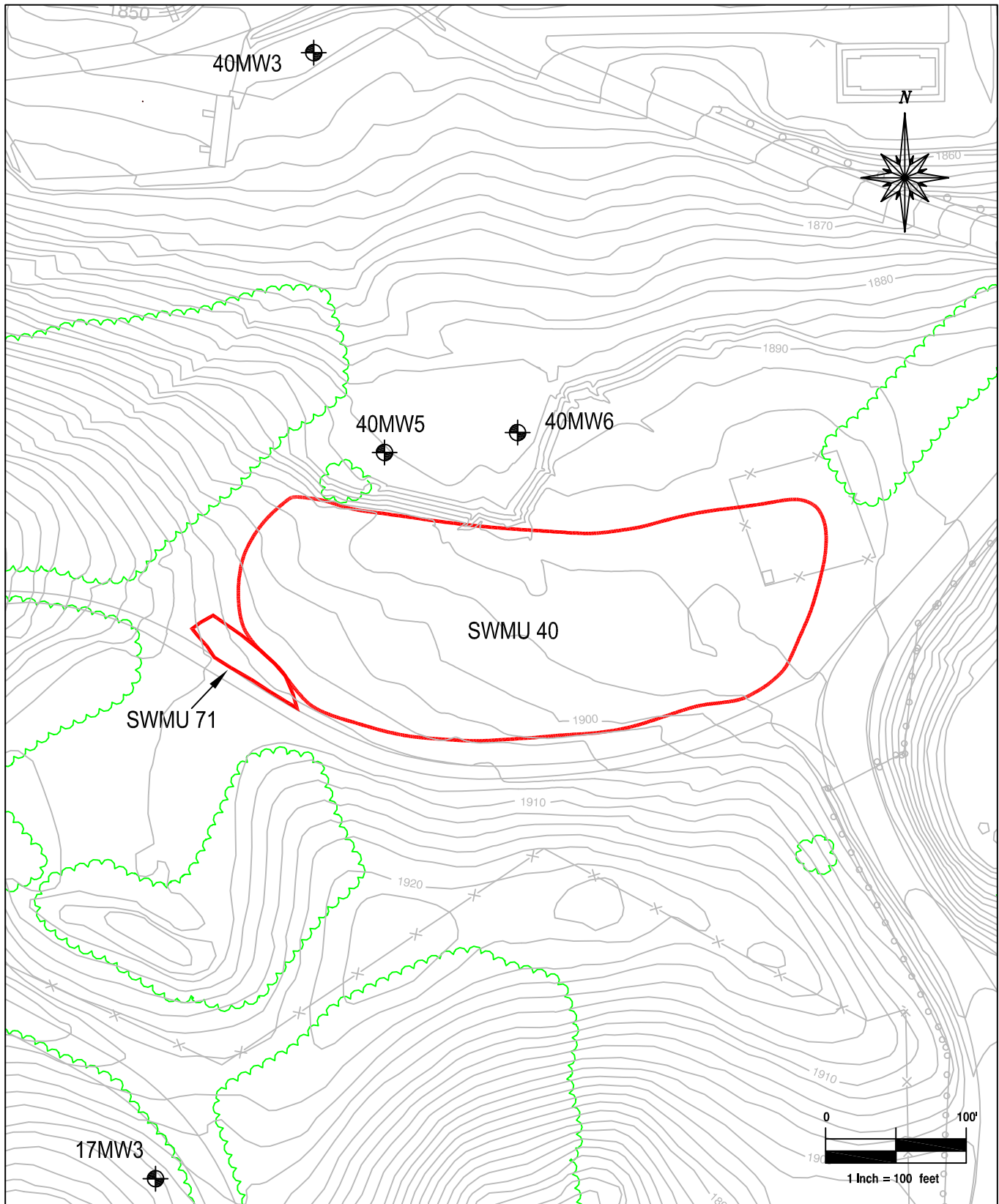
FIGURE 3-1

Soil Sample Locations

Date: February 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.3-1 SS&SB Locs

SWMUs 40 and 71

RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia



Legend

- Approximate SWMU Boundary
- Topographic Contour
- Vegetation
- x x Fence
- ⊕ Monitoring Well Location

FIGURE 3-2
Groundwater Sample Locations

Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 100 feet	File Name: Fig.3-2 GW Locs

SWMUs 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia

URS URS Group, Inc.
5540 Falmouth Street
Suite 201
Richmond, Virginia 23230

Table 3-1
Field Sample Identifiers, Depths, and Analytical Methods
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID	Date	Time	Depth (ft bgs)	Chemical Analysis																	Physical Analysis							
				TAL Metals/Hg (Unfiltered) SW-846 6010B/6020A/7471A	TAL Metals/Hg (Filtered) SW-846 6010B/6020A/7471A	DRO/GRO EPA 8015B	Pesticides SW-846 8081A	PCBs SW-846 8082	VOCs SW-846 8260B	SVOCs SW-846 8270C	Dioxin/Furans SW-846 8290	PAHs SW-846 8310	Explosives/Nitroglycerin SW-846 8308/8332	Perchlorate EPA 6850	TCLP Full List	Chemical Oxygen Demand EPA 410.4	pH SW-846 9040B	9010 Ignitability SW-846 Method	Paint Filter Test SW-846 9095	Total Organic Content ASTM D2974	Grain Size ASTM D422	Atterburg Limits ASTM D4318	Moisture Content ASTM D2216	pH ASTM D4972	Hydraulic Conductivity ASTM D5084	Soil Porosity ASTM D4972	Soil Bulk Density ASTM D4253	
SWMU 40 - Landfill Sampling																												
40SB1A	11/15/2002	945	0-1	X			X	X	X	X		X	X															
40SB1B	11/15/2002	1100	7-9	X				X	X	X		X	X															
40SB1C	11/15/2002	1115	9-10	X				X	X	X		X	X															
40SB1F	11/15/2002	1000	4-8	X				X	X	X		X	X															
40SB1F-DUP	11/15/2002	1000	4-8	X				X	X	X		X	X															
40SB2A	11/15/2002	830	0-1	X			X	X	X	X		X	X															
40SB2B	11/15/2002	900	12-13	X				X	X	X		X	X															
40SB2C	11/15/2002	915	13-15	X				X	X	X		X	X															
40SB2F	11/15/2002	845	8-12	X				X	X	X		X	X															
40SB3A	11/14/2002	1445	0-1	X			X	X	X	X		X	X															
40SB3B	11/14/2002	1500	4-8	X			X	X	X	X		X	X															
40SB3C	11/14/2002	1530	8-8.9	X				X	X	X		X	X															
40SB4A	11/14/2002	945	0-1	X			X	X	X	X		X	X					X	X	X	X	X			X			
40SB4B	11/14/2002	1045	20-24	X				X	X	X		X	X															
40SB4C	11/14/2002	1315	42-44.75	X				X	X	X		X	X					X	X	X	X	X			X			
40SB4C-DUP	11/14/2002	1315	42-44.75	X				X	X	X		X	X															
40SB4F	11/14/2002	1000	4-12	X				X	X	X		X	X															
40SB4F-DUP	11/14/2002	1000	4-12	X				X	X	X		X	X															
40SB5A	11/14/2002	845	0-1	X			X	X	X	X		X	X															
40SB5C	11/14/2002	920	8-9	X				X	X	X		X	X															
40SB5F	11/14/2002	900	4-8	X				X	X	X		X	X															
40SB6A	11/13/2002	1400	0-1	X			X	X	X	X		X	X															
40SB6C	11/13/2002	1430	12-16	X				X	X	X		X	X															
40SB6F	11/13/2002	1415	6-8	X				X	X	X		X	X															
40SB7A	11/13/2002	1100	0-1	X			X	X	X	X		X	X															
40SB7B	11/13/2002	1145	17-20	X				X	X	X		X	X															
40SB7C	11/13/2002	1200	20-20.7	X				X	X	X		X	X															
40SB7F	11/13/2002	1120	12-14	X				X	X	X		X	X															
40SB7F-DUP	11/13/2002	1120	12-14	X				X	X	X		X	X															
40SB8A	11/13/2002	1000	0-1	X			X	X	X	X		X	X															
40SB8C	11/13/2002	1030	20-25	X				X	X	X		X	X															
40SB8F	11/13/2002	1015	6.5-20	X				X	X	X		X	X															
40SB9A	11/13/2002	845	0-1	X			X	X	X	X		X	X					X		X	X	X			X			
40SB9C	11/13/2002	930	16-20	X				X	X	X		X	X															
40SB9F	11/13/2002	755	8-10	X				X	X	X		X	X															
40SB10A	11/13/2002	800	0-1	X			X	X	X	X		X	X															
40SB10B	11/13/2002	820	10-12	X				X	X	X		X	X															
40SB10C	11/13/2002	830	12-15	X				X	X	X		X	X															
40SB10F	11/13/2002	810	3-6	X				X	X	X		X	X															
40SB11B	11/12/2002	1030	13-16	X			X	X	X	X		X	X															
40SB11C	11/12/2002	1100	20-25.8	X			X	X	X	X		X	X															
40SB11F	11/12/2002	1000	2-4	X			X	X	X	X		X	X															
40SB12A	11/11/2002	1420	0-1	X			X	X	X	X		X	X															
40SB12B	11/11/2002	1450	8-11	X				X	X	X		X	X															
40SB12C	11/11/2002	1515	23-27	X				X	X	X		X	X															
40SB13A	11/19/2002	915	0-1	X			X	X	X	X		X	X															
40SB13B	11/19/2002	930	4-5	X				X	X	X		X	X															
40SB13C	11/19/2002	945	5-6	X				X	X	X		X	X															
40SB13C-DUP	11/19/2002	945	5-6	X				X	X	X		X	X															
71SB14A	4/20/2006	1650	0-0.5	X		X		X																				
71SB14B	4/20/2006	1655	2.5-3	X		X		X																				
71SB14C	4/21/2006	1100	7	X		X		X																				
71SB15A	4/21/2007	1015	0-1	X		X		X																				
71SB15A-DUP	4/21/2007	1015	0-1	X		X		X																				
71SB15B	4/21/2007	1030	4-5	X		X		X																				

Table 3-1
Field Sample Identifiers, Depths, and Analytical Methods
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID	Date	Time	Depth (ft bgs)	Chemical Analysis																Physical Analysis							
				TAL Metals/Hg (Unfiltered) SW-846 6010B/6020A/7471A	TAL Metals/Hg (Filtered) SW-846 6010B/6020A/7471A	DRO/GRO EPA 8015B	Pesticides SW-846 8081A	PCBs SW-846 8082	VOCs SW-846 8260B	SVOCs SW-846 8270C	Dioxin/Furans SW-846 8290	PAHs SW-846 8310	Explosives/Nitroglycerin SW-846 8330/8332	Perchlorate EPA 6850	TCLP Full List	Chemical Oxygen Demand EPA 410.4	pH SW-846 9040B	9010 Ignitability SW-846 Method	Paint Filter Test SW-846 9095	Total Organic Content ASTM D2974	Grain Size ASTM D422	Atterburg Limits ASTM D4318	Moisture Content ASTM D2216	pH ASTM D4972	Hydraulic Conductivity ASTM D5084	Soil Porosity ASTM D4972	Soil Bulk Density ASTM D4253
71SB15C	4/21/2007	1045	7-8	X		X		X																			
TESTPIT1F	11/20/2002	1110	5	X			X	X	X	X		X	X														
TESTPIT1F2	11/20/2002	1230	13	X			X	X	X	X		X	X														
TESTPIT2F	11/20/2002	1400	6	X			X	X	X	X	X		X	X													
TESTPIT2BP	11/20/2002	1500	11	X			X	X	X	X		X	X														
40SS1	11/11/2002	1200	0-1	X			X	X	X	X		X	X														
40SS2	11/11/2002	1140	0-1	X			X	X	X	X			X	X													
40SS3	11/11/2002	1120	0-1	X			X	X	X	X		X	X														
40SS4	11/11/2002	900	0-1	X			X	X	X	X	X		X	X													
40SS5	11/11/2002	1015	0-1	X			X	X	X	X	X		X	X													
SWMU 40 RFI Additional Sampling																											
40SS6	4/21/2007	1555	0-1						X																		
40SS7	4/21/2007	1545	0-1						X																		
40SS8	4/21/2007	1520	0-1						X																		
40SS9	4/21/2007	1500	0-1						X																		
40SS9-DUP	4/21/2007	1500	0-1						X																		
40SS10	4/21/2007	1620	0-1						X																		
40SS11	4/21/2007	1630	0-1						X																		
40SS11-DUP	4/21/2007	1630	0-1						X																		
40SS12	4/21/2007	1645	0-1						X																		
40SS13	4/21/2007	1650	0-1						X																		
40SS14	4/21/2007	1550	0-1						X																		
40SS15	4/21/2007	1535	0-1						X																		
40SS16	4/21/2007	1530	0-1						X																		
40SS17	4/21/2007	1515	0-1						X																		
40SS18	4/21/2007	1600	0-1						X																		
SWMU 40 - Groundwater																											
17MW3	8/13/2007	1805	--	X	X		X	X	X	X			X	X													
40MW3	8/14/2007	1300	--	X	X		X	X	X	X			X	X													
40MW5	8/15/2007	1215	--	X	X		X	X	X	X			X	X													
40MW5-DUP	8/15/2007	1215	--	X	X		X	X	X	X			X	X													
40MW6	8/14/2007	1940	--	X	X		X	X	X	X			X	X													
SWMU 71 - Flash Burn Area Sampling																											
71SB11A	11/11/2002	940	0-1	X			X	X	X	X		X	X														
71SB11F	11/18/2002	1145	1.4-2	X				X	X	X		X	X														
71SB11B	11/18/2002	1210	2-4.5	X				X	X	X	X	X	X					X	X	X	X	X					
71SB11C	11/18/2002	1230	6-7	X				X	X	X		X	X														
71SS11	11/11/2002	1445	0-1	X			X	X	X	X	X	X	X														
71SS12	11/11/2002	1515	0-1	X			X	X	X	X		X	X														
71SS12-DUP	11/11/2002	1515	0-1	X			X	X	X	X		X	X														
71SS13	11/18/2002	1000	0-1	X			X	X	X	X	X	X	X														
SWMU 71 RFI Additional Sampling																											
71SB12A	4/20/2007	1715	0-1	X		X		X																			
71SB12B	4/20/2007	1730	3-4	X		X		X																			
71SB12C	4/20/2007	1745	5-6	X		X		X																			
71SB13A	4/20/2006	1550	0-1	X		X		X																			
71SB13B	4/20/2006	1615	5-6	X		X		X																			
71SB13C	4/20/2006	1630	8-9	X		X		X																			
71SB16A	4/21/2007	930	0-1	X		X		X																			
71SB16B	4/21/2007	945	2.5-3.5	X		X		X																			
71SB16C	4/21/2007	1000	4-5	X		X		X																			
71SS11B	4/20/2006	1800	2-3	X		X		X																			
71SS11B-DUP	4/20/2006	1800	2-3	X		X		X																			
71SS12B	4/20/2007	1330	10.2-11.2	X		X		X																			
71SS13B	4/20/2007	1915	6-7	X		X		X																			

Table 3-1
Field Sample Identifiers, Depths, and Analytical Methods
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID	Date	Time	Depth (ft bgs)	Chemical Analysis																Physical Analysis							
				TAL Metals/Hg (Unfiltered) SW-846 6010B/6020A/7471A	TAL Metals/Hg (Filtered) SW-846 6010B/6020A/7471A	DRO/GRO EPA 8015B	Pesticides SW-846 8081A	PCBs SW-846 8082	VOCs SW-846 8260B	SVOCs SW-846 8270C	Dioxin/Furans SW-846 8290	PAHs SW-846 8310	Explosives/Nitroglycerin SW-846 8350/8352	Perchlorate EPA 6850	TCLP Full List	Chemical Oxygen Demand EPA 410.4	pH SW-846 9040B	9010 Ignitability SW-846 Method	Paint Filter Test SW-846 9095	Total Organic Content ASTM D2974	Grain Size ASTM D422	Atterburg Limits ASTM D4318	Moisture Content ASTM D2216	pH ASTM D4972	Hydraulic Conductivity ASTM D5084	Soil Porosity ASTM D4972	Soil Bulk Density ASTM D4253
IDM Samples																											
40/71 IDM50	11/22/2002	1230	--												X		X	X	X								
40/71 IDMWA	11/22/2002	1245	--												X		X	X	X								
40/71 TP1IDM1	11/21/2002	1030	--												X		X	X	X								
40/71 TP1IDM2	11/21/2002	1045	--												X		X	X	X								
40/71 TP2IDM1	11/21/2002	1100	--												X		X	X	X								
SWMU 40 IDM Water	8/23/2007	0930	--												X	X	X										
SWMU 40 IDM Soil	8/23/2007	0940	--												X		X		X								

Notes:

ft bgs = Feet Below Ground Surface
DUP = Duplicate sample
EPA = U.S. Environmental Protection Agency
SB = Soil Boring
SS = Surface Soil
GW = Groundwater
MW = Monitoring Well

TAL = Target Analyte List
PCB =Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
RFI = RCRA Facility Investigation
TCLP = Toxicity Characteristic Leaching Procedure

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4.0 NATURE AND EXTENT OF CHEMICALS

The following sections discuss the results of chemical sampling of soil and groundwater at the site and assess the nature and extent of detected chemicals in site media. Chemical results are evaluated with respect to the following: USEPA Region III R-RBCs and industrial RBCs (I-RBCs) for soil, and tap water RBCs (T-RBCs) (USEPA 2007a), which are adjusted downward for non-carcinogenic chemicals to a hazard quotient (HQ) of 0.1 to account for potential additive toxicity effects of multiple chemicals; USEPA Region III soil transfer-to-groundwater screening levels (SSLs, dilution attenuation factor (DAF)20 default values); the most current USEPA Region III ecological soil screening levels (as presented in Section 7.0); USEPA maximum contaminant levels (MCLs) for groundwater; and facility-wide background concentrations for metals in soil as provided below (IT 2001).

Facility-Wide Point Estimates for Soil

Chemical	Minimum Concentration (mg/kg)	Maximum Concentration (mg/kg)	95% Upper Tolerance Limit (UTL) of the Mean (mg/kg)
Aluminum	3,620	47,900	40,041
Arsenic	1.2	35.9	15.8
Barium	23.4	174	209
Beryllium	0.61	5.4	1.02
Cadmium	0.62	2.5	0.69
Chromium	6.3	75.8	65.3
Cobalt	5.9	130	72.3
Copper	1.6	38.7	53.5
Iron	7,250	67,700	50,962
Lead	2.1	256	26.8
Manganese	16.7	2,040	2,543
Mercury	0.038	1.2	0.13
Nickel	4.6	94.2	62.8
Thallium	1.3	5	2.11
Vanadium	12.2	114	108
Zinc	4.7	598	202

SWMUs 40 and 71 are evaluated separately for the soil nature and extent assessment due to their different characteristics and disposal histories. Groundwater sample results are evaluated on a site-wide basis for characterizing the nature and extent of dissolved phase COPCs in groundwater. With the exception of metals in soil, chemicals detected in one or more samples in a given medium at concentrations above their adjusted RBCs, SSL DAF20s, or ecological screening level are identified in the nature and extent assessment as COPCs. Metals in soil detected at concentrations above their background point estimates and an adjusted RBC, SSL DAF20, or ecological screening levels are retained as COPCs in the nature and extent assessment. The facility-wide background concentrations are used in the nature and extent assessment to evaluate the significance of background exceedances in soil and to assist in bounding the lateral and vertical extent of metals concentrations potentially attributable to historical site activities. Additional chemical specific screening information is provided below.

Dioxin/furans were detected at the sites. Dioxin/furan results were converted into one total 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) toxicity equivalents concentration (TEQ) using the Toxicity Equivalent Factors (TEF) method outlined in *Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs)* (USEPA 1989a and WHO 2005). The TEQ concentration for each sample was then compared to the appropriate media specific screening level. TEQ calculations are provided in Section 6.0 for SWMU 40 and SWMU 71 on Table 6-2. Similarly for the ecological assessment, dioxin/furan results were converted into one total 2,3,7,8-TCDD TEQ for each sample and then compared to the appropriate receptors specific screening values as presented Table 7-7 for SWMU 40 and Table 7-11 for SWMU 71.

Note that if a constituent was measure by two methods, results from the more sensitive analytical method were used. For example, if PAHs were analyzed as part of the SVOC method (Method 8270C), as well as, by a PAH specific method (Method 8310), the results from the PAH specific method were used. This also applies to explosives by Method 8330. If a PAH was detected by Method 8310 above a screening level but it was not detected by low level 8270C, the detection was not confirmed; therefore, the detection is not considered an exceedance of the screening level for the nature and extent assessment.

4.1 NATURE AND EXTENT – SWMU 40 SOIL

4.1.1 Analytical Results

Thirty-two surface soil samples, 16 buried material, and 24 subsurface soil samples for a total of 72 samples were collected for chemical analysis from SWMU 40 (Figure 3-1 and Table 3-1). Table 4-1 presents analytical results for chemicals detected in soil samples collected at SWMU 40 and screens these data with respect to adjusted RBCs, SSLs, and background concentrations. Table 4-2 (Surface Soil/Landfill Soil Cover), Table 4-3 (Landfill Material), Table 4-4 (Soil below Landfill Material/Subsurface Soil), and Table 4-5 (Total Soil) summarize the screening results for soil data including: constituents detected, minimum and maximum concentrations detected, number of detections, number of samples, and number of samples exceeding human health screening criteria or SSL DAF20 screening levels and background concentrations (inorganics only). Chemicals of potential ecological concern (COPECs) listed below were identified for the site as part of the ecological risk characterization presented in Section 7.2.3. The screenings resulted in the identification of the following COPCs, as presented in Table 4-5, and COPECs (note that chemical which exceeded both its adjusted R-RBC and I-RBC are italicized):

TAL Metals (Methods 6010B, 6020A, 7471A) – 23 TAL metals were detected in soil samples with the following screening level and background point estimate (if available) exceedances:

RBC – aluminum, antimony, *arsenic*, cadmium, chromium, *copper*, *iron*, *lead*, mercury, zinc;
SSL – arsenic, chromium, copper, zinc; and
Eco – calcium, mercury, and selenium.

TCL Pesticides (Method 8081A) – 13 pesticides were detected in soil samples with the following screening level exceedances:

RBC – none;
SSL – alpha-BHC, beta-BHC, gamma-BHC (Lindane); and
Eco – none.

TCL PCBs (Method 8082) – 6 PCBs were detected in soil samples with the following screening level exceedance:

RBC – Aroclor 1242, Aroclor 1254, Aroclor 1260;
SSL – Aroclor 1254; and
Eco – none.

TCL VOCs (Method 8260B) – 32 VOCs were detected in soil samples with the following screening level exceedances:

RBC – none;

SSL – 1,2-dibromo-3-chloropropane, 1,4-dichlorobenzene, benzene, chlorobenzene, methylene chloride, trichloroethene (TCE), vinyl chloride; and

Eco – none.

TCL SVOCs (Method 8270C) – 19 SVOCs were detected in soil samples with the following screening level exceedances:

RBC – none;

SSL – N-nitrosodiphenylamine; and

Eco – naphthalene.

PAHs (Method 8310) – 16 PAHs were detected in soil samples with the following screening level exceedances:

RBC – benzo(a)anthracene, *benzo(a)pyrene*, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene (Note: benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene detections not confirmed by low-level 8270C analysis);

SSL – benzo(a)anthracene, benzo(a)pyrene, naphthalene; and

Eco – none.

Explosives (Method 8330) and Nitroglycerin (Method 8332) – Nitroglycerin was detected in soil samples with the following screening level exceedances:

RBC – *nitroglycerin*;

SSL – none; and

Eco – none (no screening values available for explosives).

Dioxin/Furans (Method 8290) – Dioxin/furans were detected in soil samples with the following screening level exceedance:

RBC – 2,3,7,8-TCDD TEQ;

SSL – 2,3,7,8-TCDD TEQ; and

Eco – none.

4.1.2 Human Health Nature and Extent Assessment

A summary of the human health risk and background screening results for COPCs is presented in the table below.

Summary of COPCs for Soil

Chemical	Total # of Det/# of Samples	# of R-RBC/I-RBC Exceed.	Sample Exceedances		
			Surface Soil/Landfill Soil Cover	Landfill Material	Subsurface Soil /Soil Below Landfill Material
Aluminum	59/59	1/0	NA	NA	40SB10B
Antimony	43/55	2/0	NA	71SB15B, 71SB15C	NA
Arsenic	58/59	6/6	40SB1A, 71SB14A	40SB1F DUP AVG, 40SB4F DUP AVG, TestPit2F, 71SB15C	NA
Cadmium	36/59	1/0	NA	71SB15B	NA
Chromium	59/59	4/0	NA	40SB8F, 71SB15C	40SB10B, 40SB12B
Copper	57/58	2/1	NA	71SB15B, 71SB15C	NA
Iron	59/59	2/1	NA	40SB1F DUP AVG, 40SB4F DUP AVG	NA
Lead	59/59	1/1	NA	71SB15C	NA
Mercury	52/59	3/0	NA	40SB4F DUP AVG, 71SB14B, 71SB15B	NA
Zinc	59/59	1/0	NA	71SB15C	NA
Aroclor 1242	1/72	1/1	NA	40SB9F	NA
Aroclor 1254	45/72	22/4	40SB1A, 40SB12A, 40SS1, 40SS3, 40SS7, 40SS8, 40SS16, 40SS17, 71SB14A	40SB1F DUP AVG, 40SB4F DUP AVG , 40SB5F, 40SB7F DUP AVG, 40SB8F, TestPit1F, TestPit1F2, TestPit2F, 71SB14B, 71SB14C, 71SB15B, 71SB15C	40SB8C
Aroclor 1260	20/72	4/0	40SS7	40SB1F DUP AVG, 40SB4F DUP AVG	40SB13B
Benzo(a)pyrene*	20/53	3/0	40SS2, 40SS3, 40SS5	NA	NA
Dibenz(a,h)anthracene*	7/53	1/0	40SS5	NA	NA
Nitroglycerin	1/53	1/1	NA	TestPit1F	NA
DRO/GRO	6/6	3/0	NA	71SB14C, 71SB15B, 71SB15C	NA
2,3,7,8-TCDD TEQ	3/3	2/0	40SS4	TestPit2F	NA

Notes: NA=Not Applicable, DUP AVG = Duplicate Average, *Detections confirmed by both low-level 8270C and 8310 analysis, **Bold**=Sample Exceeds adjusted R-RBC and I-RBC

The nature and extent of COPCs identified in the above table, as well as SSL DAF 20 exceedances (above background concentrations for inorganics) identified in Section 4.1.1 and presented on Table 4-2 (Surface Soil/Landfill Soil Cover), Table 4-3 (Landfill Material), and Table 4-4 (Soil below landfill Material/Subsurface Soil), is discussed further in the following sections for the surface soil/soil cover, landfill material, and soil below landfill material/subsurface soil.

4.1.2.1 Surface Soil/Landfill Soil Cover

Metals

Arsenic was detected in 2 surface soil samples (40SB1A and 71SB14A) at concentrations above its adjusted R-RBC, I-RBC, and background point estimate (Figure 4-1). Although the samples also exceeded the SSL DAF 20, groundwater results did not indicate leaching of arsenic from soil to groundwater at detectable levels.

Pesticides

Pesticides were detected in surface soil/landfill soil cover samples at concentrations less than their adjusted RBCs. Beta-BHC and gamma-BHC (Lindane) were detected in one or more soil samples above their SSL DAF20s. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for beta-BHC and gamma-BHC is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of gamma-BHC or other pesticides from soil to groundwater at concentrations above adjusted T-RBCs.

PCBs

The approximate lateral and vertical extent of PCBs in surface soil/landfill soil cover at SWMU 40 at concentrations above its adjusted RBCs is shown on Figure 4-4. Aroclor 1260 was detected in soil at a concentration above its adjusted R-RBC in one sample (40SS7). Aroclor 1254 was detected above adjusted R-RBCs in eight samples (40SB1A, 40SB12A, 40SS3, 40SS7, 40SS8, 40SS16, 40SS17, 71SB14A) and above its adjusted R-RBC and I-RBC in one sample (40SS1). The primary area of impact was identified in surficial soil around boring 40SS1 as shown on Figure 4-4.

Aroclor 1254 was detected in one sample above its SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for PCBs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of Aroclor 1254 or other PCBs from soil to groundwater at detectable levels.

VOCs

VOCs were detected in surface soil/landfill soil cover at concentrations below their adjusted RBCs. Three VOCs (1,2-dibromo-3-chloropropane, benzene, and TCE) were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for VOCs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of these VOCs from soil to groundwater at detectable levels.

SVOCs and PAHs

SVOC compounds were detected in surface soil/landfill soil cover samples at concentrations below their adjusted RBCs and SSL DAF 20s.

PAH compounds benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene were detected in surface samples at concentrations above their adjusted R-RBCs. As presented in Section 4.1.2, detections were confirmed by both low-level 8270C and 8310 analysis for benzo(a)pyrene (40SS2, 40SS3, and 40SS5) and dibenz(a,h)anthracene (40SS5) at concentrations above their R-RBCs, but below their adjusted I-RBCs.

PAH compounds benzo(a)pyrene and naphthalene were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for PAHs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of PAHs/SVOCs to groundwater at detectable levels or levels above their adjusted T-RBCs.

Dioxins

Dioxin/furans were detected in two surface soil/landfill soil cover samples collected at SWMU 40. 2,3,7,8-TCDD TEQ was detected in soil at concentrations above its adjusted R-RBC in sample 40SS4, but below its adjusted R-RBC in sample 40SS5. Detected concentrations of dioxins were below its adjusted I-RBC. 2,3,7,8-TCDD TEQ detections were below its SSL DAF20

Explosives

Explosives including nitroglycerin and PETN were not detected in surface soil/landfill soil cover samples at SWMU 40.

DRO/GRO

DRO/GRO were not detected in surface soil/landfill soil cover samples above the VDEQ screening level of 100 ppm.

4.1.2.2 Landfill Material

Metals

Antimony was detected in two landfill material samples (71SB15B and 71SB15C) collected from SWMU 40 at concentrations above its adjusted R-RBC (Figure 4-2). A background point estimate is not available for antimony. The sample concentrations did not exceed the SSL DAF 20 and groundwater sample results did not indicate the leaching of antimony at concentrations above its adjusted T-RBC.

Arsenic was detected in four landfill material samples (40SB1F (duplicate averaged), 40SB4F (duplicate averaged), TestPit2F, 71SB15C) collected from SWMU 40 at a concentration above its adjusted R-RBC, I-RBC, and background point estimate (Figure 4-2). Although the four samples also exceeded the SSL DAF 20, groundwater results did not indicate leaching of arsenic from soil to groundwater at detectable levels.

Cadmium was detected in one landfill material sample (71SB15B) collected from SWMU 40 at concentrations above its adjusted R-RBC and background point estimate, but below its adjusted I-RBC (Figure 4-2). The sample concentration did not exceed the SSL DAF 20 and groundwater sample results did not indicate the leaching of cadmium at detectable concentrations.

Chromium was detected in two landfill material samples (40SB8F and 71SB15C) at concentrations above its adjusted R-RBC and facility background point estimate, but below its adjusted I-RBC (Figure 4-2). These sample concentrations also exceeded its SSL DAF20, but the groundwater sample results did not indicate the leaching of chromium at concentrations above its adjusted T-RBC.

Copper was detected in landfill material sample 71SB15B at a concentration above its adjusted R-RBC and facility background point estimate, as well as, landfill material sample 71SB15C at a concentration above its adjusted I-RBC, R-RBC, and background point estimate (Figure 4-2). Sample 71SB15C also exceeded its SSL DAF20, but the groundwater sample results did not indicate the leaching of copper at concentrations above its adjusted T-RBC.

Iron was also detected in landfill material sample 40SB1F (duplicate averaged) at a concentration above its adjusted R-RBC and facility background point estimate (Figure 4-2). Iron was detected in landfill material sample 40SB4F (duplicate averaged) at a concentration above its adjusted I-RBCs and facility background concentration. An SSL DAF20 is not available for iron, but the groundwater sample results did not indicate the leaching of iron at concentrations above its adjusted T-RBC.

Lead was detected in one landfill material sample (71SB15C) at a concentration above the residential action level (AL) of 400 mg/kg and industrial AL of 750 mg/kg is shown on Figure 4-2. An SSL DAF20 is not available for lead, but the groundwater sample results did not indicate the leaching of lead at concentrations above its drinking water AL.

Mercury was detected in three landfill material samples (40SB4F (duplicate averaged), 71SB14B, and 71SB15B) at concentrations above its adjusted R-RBC and facility background point estimate, but below its I-RBC (Figure 4-2). An SSL DAF20 is not available for mercury, but the groundwater sample results did not indicate the leaching of mercury at concentrations above its adjusted T-RBC.

Zinc was detected in one landfill material sample (71SB15C) at a concentration above its adjusted R-RBC and facility background point estimate (Figure 4-2). Sample 71SB15C also exceeded its SSL DAF20, but the groundwater sample results did not indicate the leaching of zinc at concentrations above its adjusted T-RBC.

Pesticides

Pesticides were detected in landfill material samples at concentrations below their adjusted RBCs. Alpha-BHC and beta-BHC were detected in one soil sample above their SSL DAF20s. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for alpha-BHC and beta-BHC is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of alpha-BHC or beta-BHC from soil to groundwater at detectable concentrations.

PCBs

Aroclor 1242, Aroclor 1254, and Aroclor 1260 were detected in the landfill material at concentrations above adjusted RBCs. The single detection of Aroclor 1242, which exceeded its adjusted R-RBC and adjusted I-RBC, was from sample 40SB9F. As shown on Figure 4-5, 12 landfill material samples exceeded the adjusted R-RBC for Aroclor 1254 of which three samples (40SB4F (duplicate average), TestPit1F, and 71SB14B) were above their adjusted I-RBCs. Two landfill material samples exceeded the adjusted R-RBC for Aroclor 1260 of which none exceeded its adjusted I-RBC.

Aroclor 1254 was detected in one or more soil samples above its SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for PCBs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of Aroclor 1254 or other PCBs from soil to groundwater at detectable levels.

VOCs

VOCs were detected in landfill material at concentrations below their adjusted RBCs. VOCs 1,4-dichlorobenzene, benzene, chlorobenzene, methylene chloride, TCE, and vinyl chloride were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for VOCs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of these VOCs from soil to groundwater at detectable concentrations.

SVOCs and PAHs

SVOC compounds (excluding PAHs) were detected in landfill material samples at concentrations below their adjusted RBCs and SSL DAF 20s with the exception of N-nitrosodiphenylamine which was detected in one more soil samples at concentrations above its SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway for this COPC utilizing a calculated site-specific SSL is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of N-nitrosodiphenylamine to groundwater at detectable levels.

PAH compounds benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene were detected in landfill material samples at concentrations above their adjusted R-RBCs with a benzo(a)pyrene detection above its adjusted I-RBC. As presented in Section 4.1.2, no detections were confirmed in the landfill material by both low-level 8270C and 8310.

PAH compounds benzo(a)anthracene, benzo(a)pyrene, and naphthalene were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for PAHs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of PAHs/SVOCs to groundwater at detectable levels or levels above their adjusted T-RBCs.

Dioxins

Dioxin/furans were detected in the one landfill material sample collected at SWMU 40. 2,3,7,8-TCDD TEQ was detected in soil at a concentration above its adjusted R-RBC in sample TESTPIT2F, but below its adjusted I-RBC. The detected concentration of dioxins was above its SSL DAF20. Dioxin/furans were not analyzed in groundwater.

Explosives

Explosives were not detected in landfill material samples at SWMU 40 with the exception of nitroglycerin detected in one sample (TESTPIT1F). This detection was above the adjusted R-RBC and I-RBC. An SSL DAF20 is not available for nitroglycerin, but the groundwater sample results did not indicate the leaching of nitroglycerin at detectable concentrations.

DRO/GRO

DRO/GRO were detected in 3 landfill material samples above the VDEQ screening level of 100 ppm (71SB14C, 71SB15B, and 71SB15C).

4.1.2.3 Soil Below Landfill Material/Subsurface Soil (No Landfill Material Present)

Metals

Aluminum was detected in 1 subsurface soil sample (40SB10B) at a concentration above its adjusted R-RBC and background point estimate, but below its adjusted I-RBC (Figure 4-3). An SSL DAF20 is not available for aluminum, but the groundwater sample results did not indicate the leaching of aluminum at detectable concentrations.

Chromium was detected in 2 subsurface soil samples (40SB10B and 40SB12B) at concentrations above its adjusted R-RBC and facility background point estimate, but below its adjusted I-RBC (Figure 4-3). These sample concentrations also exceeded its SSL DAF20, but the groundwater sample results did not indicate the leaching of chromium at concentrations above its adjusted T-RBC.

Pesticides

Pesticides were detected in the soil below landfill material/subsurface soil samples at concentrations below their adjusted RBCs. Alpha-BHC and beta-BHC were detected in one soil sample above their SSL DAF20s. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for alpha-BHC and beta-BHC is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of alpha-BHC or beta-BHC from soil to groundwater at detectable concentrations.

PCBs

Aroclor 1254 was detected in 2 of 24 soil samples collected below the landfill material/subsurface soil, with one soil sample below landfill material sample (40SB8C) having a concentration above its adjusted R-RBCs. The single detection of Aroclor 1260 (40SB13B) in subsurface soil exceeded its adjusted R-RBC. The detections and exceedances for Aroclor 1254 and Aroclor 1260 for soil below the landfill material/subsurface soil are presented on Figure 4-6.

PCBs were not detected in the samples above its SSL DAF20. Groundwater sample results did not indicate leaching of Aroclor 1254 or other PCBs from soil to groundwater at detectable levels.

VOCs

VOCs were detected in soil below landfill material/subsurface soil samples at concentrations below their adjusted RBCs. Two VOCs (benzene and TCE) were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration

pathway utilizing calculated site-specific SSLs for VOCs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of these VOCs from soil to groundwater at detectable levels.

SVOCs and PAHs

SVOC compound were detected in soil below landfill material/subsurface soil samples at concentrations below their adjusted RBCs and SSL DAF 20s.

PAH compounds benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene , and indeno(1,2,3-cd)pyrene were detected in soil below landfill material/subsurface soil samples at concentrations above their adjusted R-RBCs. As presented in Section 4.1.2, no detections were confirmed in the soil below landfill material/subsurface soil samples by both low-level 8270C and 8310.

PAH compounds benzo(a)anthracene, benzo(a)pyrene, and naphthalene were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing calculated site-specific SSLs for PAHs is presented in Section 4.1.4. Groundwater sample results did not indicate leaching of PAHs/SVOCs to groundwater at detectable levels or levels above their adjusted T-RBCs.

Dioxins

Dioxin/furans were not analyzed for in soil below landfill material/subsurface soil samples.

Explosives

Explosives including nitroglycerin and PETN were not detected in soil below landfill material/subsurface soil samples at SWMU 40.

DRO/GRO

DRO/GRO were not analyzed for in soil below landfill material/subsurface soil samples.

4.1.3 Ecological Nature and Extent Assessment

The nature and extent of COPECs identified at the site are based on the risk management portion of the SLERA presented in Section 7.2.3. As presented in Section 7.2.3, after consideration of spatial distribution of data at the site, mean concentrations, background concentrations, and the disposal history of the site, although the relatively minor HQ exceedances indicate the potential for adverse effects, the exceedances do not necessarily indicate that adverse effects are occurring. Based on the results and conclusions of the SLERA:

There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site on the basis of ecological risk.

4.1.4 Soil-to-groundwater Migration Assessment

As previously discussed in Section 4.1.1 and presented on Table 4-5, the concentrations for each detected chemical at the site was screened against the DAF20 SSL resulting in the identification of the following exceedances: arsenic, chromium, copper, zinc, alpha-BHC, beta-BHC, gamma-BHC (Lindane), Aroclor 1254, 1,2-dibromo-3-chloropropane, 1,4-dichlorobenzene, benzene, chlorobenzene, methylene chloride, trichloroethene (TCE), vinyl chloride, N-nitrosodiphenylamine, benzo(a)anthracene, benzo(a)pyrene, naphthalene, and 2,3,7,8-TCDD TEQ. Although arsenic, chromium, copper, and zinc were detected at a concentration in one or more samples that exceeded their DAF20 SSLs and background point estimates, these metals were not detected in groundwater samples at levels above their adjusted T-RBCs. To further refine the results of the generic SSL screening, site specific SSLs were developed for the organic chemicals identified above at the site. The development and screening using the site-specific SSLs are outlined in Section 4.1.4.1 below.

4.1.4.1 Development of Specific Soil-to-Groundwater SSLs

Site-specific soil-to-groundwater SSLs have been calculated for both SWMU 40 and SWMU 71 to evaluate the potential for leaching of COPCs to groundwater at concentrations of potential concern. EPA equation B-13 included in Appendix B of the Supplemental Guidance for Developing SSLs for Superfund Site (USEPA 2002c) has been modified to incorporate the following site-specific parameter data for each disposal area as summarized in the following table.

$$C_t = C_w(K_{oc} * f_{oc} + \frac{\theta_a + \theta_w * H'}{\rho_b}) \quad \text{Equation 4-1}$$

where:

Parameter	Definition (Units)	Value	Source
DAF	Dilution Attenuation Factor (unitless)	20	Default Value
C _t	Screening level in soil, (mg/kg)	Calculated Using Equation 4-1	USEPA 2002c
C _w	Target leachate concentration (mg/L) x Site-Specific DAF	Chemical Specific T-RBC x DAF	USEPA Region III – October 2007 RBC Table
K _{oc}	Soil organic carbon-water partition coefficient (L/kg)	Chemical Specific	Kargbo 2007
f _{oc}	Organic carbon content of soil, (kg/kg)	0.0112 (1.12%)	Estimated percent organic carbon in clay soil based on lowest total organic content (2.8%) for site soil ¹
θ _w	Water-filled soil porosity, (L _{water} /L _{soil})	0.3	Default Value
θ _a	Air-filled soil porosity, (L _{air} /L _{soil}), (η - θ _w)	0.13	Default Value
ρ _b	Dry soil bulk density	1.5 kg/L	Default Value
H'	Henry's law constant	Chemical-specific	Kargbo (2007)

Notes: RAIS = Risk Assessment Information System – Chemical Specific Factors at <http://rais.ornl.gov/>

EPA 1994b – Determination of Groundwater Dilution Attenuation Factors for Fixed Waste Sites using EPACMTP – Appendix E – Table A4.

¹ = Conversion factor of 2.5 was used to convert site-specific total organic matter to total organic carbon per EPA 2002. (page 7)

Detailed SSL calculations are presented in Appendix C.8. The leaching potential of COPCs is evaluated in the following table based on the comparisons of the site data to the site specific SSLs. Organic chemicals that exceeded their SSL DAF 20 screening values are compared against their site-specific SSLs and presented below:

Chemical	Site-specific SSL (mg/kg)	Surface Soil/ Soil Cover (MDC) (mg/kg)	Landfill Material (MDC) (mg/kg)	Soil Below Landfill Material/ Subsurface Soil (mg/kg)
alpha-BHC	4.82E-03	--	1.9E-03	9.5E-04
beta-BHC	1.69E-02	1.2E-2	3.8E-03	4.2E-03
gamma-BHC	2.33E-02	1.1E-2	--	--
Aroclor 1254	6.08E+00	2.1E+00	5E+00	--
Benzene	4.12E-03	6E-03	5.4E-01	2E-03
Chlorobenzene	2.12E+00	--	1.1E+01	--
1,2-Dibromo-3-chloropropane	1.72E-05	4E-04	--	--
1,4-Dichlorobenzene	1.87E-02	--	8.9E-01	--
Methylene Chloride	3.28E-02	--	1.7E-01	--
Trichloroethene	7.72E-04	2.2E-03	9E-03	2.1E-02
Vinyl Chloride	2.69E-04	--	2E-03	--
N-Nitrosodiphenylamine	4.02E+00	--	3.5E+00	--
Benzo(a)anthracene	2.68E+00	--	2.2E+00	5.4E-01
Benzo(a)pyrene	6.86E-01	3E-01	4.5E-01	3.8E-01
Naphthalene	7.48E-01	1.1E+00	3E+00	1.3E+00
2,3,7,8-TCDD	1.46E-05	7.41E-06	9.07E-06	--

Although detected concentrations of VOCs exceeded the calculated site-specific SSLs, these VOCs were not detected in groundwater. Naphthalene, which exceeded its site-specific SSL in 4 of 10 detections from a total of 53 soil samples collected, was detected in groundwater at levels below its adjusted T-RBC. The nature and extent for groundwater is presented in Section 4.3.

Additional discussion and assessment of the soil-to-groundwater migration pathway for chemicals identified above for which maximum detected concentrations exceeded its site-specific SSL are presented in Section 5.0.

4.2 NATURE AND EXTENT – SWMU 71 SOIL

4.2.1 Analytical Results

Seven surface soil samples and 12 subsurface soil samples for a total of 19 samples were collected for chemical analysis from SWMU 71 (Figure 3-1 and Table 3-1). Table 4-6 presents analytical results for chemicals detected in soil samples collected at SWMU 71 and screens these data with respect to adjusted RBCs, SSL DAF1s, and background concentrations. Table 4-7 (Surface Soil), Table 4-8 (Subsurface Soil), and Table 4-9 (Total Soil) summarizes the screening results for soil data including: constituents detected, minimum and maximum concentrations detected, number of detections, number of samples, and number of samples exceeding human health screening criteria or SSL DAF20 screening levels and background concentrations (inorganics only). Chemicals of potential ecological concern (COPECs) listed below were identified for the site as part of the ecological risk characterization presented in Section 7.3.3. The screenings resulted in the identification of the following COPCs, as presented on Table 4-9, and COPECs (note that chemical which exceeded both its adjusted R-RBC and I-RBC are italicized):

TAL Metals (Methods 6010B, 6020A, and 7470A) – 23 TAL metals were detected in soil samples with the following screening level and background point estimate exceedances:

RBC – aluminum, antimony, *arsenic*, chromium, iron, *vanadium*;
SSL – *arsenic*, chromium; and

Eco –antimony and calcium.

TCL Pesticides (Method 8081A) – 3 pesticides were detected in soil samples with the following screening level exceedances:

RBC – none;
SSL – beta-BHC; and
Eco – none.

TCL PCBs (Method 8082) – 4 PCBs were detected in soil samples with the following screening level exceedances:

RBC – Aroclor 1248, Aroclor 1254;
SSL – none; and
Eco – none.

TCL VOCs (Method 8260B) – 16 VOCs were detected in soil samples with the following screening level exceedances:

RBC – none;
SSL – benzene, trichloroethene, vinyl chloride; and
Eco – none.

TCL SVOCs (Method 8270C) – 4 SVOCs were detected in soil samples with the following screening level exceedances:

RBC – none;
SSL – none; and
Eco – none.

PAHs (Method 8310) – 12 PAHs were detected in soil samples with the following screening level exceedances:

RBC – benzo(a)pyrene, dibenz(a,h)anthracene;
SSL – none; and
Eco –none.

Dioxin/Furans (Method 8290) – Dioxin/furans were detected in soil samples with the following screening level exceedances:

RBC –2,3,7,8-TCDD TEQ;
SSL – none; and
Eco – none.

4.2.1.1 Human Health Nature and Extent Assessment

A summary of the human health risk and background screening results for COPCs is presented in the table below.

Chemical	Total # of Det/# of Samples	# of R-RBC/I-RBC Exceed.	Sample Exceedances		
			Surface Soil Sample(s)	Subsurface Soil Samples	
				Intermediate Sample(s)	Terminal Sample(s)
Aluminum	19/19	6/0	NA	71SS11B DUP AVG, 71SB11B, 71SB12B, 71SB13B	71SB11C, 71SB13C
Antimony	13/19	1/0	71SS13	NA	NA
Arsenic	19/19	2/2	71SS12 DUP AVG, 71SB13A	NA	NA
Chromium	19/19	2/0	NA	71SB11F	71SB13C
Iron	19/19	3/0	NA	71SS12B, 71SB12B	71SB13C

Chemical	Total # of Det/# of Samples	# of R-RBC/I-RBC Exceed.	Sample Exceedances		
			Surface Soil Sample(s)	Subsurface Soil Samples	
				Intermediate Sample(s)	Terminal Sample(s)
Vanadium	19/19	1/1	NA	71SB12B	NA
Aroclor 1248	1/19	1/0	71SB13A	NA	NA
Aroclor 1254	9/19	2/0	71SB13A	71SB11F	NA
Benzo(a)pyrene*	3/7	1/0	NA	71SB11F	NA
Dibenz(a,h)anthracene*	1/7	1/0	NA	71SB11F	NA
2,3,7,8-TCDD TEQ	3/3	1/0	NA	71SB11B	NA

Notes: NA=Not Applicable, *Detections confirmed by both low-level 8270C and 8310 analysis, **Bold**=Sample Exceeds adjusted R-RBC and I-RBC

The nature and extent of COPCs identified in the above table, as well as SSL DAF 20 exceedances (above background concentrations for inorganics) identified in Section 4.2.1 and presented on Table 4-7 (Surface Soil), Table 4-8 (Subsurface Soil), and Table 4-9 (Total Soil), is discussed further in the following sections.

Metals

Aluminum was detected in six subsurface samples (71SS11B (duplicate averaged), 71SB11B, 71SB12B, 71SB13B, 71SB11C, 71SB13C) collected at SWMU 71 at concentrations above its adjusted R-RBC and facility background concentration as shown on Figure 4-7. An SSL DAF20 is not available for aluminum, but the groundwater sample results did not indicate the leaching of aluminum at detectable concentrations.

Antimony was detected in one surface sample (71SS13) at a concentration above its adjusted R-RBC as shown on Figure 4-7. A background point estimate is not available for antimony. The sample concentration did not exceed the SSL DAF 20 and groundwater sample results did not indicate the leaching of antimony at concentrations above its adjusted T-RBC.

Arsenic was detected in two surface soil samples (71SS12 (duplicate average) and 71SB13A) collected from SWMU 71 at a concentration above its adjusted R-RBC, I-RBC, and background point estimate, as shown on Figure 4-7. Although these two surface soil samples also exceeded the SSL DAF20, groundwater sample results did not indicate the leaching of chromium at concentrations above its adjusted T-RBC.

Chromium was detected in two subsurface samples (71SB11F and 71SB13C) at concentrations above its adjusted R-RBC and facility background concentration, as shown on Figure 4-7. Although these two subsurface samples also exceeded the SSL DAF20, groundwater results did not indicate leaching of chromium from soil to groundwater at levels above the adjusted T-RBC.

Iron was detected in three subsurface samples (71SS12B, 71SB12B, and 71SB13C) collected from SWMU 71 at concentrations above its adjusted R-RBCs and facility background concentration as shown on Figure 4-7. An SSL DAF20 is not available for iron, but the groundwater sample results did not indicate the leaching of iron at concentrations above its adjusted T-RBC.

Vanadium was detected in one subsurface sample (71SB12B) at a concentration above its adjusted R-RBCs, I-RBC, and facility background concentration, as shown on Figure 4-7. This subsurface sample was below the SSL DAF20 and groundwater results did not indicate leaching of vanadium from soil to groundwater at detectable levels above the adjusted T-RBC.

Pesticides

Pesticides were detected in soil samples at concentrations below their adjusted RBCs. Beta-BHC was detected at concentrations above its SSL DAF20s in two surface soil samples. Additional discussion and

assessment of the soil-to-groundwater migration pathway utilizing site-specific SSLs for PCBs is presented in Section 4.2.3. Groundwater sample results did not indicate leaching of beta-BHC from soil to groundwater at detectable concentrations.

PCBs

Aroclor 1248 and Aroclor 1254 were detected in soil samples at concentrations above adjusted RBCs. The single detection of Aroclor 1248, which exceeded its adjusted R-RBC, is 71SB13A. For Aroclor 1254, two samples, one surface soil (71SB13A) and one subsurface soil (71SB11F), exceeded its adjusted R-RBC.

PCBs were detected at concentrations below their SSL DAF20s. Groundwater sample results did not indicate leaching of Aroclor 1254 or other PCBs from soil to groundwater at detectable levels.

VOCs

VOCs were detected in soil samples at concentrations below their adjusted RBCs. VOCs benzene, TCE, and vinyl chloride were detected in one or more samples at concentrations above their SSL DAF20. Additional discussion and assessment of the soil-to-groundwater migration pathway utilizing site-specific SSLs for VOCs is presented in Section 4.2.3. Groundwater sample results did not indicate leaching of these VOCs from soil to groundwater at detectable concentrations.

SVOCs and PAHs

SVOC compounds (excluding PAHs) were detected in surface soil/landfill soil cover samples at concentrations below their adjusted RBCs and SSL DAF 20s. PAH compounds benzo(a)pyrene and dibenz(a,h)anthracene were detected in a subsurface soil sample (71SB11F) at concentrations above their adjusted R-RBC. As presented in Section 4.2.1, these detections were confirmed in the subsurface soil by both low-level 8270C and 8310 analysis.

PAH compounds were detected soil samples at concentrations below their SSL DAF20. Groundwater sample results did not indicate leaching of PAHs/SVOCs to groundwater at detectable levels or levels above their adjusted T-RBCs.

Dioxins

2,3,7,8-TCDD TEQ was detected in one subsurface soil sample (71SB11B) at a concentration above its adjusted R-RBC, but below its adjusted I-RBCs. The detected concentration of dioxins was below its SSL DAF20. Dioxin/furans were not analyzed in groundwater.

Explosives

Explosives including nitroglycerin and PETN were not detected in soil samples at SWMU 71.

DRO/GRO

DRO/GRO were detected in soil samples below the VDEQ screening level of 100 ppm.

4.2.2 Ecological Nature and Extent Assessment

The nature and extent of COPECs identified at the site are based on the conclusion risk management portion of the SLERA presented in Section 7.3.3. After consideration of spatial distribution of data at the site, mean concentrations, background concentrations, and isolated nature of the landfill material at the site, although the relatively minor HQ exceedances indicate the potential for adverse effects, the exceedances do not necessarily indicate that adverse effects are occurring. Based on the results and conclusions of the SLERA:

There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site on the basis of ecological risk.

4.2.3 Soil-to-groundwater Assessment

As previously discussed in Section 4.2.1 and presented on Table 4-9, the concentrations for each detected chemical at the site was screened against the DAF 20SSL resulting in the identification of the following COPCs: arsenic, chromium; beta-BHC, benzene, trichloroethene, and vinyl chloride. Although arsenic and chromium were detected at a concentration in one or more samples that exceeded their DAF20 SSLs and background point estimates, these metals were not detected in groundwater samples at levels above their adjusted T-RBCs. To further refine the results of the generic SSL screening, site specific SSLs were developed for the organic chemicals identified above at the site

4.2.3.1 Development of Specific Soil-to-Groundwater SSLs

Site-specific soil-to-groundwater SSLs have been calculated for SWMU 71 in accordance with the methodology previously presented in Section 4.1.4.1. Organic chemicals that exceeded their DAF20 SSLs are compared against their site-specific SSLs and presented below:

Chemical	Site-specific SSL (mg/kg)	Surface Soil MDC (mg/kg)	Subsurface Soil MDC (mg/kg)
beta-BHC	1.69E-02	5.5E-03	--
Benzene	4.12E-03	3.2E-03	--
Trichloroethene	7.72E-04	2.1E-02	3E-03
Vinyl Chloride	2.69E-04	--	6.6E-02

Although detected concentrations of VOCs exceeded the calculated site-specific SSLs, these VOCs were not detected in groundwater. The nature and extent for groundwater is presented in Section 4.3.

Additional discussion and assessment of the soil-to-groundwater migration pathway for chemicals identified above for which maximum detected concentrations exceeded its site-specific SSLs are presented in Section 5.0.

4.3 NATURE AND EXTENT – GROUNDWATER

4.3.1 Monitoring Well Analytical Results

Monitoring well sample results from wells 17MW3, 40MW3, 40MW5, 40MW6 collected in August 2007 are summarized in Table 4-10. These data are screened in Table 4-11 with respect to adjusted T-RBCs and MCLs to identify COPCs. Monitoring well locations are shown on Figure 3-2. The screening resulted in the identification of the following COPCs:

TAL Metals (Methods 6010B, 6020A, 7470A) – Seventeen TAL metals were detected in groundwater at concentrations below their adjusted T-RBCs and MCLs.

TCL VOCs (Method 8260B) – Three VOCs were detected in groundwater at concentrations below their adjusted T-RBCs and MCLs with the exception of chloroform which exceeded its adjusted T-RBC.

TCL SVOCs (Method 8270C) – Six SVOCs were detected in groundwater at concentrations below their adjusted T-RBCs.

PAHs (Method 8310) – PAHs were not detected in groundwater.

TCL Pesticides (Method 8081A) – Two pesticides were detected in groundwater at concentrations below their adjusted T-RBCs.

TCL PCBs (Method 8082) – PCBs were not detected in groundwater.

Explosives (Method 8330) and Nitroglycerin (Method 8332) – Explosives and nitroglycerin were not detected in groundwater.

Perchlorate (Method 6850) – Perchlorate was detected in groundwater at a concentration above its adjusted T-RBC.

4.3.2 Human Health Nature and Extent Assessment

The groundwater risk screening identified perchlorate and chloroform as COPCs for groundwater. The nature and extent of these COPCs in groundwater is discussed in the following sections.

4.3.2.1 Perchlorate

As shown on Figure 4-8, groundwater samples collected from monitoring wells 40MW5 and 40MW6 located immediately adjacent to the landfill area had perchlorate concentrations (0.52 and 0.655 µg/L) below the adjusted T-RBC of 2.56 µg/L. The groundwater sample collected from monitoring well 40MW3 located downgradient of the landfill had a perchlorate concentration (0.52 µg/L) below the adjusted T-RBC of 2.56 µg/L. A higher perchlorate concentration above the adjusted T-RBC was detected in the sample collected from crossgradient well 17MW3 (5.2 µg/L) as shown on Figure 4-8. Similar perchlorate concentrations also were detected in groundwater samples collected from the SWMU 17/Former Lead Furnace Area (FLFA) upgradient of SWMU 40 during an RFI for the FLFA conducted by Shaw Environment and Infrastructure (Shaw) in August 2007 (Shaw 2008). Perchlorate concentrations detected in the Shaw samples were 5.40 µg/L at well 17MW2 and 5.33 µg/L at well LFMW01 (Figure 2-18). Perchlorate is currently being detected at low levels in numerous groundwater samples at RFAAP. The new lab detection method is possibly the reason for consistent low level perchlorate detections throughout the facility such as those detected in the wells located immediately adjacent to SWMUs 40 and 71. The samples located immediately adjacent to and downgradient of the landfill (40MW3, 40MW5, and 40MW6) were below the unadjusted T-RBC; therefore, perchlorate was not identified as a COPC in groundwater for SWMUs 40 and 71.

4.3.2.2 Chloroform

Chloroform was detected in samples collected from wells 40MW3 (19 µg/L), 40MW5 DUP AVG (23 µg/L), and 40MW6 (24 µg/L) at concentrations above its T-RBC (0.155 µg/L) but below the USEPA MCL of 80 µg/L for total halomethanes (Figure 4-8).

4.4 NATURE AND EXTENT SUMMARY

4.4.1 SWMU 40 Nature and Extent Summary

The primary site-related COPCs in soil at SWMU 40 are metals and PCBs. These conclusions are supported by the results of the human health and ecological risks assessments presented in Sections 6.0 and 7.0, respectively. As presented in Section 4.1, the COPCs are primarily limited to the landfill material itself with the exception of a surficial area of PCB contamination in soil located adjacent to the northern escarpment of the landfill (See Figures 4-1 through 4-6). It is important to note that the landfill material is heterogeneous in nature; therefore, the delineation of isoconcentrations of chemicals detected in the landfill material is not feasible for the site.

Although site-specific SSLs exceedances at the site were identified for VOCs and naphthalene, the groundwater testing at the site did not result in the detection of these VOCs in groundwater or naphthalene at levels above its adjusted RBC.

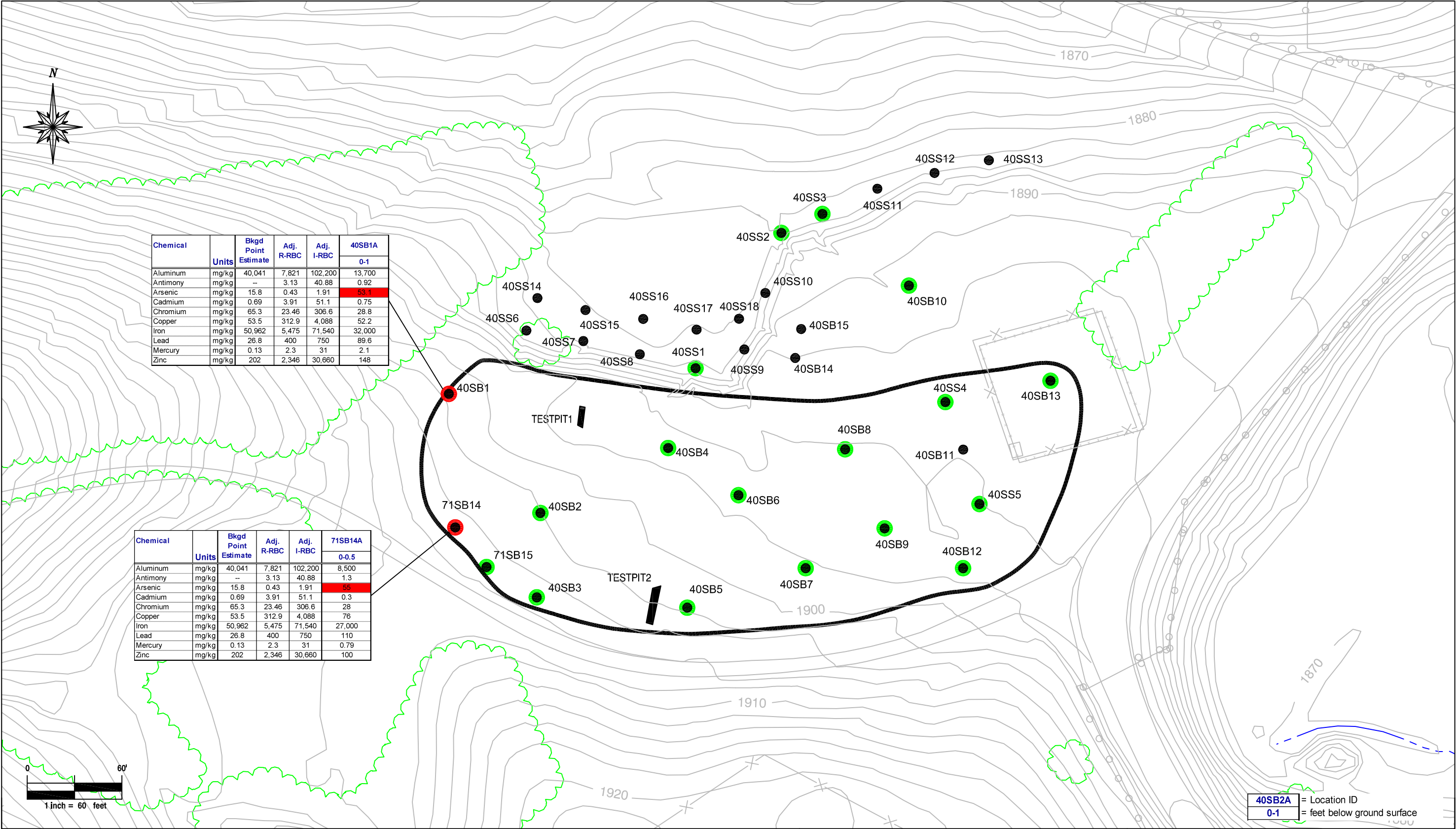
4.4.2 SWMU 71 Nature and Extent Summary

The primary site-related COPCs in soil SWMU 71 are metals (see Figure 4-7). These conclusions are supported by the results of the human health and ecological risks assessments presented in Sections 6.0 and 7.0, respectively. Although site-specific SSLs exceedances at the site were identified for VOCs and naphthalene, the groundwater testing at the site did not result in the detection of these VOCs in groundwater.

4.4.3 Groundwater Nature and Extent Summary

The primary potentially site-related COPC in groundwater at SWMUs 40 and 71 is chloroform (see Figure 4-8). Chloroform was detected at concentrations above its T-RBC (0.155 µg/L) but below the USEPA MCL for total halomethanes (80 µg/L) in samples collected from adjacent to the landfill area and at 40MW3 downgradient of SWMU 40. Extensive source characterization was conducted at SWMUs 40 and 71 including the collection of 91 soil samples many of which were collected from landfill material and soil below the landfill material at SWMU 40. Chloroform was not detected in these samples. The lack of any detections and absence of other volatiles in groundwater samples suggests a potential alternate source for chloroform in groundwater. Studies and groundwater investigations have shown the presence of chloroform in most groundwater samples collected at the facility regardless of location. The concentrations of chloroform detected in monitoring wells at SWMUs 40 and 71 are within the range of chloroform levels present in the water transmitted through water lines at the facility. The landfill area is located downgradient of developed areas containing water lines that could be leaking, which may have been the source of chloroform. Based on the historical use of SWMU 40 (i.e., sanitary landfill), chloroform could be a potential site-related groundwater COPC, but it should be noted that no source of chloroform has been identified within the landfill material or soil beneath the landfill material at SWMU 40. Also it should be noted that based on the historical use of SWMU 71 (i.e., flash and burn area), the site-related soil COPCs identified (metals), and the small size of the site, chloroform is not considered a site-related COPC in groundwater for SWMU 71.

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Chemical	Units	Bkgd Point Estimate	Adj. R-RBC	Adj. I-RBC	40SB1A 0-1
Aluminum	mg/kg	40,041	7,821	102,200	13,700
Antimony	mg/kg	--	3.13	40.88	0.92
Arsenic	mg/kg	15.8	0.43	1.91	53.1
Cadmium	mg/kg	0.69	3.91	51.1	0.75
Chromium	mg/kg	65.3	23.46	306.6	28.8
Copper	mg/kg	53.5	312.9	4,088	52.2
Iron	mg/kg	50,962	5,475	71,540	32,000
Lead	mg/kg	26.8	400	750	89.6
Mercury	mg/kg	0.13	2.3	31	2.1
Zinc	mg/kg	202	2,346	30,660	148

Chemical	Units	Bkgd Point Estimate	Adj. R-RBC	Adj. I-RBC	71SB14A 0-0.5
Aluminum	mg/kg	40,041	7,821	102,200	8,500
Antimony	mg/kg	--	3.13	40.88	1.3
Arsenic	mg/kg	15.8	0.43	1.91	55
Cadmium	mg/kg	0.69	3.91	51.1	0.3
Chromium	mg/kg	65.3	23.46	306.6	28
Copper	mg/kg	53.5	312.9	4,088	76
Iron	mg/kg	50,962	5,475	71,540	27,000
Lead	mg/kg	26.8	400	750	110
Mercury	mg/kg	0.13	2.3	31	0.79
Zinc	mg/kg	202	2,346	30,660	100

Legend

Approximate SWMU Boundary

Soil Boring / Surface Sample Location (SB / SS)

Exceeds Adjusted Residential Risk-Based Concentration (R-RBC), Adjusted Industrial RBC (I-RBC), and Facility-wide Background Point Estimate

mg/kg

Milligrams per kilogram

Parameters do not exceed Adjusted RBCs

Parameters exceed Adjusted R-RBC, Adjusted I-RBC, and Facility-wide Background Point Estimate

FIGURE 4-1

Metals - Surface Soil/Soil Cover

Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.4-1 Metals -SS/SC

SWMUs 40 and 71

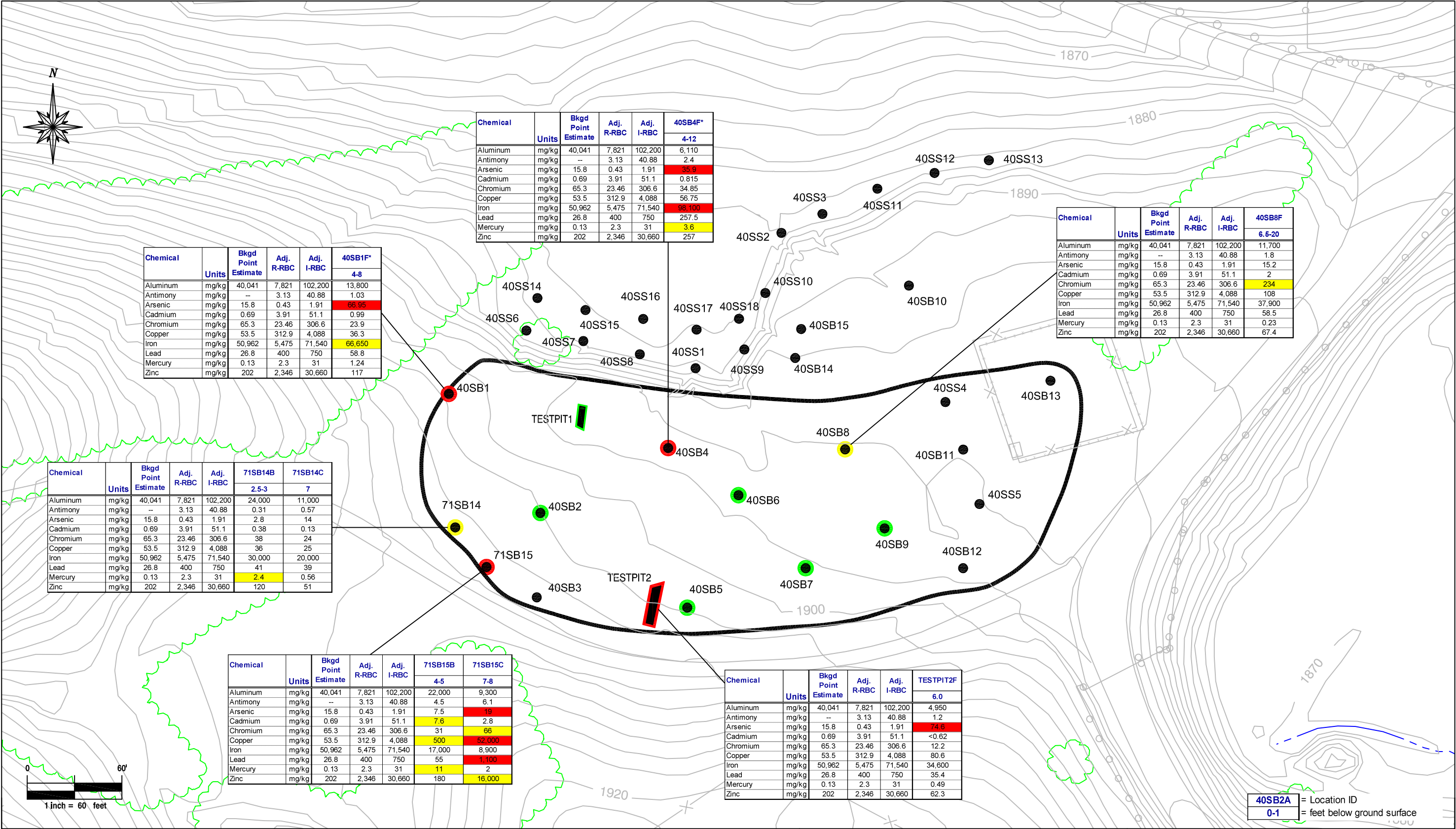
RFI / CMS Report

Radford Army Ammunition Plant

Radford, Virginia

URS

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Suite 201
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Legend

- Approximate SWMU Boundary
- Soil Boring / Surface Sample Location (SB / SS)
- Exceeds Adjusted Residential Risk-Based Concentration (R-RBC) and Facility-wide Background Point Estimate
- Exceeds Adjusted R-RBC, Adjusted Industrial RBC (I-RBC), and Facility-wide Background Point Estimate

- Parameters do not exceed Adjusted RBCs
 - Parameters exceed Adjusted Residential RBC and Facility-wide Background Point Estimate
 - Parameters exceed Adjusted R-RBC, Adjusted I-RBC, and Facility-wide Background Point Estimate
- mg/kg Milligrams per kilogram
* Duplicate Average

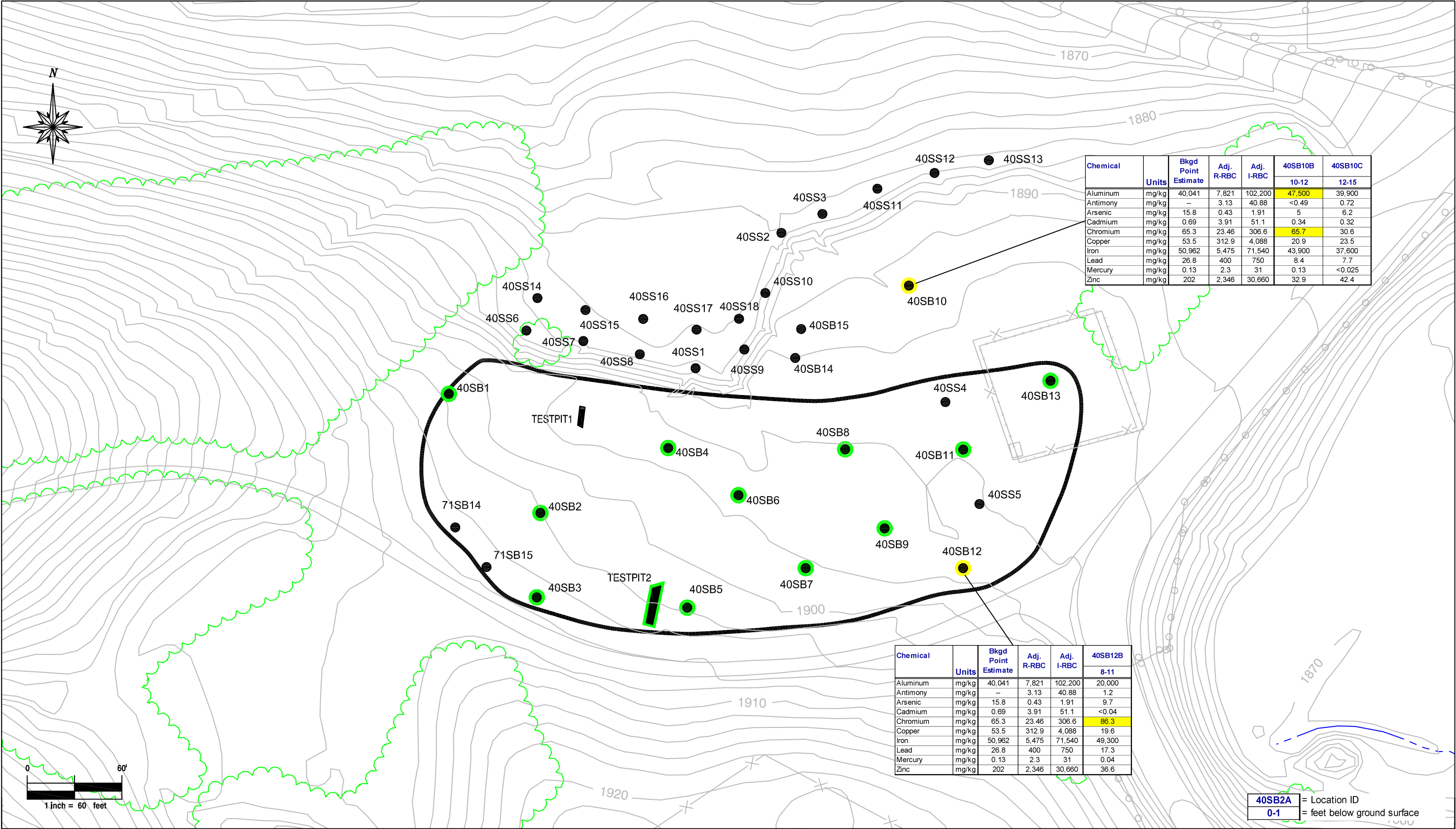
FIGURE 4-2
Metals - Landfill Material

Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.4-2 Metals -LF Mat

SWMUs 40 and 71
RFI / CMS Report
Radford Army Ammunition Plant
Radford, Virginia



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Legend

- Approximate SWMU Boundary
- Soil Boring / Surface Sample Location (SB / SS)
- Exceeds Adjusted Residential Risk-Based Concentration (R-RBC) and Facility-wide Background Point Estimate
- Parameters do not exceed Adjusted RBCs
- Parameters exceed Adjusted R-RBC and Facility-wide Background Point Estimate
- mg/kg Milligrams per kilogram

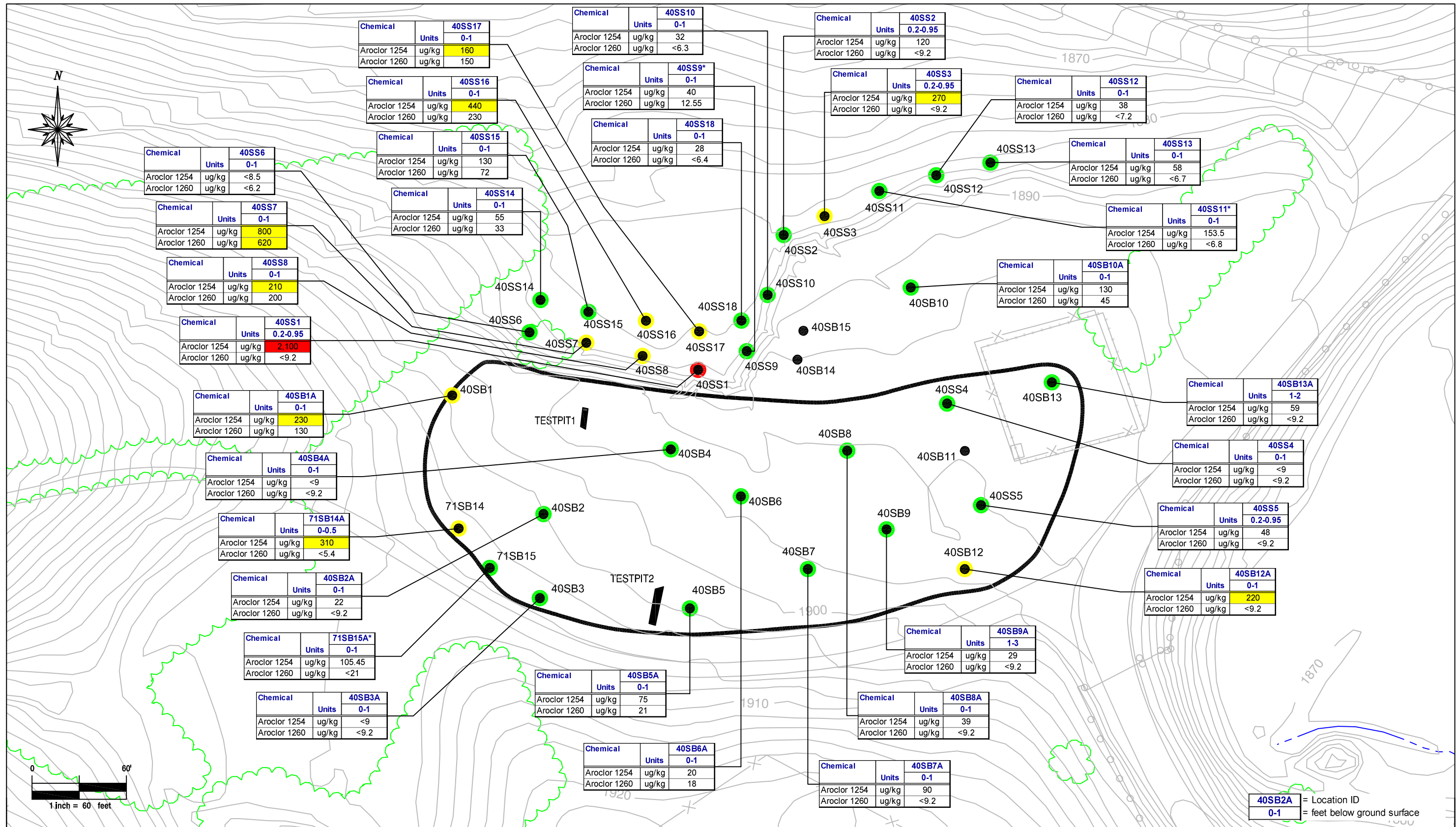
FIGURE 4-3
Metals -
Soils Below Landfill Material / No Landfill Material Present

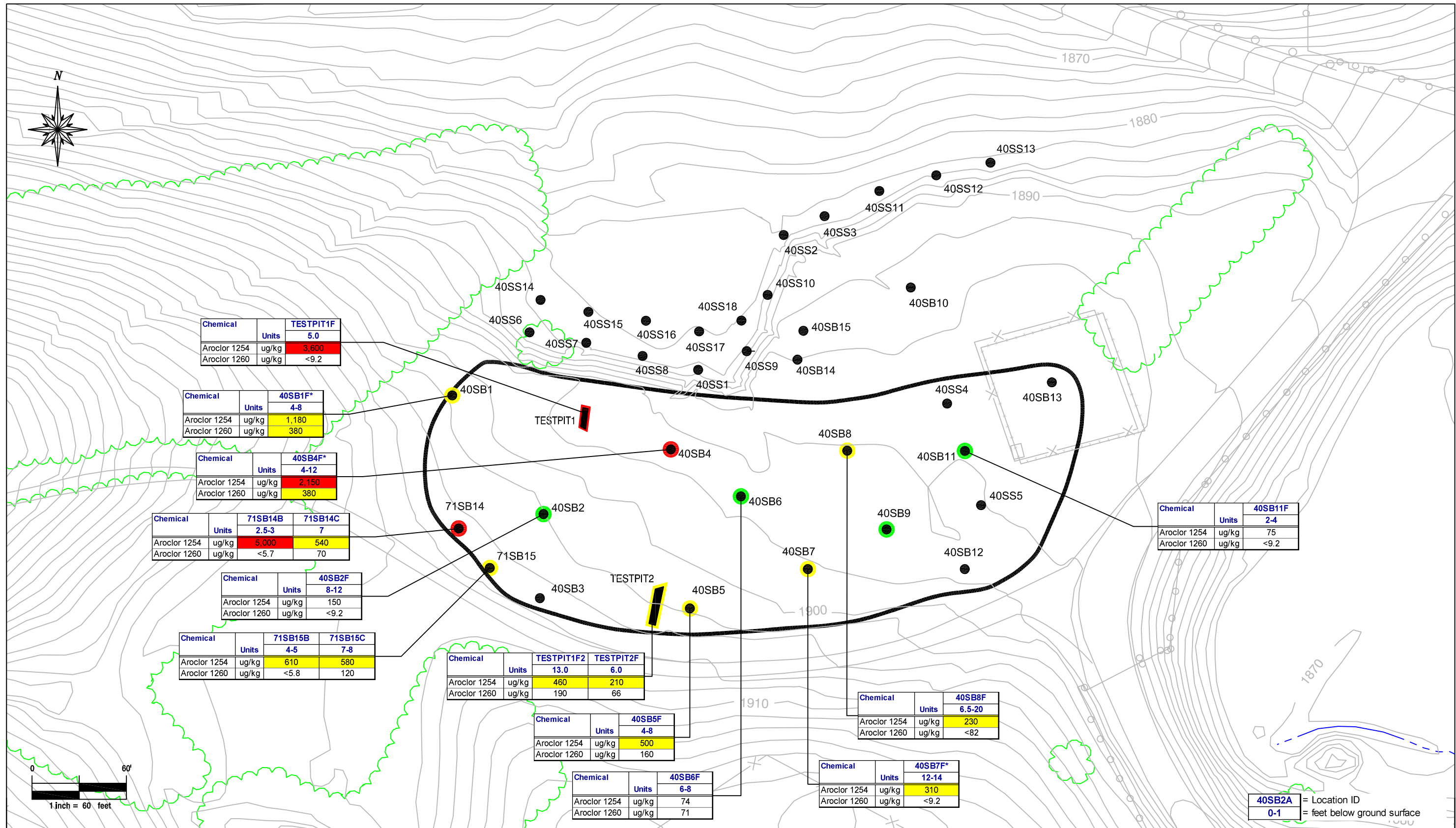
Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.4-3 Metals - Below LF Mat

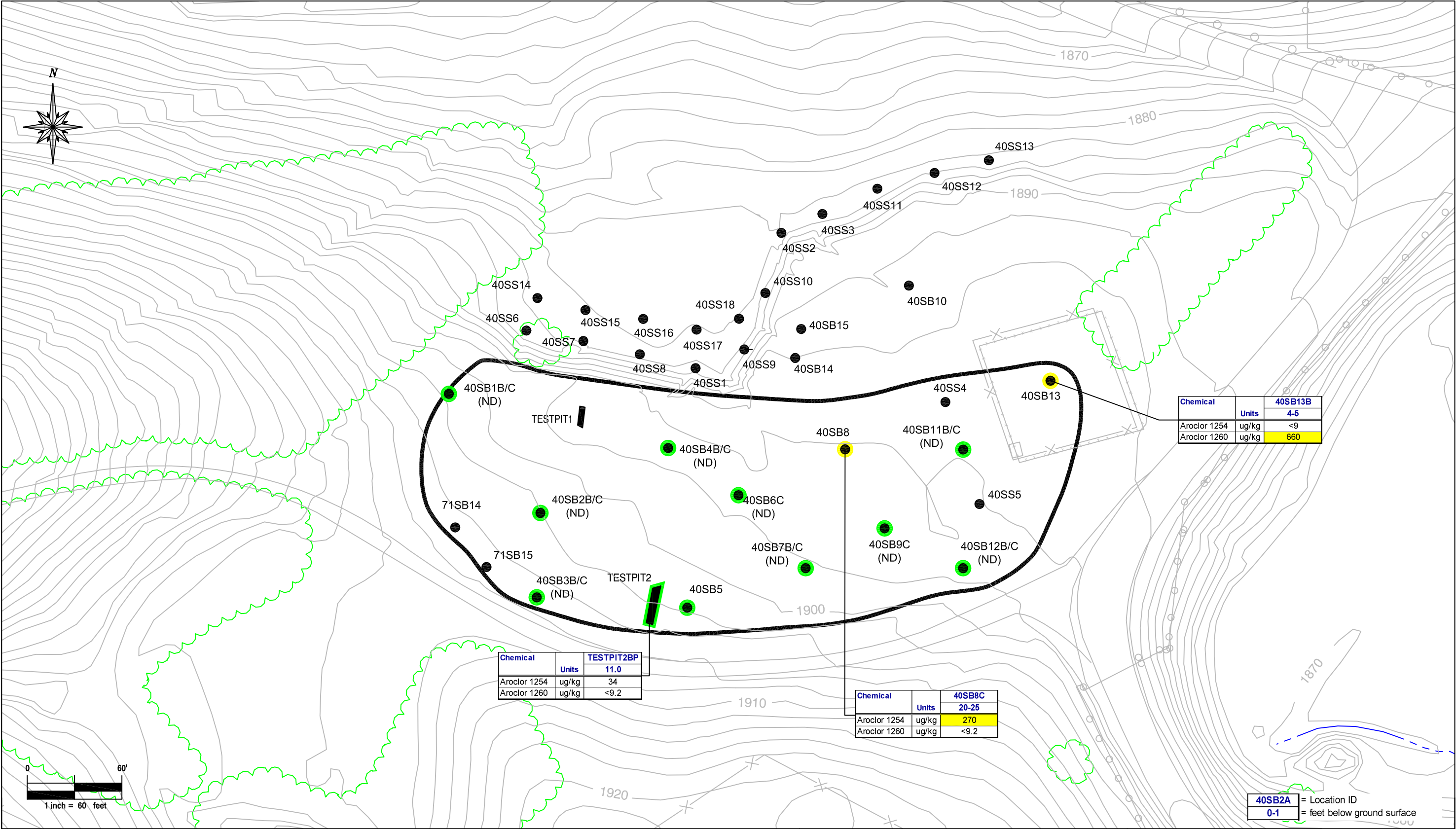
SWMUs 40 and 71
RFI / CMS Report
Radford Army Ammunition Plant
Radford, Virginia

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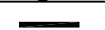
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Richmond, Virginia 23230







Legend



Approximate SWMU Boundary

Soil Boring / Surface Sample Location (SB / SS)

Exceeds Adjusted Residential Risk-Based Concentration (R-RBC) of 156 ug/kg for Aroclor 1254 and 319 ug/kg for Aroclor 1260



Parameters do not exceed Adjusted RBCs

Parameters exceed Adjusted Residential RBC only

ug/kg

Micrograms per kilogram

(ND)

Not Detected

FIGURE 4-6

PCBs -

Soils Below Landfill Material / No Landfill Material Present

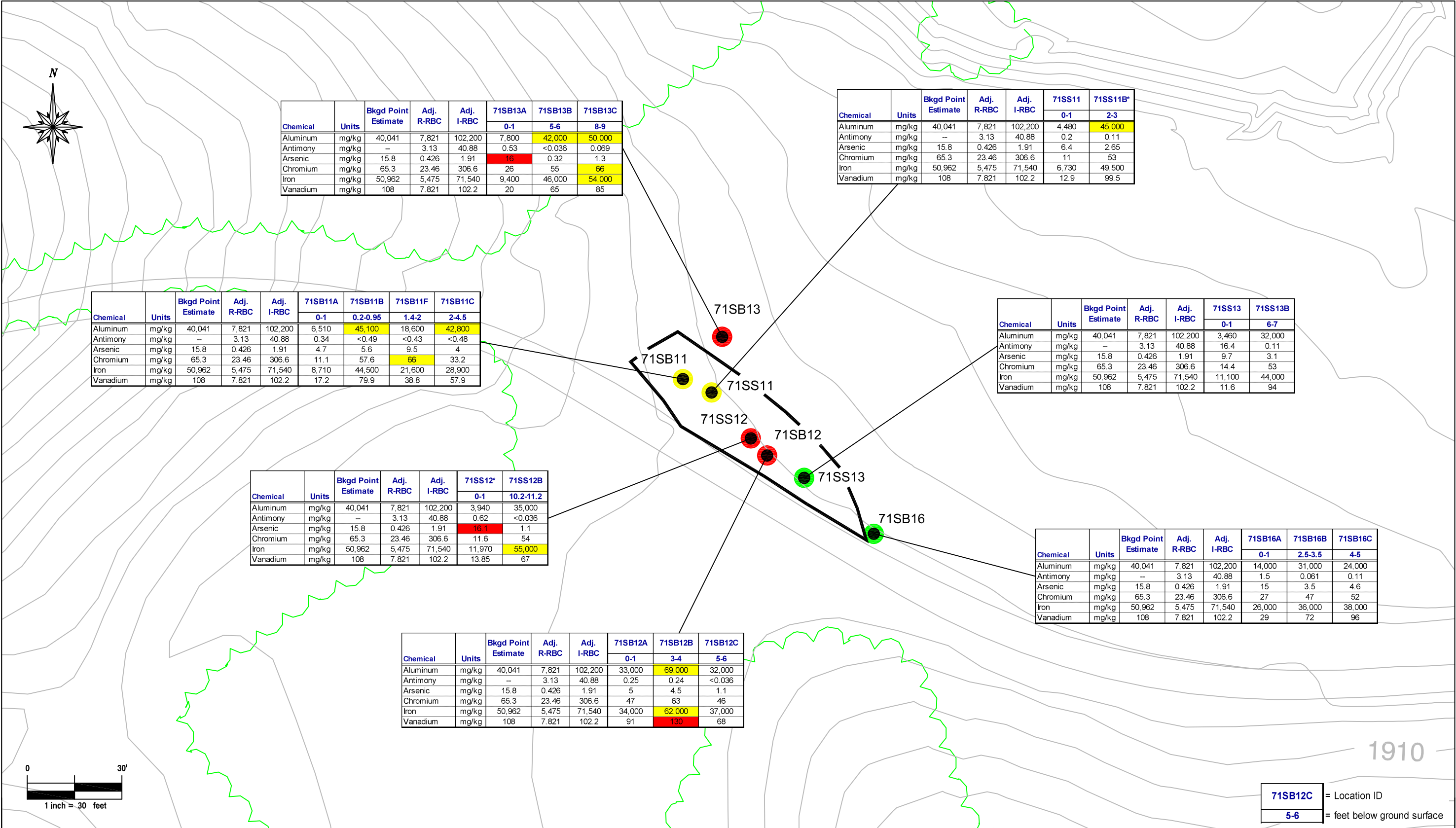
Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.4-6 PCBs- SS/SC

SWMUs 40 and 71

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Radford, Virginia



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Legend

- Approximate SWMU Boundary
- Soil Boring / Surface Sample Location (SB / SS)
- Exceeds Adjusted Residential Risk-Based Concentration (R-RBC) and Facility-wide Background Point Estimate
- Exceeds Adjusted R-RBC, Adjusted Industrial RBC (I-RBC), and Facility-wide Background Point Estimate

- Parameters do not exceed Adjusted RBCs
- Parameters exceed Adjusted Residential RBC and Facility-wide Background Point Estimate
- Parameters exceed Adjusted R-RBC, Adjusted I-RBC, and Facility-wide Background Point Estimate
- mg/kg: Milligrams per kilogram
- *: Duplicate Average

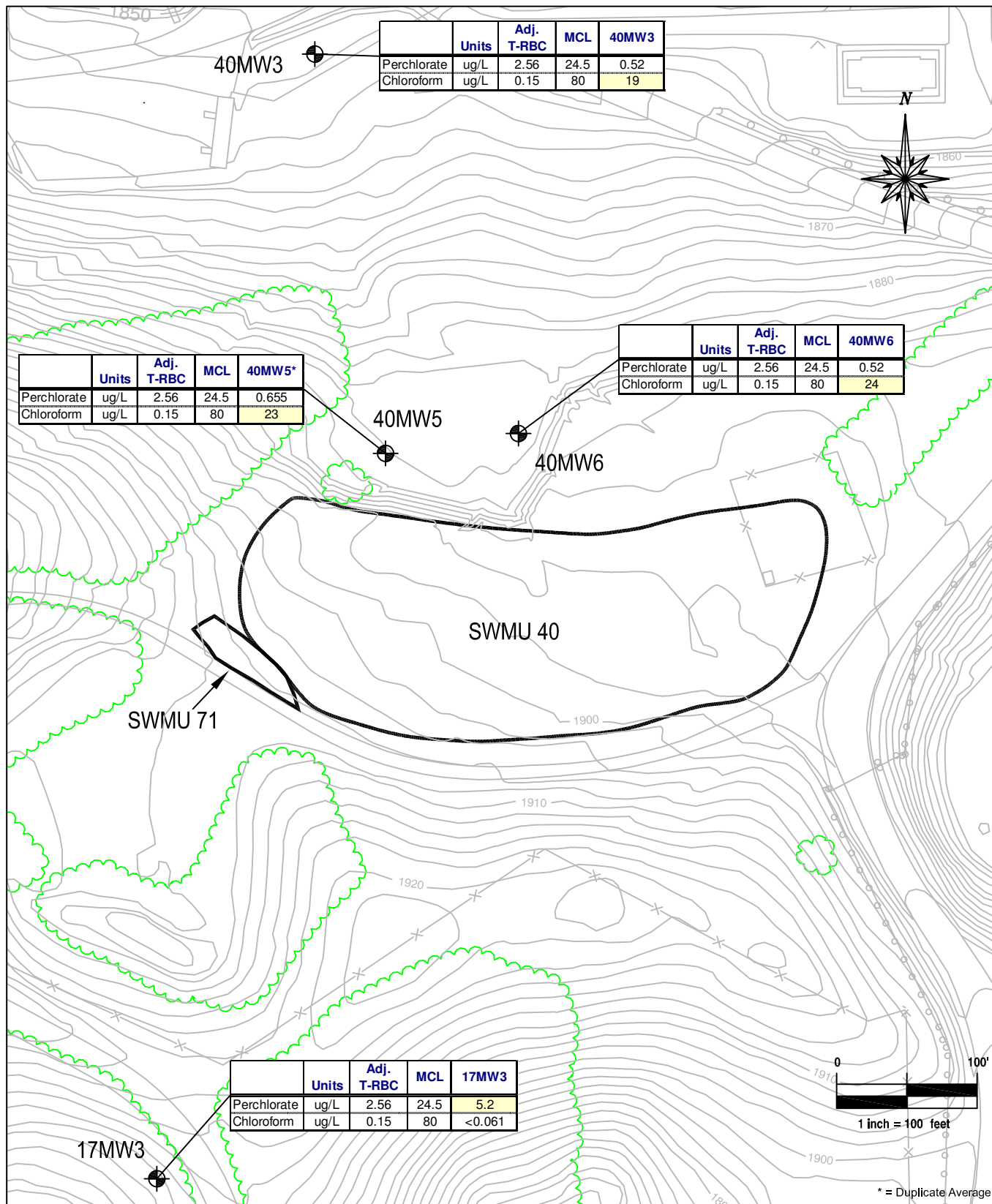
FIGURE 4-7
Metals - SWMU 71

Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 30 feet	File Name: Fig.4-7 Metals -SWMU71



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Legend

- Approximate SWMU Boundary
- Topographic Contour (feet, mean sea level)
- Monitoring Well Location
- ug/L Micrograms per Liter
- Exceeds Maximum Contaminant Level (MCL)
- Exceeds Adjusted Tap Water RBC (T-RBC)

FIGURE 4-8

Groundwater Sample Results

Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 100 feet	File Name: Fig.4-8 GW Results

SWMUs 40 and 71

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Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB1A 11/15/2002 0-1				MDL	RL	40SB1B 11/15/2002 7-9				MDL	RL	40SB1C 11/15/2002 9-10				MDL	RL	40SB1F 11/15/2002 4-8				MDL	RL	40SB1F-DUP(D-5) 11/15/2002 4-8				MDL	RL	40SB2A 11/15/2002 0-1				MDL	RL	40SB2B 11/15/2002 12-13				MDL	RL																																																																																																																																																																																																																																																																																																																																																																												
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Table 4-1
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SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB1A 11/15/2002 0-1				MDL	RL	40SB1B 11/15/2002 7-9				MDL	RL	40SB1C 11/15/2002 9-10				MDL	RL	40SB1F 11/15/2002 4-8				MDL	RL	40SB1F-DUP(D-5) 11/15/2002 4-8				MDL	RL	40SB2A 11/15/2002 0-1				MDL	RL	40SB2B 11/15/2002 12-13				MDL	RL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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								Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r	
Octadecanoic Acid	--	--	--	--	--	--	--	NI					NI					NI						NI						NI					NI					NI																	
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	400	NJ,NJ,t	0	0		NI					NI						NI						NI					NI					NI																	
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI					NI					NI						NI						NI					NI					NI																	
Pentadecanoic Acid	--	--	--	--	--	--	--	210	NJ,NJ,t	0	0		NI					NI						NI						NI					NI					NI																	
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI					NI					740	NJ,NJ,t	0	0			NI					NI					NI					NI																		
Phenol, 4,4'-(1-Methylethyldiene)bis-	--	--	--	--	--	--	--	NI					NI					NI						NI					NI					NI					NI																		
Sulfur	--	--	--	--	--	--	--	NI					NI					NI						NI					NI					NI					NI																		
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	1,800	NJ,NJ,t	0	0		1,100	NJ,NJ,t	0	0		NI						12,000	NJ,NJ,t	0	0		5,600	NJ,NJ,t	0	0		500	NJ,NJ,t	0	0		8,600	NJ,NJ,t	0	0															
Testosterone	58-22-0	--	--	--	--	--	--	NI					NI					NI						NI					NI					NI					NI																		
Tetradecanoic Acid	--	--	--	--	--	--	--	NI					NI					NI						NI					NI					NI					NI																		
TCL PAHs (ug/kg)																																																									
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	1,200	P,J,g	5.8	51	<58	U	5.9	58	<60	U	5.9	60	640		5.8	76	3,400	PZ,J,g	5.8	1,200	<51	U	5.9	51	<55	U	5.8	55																						
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<51	U	5.9	51	<58	U	5.9	58	<60	U	5.9	60	320	JPZ,J,g	5.9	1,500	2,000	PZ,J,g	5.9	1,200	<51	U	5.9	51	<55	U	5.9	55																						
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<51	U	5.4	51	<58	U	5.4	58	<60	U	5.4	60	<76	U	5.4	76	<58	U	5.4	58	<51	U	5.4	51	<55	U	5.4	55																						
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	14	J	2.2	10	<12	U	2.2	12	<12	U	2.2	12	820	PZ,J,g	2.2	300	3,700	PZ,J,g	2.2	230	<10	U	2.2	10	<11	U	2.2	11																						
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	35	J	1.6	10	<12	U	1.6	12	<12	U	1.6	12	<15	U	1.6	15	<11	U	1.6	11	<10	U	1.6	10	<11	U	1.6	11																						
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	32	JP,J,g	1.7	10	<12	U	1.7	12	<12	U	1.7	12	98	JPZ,J,g	1.7	300	<11	U	1.7	11	<10	U	1.7	10	<11	U	1.7	11																						
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<10	U	3.6	10	<12	U	3.6	12	<12	U	3.6	12	<15	U	3.6	15	<11	U	3.6	11	<10	U	3.6	10	<11	U	3.6	11																						
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<10	U	1.4	10	<12	U	1.4	12	<12	U	1.4	12	<15	U	1.4	15	<11	U	1.4	11	<10	U	1.4	10	<11	U	1.4	11																						
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	680	P,J,g	2.4	10	<12	U	2.4	12	<12	U	2.4	12	3,700	PZ,J,g	2.4	300	3,000	PZ,J,g	2.4	230	<10	U	2.4	10	2,100	PZ,J,g	2.4	220																						
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<10	U	4.2	10	<12	U	4.2	12	<12	U	4.2	12	<15	U	4.2	15	200	JZ	4.2	230	<10	U	4.2	10	<11	U	4.2	11																						
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	170	P,J,g	2.1	21	7.6	J	2.1	24	<24	U	2.1	24	450	P,J,g	2.1	31	320		2.1	23	20	JP,J,g	2.1	21	<22	U	2.1	22																						
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<51	U	14	51	<58	U	14	58	<60	U	14	60	<76	U	14	76	<51	U	14	58	<51	U	14	51	<55	U	14	55																						
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	<10	U	2.5	10	<12	U	2.5	12	<12	U	2.5	12	<15	U	2.5	15	<11	U	2.5	11	<10	U	2.5	10	<11	U	2.5	11																						
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	<51	U	14	51	<58	U	14	58	<60	U	14	60	<76	U	14	76	1,600	PZ,J,g	14	1,200	<51	U	14	51	<55	U	14	55																						
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<51	U	8.5	51	<58	U	8.5	58	<60	U	8.5	60	<76	U	8.5	76	<58	U	8.5	58	<51	U	8.5	51	<55	U	8.5	55																						
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	87	JP,J,g	4.3	21	23	J	4.3	24	<24	U	4.3	24	370	JPZ,J,g	4.3	620	350	JZ,J,g	4.3	460	20	JP,J,g	4.3	21	<22	U	4.3	22																						
Dioxin/Furans (pg/g)																																																									
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT					NT					NT						NT						NT					NT					NT																	
Total HxCDD	34465-46-8	--	--	--	--	--	--																																																		

Table 4-1
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SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB2C 11/15/2002 13-15				MDL	RL	40SB2F 11/15/2002 8-12				MDL	RL	40SB3A 11/14/2002 0-1				MDL	RL	40SB3B 11/14/2002 4-8				MDL	RL	40SB3C 11/14/2002 8-8.9				MDL	RL	40SB4A 11/14/2002 0-1				MDL	RL	40SB4B 11/14/2002 20-24				MDL	RL																																																																																																																																																																																																																																																																																																																																																																																
								Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	L

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB2C 11/15/2002 13-15		MDL	RL	40SB2F 11/15/2002 8-12		MDL	RL	40SB3A 11/14/2002 0-1		MDL	RL	40SB3B 11/14/2002 4-8		MDL	RL	40SB3C 11/14/2002 8-8.9		MDL	RL	40SB4A 11/14/2002 0-1		MDL	RL	40SB4B 11/14/2002 20-24		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Benzene, 2-Ethethyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Camphor	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI			14	NJ,NJ,t	0	0	NI								
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Ether	--	--	--	--	--	--	--	150	NJ,NJ,t	0	0	NI				NI				NI				NI				NI				NI							
Hexanal	--	--	--	--	--	--	--	NI				NI				52	NJ,NJ,t	0	0	NI				NI				NI				NI							
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Methanethiol	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Nonanal	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentanal	--	--	--	--	--	--	--	NI				NI				19	NJ,NJ,t	0	0	NI				NI				NI				NI							
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	<490	U	22	490	35	J	22	430	<420	U	22	420	<520	U	22	520	<480	U	22	480	<400	U	22	400	<440	U	22	440				
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	<490	U	20	490	31	J	20	430	<420	U	20	420	<520	U	20	520	<480	U	20	480	<400	U	20	400	<440	U	20	440				
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	<490	U	21	490	<430	U	21	430	<420	U	21	420	<520	U	21	520	<480	U	21	480	<400	U	21	400	<440	U	21	440				
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	78	J,J,c	24	490	<430	U,UJ,c	24	430	<420	U	24	420	<520	U	24	520	<480	U	24	480	<400	U,UJ,c	24	400	<440	U	24	440				
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	<490	U	29	490	<430	U	29	430	<420	U	29	420	<520	U	29	520	<480	U	29	480	<400	U	29	400	<440	U	29	440				
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	<490	U	48	490	<430	U	48	430	<420	U	48	420	<520	U	48	520	<480	U	48	480	<400	U	48	400	<440	U	48	440				
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<490	U	31	490	160	J	31	430	<420	U	31	420	<520	U	31	520	<480	U	31	480	<400	U	31	400	<440	U	31	440				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<490	U	17	490	<430	U	17	430	<420	U	17	420	<520	U	17	520	<480	U	17	480	<400	U	17	400	<440	U	17	440				
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	<490	U	23	490	<430	U	23	430	<420	U	23	420	<520	U	23	520	<480	U	23	480	<400	U	23	400	<440	U	23	440				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<490	U	25	490	69	J	25	430	<420	U	25	420	<520	U	25	520	<480	U	25	480	<400	U	25	400	<440	U	25	440				
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	<490	U	39	490	<430	U	39	430	<420	U	39	420	<520	U	39	520	<480	U	39	480	<400	U	39	400	<440	U	39	440				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<490	U	29	490	83	J	29	430	<420	U	29	420	<520	U	29	520	<480	U	29	480	<400	U	29	400	<440	U	29	440				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<490	U	23	490	48	J	23	430	<420	U	23	420	<520	U	23	520	<480	U	23	480	<400	U	23	400	<440	U	23	440				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<490	U	36	490	<430	U	36	430	<420	U	36	420	<520	U	36	520	<480	U	36	480	<400	U	36	400	<440	U	36	440				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<490	U	23	490	32	J	23	430	<420	U	23	420	<520	U	23	520	<480	U	23	480	<400	U	23	400	<440	U	23	440				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<490	U	29	490	59	J	29	430	<420	U	29																					

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Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB2C 11/15/2002 13-15		MDL	RL	40SB2F 11/15/2002 8-12		MDL	RL	40SB3A 11/14/2002 0-1		MDL	RL	40SB3B 11/14/2002 4-8		MDL	RL	40SB3C 11/14/2002 8-8.9		MDL	RL	40SB4A 11/14/2002 0-1		MDL	RL	40SB4B 11/14/2002 20-24		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	2,000	NJ,NJ,t	0	0	NI				NI				NI				NI				340	NJ,NJ,t	0	0	NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				7,500	NJ,NJ,t	0	0	NI				250	NJ,NJ,t	0	0	NI				NI				960	NJ,NJ,t	0	0				
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<63	U	5.8	63	<54	U	5.8	54	47	J,J,c	5.9	54	17	J,J,c	5.9	67	<61	U	5.9	61	<49	U	5.8	49	<57	U	5.9	57				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<63	U	5.9	63	<54	U	5.9	54	<54	U	5.9	54	<67	U	5.9	67	<61	U	5.9	61	<49	U	5.9	49	<57	U	5.9	57				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<63	U	5.4	63	<54	U	5.4	54	<54	U	5.4	54	<67	U	5.4	67	<61	U	5.4	61	<49	U	5.4	49	<57	U	5.4	57				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<12	U	2.2	12	<11	U	2.2	11	29		2.2	11	<13	U	2.2	13	<12	U	2.2	12	<9.8	U	2.2	9.8	<11	U	2.2	11				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<12	U	1.6	12	<11	U	1.6	11	41	P,J,g	1.6	11	<13	U	1.6	13	<12	U	1.6	12	<9.8	U	1.6	9.8	<11	U	1.6	11				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<12	U	1.7	12	56	JPZ,J,g	1.7	220	63	BP,J,g	1.7	11	<13	U	1.7	13	<12	U	1.7	12	19	JPZ,J,g	1.7	49	8.4	BJP,B,z	1.7	11				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<12	U	3.6	12	<11	U	3.6	11	24	P,J,g	3.6	11	<13	U	3.6	13	<12	U	3.6	12	<9.8	U	3.6	9.8	<11	U	3.6	11				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<12	U	1.4	12	<11	U	1.4	11	53	P,J,g	1.4	11	<13	U	1.4	13	<12	U	1.4	12	<9.8	U	1.4	9.8	<11	U	1.4	11				
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	2,000	PZ,J,g	2.4	250	1,900	PZ,J,g	2.4	220	<11	U	2.4	11	<13	U	2.4	13	<12	U	2.4	12	<9.8	U	2.4	9.8	<11	U	2.4	11				
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<12	U	4.2	12	<11	U	4.2	11	44		4.2	11	<13	U	4.2	13	<12	U	4.2	12	<9.8	U	4.2	9.8	16	P	4.2	11				
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	<25	U	2.1	25	150	P,J,g	2.1	22	67		2.1	22	<27	U	2.1	27	<25	U	2.1	25	<20	U	2.1	20	21	BJP,J,g	2.1	23				
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<63	U	14	63	<54	U	14	54	<54	U	14	54	<67	U	14	67	<61	U	14	61	<49	U	14	49	<57	U	14	57				
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	<12	U	2.5	12	<11	U	2.5	11	48		2.5	11	<13	U	2.5	13	<12	U	2.5	12	<9.8	U	2.5	9.8	<11	U	2.5	11				
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	<63	U	14	63	<54	U	14	54	<54	U	14	54	<67	U	14	67	<61	U	14	61	<49	U	14	49	<57	U	14	57				
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<63	U	8.5	63	<54	U	8.5	54	22	J	8.5	54	<67	U	8.5	67	<61	U	8.5	61	<49	U	8.5	49	<57	U	8.5	57				
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	310	JPZ,J,g	4.3	510	300	JPZ,J,g	4.3	440	35	B,B,z	4.3	22	<27	U	4.3	27	14	BJ,B,z	4.3	25	67	JPZ,J,g	4.3	100	<23	U	4.3	23				
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT		</																									

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB4C 11/14/2002 42-44.75			MDL	RL	40SB4C-DUP(D-4) 11/14/2002 42-44.75			MDL	RL	40SB4F 11/14/2002 4-12			MDL	RL	40SB4F-DUP(D-3) 11/14/2002 4-12			MDL	RL	40SB5A 11/14/2002 0-1			MDL	RL	40SB5C 11/14/2002 8-9			MDL	RL	40SB5F 11/14/2002 4-8			MDL	RL												
								Result	LQ	VQ, r			Result	LQ	VQ, r			Result	LQ	VQ, r			Result	LQ	VQ, r			Result	LQ	VQ, r			Result	LQ	VQ, r			Result	LQ	VQ, r			Result	LQ	VQ, r	Result	LQ	VQ, r	Result	LQ	VQ, r	Result	LQ	VQ, r
TAL Metals (mg/kg)																																																						
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	30,700			3.1	14.3	24,500			2.9	13.4	7,460	*J,k	3	13.8	4,760		3.1	14.3	16,600	*J,k	2.5	11.3	14,400	*J,k	2.4	11	26,100	*J,k	3.6	16.3																	
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	<1.4	UN,UL,m	0.53	1.4	0.58	BN,K,w	0.5	1.3	3.1	N,L,m	0.51	1.4	1.7	N,K,w	0.53	1.4	0.53	BN,L,m	0.42	1.1	0.53	BN,L,m	0.41	1.1	0.62	BN,L,m	0.6	1.6																			
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	8	N,L,m	0.36	1.4	3	N,L,m	0.33	1.3	51	*J,k	0.34	1.4	20.8	N,L,m	0.36	1.4	4.3	*J,k	0.28	1.1	<1.1	U*,UL,w	0.27	1.1	4	*J,k	0.41	1.6																			
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	77.7	NE,L,m	0.03	1.4	30.4	NE,L,m	0.03	1.3	110	*J,k	0.03	1.4	97.1	NE,L,m	0.03	1.4	19.2	*J,k	0.02	1.1	25.7	*J,k	0.02	1.1	71.2	*J,k	0.03	1.6																			
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	2	NE,L,m	0.01	0.72	2.8	NE,L,m	0.01	0.67	0.32	B	0.01	0.69	0.25	BNE,K,w	0.01	0.72	0.35	B	0.01	0.57	0.69		0.01	0.55	1.4		0.02	0.81																			
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	0.5	BN,K,w	0.06	0.72	0.34	BN,K,w	0.05	0.67	1.1		0.06	0.69	0.53	BN,K,w	0.06	0.72	<0.57	U	0.05	0.57	0.3	B	0.04	0.55	0.57	B	0.07	0.81																			
Calcium	7440-70-2	--	--	--	--	--	--	1,700	*E	1.4	143	2,020	*E,J,s	1.3	134	31,100	*J,k	1.3	138	5,710	*J,k	1.1	113	8,210	*J,k	2.1	220	102,000	*J,k	2.1	220	19,200	*J,k	1.6	163																			
Chromium ^[4]	7440-47-3	65.3	N	23.46	N	306.6	42.05	42.7	NE,L,m	0.09	0.72	41.3	NE,L,m	0.08	0.67	38.5	N*,J,k	0.08	0.69	31.2	NE,L,m	0.09	0.72	17.9	N*,J,k	0.07	0.57	21.9	N*,J,k	0.07	0.55	40.6	N*,J,k	0.1	0.81																			
Cobalt	7440-48-4	72.3	--	--	--	--	--	9.8	N*E,L,m	0.09	0.72	11.3	N*E,L,m	0.08	0.67	8.6	*J,k	0.08	0.69	3.2	N*E,L,m	0.09	0.72	3.3	*J,k	0.07	0.57	5.3	*J,k	0.07	0.55	9.4	*J,k	0.1	0.81																			
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	38.3	N*E,L,m	0.2	0.72	7.9	N*E,L,m	0.19	0.67	77.7	N*,J,k	0.19	0.69	35.8	N*E,L,m	0.2	0.72	5.9	N*,J,k	0.16	0.57	3.5	N*,J,k	0.15	0.55	98.2	N*,J,k	0.23	0.81																			
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	37,800	E,J,s	2	14.3	25,100	E,J,s	1.8	13.4	130,000	*J,k	9.4	68.9	66,200	E,J,s	3.9	28.7	21,600	*J,k	1.6	11.3	18,500	*J,k	1.5	11	35,100	*J,k	2.2	16.3																			
Lead ^[2]	7439-92-1	26.8	--	400	--	750	--	17.2		0.33	0.43	3.4		0.31	0.4	206	*J,k	0.32	0.41	309		0.33	0.43	18.2	*J,k	0.26	0.34	2.4	*J,k	0.25	0.33	62	*J,k	0.37	0.49																			
Magnesium	7439-95-4	--	--	--	--	--	--	18,300	*E,J,k	0.87	143	42,100	*E,J,k	0.82	134	11,300	*J,k	0.84	138	1,180	*E,J,k	0.87	143	4,260	*J,k	0.69	113	66,200	*J,k	0.67	110	28,900	*J,k	0.99	163																			
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	739	E,J,s	0.03	1.4	300	E,J,s	0.03	1.3	623	*J,k	0.03	1.4	445	E,J,s	0.03	1.4	117	*J,k	0.02	1.1	198	*J,k	0.02	1.1	325	*J,k	0.03	1.6																			
Mercury ^[3]	7439-97-6	0.13	N	2.35	N	30.66	--	0.088		0.025	0.05	<0.047	U	0.023	0.047	1.9	*J,k	0.023	0.047	5.3		0.12	0.24	0.084	*J,k	0.018	0.035	<0.039	U*,J,k	0.019	0.039	0.23	*J,k	0.026	0.052																			
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	31.6	NE,L,m	0.14	0.72	31.6	NE,L,m	0.13	0.67	34.8	*J,k	0.14	0.69	18.3	NE,L,m	0.14	0.72	7.3	*J,k	0.11	0.57	15	*J,k	0.11	0.55	27.8	*J,k	0.16	0.81																			
Potassium	7440-09-7	--	--	--	--	--	--	4,820	*E,J,k	16.9	143	10,800	*E,J,k	15.9	134	1,070	E,J,s	16.3	138	495	*E,J,k	17	143	502	E,J,s	13.4	113	3,880	E,J,s	13	110	3,180	E,J,s	19.3	163																			
Selenium	7782-49-2	--	N	39.11	N	511	18.98	1.4	N,K,w	0.47	0.72	0.62	BN,K,w	0.44	0.67	5.7	*J,k	0.45	0.69	3.7	N,L,m	0.47	0.72	1.3	*J,k	0.37	0.57	<0.55	U*,UJ,k	0.36	0.55	1.9	*J,k	0.54	0.81																			
Silver	7440-22-4	--	N	39.11	N	511	31.03	<0.72	U	0.1	0.72	<0.67	U	0.09	0.67	0.99		0.1	0.69	0.45	B,K,w	0.1	0.72	<0.57	U	0.08	0.57	<0.55	U	0.08	0.55	0.17	B	0.11	0.81																			
Sodium	7440-23-5	--	--	--	--	--	--	202	B,B,x	35.6	286	191	B,B,x	33.3	268	930		34.3	276	495		35.6	287	219	B,L,w	28.2	227	1,790		27.3	220	1,960		40.5	326																			
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	<1.4	UN,UL,m	0.73	1.4	<1.3	UN,UL,m	0.68	1.3	<1.4	UN*,R,m	0.7	1.4	<1.4	UN,UL,m	0.73	1.4	<1.1	UN*,R,m	0.58	1.1	<1.1	UN*,R,m	0.56	1.1	<1.6	UN*,R,m	0.83	1.6																			
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	64	NE,L,m	0.1	2.9	51.8	NE,L,m	0.09	2.7	11.6	*J,k	0.1	2.8	7.4	NE,L,m	0.1	2.9	43.5	*J,k	0.08	2.3	31.6	*J,k	0.08	2.2	52.6	*J,k	0.11	3.3																			
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	65.1	NE,L,m	0.14	2.9	43.5	NE,L,m	0.13	2.7	316	*J,k	0.14	2.8	198	NE,L,m	0.14	2.9	113	*J,k	0.11	2.3	30.8	*J,k	0.11	2.2	79.4	*J,k	0.16	3.3																			
Pesticides/PCBs (ug/kg)																																																						
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	NT				NT				NT				NT				NT			<2	U	0.4	2	NT			NT																				
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	NT				NT				NT				NT				NT			<6	U,UJ,c	0.39	6	NT			NT																				
Aldrin	309-00-2	--	C	3.8E+01	C	1.7E+02	7.7E+00	NT				NT				NT				NT				NT			<1	U	0.17	1	NT			NT																				
alpha-BHC	319-84-6	--	C	1.0E+02	C	4.5E+02	8.9E-01	NT				NT				NT				NT				NT			<1	U	0.26	1	NT			NT																				
alpha-Chlordane ^[4]	5103-71-9	--	C	1.8E+03	C	8.2E+03	--	NT				NT				NT				NT				NT			<2	U	0.22	2	NT			NT																				
beta-BHC	319-85-7	--	C	3.5E+02	C	1.6E+03	3.1E+00	NT				NT				NT				NT				NT			<2	U	0.28	2	NT			NT																				
delta-BHC ^[5]	319-86-8	--	C	1.0E+02	C	4.5E+02	--	NT				NT				NT				NT				NT			<1	U	0.15	1	NT			NT																				
Endosulfan Sulfate ^[5]	1031-07-8	--	N	4.7E+04	N	6.1E+05	--	NT				NT				NT				NT				NT			<4	U	0.4	4	NT			NT																				
Endrin	72-20-8	--	N	2.3E+03	N	3.1E+04	5.4E+03	NT				NT				NT				NT				NT			<4	U	0.35	4	NT			NT																				
Endrin Ketone ^[7]	53494-70-5	--	N	2.3E+03	N	3.1E+04	--	NT				NT				NT				NT				NT			<10	U	0.39	10	NT			NT																				
gamma-BHC (Lindane)	58-89-9	--	C	4.9E+02	C	2.2E+03	4.3E+00	NT				NT				NT				NT				NT			<1	U	0.22	1	NT			NT																				
gamma-Chlordane ^[4]	5103-74-2	--	C	1.8E+03	C	8.2E+03	--	NT				NT				NT				NT				NT			<1	U	0.35	1	NT			NT																				
Methoxychlor	72-43-5	--	N	3.9E+04	N	5.1E+05	3.1E+05	NT				NT				NT				NT				NT			<10	U,UJ,c	1.4	10	NT			NT																				
Aroclor 1016 ^[6]	12674-11-2	--	N	5.5E+02	N	7.2E+03	4.2E+03	<49	U	15	49	<47	U	15	47	<970	U	15	970	<240	U	15	240	<78	U	15	78	<38	U	15	38	<38	U	5.4	38	<210	U	15	110															
Aroclor 1232	11141-16-5	--	C	3.2E+02	C	1.4E+03	--	<49	U	5.4	49	<47	U	5.4	47	<970	U	5.4	970	<240	U	5.4	240	<78	U	5.4	78	<38	U	5.4	38	<110	U	5.4	110																			
Aroclor 1242	53469-21-9	--	C	3.2E+02	C	1.4E+03	--	<34	U	10	34	<33	U	10	33	<670	U	10	670	<170	U	10	170	<54	U	10	54	<26	U	10	26	<78	U	10	78																			
Aroclor 1248	12672-29-6	--	C	3.2E+02	C	1.4E+03	--	<34	U	9.1	34	<33	U	9.1	33	<670	U	9.1	670	<170	U	9.1	170	<54	U	9.1	54	<26	U	9.1	26	<78	U	9.1	78																			
Aroclor 1254 ^[4]	11097-69-1	--	N	1.6E+02	C	1.4E+03	1.1E+03	<34	U	9	34	<33	U	9	33	2,600	P,J,g	9	670	1,700	PD,J,g	9	170	75	U	9	54	<26	U	9	26	500		9	78																			
Aroclor 1260	11096-82-5	--	C	3.2E+02	C	1.4E+03	--	<49	U	9.2	49	<47	U	9.2	47	350	J	9.2																																				

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB4C 11/14/2002 42-44.75		MDL	RL	40SB4C-DUP(D-4) 11/14/2002 42-44.75		MDL	RL	40SB4F 11/14/2002 4-12		MDL	RL	40SB4F-DUP(D-3) 11/14/2002 4-12		MDL	RL	40SB5A 11/14/2002 0-1		MDL	RL	40SB5C 11/14/2002 8-9		MDL	RL	40SB5F 11/14/2002 4-8		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				2,300	NJ,NJ,t	0	0	NI				NI				NI				NI				NI			
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				20	NJ,NJ,t	0	0	NI			
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Camphor	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				16	NJ,NJ,t	0	0	NI			
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				5	NJ,NJ,t	0	0	NI				NI			
Ether	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Hexanal	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Methanethiol	--	--	--	--	--	--	--	NI				NI				44	NJ,NJ,t	0	0	NI				NI				NI				NI				NI			
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				1,400	NJ,NJ,t	0	0	NI				NI				NI				NI				NI			
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI				530	NJ,NJ,t	0	0	NI				NI				13	NJ,NJ,t	0	0	NI			
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				2,300	NJ,NJ,t	0	0	NI				NI				NI				NI				NI			
Nonanal	--	--	--	--	--	--	--	NI				NI				58	NJ,NJ,t	0	0	NI				NI				NI				NI				NI			
Pentanal	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI				NI			
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	<500	U	22	500	<480	U	22	480	71	J	22	490	94	J	22	490	<400	U	22	400	<390	U	22	390	<570	U	22	570				
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	<500	U	20	500	<480	U	20	480	<490	U	20	490	<490	U	20	490	<400	U	20	400	<390	U	20	390	<570	U	20	570				
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	<500	U	21	500	<480	U	21	480	<490	U	21	490	<490	U	21	490	<400	U	21	400	<390	U	21	390	<570	U	21	570				
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	<500	U	24	500	<480	U	24	480	200	J,J,c	24	490	1,000	J,r	24	490	<400	U	24	400	<390	U	24	390	68	J	24	570				
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	<500	U	29	500	<480	U	29	480	<490	U	29	490	<490	U	29	490	<400	U	29	400	<390	U	29	390	<570	U	29	570				
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	<500	U	48	500	<480	U	48	480	73	J	48	490	160	J,J,r	48	490	<400	U	48	400	<390	U	48	390	<570	U	48	570				
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<500	U	31	500	<480	U	31	480	<490	U	31	490	<490	U	31	490	<400	U	31	400	<390	U	31	390	<570	U	31	570				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<500	U	17	500	<480	U	17	480	<490	U	17	490	<490	U	17	490	<400	U	17	400	<390	U	17	390	<570	U	17	570				
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	<500	U	23	500	<480	U	23	480	<490	U	23	490	<490	U	23	490	<400	U	23	400	<390	U	23	390	<570	U	23	570				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<500	U	25	500	<480	U	25	480	<490	U	25	490	<490	U	25	490	<400	U	25	400	<390	U	25	390	<570	U	25	570				
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	<500	U	39	500	<480	U	39	480	<490	U	39	490	<490	U	39	490	<400	U	39	400	<390	U	39	390	<570	U	39	570				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<500	U	29	500	<480	U	29	480	<490	U	29	490	51	J	29	490	<400	U	29	400	<390	U	29	390	<570	U	29	570				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<500	U	23	500	<480	U	23	480	<490	U	23	490	<490	U	23	490	<23	U	23	400	<390	U	23	390	<570	U	23	570				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<500	U	36	500	<480	U	36	480	<490	U	36	490	58	J	36	490	<40</															

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Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB4C 11/14/2002 42-44.75		MDL	RL	40SB4C-DUP(D-4) 11/14/2002 42-44.75		MDL	RL	40SB4F 11/14/2002 4-12		MDL	RL	40SB4F-DUP(D-3) 11/14/2002 4-12		MDL	RL	40SB5A 11/14/2002 0-1		MDL	RL	40SB5C 11/14/2002 8-9		MDL	RL	40SB5F 11/14/2002 4-8		MDL	RL					
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r	
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				3,700	NJ,NJ,t	0	0			6,600	NJ,NJ,t	0	0	NI						NI								
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI					NI					NI					NI						NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI					NI					NI					NI						NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI					NI					NI					NI						NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI					NI					NI					NI						NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				2,300	NJ,NJ,t	0	0			3,300	NJ,NJ,t	0	0	NI						NI								
Sulfur	--	--	--	--	--	--	--	NI				NI				5,200	NJ,NJ,t	0	0			NI				NI						NI								
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	270	NJ,NJ,t	0	0	NI					NI					19,000	NJ,NJ,t	0	0	NI						4,700	NJ,NJ,t	0	0	13,000	NJ,NJ,t	0	0	
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI					NI					NI					NI						NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI					NI					NI					NI						NI							
TCL PAHs (ug/kg)																																								
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	15	BJ,J,c	5.9	63	740	P,J,c	5.9	61	<63	U	5.8	63			1,900	PZ,J,c	5.9	1,500	<51	U	5.9	51			1,300	PZ,J,g	5.8	490	<72	U	5.8	72	
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<63	U	5.9	63	<61	U	5.9	61	<63	U	5.9	63			<62	U	5.9	62	<51	U	5.9	51			74	JPZ,J,g	5.9	490	660	JPZ,J,g	5.9	1,400	
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<63	U	5.4	63	<61	U	5.4	61	<63	U	5.4	63			<62	U	5.4	62	<51	U	5.4	51			<49	U	5.4	49	<72	U	5.4	72	
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<12	U	2.2	12	<12	U	2.2	12	<12	U	2.2	12			3,800	PZ,J,g	2.2	300	<10	U	2.2	10			<9.8	U	2.2	9.8	<14	U	2.2	14	
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<12	U	1.6	12	2.9	J	1.6	12	<12	U	1.6	12			900	BEP,J,g	1.6	12	3.8	J	1.6	10			<9.8	U	1.6	9.8	<14	U	1.6	14	
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	13	BP,B,z	1.7	12	24	BP,B,z	1.7	12	78	JPZ,J,g	1.7	250			850	BEP,J,g	1.7	12	4.2	J	1.7	10			<9.8	U	1.7	9.8	160	JPZ,J,g	1.7	290	
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<12	U	3.6	12	<12	U	3.6	12	<12	U	3.6	12			<12	U	3.6	12	<10	U	3.6	10			<9.8	U	3.6	9.8	<14	U	3.6	14	
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<12	U	1.4	12	<12	U	1.4	12	42	JPZ,J,g	1.4	250			1,000	EP,J,g	1.4	12	<10	U	1.4	10			24	JPZ,J,g	1.4	98	<14	U	1.4	14	
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	<12	U	2.4	12	<12	U	2.4	12	2,300	PZ,J,g	2.4	250			470	Z,K,s	2.4	300	4.5	J	2.4	10			1,500	PZ,J,g	2.4	98	2,300	PZ,J,g	2.4	290	
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<12	U	4.2	12	<12	U	4.2	12	<12	U	4.2	12			<12	U	4.2	12	<10	U	4.2	10			<9.8	U	4.2	9.8	<14	U	4.2	14	
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	<25	U	2.1	25	<25	U	2.1	25	760	EP,J,g	2.1	25			2,400	EP,J,g	2.1	25	<20	U	2.1	20			<20	U	2.1	20	550	P,J,g	2.1	29	
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<63	U	1.4	63	<61	U	1.4	61	<63	U	1.4	63			<62	U	1.4	62	<51	U	1.4	51			<49	U	1.4	49	<72	U	1.4	72	
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	<12	U	2.5	12	<12	U	2.5	12	<12	U	2.5	12			650	BEP,J,g	2.5	12	<10	U	2.5	10			<9.8	U	2.5	9.8	<14	U	2.5	14	
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	<63	U	1.4	63	<61	U	1.4	61	<63	U	1.4	63			<62	U	1.4	62	<51	U	1.4	51			<49	U	1.4	49	<72	U	1.4	72	
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<63	U	8.5	63	<61	U	8.5	61	<63	U	8.5	63			780	K,s	8.5	62	<51	U	8.5	51			<49	U	8.5	49	<72	U	8.5	72	
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	14	BJ,B,z	4.3	25	28	BP,B,z	4.3	25	280	JPZ,J,g	4.3	510			810	BE,K,s	4.3	25	<20	U		4.3	20			120	JPZ,J,g	4.3	200	940	PZ,J,g	4.3	590
Dioxin/Furans (pg/g)																																								
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				NT					NT					NT						NT					NT			
Nitroglycerin (mg/kg)																																								
Nitroglycerin	55-63-0	--	N	7.8E-01	N	1.0E+01	--	<10	U	1	10	<																												

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Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB6A 11/13/2002 0-1			40SB6C 11/13/2002 12-16			40SB6F 11/13/2002 6-8			40SB7A 11/13/2002 0-1			40SB7B 11/13/2002 17-20			40SB7C 11/13/2002 20-20.7			40SB7F 11/13/2002 12-14															
								Result	LQ, VQ, r	MDL	RL	Result	LQ, VQ, r	MDL	RL	Result	LQ, VQ, r	MDL	RL	Result	LQ, VQ, r	MDL	RL	Result	LQ, VQ, r	MDL	RL	Result	LQ, VQ, r	MDL	RL	Result	LQ, VQ, r	MDL	RL						
TAL Metals (mg/kg)																																									
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	13,000		2.6	11.8		21,500	3	13.6		12,600	2.5	11.5		17,700	2.5	11.6		21,800	3	13.9		34,200	3	13.6		5,720	3.1	14.1						
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	0.5	BN,K,w	0.44	1.2		<1.4	UN,UL,m	0.5	1.4		<1.1	UN,UL,m	0.43	1.1		<1.2	UN,UL,m	0.43	1.2		0.53	BN,K,w	0.51	1.4		0.83	BN,K,w	0.5	1.4		0.56	BN,K,w	0.52	1.4
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	3.4	N,L,m	0.3	1.2		2.9	N,L,m	0.34	1.4		5.6	N,L,m	0.29	1.1		4	N,L,m	0.29	1.2		6.5	N,L,m	0.35	1.4		5.1	N,L,m	0.34	1.4		0.98	BN,K,w	0.35	1.4
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	68.6	NE,L,m	0.02	1.2		68	NE,L,m	0.03	1.4		101	NE,L,m	0.02	1.1		50	NE,L,m	0.02	1.2		49.7	NE,L,m	0.03	1.4		54.7	NE,L,m	0.03	1.4		35.5	NE,L,m	0.03	1.4
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	0.48	BNE,K,w	0.01	0.59		1.3	NE,K,w	0.01	0.68		0.67	NE,K,w	0.01	0.57		0.54	BNE,K,w	0.01	0.58		1.4	NE,L,m	0.01	0.7		1.6	NE,L,m	0.01	0.68		0.29	BNE,K,w	0.01	0.7
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	0.09	BN,K,w	0.05	0.59		<0.68	UN,UL,m	0.05	0.68		0.24	BN,K,w	0.05	0.57		0.09	BN,K,w	0.05	0.58		0.17	BN,K,w	0.06	0.7		0.29	BN,K,w	0.05	0.68		0.3	BN,K,w	0.06	0.7
Calcium	7440-70-2	--	--	--	--	--	--	15,700	*E,J,s	1.1	118		1,940	*E,J,s	1.3	136		17,800	*E,J,s	1.1	115		9,430	*E,J,s	1.1	116		2,090	*E,J,s	1.3	139		2,570	*E,J,s	1.3	136		6,250	*E,J,s	1.4	141
Chromium ⁽¹⁾	7440-47-3	65.3	N	23.46	N	306.6	42.05	24.5	NE,L,m	0.07	0.59		30	NE,L,m	0.08	0.68		21.5	NE,L,m	0.07	0.57		21.6	NE,L,m	0.07	0.58		47	NE,L,m	0.08	0.7		40.9	NE,L,m	0.08	0.68		24.8	NE,L,m	0.08	0.7
Cobalt	7440-48-4	72.3	--	--	--	--	--	5.1	N*E,L,m	0.07	0.59		9	N*E,L,m	0.08	0.68		7.9	N*E,L,m	0.07	0.57		8.2	N*E,L,m	0.07	0.58		6.4	N*E,L,m	0.08	0.7		11.1	N*E,L,m	0.08	0.68		5.1	N*E,L,m	0.08	0.7
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	7.8	N*E,L,m	0.17	0.59		14.1	N*E,L,m	0.19	0.68		7.6	N*E,L,m	0.16	0.57		2.1	N*E,L,m	0.16	0.58		38	N*E,L,m	0.19	0.7		18.6	N*E,L,m	0.19	0.68		9.9	N*E,L,m	0.2	0.7
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	17,400	E,J,s	1.6	11.8		25,300	E,J,s	1.9	13.6		22,100	E,J,s	1.6	11.5		25,900	E	1.6	11.6		26,100	E,J,s	1.9	13.9		31,100	E,J,s	1.9	13.6		10,900	E,J,s	1.9	14.1
Lead ⁽²⁾	7439-92-1	26.8	--	400	--	750	--	20.5		0.27	0.35		9.9		0.31	0.41		39.1		0.26	0.34		17.5		0.27	0.35		16.5		0.32	0.42		6.6		0.31	0.41		15		0.32	0.42
Magnesium	7439-95-4	--	--	--	--	--	--	9,500	*E,J,k	0.72	118		15,900	*E,J,k	0.83	136		12,200	*E,J,k	0.7	115		5,690	*E,J,k	0.71	116		26,100	*E,J,k	0.85	139		47,500	*E,J,k	0.83	136		2,200	*E,J,k	0.86	141
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	478	E,J,s	0.02	1.2		266	E,J,s	0.03	1.4		348	E,J,s	0.02	1.1		323	E,J,s	0.02	1.2		294	E,J,s	0.03	1.4		162	E,J,s	0.03	1.4		135	E,J,s	0.03	1.4
Mercury ⁽³⁾	7439-97-6	0.13	N	2.35	N	30.66	--	0.098		0.019	0.037		0.06		0.02	0.041		0.093		0.02	0.039		0.096		0.018	0.035		0.048		0.023	0.046		0.027	B	0.024	0.048		1.8		0.021	0.041
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	6.1	NE,L,m	0.12	0.59		19.9	NE,L,m	0.14	0.68		11.5	NE,L,m	0.11	0.57		9.2	NE,L,m	0.12	0.58		26.1	NE,L,m	0.14	0.7		27.5	NE,L,m	0.14	0.68		15	NE,L,m	0.14	0.7
Potassium	7440-09-7	--	--	--	--	--	--	889	*E,J,k	14	118		2,560	*E,J,k	16.1	136		1,940	*E,J,k	13.6	115		1,330	*E,J,k	13.8	116		5,570	*E,J,k	16.5	139		7,610	*E,J,k	16.1	136		482	*E,J,k	16.7	141
Selenium	7782-49-2	--	N	39.11	N	511	18.98	1.2	N,K,w	0.39	0.59		0.93	N,K,w	0.45	0.68		1	N,K,w	0.38	0.57		1.3	N,L,m	0.38	0.58		0.69	BN,K,w	0.46	0.7		0.8	N,K,w	0.45	0.68		0.61	BN,K,w	0.46	0.7
Silver	7440-22-4	--	N	39.11	N	511	31.03	<0.59	U	0.08	0.59		<0.68	U	0.1	0.68		<0.57	U	0.08	0.57		<0.58	U	0.08	0.58		<0.1	U	0.1	0.7		<0.68	U	0.1	0.68		0.82		0.1	0.7
Sodium	7440-23-5	--	--	--	--	--	--	249	B,x	29.4	237		316	B,x	33.8	272		291	B,x	28.6	230		132	B,B,x	29	233		1,950		34.6	278		6,670		33.8	272		598		35	282
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3,638	<1.2	UN,UL,m	0.6	1.2		<1.4	UN,UL,m	0.69	1.4		<1.1	UN,UL,m	0.59	1.1		<1.2	UN,UL,m	0.59	1.2		<1.4	UN,UL,m	0.71	1.4		<1.4	UN,UL,m	0.69	1.4		<1.4	UN,UL,m	0.72	1.4
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	39.1	NE,L,m	0.08	2.4		51.2	NE,L,m	0.1	2.7		36.9	NE,L,m	0.08	2.3		49.4	NE,L,m	0.08	2.3		61.9	NE,L,m	0.1	2.8		62.4	NE,L,m	0.1	2.7		15.4	NE,L,m	0.1	2.8
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	79.9	NE,L,m	0.12	2.4		38.6	NE,L,m	0.14	2.7		88.3	NE,L,m	0.11	2.3		33.9	NE,L,m	0.12	2.3		46.7	NE,L,m	0.14	2.8		53.5	NE,L,m	0.14	2.7		31.2	NE,L,m	0.14	2.8
Pesticides/PCBs (ug/kg)																																									
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	<2.1	U	0.4	2.1		NT					NT					<2	U	0.4	2		NT					NT				NT				
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	<6.1	U	0.39	6.1		NT					NT					<5.9	U	0.39	5.9		NT					NT				NT				
Aldrin	309-00-2	--	C	3.8E+01	C	1.7E+02	7.7E+00	<1																																	

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Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB6A 11/13/2002 0-1		MDL	RL	40SB6C 11/13/2002 12-16		MDL	RL	40SB6F 11/13/2002 6-8		MDL	RL	40SB7A 11/13/2002 0-1		MDL	RL	40SB7B 11/13/2002 17-20		MDL	RL	40SB7C 11/13/2002 20-20.7		MDL	RL	40SB7F 11/13/2002 12-14		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Camphor	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Ether	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Hexanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Methanethiol	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Nonanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Pentanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				1,200	NJ,NJ,t	0	0	NI						
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	<400	U	22	400	<450	U	22	450	<410	U	22	410	<390	U	22	390	<480	U	22	480	<470	U	22	470	<470	U	22	470		470		
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	35	J	20	400	<450	U	20	450	<410	U	20	410	<390	U	20	390	<480	U	20	480	<470	U	20	470	<470	U	20	470		470		
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	40	J	21	400	<450	U	21	450	<410	U	21	410	<390	U	21	390	<480	U	21	480	<470	U	21	470	<470	U	21	470		470		
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	<400	U	24	400	<450	U	24	450	<410	U	24	410	<390	U	24	390	<480	U	24	480	<470	U	24	470	<470	U	24	470		470		
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	<400	U	29	400	<450	U	29	450	<410	U	29	410	<390	U	29	390	<480	U	29	480	<470	U	29	470	<470	U	29	470		470		
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	<400	U	48	400	<450	U	48	450	<410	U	48	410	<390	U	48	390	<480	U	48	480	<470	U	48	470	<470	U	48	470		470		
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<400	U	31	400	<450	U	31	450	<410	U	31	410	<390	U	31	390	<480	U	31	480	<470	U	31	470	<470	U	31	470		470		
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<400	U	17	400	<450	U	17	450	<410	U	17	410	<390	U	17	390	<480	U	17	480	<470	U	17	470	<470	U	17	470		470		
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	<400	U	23	400	<450	U	23	450	<410	U	23	410	<390	U	23	390	<480	U	23	480	<470	U	23	470	<470	U	23	470		470		
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<400	U	25	400	<450	U	25	450	<410	U	25	410	<390	U	25	390	<480	U	25	480	<470	U	25	470	<470	U	25	470		470		
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	<400	U	39	400	<450	U	39	450	<410	U	39	410	<390	U	39	390	<480	U	39	480	<470	U	39	470	<470	U	39	470		470		
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<400	U	29	400	<450	U	29	450	<410	U	29	410	<390	U	29	390	<480	U	29	480	<470	U	29	470	<470	U	29	470		470		
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<400	U	23	400	<450	U	23	450	<410	U	23	410	<390	U	23	390	<480	U	23	480	<470	U	23	470	<470	U	23	470		470		
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<400	U	36	400	<450	U	36	450	<410	U	36	410	<390	U	36	390	<480	U	36	480	<470	U	36	470	<470	U	36	470		470		
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<400	U	23	400	<450	U	23	450	<410	U	23	410	<390	U	23	390	<480	U	23	480	<470	U	23	470	<470	U	23	470		470		

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								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	3,600	NJ,NJ,t	0	0	25,000	NJ,NJ,t	0	0	NI				NI				7,200	NJ,NJ,t	0	0	1,600	NJ,NJ,t	0	0	NI							
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	21	J,J,c	5.9	51	55	JP,J,c	5.9	57	<52	U	5.9	52	<49	U	5.9	49	<61	U	5.9	61	<60	U	5.8	60	9,100	EP,J,c	5.9	60				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<51	U	5.9	51	<57	U	5.9	57	<52	U	5.9	52	<49	U	5.9	49	<61	U	5.9	61	<60	U	5.9	60	<60	U	5.9	60				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<51	U	5.4	51	<57	U	5.4	57	<52	U	5.4	52	<49	U	5.4	49	<61	U	5.4	61	<60	U	5.4	60	<60	U	5.4	60				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<10	U	2.2	10	<11	U	2.2	11	230	Z,K,s	2.2	210	27		2.2	9.8	<12	U	2.2	12	<12	U	2.2	12	300	PZ,K,s	2.2	59				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<10	U	1.6	10	16	P,J,g	1.6	11	170	K,s	1.6	10	31		1.6	9.8	<12	U	1.6	12	<12	U	1.6	12	<12	U	1.6	12				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	5.4	JP,J,g	1.7	10	<11	U	1.7	11	170	K,s	1.7	10	42	P,J,g	1.7	9.8	<12	U,UJ,c	1.7	12	<12	U,UJ,c	1.7	12	280	EP,J,c	1.7	12				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<10	U	3.6	10	<11	U	3.6	11	92	JPZ,J,g	3.6	210	51	P,J,g	3.6	9.8	<12	U	3.6	12	<12	U	3.6	12	<12	U	3.6	12				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	10	JP,J,d	1.4	10	65	P,J,d	1.4	11	200	P,J,g	1.4	10	53	P,J,d	1.4	9.8	<12	U	1.4	12	<12	U	1.4	12	<12	U	1.4	12				
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	5.2	J	2.4	10	<11	U	2.4	11	2,500	PZ,J,g	2.4	210	210	EP,J,g	2.4	9.8	1,800	PZ,J,g	2.4	120	<12	U	2.4	12	25	JPZ,K,s	2.4	59				
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<10	U	4.2	10	<11	U	4.2	11	<10	U	4.2	10	19	P,J,g	4.2	9.8	<12	U	4.2	12	<12	U	4.2	12	<12	U	4.2	12				
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	26	P,J,g	2.1	21	22	JP,J,g	2.1	23	770	E,J,q	2.1	21	130	P,J,g	2.1	20	<25	U	2.1	25	<24	U	2.1	24	310	P,K,s	2.1	24				
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<51	U	14	51	<57	U	14	57	<52	U	14	52	<49	U	14	49	<61	U	14	61	<60	U	14	60	<60	U	14	60				
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	6.9	J	2.5	10	<11	U	2.5	11	120	K,s	2.5	10	14	P,J,g	2.5	9.8	<12	U	2.5	12	<12	U	2.5	12	<12	U	2.5	12				
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	33	J,J,d	14	51	<57	U	14	57	<52	U	14	52	<49	U	14	49	<61	U	14	61	<60	U	14	60	5,500	PZ,J,d	14	300				
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<51	U	8.5	51	<57	U	8.5	57	500	K,s	8.5	52	55		8.5	49	<61	U	8.5	61	<60	U	8.5	60	190	P,K,s	8.5	60				
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	17	JP,J,g	4.3	21	<23	U	4.3	23	750	PZ,J,g	4.3	420	68		4.3	20	90	JPZ,J,g	4.3	250	<24	U	4.3	24	190	PZ,K,s	4.3	120				
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT				NT				NT															

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB7F-DUP(D-2) 11/13/2002 12-14			MDL	RL	40SB8A 11/13/2002 0-1			MDL	RL	40SB8C 11/13/2002 20-25			MDL	RL	40SB8F 11/13/2002 6.5-20			MDL	RL	40SB8A 11/13/2002 0-1			MDL	RL	40SB9C 11/13/2002 16-20			MDL	RL	40SB9F 11/13/2002 8-10			MDL	RL															
								Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r	
TAL Metals (mg/kg)																																																									
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	17,700		2.9	13.4	17,900		6.4	11.3	17,000		2.7	12.5	11,700		6.9	12.1	19,200		6.9	12.2	26,200		7.4	13	14,800		6.5	11.5																						
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	<1.3	UN,UL,m	0.49	1.3	0.52	BN,L,m	0.14	1.1	0.57	BN,K,w	0.46	1.3	1.8	N,L,m	0.15	1.2	0.49	BN,L,m	0.15	1.2	0.64	BN,L,m	0.16	1.3	0.54	BN,L,m	0.14	1.1																						
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	3.3	N,L,m	0.33	1.3	3	N,K,m	0.34	1.1	7.2	N,L,m	0.31	1.3	15.2	N,K,m	0.36	1.2	4.1	N,K,m	0.37	1.2	5.7	N,K,m	0.39	1.3	4.2	N,K,m	0.34	1.1																						
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	65.3	NE,L,m	0.03	1.3	73.5		0.03	1.1	77.5	NE,L,m	0.03	1.3	116		0.04	1.2	51.7		0.04	1.2	51.8		0.04	1.3	60		0.03	1.1																						
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	0.88	NE,L,m	0.01	0.67	0.5	B	0.02	0.57	0.78	NE,L,m	0.01	0.63	0.82		0.02	0.61	0.44	B	0.02	0.61	1.4		0.03	0.65	0.52	B	0.02	0.57																						
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	1.7	N,L,m	0.05	0.67	<0.57	U	0.03	0.57	0.1	BN,K,w	0.05	0.63	2		0.04	0.61	<0.61	U	0.04	0.61	<0.65	U	0.04	0.65	<0.57	U	0.03	0.57																						
Calcium	7440-70-2	--	--	--	--	--	--	41,900	*E	1.3	134	1,250	L,p	1.7	113	7,200	*E,J,s	1.2	125	10,600	L,p	1.8	121	2,130	L,p	1.8	122	426	L,p	2	130	64,000	L,p	1.7	115																						
Chromium ⁽¹⁾	7440-47-3	65.3	N	23.46	N	306.6	42.05	32	NE,L,m	0.08	0.67	22.4		0.09	0.57	29.5	NE,L,m	0.08	0.63	234		0.1	0.61	22.7		0.1	0.61	39.5		0.1	0.65	17.5		0.09	0.57																						
Cobalt	7440-48-4	72.3	--	--	--	--	--	4.3	N*E,L,m	0.08	0.67	7.4	*	0.08	0.57	10.8	N*E,L,m	0.08	0.63	11.9	*	0.08	0.61	6.6	*	0.09	0.61	13.5	*	0.09	0.65	7	*	0.08	0.57																						
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	23.2	N*E,L,m	0.19	0.67	11.5	N,K,m	0.17	0.57	16.1	N*E,L,m	0.18	0.63	108	N,K,m	0.18	0.61	11.6	N,K,m	0.18	0.61	25.4	N,K,m	0.2	0.65	20.4	N,K,m	0.17	0.57																						
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	18,800	E,J,s	1.8	13.4	26,800		1.4	11.3	27,900	E,J,s	1.7	12.5	37,900		1.5	12.1	26,600		1.5	12.2	32,100		1.6	13	17,600		1.4	11.5																						
Lead ⁽²⁾	7439-92-1	26.8	--	400	--	750	--	11.8		0.31	0.4	15.5	N,K,m	0.14	0.34	52.6		0.29	0.38	58.5	N,K,m	0.15	0.36	16.6	N,K,m	0.15	0.37	10	N,K,m	0.16	0.39	18.5	N,K,m	0.14	0.34																						
Magnesium	7439-95-4	--	--	--	--	--	--	29,100	*E,J,k	0.81	134	1,230	*	1.4	113	5,940	*E,J,k	0.76	125	4,440	*	1.5	121	1,940	*	1.5	122	13,700	*	1.6	130	36,800	*	1.4	115																						
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	194	E,J,s	0.03	1.3	611	N,K,m	0.02	1.1	524	E,J,s	0.03	1.3	392	N,K,m	0.02	1.2	262	N,K,m	0.02	1.2	236	N,K,m	0.03	1.3	272	N,K,m	0.02	1.1																						
Mercury ⁽³⁾	7439-97-6	0.13	N	2.35	N	30.66	--	0.68		0.022	0.044	0.075		0.019	0.037	0.4		0.022	0.043	0.23		0.019	0.039	0.068		0.018	0.036	0.058		0.022	0.043	0.026	B	0.021	0.042																						
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	18.9	NE,L,m	0.13	0.67	6.5		0.11	0.57	10.8	NE,L,m	0.13	0.63	77.7		0.12	0.61	7		0.12	0.61	21.3		0.13	0.65	10.5		0.11	0.57																						
Potassium	7440-09-7	--	--	--	--	--	--	4,280	*E,J,k	15.8	134	833	*E,J,s	4.5	113	1,300	*E,J,k	14.8	125	802	*E,J,s	4.9	121	720	*E,J,s	4.9	122	3,670	*E,J,s	5.2	130	1,740	*E,J,s	4.6	115																						
Selenium	7782-49-2	--	N	39.11	N	511	18.98	0.56	BN,K,w	0.44	0.67	1.5	N,L,m	0.34	0.57	1.7	N	0.41	0.63	3.6	N,L,m	0.36	0.61	1.2	N,L,m	0.37	0.61	1.2	N,L,m	0.39	0.65	0.45	BN,L,m	0.34	0.57																						
Silver	7440-22-4	--	N	39.11	N	511	31.03	4.6		0.09	0.67	<0.57	U	0.09	0.57	<0.63	U	0.09	0.63	0.12	B,K,w	0.1	0.61	<0.61	U	0.1	0.61	<0.65	U	0.1	0.65	<0.57	U	0.09	0.57																						
Sodium	7440-23-5	--	--	--	--	--	--	1,540		33.2	267	88.7	B,B,x	34.4	226	498		31.1	250	345	B,x	37	243	93.5	B,B,x	37.1	244	4,460		39.6	260	4,110		34.9	229																						
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	<1.3	UN,UL,m	0.68	1.3	<1.1	UN,UL,m	0.27	1.1	<1.3	UN,UL,m	0.64	1.3	<1.2	UN,UL,m	0.29	1.2	<1.2	UN,UL,m	0.29	1.2	<1.3	UN,UL,m	0.31	1.3	<1.1	UN,UL,m	0.28	1.1																						
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	38	NE,L,m	0.09	2.7	53.1		0.08	2.3	51.1	NE,L,m	0.09	2.5	34.8		0.08	2.4	56.9		0.09	2.4	31.2		0.09	2.6	31.2		0.08	2.3																						
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	42.6	NE,L,m	0.13	2.7	34.4	L,p	0.12	2.3	79	NE,L,m	0.13	2.5	67.4	L,p	0.13	2.4	31.7	L,p	0.13	2.4	36.6	L,p	0.14	2.6	49.2	L,p	0.13	2.3																						
Pesticides/PCBs (ug/kg)																																																									
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	NT				<2.1	U	0.4	2.1	NT				NT				<2.1	U	0.4	2.1	NT				NT																									
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	NT				<6.2	U	0.39	6.2	NT				NT				<6.1	U	0.39	6.1	NT				NT																									
Aldrin	309-00-2	--	C	3.8E+01	C	1.7E+02	7.7E+00	NT				<1	U	0.17	1	NT				NT				<1	U	0.17	1	NT				NT																									
alpha-BHC	319-84-6	--	C	1.0E+02	C	4.5E+02	8.9E-01	NT				<1	U	0.26	1	NT				NT				<1	U	0.26	1	NT				NT																									
alpha-Chlordane ⁽⁴⁾	5103-71-9	--	C	1.8E+03	C	8.2E+03	--	NT				<2.1	U	0.22	2.1	NT				NT				<2.1	U	0.22	2.1	NT				NT																									
beta-BHC	319-85-7	--	C	3.5E+02	C	1.6E+03	3.1E+00	NT				7.4	P,J,g	0.28	2.1	NT				NT				6.6	P,J,g	0.28	2.1																														

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB7F-DUP(D-2) 11/13/2002 12-14		MDL	RL	40SB8A 11/13/2002 0-1		MDL	RL	40SB8C 11/13/2002 20-25		MDL	RL	40SB8F 11/13/2002 6.5-20		MDL	RL	40SB9A 11/13/2002 0-1		MDL	RL	40SB9C 11/13/2002 16-20		MDL	RL	40SB9F 11/13/2002 8-10		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Benzene, 2-Etheryl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Camphor	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Ether	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Hexanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Methanethiol	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Nonanal	--	--	--	--	--	--	--	15	NJ,NJ,t	0	0	NI				NI					NI				NI				NI				NI						
Pentanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI					1,200	NJ,NJ,t	0	0	NI				140	NJ,NJ,t	0	0	150	NJ,NJ,t	0	0			
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	<450	U	22	450	<410	U	22	410	<430	U	22	430	<420	U	22	420	<400	U	22	400	<430	U	22	430	<410	U	22	410				
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	<450	U	20	450	<410	U	20	410	<430	U	20	430	<420	U	20	420	<400	U	20	400	<430	U	20	430	<410	U	20	410				
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	<450	U	21	450	<410	U	21	410	<430	U	21	430	<420	U	21	420	<400	U	21	400	<430	U	21	430	<410	U	21	410				
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	<450	U	24	450	<410	U	24	410	33	J	24	430	<420	U	24	420	<400	U	24	400	<430	U	24	430	51	J	24	410				
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	<450	U	29	450	<410	U	29	410	<430	U	29	430	<420	U	29	420	<400	U	29	400	<430	U	29	430	130	J,J,r	29	410				
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	<450	U	48	450	<410	U	48	410	<430	U	48	430	<420	U	48	420	<400	U	48	400	<430	U	48	430	570	J,r	48	410				
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<450	U	31	450	<410	U	31	410	<430	U	31	430	<420	U	31	420	<400	U	31	400	<430	U	31	430	<410	U	31	410				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<450	U	17	450	<410	U	17	410	<430	U	17	430	<420	U	17	420	<400	U	17	400	<430	U	17	430	<410	U	17	410				
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	60	J	23	450	<410	U	23	410	<430	U	23	430	<420	U	23	420	<400	U	23	400	<430	U	23	430	<410	U	23	410				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<450	U	25	450	47	J,J,r	25	410	<430	U	25	430	<420	U	25	420	<400	U	25	400	<430	U	25	430	<410	U	25	410				
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	200	J	39	450	<410	U	39	410	<430	U	39	430	<420	U	39	420	<400	U	39	400	<430	U	39	430	<410	U,UJ,c	39	410				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<450	U	29	450	270	J	29	410	<430	U	29	430	<420	U	29	420	<400	U	29	400	<430	U	29	430	<410	U	29	410				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<450	U	23	450	200	J	23	410	<430	U	23	430	<420	U	23	420	<400	U	23	400	<430	U	23	430	<410	U	23	410				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<450	U	36	450	180	J	36	410	<430	U	36	430	<420	U	36	420	<400	U	36	400	<430	U	36	430	<410	U	36	410				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<450	U	23	450	110	J	23	410	<430	U	23	430	65	J	23	420	<400	U	23	400	<430	U	23	430	<410	U	23	410				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03E																																			

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB7F-DUP(D-2) 11/13/2002 12-14		MDL	RL	40SB8A 11/13/2002 0-1		MDL	RL	40SB8C 11/13/2002 20-25		MDL	RL	40SB8F 11/13/2002 6.5-20		MDL	RL	40SB9A 11/13/2002 0-1		MDL	RL	40SB9C 11/13/2002 16-20		MDL	RL	40SB9F 11/13/2002 8-10		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				17,000	NJ,NJ,t	0	0	NI				NI				NI				NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				1,500	NJ,NJ,t	0	0	13,000	NJ,NJ,t	0	0				
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<58	U	5.9	58	<52	U	5.9	52	1,200	PZ,J,c	5.9	270	6,400	PZ,K,s	5.9	1,300	<51	U	5.9	51	<54	U	5.9	54	6,500	EP,K,s	5.9	1,000				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<58	U	5.9	58	<52	U	5.9	52	210	JPZ,K,s	5.9	270	<53	U	5.9	53	<51	U	5.9	51	<54	U	5.9	54	<53	U	5.9	53				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<58	U	5.4	58	<52	U	5.4	52	130	JPZ,K,s	5.4	270	<53	U	5.4	53	<51	U	5.4	51	<54	U	5.4	54	<53	U	5.4	53				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	140	JPZ,J,g	2.2	230	28		2.2	10	540	PZ,K,s	2.2	54	<11	U	2.2	11	30	P,J,g	2.2	10	<11	U	2.2	11	<10	U	2.2	10				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<11	U	1.6	11	14		1.6	10	380	Z,K,s	1.6	54	<11	U	1.6	11	<10	U	1.6	10	<11	U	1.6	11	<10	U	1.6	10				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	86	JZ,K,s	1.7	230	31	J,c	1.7	10	460	Z,J,c	1.7	54	<11	U	1.7	11	160	J,c	1.7	10	<11	U	1.7	11	95	K,s	1.7	10				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<11	U	3.6	11	<10	U	3.6	10	250	PZ,K,s	3.6	54	<11	U	3.6	11	<10	U	3.6	10	<11	U	3.6	11	<10	U	3.6	10				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<11	U	1.4	11	29	P,J,g	1.4	10	570	EP,J,c	1.4	11	<11	U	1.4	11	<10	U	1.4	10	<11	U	1.4	11	<10	U	1.4	10				
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	2,400	PZ,J,g	2.4	230	140	P,J,g	2.4	10	640	PZ,K,s	2.4	54	<11	U	2.4	11	57	P,J,g	2.4	10	<11	U	2.4	11	1,900	PZ,K,s	2.4	210				
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<11	U	4.2	11	<10	U	4.2	10	160	PZ,J,c	4.2	54	<11	U	4.2	11	<10	U	4.2	10	<11	U	4.2	11	<10	U	4.2	10				
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	<23	U	2.1	23	84		2.1	21	3,200	EP,K,s	2.1	22	<22	U	2.1	22	46		2.1	21	<22	U	2.1	22	380	P,K,s	2.1	21				
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<58	U	14	58	<52	U	14	52	160	JPZ,K,s	14	270	<53	U	14	53	<51	U	14	51	<54	U	14	54	<53	U	14	53				
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	<11	U	2.5	11	180	P,J,g	2.5	10	3,600	EP,K,s	2.5	11	<11	U	2.5	11	150	P,J,g	2.5	10	<11	U	2.5	11	<10	U	2.5	10				
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	690	JPZ,J,d	14	1,200	78	P,J,g	14	52	1,300	EP,K,s	14	54	<53	U	14	53	<51	U	14	51	<54	U	14	54	<53	U	14	53				
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<58	U	8.5	58	14	J	8.5	52	1,100	Z,K,s	8.5	270	<53	U	8.5	53	<51	U	8.5	51	<54	U	8.5	54	<53	U	8.5	53				
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	310	K,s	4.3	23	67	P,J,c	4.3	21	1,100	PZ,K,s	4.3	110	270	JPZ,K,s	4.3	540	<21	U	4.3	21	51	P,J,c	4.3	22	280	JPZ,K,s	4.3	420				
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT				NT																			

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB10A 11/13/2002 0-1				MDL	RL	40SB10B 11/13/2002 10-12				MDL	RL	40SB10C 11/13/2002 12-15				MDL	RL	40SB10F 11/13/2002 3-6				MDL	RL	40SB11B 11/12/2002 13-16				MDL	RL	40SB11C 11/12/2002 20-25.8				MDL	RL	40SB11F 11/12/2002 2-4				MDL	RL						
								Result	LQ	VQ	r			Result	LQ	VQ	r			Result	LQ	VQ	r			Result	LQ	VQ	r			Result	LQ	VQ	r			Result	LQ	VQ	r			Result	LQ	VQ	r			Result	LQ	VQ	r	Result	LQ
TAL Metals (mg/kg)																																																							
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	14,000			2.5	11.5	47,500			2.9	13.3	39,900			3	13.6	17,000			2.5	11.6	29,400			7.1	12.6	35,100			7.5	13.2	11,900			6.1	10.8													
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	0.65	BN,K,w	0.43	1.2		<1.3	UN,UL,m	0.49	1.3	0.72	BN,K,w	0.5	1.4				<1.2	UN,UL,m	0.43	1.2	0.46	BN,L,m	0.15	1.3	0.53	BN,L,m	0.16	1.3	0.39	BN,L,m	0.13	1.1																
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	4.5	N,L,m	0.29	1.2		5	N,L,m	0.33	1.3	6.2	N,L,m	0.34	1.4				9.1	N,L,m	0.29	1.2	5.6	N,K,m	0.38	1.3	6.5	N,K,m	0.4	1.3	3.4	N,K,m	0.32	1.1																
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	46.5	NE,L,m	0.02	1.2		94.3	NE,L,m	0.03	1.3	80.4	NE,L,m	0.03	1.4				58.1	NE,L,m	0.02	1.2	52.5		0.04	1.3	50		0.04	1.3	40.9		0.03	1.1																
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	0.53	BNE,K,w	0.01	0.58		3	NE,L,m	0.01	0.66	2.3	NE,L,m	0.01	0.68				0.42	BNE,K,w	0.01	0.58	2.1		0.03	0.63	1.7		0.03	0.66	0.24	B	0.02	0.54																
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	0.12	BN,K,w	0.05	0.58		0.34	BN,K,w	0.05	0.66	0.32	BN,K,w	0.05	0.68				0.08	BN,K,w	0.05	0.58	<0.63	U	0.04	0.63	<0.66	U	0.04	0.66	<0.54	U	0.03	0.54																
Calcium	7440-70-2	--	--	--	--	--	--	26,300	*E,J,s	1.1	115		1,540	*E,J,s	1.3	133	1,830	*E,J,s	1.3	136				2,490	*E,J,s	1.1	116	1,390	L,p	1.9	126	2,240	L,p	2	132	26,100	L,p	1.6	108																
Chromium ⁽¹⁾	7440-47-3	65.3	N	23.46	N	306.6	42.05	24.7	NE,L,m	0.07	0.58		65.7	NE,L,m	0.08	0.66	30.8	NE,L,m	0.08	0.68				24	NE,L,m	0.07	0.58	33.7		0.1	0.63	32.8		0.11	0.66	16.2		0.09	0.54																
Cobalt	7440-48-4	72.3	--	--	--	--	--	6.7	N*E,L,m	0.07	0.58		6.3	N*E,L,m	0.08	0.66	5.7	N*E,L,m	0.08	0.68				3.2	N*E,L,m	0.07	0.58	7	*	0.09	0.63	6	*	0.09	0.66	5	*	0.08	0.54																
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	<0.58	UN*E,UL	0.16	0.58		20.9	N*E,L,m	0.19	0.66	23.5	N*E,L,m	0.19	0.68				14.8	N*E,L,m	0.16	0.58	26.7	N,K,m	0.19	0.63	27.7	N,K,m	0.2	0.66	10	N,K,m	0.16	0.54																
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	23,900	E,J,s	1.6	11.5		43,900	E,J,s	1.8	13.3	37,600	E,J,s	1.9	13.6				32,500	E,J,s	1.6	11.6	33,400		1.6	12.6	29,500		1.7	13.2	18,100		1.4	10.8																
Lead ⁽²⁾	7439-92-1	26.8	--	400	--	750	--	19.4		0.27	0.35		8.4		0.31	0.4	7.7		0.31	0.41				44.2		0.27	0.35	11.9	N,K,m	0.15	0.38	9.1	N,K,m	0.16	0.4	13.2	N,K,m	0.13	0.32																
Magnesium	7439-95-4	--	--	--	--	--	--	15,700	*E,J,k	0.7	115		9,240	*E,J,k	0.81	133	25,800	*E,J,k	0.83	136				1,290	*E,J,k	0.71	116	8,560	*	1.5	126	27,400	*	1.6	132	14,400	*	1.3	108																
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	318	E,J,s	0.02	1.2		213	E,J,s	0.03	1.3	463	E,J,s	0.03	1.4				294	E,J,s	0.02	1.2	271	N,K,m	0.03	1.3	262	N,K,m	0.03	1.3	282	N,K,m	0.02	1.1																
Mercury ⁽³⁾	7439-97-6	0.13	N	2.35	N	30.66	--	0.042		0.017	0.034		0.13		0.02	0.041	<0.049	U	0.025	0.049				0.18		0.02	0.04	0.094		0.021	0.042	0.037	B	0.02	0.041	0.18		0.017	0.035																
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	6.5	NE,L,m	0.12	0.58		36	NE,L,m	0.13	0.66	25.7	NE,L,m	0.14	0.68				6.3	NE,L,m	0.12	0.58	32.4		0.13	0.63	26.2		0.13	0.66	3.6		0.11	0.54																
Potassium	7440-09-7	--	--	--	--	--	--	1,010	*E,J,k	13.7	115		3,800	*E,J,k	15.7	133	4,450	*E,J,k	16.1	136				949	*E,J,k	13.7	116	2,180	*E,J,s	5	126	5,100	*E,J,s	5.3	132	382	*E,J,s	4.3	108																
Selenium	7782-49-2	--	N	39.11	N	511	18.98	0.91	N,K,w	0.38	0.58		1.5	N,L,m	0.44	0.66	1.1	N,K,w	0.45	0.68				2.8	N,L,m	0.38	0.58	0.95	N,L,m	0.38	0.63	0.62	BN,L,m	0.4	0.66	0.82	N,L,m	0.32	0.54																
Silver	7440-22-4	--	N	39.11	N	511	31.03	<0.58	U	0.08	0.58		<0.66	U	0.09	0.66	<0.68	U	0.1	0.68				<0.58	U	0.08	0.58	<0.63	U	0.1	0.63	<0.66	U	0.11	0.66	<0.54	U	0.09	0.54																
Sodium	7440-23-5	--	--	--	--	--	--	135	B,B,x	28.7	231		135	B,B,x	33	265	121	B,B,x	33.8	272				206	B,B,x	28.8	231	<252	U	38.3	252	<265	U	40.3	265	223	B,x	32.9	216																
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	<1.2	UN,UL,m	0.59	1.2		<1.3	UN,UL,m	0.68	1.3	<1.4	UN,UL,m	0.69	1.4				<1.2	UN,UL,m	0.59	1.2	<1.3	UN,UL,m	0.3	1.3	<1.3	UN,UL,m	0.32	1.3	<1.1	UN,UL,m	0.26	1.1																
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	48.7	NE,L,m	0.08	2.3		88.6	NE,L,m	0.09	2.7	62.5	NE,L,m	0.1	2.7				56.6	NE,L,m	0.08	2.3	58.3		0.09	2.5	55.4		0.09	2.6	36		0.08	2.2																
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	27.1	NE,L,m	0.12	2.3		32.9	NE,L,m	0.13	2.7	42.4	NE,L,m	0.14	2.7				73.3	NE,L,m	0.12	2.3	38.1	L,p	0.14	2.5	52.1	L,p	0.15	2.6	15.8	L,p	0.12	2.2																
Pesticides/PCBs (ug/kg)																																																							
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	1.8	JP,J,g	0.4	2		NT				NT						NT					<2.2	U	0.4	2.2	<2.3	U	0.4	2.3	<2	U	0.4	2																
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	<5.9	U	0.39	5.9		NT				NT						NT					<6.3	U	0.39	6.3	<6.8	U	0.39	6.8	<5.9	U	0.39	5.9																
Aldrin	309-00-2	--	C	3.8E+01	C	1.7E+02	7.7E+00	<0.98	U	0.17	0.98		NT				NT						NT					<1.1	U	0.17	1.1	<1.1	U	0.17	1.1	<0.98	U	0.17	0.98																
alpha-BHC	319-84-6	--	C	1.0E+02	C	4.5E+02	8.9E-01	<0.98	U	0.26																																													

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Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB10A 11/13/2002 0-1		MDL	RL	40SB10B 11/13/2002 10-12		MDL	RL	40SB10C 11/13/2002 12-15		MDL	RL	40SB10F 11/13/2002 3-6		MDL	RL	40SB11B 11/12/2002 13-16		MDL	RL	40SB11C 11/12/2002 20-25.8		MDL	RL	40SB11F 11/12/2002 2-4		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	80	NJ,NJ,t	0	0	NI				NI							NI					NI				NI							
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Camphor	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Ether	--	--	--	--	--	--	--	NI				NI				NI							11	NJ,NJ,t	0	0	NI					NI							
Hexanal	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Indan, 1-Methyl-	--	--	--	--	--	--	--	57	NJ,NJ,t	0	0	NI				NI							NI					NI				NI							
Methanethiol	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Nonanal	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Pentanal	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI							NI					NI				NI							
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	<390	U	22	390	<460	U	22	460	<490	U	22	490	<400	U	22	400	<420	U	22	420	<450	U	22	450	<390	U	22	390				
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	<390	U	20	390	<460	U	20	460	<490	U	20	490	<400	U	20	400	<420	U	20	420	<450	U	20	450	<390	U	20	390				
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	<390	U	21	390	<460	U	21	460	<490	U	21	490	<400	U	21	400	<420	U	21	420	<450	U	21	450	<390	U	21	390				
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	<390	U	24	390	<460	U	24	460	<490	U	24	490	<400	U	24	400	<420	U	24	420	<450	U	24	450	<390	U	24	390				
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	<390	U	29	390	<460	U	29	460	<490	U	29	490	<400	U	29	400	<420	U	29	420	<450	U	29	450	<390	U	29	390				
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	<390	U	48	390	<460	U	48	460	<490	U	48	490	<400	U	48	400	<420	U	48	420	<450	U	48	450	<390	U	48	390				
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<390	U	31	390	<460	U	31	460	<490	U	31	490	<400	U	31	400	<420	U	31	420	<450	U	31	450	<390	U	31	390				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<390	U	17	390	<460	U	17	460	<490	U	17	490	<400	U	17	400	<420	U	17	420	<450	U	17	450	<390	U	17	390				
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	<390	U	23	390	<460	U	23	460	<490	U	23	490	<400	U	23	400	<420	U	23	420	<450	U	23	450	<390	U	23	390				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<390	U	25	390	<460	U	25	460	<490	U	25	490	<400	U	25	400	<420	U	25	420	<450	U	25	450	<390	U	25	390				
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	<390	U	39	390	<460	U	39	460	<490	U	39	490	<400	U	39	400	<420	U	39	420	<450	U	39	450	<390	U	39	390				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<390	U	29	390	<460	U	29	460	<490	U	29	490	<400	U	29	400	<420	U	29	420	<450	U	29	450	<390	U	29	390				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<390	U	23	390	<460	U	23	460	<490	U	23	490	<400	U	23	400	<420	U	23	420	<450	U	23	450	<390	U	23	390				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<390	U	36	390	<460	U	36	460	<490	U	36	490	<400	U	36	400	<420	U	36	420	<450	U	36	450	<390	U	36	390				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<390	U	23	390	<460	U	23	460	<490	U	23	490	<400	U	23	400	<420	U	23	420	<450	U	23	450	<390	U	23	390				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<390	U																														

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Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB10A 11/13/2002 0-1		MDL	RL	40SB10B 11/13/2002 10-12		MDL	RL	40SB10C 11/13/2002 12-15		MDL	RL	40SB10F 11/13/2002 3-6		MDL	RL	40SB11B 11/12/2002 13-16		MDL	RL	40SB11C 11/12/2002 20-25.8		MDL	RL	40SB11F 11/12/2002 2-4		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				NI				2,200	NJ,NJ,t	0	0	2,200	NJ,NJ,t	0	0	NI				NI				7,800	NJ,NJ,t	0	0				
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<49	U,U,L,s	5.9	49	1,500	PZ,J,c	5.9	120	<62	U	5.9	62	<51	U	5.9	51	<53	U	5.9	53	<58	U	5.9	58	<49	U	5.9	49				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<49	U,U,L,s	5.9	49	<59	U	5.9	59	<62	U	5.9	62	<51	U	5.9	51	<53	U	5.9	53	12	J,J,c	5.9	58	1,300	PZ,J,c	5.9	990				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<49	U,U,L,s	5.4	49	<59	U	5.4	59	<62	U	5.4	62	<51	U	5.4	51	<53	U	5.4	53	<58	U	5.4	58	<49	U	5.4	49				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	11	L,s	2.2	9.8	<12	U	2.2	12	<12	U	2.2	12	<10	U	2.2	10	<10	U	2.2	10	<11	U	2.2	11	<9.8	U	2.2	9.8				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	19	P,L,s	1.6	9.8	35	P,J,g	1.6	12	<12	U	1.6	12	<10	U	1.6	10	<10	U	1.6	10	<11	U	1.6	11	45	JPZ,K,s	1.6	200				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	18	J,c	1.7	9.8	18	P,J,c	1.7	12	<12	U,UJ,c	1.7	12	<10	U,UJ,c	1.7	10	<10	U	1.7	10	16	P,J,c	1.7	11	<9.8	U	1.7	9.8				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	10	JP,L,s	3.6	9.8	<12	U	3.6	12	<12	U	3.6	12	<10	U	3.6	10	<10	U	3.6	10	<11	U	3.6	11	<9.8	U	3.6	9.8				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	18	L,s	1.4	9.8	<12	U	1.4	12	<12	U	1.4	12	<10	U	1.4	10	<10	U	1.4	10	<11	U	1.4	11	<9.8	U	1.4	9.8				
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	94	P,L,s	2.4	9.8	<12	U	2.4	12	<12	U	2.4	12	<10	U	2.4	10	<10	U	2.4	10	<11	U	2.4	11	2,200	PZ,K,s	2.4	200				
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<9.8	U,U,L,s	4.2	9.8	<12	U	4.2	12	<12	U	4.2	12	<10	U	4.2	10	<10	U	4.2	10	<11	U	4.2	11	<9.8	U	4.2	9.8				
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	58	L,s	2.1	20	<24	U	2.1	24	<25	U	2.1	25	25	2.1	21	<22	U	2.1	22	<23	U	2.1	23	280	P,K,s	2.1	20					
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<49	U,U,L,s	14	49	<59	U	14	59	<62	U	14	62	<51	U	14	51	<53	U	14	53	<58	U	14	58	<49	U	14	49				
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	11	L,s	2.5	9.8	<12	U	2.5	12	<12	U	2.5	12	<10	U	2.5	10	<10	U	2.5	10	<11	U	2.5	11	<9.8	U	2.5	9.8				
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	26	J,J,d	14	49	<59	U	14	59	<62	U	14	62	<51	U	14	51	<53	U	14	53	<58	U	14	58	<49	U	14	49				
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	24	J,L,s	8.5	49	<59	U	8.5	59	<62	U	8.5	62	<51	U	8.5	51	<53	U	8.5	53	<58	U	8.5	58	<49	U	8.5	49				
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	41	P,J,c	4.3	20	<24	U	4.3	24	<25	U	4.3	25	51	P,J,c	4.3	21	<22	U	4.3	22	18	J,J,c	4.3	23	340	JPZ,K,s	4.3	400				
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--																																			

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB12A 11/11/2002 0-1			MDL	RL	40SB12B 11/11/2002 8-11			MDL	RL	40SB12C 11/11/2002 23-27			MDL	RL	40SB13A 11/19/2002 0-1			MDL	RL	40SB13B 11/19/2002 4-5			MDL	RL	40SB13C 11/19/2002 5-6			MDL	RL	40SB13C-DUP(D-6) 11/19/2002 5-6			MDL	RL												
								Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r		Result	LQ, VQ, r	
TAL Metals (mg/kg)																																																						
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	16,000		6.4	11.3		20,000		7.7	13.5		26,000		8.7	15.4		12,200		2.6	11.8		20,100		2.6	12		15,000		2.6	12		22,700		2.6	11.8													
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	0.49	BN,L,m	0.14	1.1	1.2	BN,L,m	0.16	1.3	0.55	BN,L,m	0.18	1.5	<1.2	UN,R,m	0.44	1.2	<1.2	UN,R,m	0.45	1.2	<1.2	UN,R,m	0.44	1.2	<1.2	UN,R,m	0.44	1.2	<1.2	UN,R,m	0.44	1.2	<1.2	UN,R,m	0.44	1.2											
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	5.3	N,K,m	0.34	1.1	9.7	N,K,m	0.4	1.3	7.1	N,K,m	0.46	1.5	2.8	N,L,o	0.29	1.2	3	N,L,o	0.3	1.2	4.7	N,L,o	0.3	1.2	2.2	N,L,o	0.29	1.2	4.7	N,L,o	0.29	1.2	4.7	N,L,o	0.29	1.2											
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	67.8		0.03	1.1	46		0.04	1.3	36.3		0.05	1.5	37.7		0.02	1.2	61.7		0.02	1.2	47		0.02	1.2	44.8		0.02	1.2	47		0.02	1.2	44.8		0.02	1.2											
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	0.74		0.02	0.57	1.3		0.03	0.67	1.3		0.03	0.77	0.34	B	0.01	0.59	0.81		0.01	0.6	0.55	B	0.01	0.6	1		0.01	0.6	1		0.01	0.59	0.59		0.01	0.59											
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	<0.57	U	0.03	0.57	<0.67	U	0.04	0.67	<0.77	U	0.05	0.77	<0.59	U	0.05	0.59	0.14	B,K,w	0.05	0.6	0.15	B,K,w	0.05	0.6	0.21	B,K,w	0.05	0.6	0.21	B,K,w	0.05	0.6	0.21	B,K,w	0.05	0.59											
Calcium	7440-70-2	--	--	--	--	--	--	7,960	L,p	1.7	113	657	L,p	2	135	1,730	L,p	2.3	154	4,100		1.1	118	3,340		1.2	120	33,400		1.2	120	61,800		1.2	120	61,800		1.1	118	118		1.1	118											
Chromium ⁽¹⁾	7440-47-3	65.3	N	23.46	N	306.6	42.05	21.4		0.09	0.57	86.3		0.11	0.67	39.1		0.12	0.77	18.2		0.07	0.59	27.6		0.07	0.6	27.6		0.07	0.6	29.8		0.07	0.6	29.8		0.07	0.59	0.59		0.07	0.59											
Cobalt	7440-48-4	72.3	--	--	--	--	--	8.2	*	0.08	0.57	14	*	0.09	0.67	6	*	0.11	0.77	6.1		0.07	0.59	7.4		0.07	0.6	6.6		0.07	0.6	43.1		0.07	0.6	43.1		0.07	0.59	0.59		0.07	0.59											
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	21.9	N,K,m	0.17	0.57	19.6	N,K,m	0.2	0.67	24.1	N,K,m	0.23	0.77	2.6	*,J,k	0.16	0.59	13.5	*,J,k	0.17	0.6	7.5	*,J,k	0.17	0.6	7.5	*,J,k	0.17	0.6	7.5	*,J,k	0.17	0.6	7.5	*,J,k	0.16	0.59											
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	21,200		1.4	11.3	49,300		1.7	13.5	29,900		1.9	15.4	23,000		1.6	11.8	25,300		1.6	12	23,600		1.6	12	25,600		1.6	12	25,600		1.6	11.8	11.8		1.6	11.8											
Lead ⁽²⁾	7439-92-1	26.8	--	400	--	750	--	26.2	N,K,m	0.14	0.34	17.3	N,K,m	0.16	0.4	53.6	N,K,m	0.18	0.46	15		0.27	0.35	23.3		0.28	0.36	16.8		0.28	0.36	15.4		0.27	0.35	15.4		0.27	0.35	0.35		0.27	0.35											
Magnesium	7439-95-4	--	--	--	--	--	--	8,290	*	1.4	113	7,090	*	1.7	135	51,800	*	1.9	154	2,280		0.72	118	8,440		0.73	120	9,760		0.73	120	27,600		0.73	120	27,600		0.73	120	27,600		0.73	120											
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	344	N,K,m	0.02	1.1	699	N,K,m	0.03	1.3	474	N,K,m	0.03	1.5	266		0.02	1.2	304		0.02	1.2	180		0.02	1.2	791		0.02	1.2	791		0.02	1.2	791		0.02	1.2											
Mercury ⁽³⁾	7439-97-6	0.13	N	2.35	N	30.66	--	0.15		0.018	0.037	0.04		0.02	0.039	<0.053	U	0.026	0.053	0.046		0.02	0.039	0.081		0.019	0.039	0.063		0.019	0.038	0.027	B	0.019	0.038	0.027	B	0.019	0.038	0.038		0.019	0.038											
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	12.2		0.11	0.57	16.6		0.13	0.67	26.7		0.15	0.77	4.8		0.12	0.59	11.8		0.12	0.6	7.3		0.12	0.6	74.9		0.12	0.6	74.9		0.12	0.59	0.59		0.12	0.59											
Potassium	7440-09-7	--	--	--	--	--	--	1,410	*E,J,s	4.5	113	1,340	*E,J,s	5.4	135	8,040	*E,J,s	6.2	154	579		13.9	118	1,780		14.3	120	1,840		14.2	120	5,600		14.2	120	5,600		14.2	120	5,600		14.2	120											
Selenium	7782-49-2	--	N	39.11	N	511	18.98	0.85	N,L,m	0.34	0.57	2.5	N,L,m	0.4	0.67	0.91	N,L,m	0.46	0.77	1.6	N,L,m	0.39	0.59	1.7	N,L,m	0.4	0.6	3.4	N,L,m	0.4	0.6	0.7	N,K,w	0.39	0.59	0.7	N,K,w	0.39	0.59	0.59		0.39	0.59											
Silver	7440-22-4	--	N	39.11	N	511	31.03	<0.57	U	0.09	0.57	<0.67	U	0.11	0.67	<0.77	U	0.12	0.77	0.12	B	0.08	0.59	0.11	B	0.08	0.6	0.16	B	0.08	0.6	<0.59	U	0.08	0.59	<0.59	U	0.08	0.59	<0.59	U	0.08	0.59											
Sodium	7440-23-5	--	--	--	--	--	--	86.8	B,B,x	34.5	227	188	B,B,x	41.1	270	4,760		46.8	307	124	B,B,x	29.3	235	126	B,B,x	29.9	241	126	B,B,x	29.8	240	174	B,B,x	29.3	236	174	B,B,x	29.3	236	236		29.3	236											
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	<1.1	UN,UL,m	0.27	1.1	0.82	BN,K,w	0.32	1.3	<1.5	UN,UL,m	0.37	1.5	<1.2	UN,R,m	0.6	1.2	<1.2	UN,R,m	0.61	1.2	<1.2	UN,R,m	0.61	1.2	<1.2	UN,R,m	0.6	1.2	<1.2	UN,R,m	0.6	1.2	<1.2	UN,R,m	0.6	1.2											
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	39.9		0.08	2.3	95.2		0.09	2.7	60.8		0.11	3.1	40.7	N,K,m	0.08	2.4	48	N,K,m	0.08	2.4	48	N,K,m	0.08	2.4	59.1	N,K,m	0.08	2.4	59.1	N,K,m	0.08	2.4	59.1	N,K,m	0.08	2.4											
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	71.1	L,p	0.12	2.3	36.6	L,p	0.15	2.7	54.4	L,p	0.17	3.1	18.9	*E,J,k	0.12	2.4	56.7	*E,J,k	0.12	2.4	27.7	*E,J,k	0.12	2.4	44.4	*E,J,k	0.12	2.4	44.4	*E,J,k	0.12	2.4	44.4	*E,J,k	0.12	2.4											
Pesticides/PCBs (ug/kg)																																																						
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	<2	U	0.4	2	NT				NT							<2	U	0.4	2	NT							NT							NT													
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	<5.9	U	0.39	5.9	NT				NT							<5.9	U	0.39	5.9	NT							NT							NT													
Aldrin	309-00-2	--	C	3																																																		

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB12A 11/11/2002 0-1		MDL	RL	40SB12B 11/11/2002 8-11		MDL	RL	40SB12C 11/11/2002 23-27		MDL	RL	40SB13A 11/19/2002 0-1		MDL	RL	40SB13B 11/19/2002 4-5		MDL	RL	40SB13C 11/19/2002 5-6		MDL	RL	40SB13C-DUP(D-6) 11/19/2002 5-6		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Camphor	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Ether	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Hexanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Methanethiol	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Nonanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Pentanal	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI				NI						
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	<390	U	22	390	<450	U	22	450	<540	U	22	540	<390	U	22	390	<400	U	22	400	<400	U	22	400	<400	U	22	400	<400	U	22	400
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	<390	U	20	390	<450	U	20	450	<540	U	20	540	<390	U	20	390	<400	U	20	400	<400	U	20	400	<400	U	20	400	<400	U	20	400
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	<390	U	21	390	<450	U	21	450	<540	U	21	540	<390	U	21	390	<400	U	21	400	<400	U	21	400	<400	U	21	400	<400	U	21	400
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	<390	U	24	390	<450	U	24	450	<540	U	24	540	<390	U	24	390	<400	U	24	400	<400	U	24	400	<400	U	24	400	<400	U	24	400
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	<390	U	29	390	<450	U	29	450	<540	U	29	540	<390	U	29	390	<400	U	29	400	<400	U	29	400	<400	U	29	400	<400	U	29	400
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	<390	U	48	390	<450	U	48	450	<540	U	48	540	<390	U	48	390	<400	U	48	400	<400	U	48	400	<400	U	48	400	<400	U	48	400
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<390	U	31	390	<450	U	31	450	<540	U	31	540	<390	U	31	390	<400	U	31	400	<400	U	31	400	<400	U	31	400	<400	U	31	400
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<390	U	17	390	<450	U	17	450	<540	U	17	540	<390	U	17	390	<400	U	17	400	<400	U	17	400	<400	U	17	400	<400	U	17	400
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	<390	U	23	390	<450	U	23	450	<540	U	23	540	<390	U	23	390	<400	U	23	400	<400	U	23	400	<400	U	23	400	<400	U	23	400
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<390	U	25	390	<450	U	25	450	<540	U	25	540	<390	U	25	390	<400	U	25	400	<400	U	25	400	<400	U	25	400	<400	U	25	400
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	<390	U	39	390	<450	U	39	450	<540	U	39	540	<390	U	39	390	<400	U	39	400	<400	U	39	400	<400	U	39	400	<400	U	39	400
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<390	U	29	390	<450	U	29	450	<540	U	29	540	<390	U	29	390	<400	U	29	400	<400	U	29	400	<400	U	29	400	<400	U	29	400
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<390	U	23	390	<450	U	23	450	<540	U	23	540	<390	U	23	390	<400	U	23	400	<400	U	23	400	<400	U	23	400	<400	U	23	400
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<390	U	36	390	<450	U	36	450	<540	U	36	540	<390	U	36	390	<400	U	36	400	<400	U	36	400	<400	U	36	400	<400	U	36	400
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N																																				

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SB12A 11/11/2002 0-1		MDL	RL	40SB12B 11/11/2002 8-11		MDL	RL	40SB12C 11/11/2002 23-27		MDL	RL	40SB13A 11/19/2002 0-1		MDL	RL	40SB13B 11/19/2002 4-5		MDL	RL	40SB13C 11/19/2002 5-6		MDL	RL	40SB13C-DUP(D-6) 11/19/2002 5-6		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				NI				NI					540	NJ,NJ,t	0	0	2,000	NJ,NJ,t	0	0	300	NJ,NJ,t	0	0	1,300	NJ,NJ,t	0	0			
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI					NI				NI				NI			NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<49	U	5.9	49	<57	U	5.9	57	<69	U	5.9	69	<49	U	5.8	49	<51	U	5.8	51	380	PZ,J,g	5.9	260	<51	U	5.9	51				
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<49	U	5.9	49	<57	U	5.9	57	<69	U	5.9	69	<49	U	5.9	49	<51	U	5.9	51	<51	U	5.9	51	<51	U	5.9	51				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<49	U	5.4	49	<57	U	5.4	57	<69	U	5.4	69	<49	U	5.4	49	<51	U	5.4	51	130	JZ	5.4	260	<51	U	5.4	51				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<9.8	U	2.2	9.8	<11	U	2.2	11	<14	U	2.2	14	<9.8	U	2.2	9.8	<10	U	2.2	10	170	Z	2.2	51	5.4	JP,J,g	2.2	10				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<9.8	U	1.6	9.8	<11	U	1.6	11	<14	U	1.6	14	22	P,J,g	1.6	9.8	33	P,J,g	1.6	10	100		1.6	10	8	J	1.6	10				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<9.8	U	1.7	9.8	<11	U	1.7	11	8.4	J	1.7	14	25	JZ	1.7	49	35	JPZ,J,g	1.7	51	140	P,J,g	1.7	10	<10	U	1.7	10				
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<9.8	U	3.6	9.8	<11	U	3.6	11	<14	U	3.6	14	<9.8	U	3.6	9.8	<10	U	3.6	10	60		3.6	10	<10	U	3.6	10				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	110	P,J,g	1.4	9.8	<11	U	1.4	11	<14	U	1.4	14	<9.8	U	1.4	9.8	<10	U	1.4	10	160	P,J,g	1.4	10	2.5	J	1.4	10				
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	<9.8	U	2.4	9.8	<11	U	2.4	11	<14	U	2.4	14	310	PZ,J,g	2.4	49	550	PZ,J,g	2.4	51	390	PZ,J,g	2.4	51	140	P,J,g	2.4	10				
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<9.8	U	4.2	9.8	<11	U	4.2	11	<14	U	4.2	14	<9.8	U	4.2	9.8	<10	U	4.2	10	<10	U	4.2	10	<10	U	4.2	10				
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	39	P,J,g	2.1	20	<23	U	2.1	23	<28	U	2.1	28	64	P,J,g	2.1	20	62	P	2.1	21	800	E,J,q	2.1	21	22		2.1	21				
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<49	U	14	49	<57	U	14	57	<69	U	14	69	<49	U	14	49	<51	U	14	51	<51	U	14	51	<51	U	14	51				
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	<9.8	U	2.5	9.8	<11	U	2.5	11	<14	U	2.5	14	<9.8	U	2.5	9.8	<10	U	2.5	10	550	EP,J,q	2.5	10	240	EP,J,g	2.5	10				
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	<49	U	14	49	<57	U	14	57	<69	U	14	69	<49	U	14	49	<51	U	14	51	<51	U	14	51	<51	U	14	51				
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<49	U	8.5	49	<57	U	8.5	57	<69	U	8.5	69	<49	U	8.5	49	<51	U	8.5	51	420		8.5	51	<51	U	8.5	51				
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	12	JP,J,g	4.3	20	<23	U	4.3	23	<28	U	4.3	28	85	JPZ,J,g	4.3	100	92	JPZ,J,g	4.3	100	430	E,J,q	4.3	21	8.6	J	4.3	21				
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT					NT				NT				NT				NT						

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	TESTPIT1F 11/20/2002 5				MDL	RL	TESTPIT1F2 11/20/2002 13				MDL	RL	TESTPIT2BP 11/20/2002 11				MDL	RL	TESTPIT2F 11/20/2002 6				MDL	RL	40SS1 11/11/2002 0-1				MDL	RL	40SS2 11/11/2002 0-1				MDL	RL	40SS3 11/11/2002 0-1				MDL	RL								
								Result	LQ, VQ, r					Result	LQ, VQ, r					Result	LQ, VQ, r					Result	LQ, VQ, r					Result	LQ, VQ, r					Result	LQ, VQ, r					Result	LQ, VQ, r					Result	LQ, VQ, r			Result	LQ, VQ, r		
TAL Metals (mg/kg)																																																									
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	13,200			2.7	12.3	11,000			3.1	14.1	24,000	*J,k		2.8	13		4,950	*J,k		2.7	12.5	14,200		7.1	12.4	15,300		6.8	12	14,500		6.6		11.7																
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	0.76	BN,L,w	0.46	1.2	<1.4	UN,R,m	0.52	1.4			0.54	BN,L,m	0.48	1.3		1.2	BN,L,m	0.46	1.2	0.51	BN,L,m	0.15	1.2	0.54	BN,L,m	0.14	1.2	0.57	BN,L,m	0.14	1.2																			
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	5.1	N,L,o	0.31	1.2	11.8	N,L,o	0.35	1.4			2.3	*L,w	0.33	1.3		74.6	*J,k	0.31	1.2	6.5	N,K,m	0.37	1.2	5	N,K,m	0.36	1.2	5	N,K,m	0.35	1.2																			
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	84.5		0.02	1.2	102		0.03	1.4			49.5	*J,k	0.03	1.3		65.2	*J,k	0.02	1.2	96.8		0.04	1.2	56.5		0.04	1.2	57		0.04	1.2																			
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	0.59	B	0.01	0.62	0.59	B	0.01	0.71			3		0.01	0.65		0.58	B	0.01	0.62	0.66		0.02	0.62	0.47	B	0.02	0.6	0.63		0.02	0.58																			
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	1.2	K,w	0.05	0.62	0.87	K,w	0.06	0.71			<0.65	U	0.05	0.65		<0.62	U	0.05	0.62	<0.62	U	0.04	0.62	<0.6	U	0.04	0.6	<0.58	U	0.04	0.58																			
Calcium	7440-70-2	--	--	--	--	--	--	19,900		1.2	123	18,600		1.4	141			1,180	*J,k	1.2	130		1,320	*J,k	1.2	125	12,900	L,p	1.9	124	2,560	L,p	1.8	120	5,070	L,p	1.8	117																			
Chromium ⁽³⁾	7440-47-3	65.3	N	23.46	N	306.6	42.05	31.4		0.07	0.62	27.7		0.08	0.71			33.8	N*,J,k	0.08	0.65		12.2	N*,J,k	0.07	0.62	26.9		0.1	0.62	21.5		0.1	0.6	37.6		0.09	0.58																			
Cobalt	7440-48-4	72.3	--	--	--	--	--	8		0.07	0.62	10.1		0.08	0.71			7.2	*J,k	0.08	0.65		8.1	*J,k	0.07	0.62	11.3	*	0.09	0.62	6	*	0.08	0.6	8.5	*	0.08	0.58																			
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	53.2	*J,k	0.17	0.62	30.3	*J,k	0.2	0.71			28.6	N*,J,k	0.18	0.65		80.6	N*,L,w	0.17	0.62	30.8	N,K,m	0.19	0.62	11.5	N,K,m	0.18	0.6	13.9	N,K,m	0.18	0.58																			
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	27,400		1.7	12.3	29,000		1.9	14.1			36,000	*J,k	1.8	13		34,600	*J,k	1.7	12.5	22,500		1.6	12.4	24,400		1.5	12	27,100		1.5	11.7																			
Lead ⁽²⁾	7439-92-1	26.8	--	400	--	750	--	158		0.28	0.37	92.6		0.32	0.42			18.7	*J,k	0.3	0.39		35.4	*J,k	0.29	0.37	37.9	N,K,m	0.15	0.37	21.3	N,K,m	0.14	0.36	21.7	N,K,m	0.14	0.35																			
Magnesium	7439-95-4	--	--	--	--	--	--	11,600		0.75	123	10,900		0.86	141			7,610	*J,k	0.79	130		1,530	*J,k	0.76	125	8,310	*	1.5	124	1,970	*	1.5	120	3,950	*	1.4	117																			
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	538		0.02	1.2	443		0.03	1.4			607	*J,k	0.03	1.3		274	*J,k	0.02	1.2	318	N,K,m	0.02	1.2	318	N,K,m	0.02	1.2	487	N,K,m	0.02	1.2																			
Mercury ⁽²⁾	7439-97-6	0.13	N	2.35	N	30.66	--	0.85		0.021	0.041	0.42		0.022	0.045			0.12	*J,k	0.022	0.044		0.49	*J,k	0.021	0.042	0.27		0.02	0.041	0.096		0.018	0.036	0.08		0.02	0.039																			
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	16.4		0.12	0.62	9.8		0.14	0.71			30.7	*J,k	0.13	0.65		17.1	*J,k	0.12	0.62	8.6		0.12	0.62	6.3		0.12	0.6	7.3		0.12	0.58																			
Potassium	7440-09-7	--	--	--	--	--	--	1,360		14.6	123	1,140		16.7	141			1,410	E,J,s	15.4	130		1,100	E,J,s	14.8	125	1,010	*E,J,s	5	124	1,020	*E,J,s	4.8	120	1,170	*E,J,s	4.7	117																			
Selenium	7782-49-2	--	N	39.11	N	511	18.98	1.9	N,L,m	0.41	0.62	4.1	N,L,m	0.47	0.71			1.9	*J,k	0.43	0.65		7	*J,k	0.41	0.62	1.3	N,L,m	0.37	0.62	1	N,L,m	0.36	0.6	1.2	N,L,m	0.35	0.58																			
Silver	7440-22-4	--	N	39.11	N	511	31.03	0.34	B	0.09	0.62	0.48	B	0.1	0.71			<0.65	U	0.09	0.65		0.6	B	0.09	0.62	<0.62	U	0.1	0.62	<0.6	U	0.1	0.6	<0.58	U	0.09	0.58																			
Sodium	7440-23-5	--	--	--	--	--	--	374	B,x	30.7	247	1,230		35.1	282			1,170		32.3	260		207	B,L,w	31	249	188	B,B,x	37.9	249	96.5	B,B,x	36.4	239	101	B,B,x	35.6	234																			
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	<1.2	UN,R,m	0.63	1.2	<1.4	UN,R,m	0.72	1.4			<1.3	UN*,R,m	0.66	1.3		<1.2	UN*,R,m	0.64	1.2	<1.2	UN,UL,m	0.3	1.2	<1.2	UN,UL,m	0.29	1.2	<1.2	UN,UL,m	0.28	1.2																			
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	38.5	N,K,m	0.09	2.5	35.1	N,K,m	0.1	2.8			49.3	*J,k	0.09	2.6		10.7	*J,k	0.09	2.5	43.5		0.09	2.5	49.2		0.08	2.4	54.5		0.08	2.3																			
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	158	*E,J,k	0.12	2.5	725	*E,J,k	0.14	2.8			34	*J,k	0.13	2.6		62.3	*J,k	0.12	2.5	72.4	L,p	0.14	2.5	42.9	L,p	0.13	2.4	46.8	L,p	0.13	2.3																			
Pesticides/PCBs (ug/kg)																																																									
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	<44	U	0.4	44	<2.4	U,UL,s	0.4	2.4			<2.3	U	0.4	2.3		<2.1	U	0.4	2.1	<11	U		0.4	11	<2.1	U,UJ,c	0.4	2.1	<2.2	U		0.4	2.2																	
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	<130	U	0.39	130	<7.1	U,UL,s	0.39</																																											

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Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	TESTPIT1F 11/20/2002 5			MDL	RL	TESTPIT1F2 11/20/2002 13			MDL	RL	TESTPIT2BP 11/20/2002 11			MDL	RL	TESTPIT2F 11/20/2002 6			MDL	RL	40SS1 11/11/2002 0-1			MDL	RL	40SS2 11/11/2002 0-1			MDL	RL	40SS3 11/11/2002 0-1			MDL	RL												
								Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r			Result	LQ, VQ, r	LQ, VQ, r	Result	LQ, VQ, r	LQ, VQ, r	Result	LQ, VQ, r	LQ, VQ, r	Result	LQ, VQ, r	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	100	NJ,NJ,t	0	0	NI					NI						NI					NI				NI				NI				NI														
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				85	NJ,NJ,t	0	0	NI							NI					NI				NI				NI				NI														
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Camphene	79-92-5	--	--	--	--	--	--	NI				NI					NI						NI					240	NJ,NJ,t	0	0	NI				NI				NI														
Camphor	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI					28	NJ,NJ,t	0	0	NI			NI				NI				NI				NI				NI														
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Ether	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Hexanal	--	--	--	--	--	--	--	NI				NI					NI						NI					63	NJ,NJ,t	0	0	NI				NI				NI														
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Methanethiol	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Naphthalene, Decahydro-	--	--	--	--	--	--	--	1,900	NJ,NJ,t	0	0	140	NJ,NJ,t	0	0	NI							NI					NI				NI				NI				NI														
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				43	NJ,NJ,t	0	0	NI							NI					NI				NI				NI				NI														
Nonanal	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Pentanal	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI					NI						NI					NI				NI				NI				NI														
TCL SVOCs (ug/kg)																																																						
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	44	J	22	420	54	J	22	470	<440	U	22	440	75	J	22	410	<420	U	22	420	<410	U	22	410	<420	U	22	410	<420	U	22	410	<420	U	22	420											
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	<420	U	20	420	<470	U	20	470	<440	U	20	440	<410	U	20	410	<420	U	20	420	<410	U	20	410	<420	U	20	410	<420	U	20	410	<420	U	20	420											
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	<420	U	21	420	<470	U	21	470	<440	U	21	440	<410	U	21	410	<420	U	21	420	<410	U	21	410	<420	U	21	410	<420	U	21	410	<420	U	21	420											
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	91	J	24	420	110	J	24	470	<440	U	24	440	390	J	24	410	<420	U	24	420	<410	U	24	410	<420	U	24	410	<420	U	24	410	<420	U	24	420											
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	82	J	29	420	<470	U	29	470	<440	U	29	440	<410	U	29	410	<420	U	29	420	<410	U	29	410	<420	U	29	410	<420	U	29	410	<420	U	29	420											
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	68	J	48	420	<470	U	48	470	<440	U	48	440	97	J	48	410	<420	U	48	420	<410	U	48	410	<420	U	48	410	<420	U	48	410	<420	U	48	420											
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<420	U	31	420	<470	U	31	470	<440	U	31	440	<410	U	31	410	<420	U	31	420	<410	U	31	410	<420	U	31	410	<420	U	31	410	<420	U	31	420											
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<420	U	17	420	<470	U	17	470	<440	U	17	440	<410	U	17	410	<420	U	17	420	<410	U	17	410	<420	U	17	410	<420	U	17	410	<420	U	17	420											
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	<420	U	23	420	<470	U	23	470	<440	U	23	440	<410	U	23	410	<420	U	23	420	<410	U	23	410	<420	U	23	410	<420	U	23	410	<420	U	23	420											
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<420	U	54	420	<470	U	25	470	<440	U	25	440	<410	U	25	410	<420	U	25	420	<410	U	25	410	<420	U	25	410	<420	U	25	410	<420	U	25	420											
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	120	J,J,r	39	420	<470	U	39	470	<440	U	39	440	<410	U	39	410																															

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Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	TESTPIT1F 11/20/2002 5		MDL	RL	TESTPIT1F2 11/20/2002 13		MDL	RL	TESTPIT2BP 11/20/2002 11		MDL	RL	TESTPIT2F 11/20/2002 6		MDL	RL	40SS1 11/11/2002 0-1		MDL	RL	40SS2 11/11/2002 0-1		MDL	RL	40SS3 11/11/2002 0-1		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				2,300	NJ,NJ,t	0	0	NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	18,000	NJ,NJ,t	0	0	15,000	NJ,NJ,t	0	0	970	NJ,NJ,t	0	0	3,400	NJ,NJ,t	0	0	NI				NI				NI							
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<54	U	5.9	54	<60	U	5.9	56	<56	U	5.9	56	<52	U,UJ,m	5.8	52	<53	U	5.9	53	560	PZ,K,s	5.9	260	190	P,J,g	5.9	53				
Acenaphthylene ⁽⁸⁾	208-96-8	--	N	2.3E+05	N	3.1E+06	--	4,100	PZ,J,g	5.9	2700	980	JPZ,J,g	5.9	1200	<56	U	5.9	56	820	JPZ,J,g	5.9	1000	<53	U	5.9	53	<52	U	5.9	52	<53	U	5.9	53				
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	<54	U	5.4	54	<60	U	5.4	60	<56	U	5.4	56	<52	U	5.4	52	<53	U	5.4	53	120	JPZ,K,s	5.4	260	<53	U	5.4	53				
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<11	U	2.2	11	1,200	PZ,J,g	2.2	240	<11	U	2.2	11	<20	PZ,J,g	2.2	210	40	P,K,s	2.2	10	120	PZ,K,s	2.2	51	83	P,J,g	2.2	10				
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<11	U	1.6	11	<12	U	1.6	12	<11	U	1.6	11	<10	U	1.6	10	16	K,s	1.6	10	300	Z,K,s	1.6	51	62	P,J,g	1.6	10				
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	330	JPZ,J,g	1.7	530	<12	U	1.7	12	<11	U	1.7	11	150	JPZ,J,g	1.7	210	110	P,K,s	1.7	10	380	E,K,s	1.7	10	100		1.7	10				
Benzo(g,h,i)perylene ⁽²⁰⁾	191-24-2	--	N	2.3E+05	N	3.1E+06	--	<11	U	3.6	11	<12	U	3.6	12	<11	U	3.6	11	<10	U	3.6	10	<10	U	3.6	10	140	K,s	3.6	10	110	P,J,g	3.6	10				
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<11	U	1.4	11	<12	U	1.4	12	<11	U	1.4	11	42	JPZ,J,g	1.4	210	26	P,K,s	1.4	10	370	EP,K,s	1.4	10	100	P,J,g	1.4	10				
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	2,800	PZ,J,g	2.4	530	2,600	PZ,J,g	2.4	240	<11	U	2.4	11	2,400	PZ,J,g	2.4	210	17	P,K,s	2.4	10	350	Z,K,s	2.4	51	83	P,J,g	2.4	10				
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<11	U	4.2	11	<12	U	4.2	12	<11	U	4.2	11	<10	U	4.2	10	<10	U	4.2	10	<10	U	4.2	10	25	P,J,g	4.2	10				
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	990	EP,J,g	2.1	22	490	EP,J,g	2.1	24	<23	U	2.1	23	1,600	EP,J,g	2.1	21	99	P,K,s	2.1	22	1,500	E,J,c	2.1	21	530	EP,J,g	2.1	22				
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	<54	U	14	54	<60	U	14	60	<56	U	14	56	<52	U	14	52	<53	U	14	53	<52	U	14	52	<53	U	14	53				
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	<11	U	2.5	11	<12	U	2.5	12	<11	U	2.5	11	<10	U	2.5	10	110	P,K,s	2.5	10	250	E,K,s	2.5	10	<10	U	2.5	10				
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	<54	U	14	54	420	JPZ,J,g	14	1200	<56	U	14	56	<52	U,UJ,m	14	52	<53	U	14	53	250	JZ,K,s	14	260	160		14	53				
Phenanthrene ⁽²⁰⁾	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<54	U	8.5	54	<60	U	8.5	60	<56	U	8.5	56	330		8.5	52	<53	U	8.5	53	550	J,c	8.5	52	120		8.5	53				
Pyrene	129-00-4	--	N	2.3E+05	N	3.1E+06	6.8E+05	650	JPZ,J,g	4.3	1100	170	JPZ,J,g	4.3	480	<23	U	4.3	23	450	PZ,J,g	4.3	420	43	P,K,s	4.3	22	730	Z,K,s	4.3	100	230		4.3	22				
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				7,250	E,J,q	4.2	9.8	NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				124		3.1	9.8	NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				431		1.7	4.9	NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				44.3		0.8	4.9	NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				2.9	J	1.1	4.9	NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				1.3	J	0.7	4.9	NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				2.3	JB	0.4	4.9	NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				10.6		0.7	4.9	NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				1.1	J	0.4	4.9	NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				3.9	J	0.7	4.9	NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				<4.9		0.6	4.9	NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				<4.9		0.5	4.9	NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				1.2	MJ	0.5	4.9	NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				0.38	MJ	0.3	4.9	NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				1.5	M	0.1	1	NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				907		1.7	4.9	NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				201	MX,J,w	0.9	4.9	NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT				77.1		0.7	4.9	NT				NT				NT							
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				NT				105	MX,J,w	0.5	4.9	NT				NT				NT							
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				NT				2.1	M	0.5	4.9	NT				NT				NT							
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				NT				13.2	MX,J,w	0.3	4.9	NT				NT				NT							
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				NT				9.8	MX,J,w	0.2	1	NT				NT				NT							
Nitroglycerin (mg/kg)																																							
Nitroglycerin	55-63-0	--	N	7.8E-01	N	1.0E+01	--	130	P,J,g	1	10	<10	U		1	10	<10	U		1	10	<10	U		1	10	<10	U		1	10	<10	U		1	10			
DRO/GRO (mg/kg)																																							
DRO	--	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
GRO	--	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Percent Solids (%)																																							
Percent Solids	--	--																																					

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SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SS4 11/11/2002 0-1			MDL	RL	40SS5 11/11/2002 0-1			MDL	RL	40SS6 4/21/2006 0-1			MDL	RL	40SS7 4/21/2006 0-1			MDL	RL	40SS8 4/21/2006 0-1			MDL	RL	40SS9 4/21/2006 0-1			MDL	RL	40SS9-DUP(Dup-1) 4/21/2006 0-1			MDL	RL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	1,780		9.3	16.5		659		7.9	14		NT																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											

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Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SS4 11/11/2002 0-1				MDL	RL	40SS5 11/11/2002 0-1				MDL	RL	40SS6 4/21/2006 0-1				MDL	RL	40SS7 4/21/2006 0-1				MDL	RL	40SS8 4/21/2006 0-1				MDL	RL	40SS9 4/21/2006 0-1				MDL	RL	40SS9-DUP(Dup-1) 4/21/2006 0-1				MDL	RL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r						
TAL Metals (mg/kg)																																			
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	NT				NT				NT				NT				NT					NT						
Antimony	7440-36-0	--	N	3.13	N	40.88	13.2	NT				NT				NT				NT				NT					NT						
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	NT				NT				NT				NT				NT					NT						
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	NT				NT				NT				NT				NT					NT						
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	NT				NT				NT				NT				NT					NT						
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	NT				NT				NT				NT				NT					NT						
Calcium	7440-70-2	--	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
Chromium ^[1]	7440-47-3	65.3	N	23.46	N	306.6	42.05	NT				NT				NT				NT				NT					NT						
Cobalt	7440-48-4	72.3	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	NT				NT				NT				NT				NT					NT						
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	NT				NT				NT				NT				NT					NT						
Lead ^[2]	7439-92-1	26.8	--	400	--	750	--	NT				NT				NT				NT				NT					NT						
Magnesium	7439-95-4	--	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	NT				NT				NT				NT				NT					NT						
Mercury ^[3]	7439-97-6	0.13	N	2.35	N	30.66	--	NT				NT				NT				NT				NT					NT						
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	NT				NT				NT				NT				NT					NT						
Potassium	7440-09-7	--	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
Selenium	7782-49-2	--	N	39.11	N	511	18.98	NT				NT				NT				NT				NT					NT						
Silver	7440-22-4	--	N	39.11	N	511	31.03	NT				NT				NT				NT				NT					NT						
Sodium	7440-23-5	--	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	NT				NT				NT				NT				NT					NT						
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	NT				NT				NT				NT				NT					NT						
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	NT				NT				NT				NT				NT					NT						
Pesticides/PCBs (ug/kg)																																			
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	NT				NT				NT				NT				NT					NT						
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	NT				NT				NT				NT				NT					NT						
Aldrin	309-00-2	--	C	3.8E+01	C	1.7E+02	7.7E+00	NT				NT				NT				NT				NT					NT						
alpha-BHC	319-84-6	--	C	1.0E+02	C	4.5E+02	8.9E-01	NT				NT				NT				NT				NT					NT						
alpha-Chlordane ^[4]	5103-71-9	--	C	1.8E+03	C	8.2E+03	--	NT				NT				NT				NT				NT					NT						
beta-BHC	319-85-7	--	C	3.5E+02	C	1.6E+03	3.1E+00	NT				NT				NT				NT				NT					NT						
delta-BHC ^[5]	319-86-8	--	C	1.0E+02	C	4.5E+02	--	NT				NT				NT				NT				NT					NT						
Endosulfan Sulfate ^[6]	1031-07-8	--	N	4.7E+04	N	6.1E+05	--	NT				NT				NT				NT				NT					NT						
Endrin	72-20-8	--	N	2.3E+03	N	3.1E+04	5.4E+03	NT				NT				NT				NT				NT					NT						
Endrin Ketone ^[7]	53494-70-5	--	N	2.3E+03	N	3.1E+04	--	NT				NT				NT				NT				NT					NT						
gamma-BHC (Lindane)	58-89-9	--	C	4.9E+02	C	2.2E+03	4.3E+00	NT				NT				NT				NT				NT					NT						
gamma-Chlordane ^[8]	5103-74-2	--	C	1.8E+03	C	8.2E+03	--	NT				NT				NT				NT				NT					NT						
Methoxychlor	72-43-5	--	N	3.9E+04	N	5.1E+05	3.1E+05	NT				NT				NT				NT				NT					NT						
Aroclor 1016 ^[9]	12674-11-2	--	N	5.5E+02	N	7.2E+03	4.2E+03	<94 U		6.1	94	<97 U		6.3	97	<100 U		6.6	100	<110 U		7	110	<100 U		6.5	100	<99 U		6.4	99	<100 U		6.7	100
Aroclor 1232	11141-16-5	--	C	3.2E+02	C	1.4E+03	--	<94 U		6.4	94	<97 U		6.6	97	<100 U		6.9	100	<110 U		7.4	110	<100 U		6.8	100	<99 U		6.7	99	<100 U		7	100
Aroclor 1242	53469-21-9	--	C	3.2E+02	C	1.4E+03	--	<47 U		8.9	47	<49 U		9.1	49	<51 U		9.5	51	<54 U		10	54	<50 U		9.4	50	<49 U		9.3	49	<52 U		9.7	52
Aroclor 1248	12672-29-6	--	C	3.2E+02	C	1.4E+03	--	<47 U		5.3	47	<49 U		5.4	49	<51 U		5.7	51	<54 U		6.1	54	<50 U		5.6	50	<49 U		5.5	49	<52 U		5.8	52
Aroclor 1254 ^[10]	11097-69-1	--	N	1.6E+02	C	1.4E+03	1.1E+03	32 J		8.6	47	47 J		8.8	49	260		9.2	51	38 J		9.8	54	58		9.1	50	55 J,g		9	49	130		9.4	52
Aroclor 1260	11096-82-5	--	C	3.2E+02	C	1.4E+03	--	<94 U		6.3	94	<97 U		6.5	97	<100 U		6.8	100	<100 U		7.2	110	<100 U		6.7	100	33 J		6.6	99	72 J		6.9	100
TCL VOCs (ug/kg)																																			
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	--	N	2.3E+08	N	3.1E+09	2.3E+06	NT				NT				NT				NT				NT					NT						
1,1-Dichloroethane	75-34-3	--	N	1.6E+06	N	2.0E+07	5.1E+03	NT				NT				NT				NT				NT					NT						
1,2,4-Trichlorobenzene	120-82-1	--	N	7.8E+04	N	1.0E+06	2.4E+03	NT				NT				NT				NT				NT					NT						
1,2-Dibromo-3-Chloropropane	96-12-8	--	C	2.0E+02	C	3.6E+03	3.7E-03	NT				NT				NT				NT				NT					NT						
1,2-Dichlorobenzene	95-50-1	--	N	7.0E+05	N	9.2E+06	4.6E+03	NT				NT				NT				NT				NT					NT						
1,3-Dichlorobenzene	541-73-1	--	N	2.3E+04	N	3.1E+05	2.9E+02	NT				NT				NT				NT				NT					NT						
1,4-Dichlorobenzene	106-46-7	--	C	2.7E+04	C	1.2E+05	4.2E+00	NT				NT				NT				NT				NT					NT						
2-Butanone	78-93-3	--	N	4.7E+06	N	6.1E+07	2.9E+04	NT				NT				NT				NT				NT					NT						
2-Hexanone	591-78-6	--	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	--	NT				NT				NT				NT				NT					NT						
Acetone	67-64-1	--	N	7.0E+06	N	9.2E+07	2.2E+04	NT				NT				NT				NT				NT					NT						
Benzene	71-43-2	--	C	1.2E+04	C	5.2E+04	1.9E+00	NT				NT				NT				NT				NT					NT						
Bromomethane	74-83-9	--	N	1.1E+04	N	1.4E+05	4.1E+01	NT				NT				NT				NT				NT					NT						
Carbon Disulfide	75-15-0	--	N	7.8E+05	N	1.0E+07	1.9E+04	NT				NT				NT				NT				NT					NT						
Chlorobenzene	108-90-7	--	N	1.6E+05	N	2.0E+06	6.8E+02	NT				NT				NT				NT				NT					NT						
Chloromethane	74-87-3	--	--	--	--	--	9.3E+02	NT				NT				NT				NT				NT					NT						
cis-1,2-Dichloroethene	156-59-2	--	N	7.8E+04	N	1.0E+06	--	NT				NT				NT				NT				NT					NT						
Cyclohexane	110-82-7	--	--	--	--	--	--	NT																											

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								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Camphene	79-92-5	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Camphor	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Dimethyl Sulfide	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Ether	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Hexanal	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Methanethiol	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Nonanal	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentanal	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur Dioxide	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL SVOCs (ug/kg)																																							
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	NT				NT				NT				NT				NT				NT				NT							
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	NT				NT				NT				NT				NT				NT				NT							
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	NT				NT				NT				NT				NT				NT				NT							
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	NT				NT				NT				NT				NT				NT				NT							
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	NT				NT				NT				NT				NT				NT				NT							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT				NT				NT				NT				NT				NT				NT							
Acenaphthylene ⁽¹⁰⁾	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	NT				NT				NT				NT				NT				NT				NT							
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	NT				NT				NT				NT				NT				NT				NT							
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	NT				NT				NT				NT				NT				NT				NT							
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT				NT				NT				NT				NT				NT				NT							
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT				NT				NT				NT				NT				NT				NT							
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT				NT				NT				NT				NT				NT				NT							
Benzo(g,h,i)perylene ⁽¹⁰⁾	191-24-2	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT				NT				NT				NT				NT				NT				NT							
Bis(2-ethylhexyl)phthalate	117-81-7	--	C	4.6E+04	C	2.0E+05	2.9E+06	NT				NT				NT				NT				NT				NT				NT							
Butylbenzylphthalate	85-68-7	--	N	1.6E+06	N	2.0E+07	1.7E+07	NT				NT				NT				NT				NT				NT				NT							
Caprolactam	105-60-2	--	N	3.9E+06	N	5.1E+07	--	NT				NT				NT				NT				NT				NT				NT							
Carbazole	86-74-8	--	C	3.2E+04	C	1.4E+05	4.7E+02	NT				NT				NT				NT				NT				NT				NT							
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT				NT				NT				NT				NT				NT				NT							
Di-n-butylphthalate	84-74-2	--	N	7.8E+05	N	1.0E+07	5.0E+06	NT				NT				NT				NT				NT				NT				NT							
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--</																																

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SS10 4/21/2006 0-1		MDL	RL	40SS11 4/21/2006 0-1		MDL	RL	40SS11-DUP(Dup-5) 4/21/2006 0-1		MDL	RL	40SS12 4/21/2006 0-1		MDL	RL	40SS13 4/21/2006 0-1		MDL	RL	40SS14 4/21/2006 0-1		MDL	RL	40SS15 4/21/2006 0-1		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT				NT				NT				NT				NT				NT				NT							
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	NT				NT				NT				NT				NT				NT				NT							
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT				NT				NT				NT				NT				NT				NT							
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT				NT				NT				NT				NT				NT				NT							
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT				NT				NT				NT				NT				NT				NT							
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT				NT				NT				NT				NT				NT				NT							
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT				NT				NT				NT				NT				NT				NT							
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	NT				NT				NT				NT				NT				NT				NT							
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	NT				NT				NT				NT				NT				NT				NT							
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	NT				NT				NT				NT				NT				NT				NT							
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	NT				NT				NT				NT				NT				NT				NT							
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	NT				NT				NT				NT				NT				NT				NT							
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	NT				NT				NT				NT				NT				NT				NT							
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Nitroglycerin (mg/kg)																																							
Nitroglycerin	55-63-0	--	N	7.8E-01	N	1.0E+01	--	NT				NT				NT				NT				NT				NT				NT							
DRO/GRO (mg/kg)																																							
DRO	--	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
GRO	--	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Percent Solids (%)																																							
Percent Solids	--	--	--	--	--	--	--	70		0.1	0.1	68		0.1	0.1	65		0.1	0.1	61		0.1	0.1	66		0.1	0.1	67		0.1	0.1	64		0.1	0.1				

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

[illegible]

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	40SS16 4/21/2006 0-1		MDL	RL	40SS17 4/21/2006 0-1		MDL	RL	40SS18 4/21/2006 0-1		MDL	RL	71SB14A 4/20/2006 0-0.5		MDL	RL	71SB14B 4/20/2006 2.5-3		MDL	RL	71SB14C 4/21/2006 7		MDL	RL	71SB15A 4/21/2006 0-1		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI				NI				NI				NI				NI							
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT				NT				NT				NT				NT				NT				NT							
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	NT				NT				NT				NT				NT				NT				NT							
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT				NT				NT				NT				NT				NT				NT							
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT				NT				NT				NT				NT				NT				NT							
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT				NT				NT				NT				NT				NT				NT							
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT				NT				NT				NT				NT				NT				NT							
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT				NT				NT				NT				NT				NT				NT							
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	NT				NT				NT				NT				NT				NT				NT							
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	NT				NT				NT				NT				NT				NT				NT							
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	NT				NT				NT				NT				NT				NT				NT							
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	NT				NT				NT				NT				NT				NT				NT							
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	NT				NT				NT				NT				NT				NT				NT							
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT				NT				NT							
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	NT				NT				NT				NT				NT				NT				NT							
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				NT				NT				NT				NT				NT							
Nitroglycerin (mg/kg)																																							
Nitroglycerin	55-63-0	--	N	7.8E-01	N	1.0E+01	--	NT				NT				NT				NT				NT				NT				NT							
DRO/GRO (mg/kg)																																							
DRO	--	--	--	--	--	--	--	NT				NT				68			1	8.2	68		1.1	8.7	130		1.1	8.4	21		1	8							
GRO	--	--	--	--	--	--	--	NT				NT				<6.1	U	0.95	6.1	<6.5	U	1	6.5	13		0.98	6.2	<6	U	0.93	6								
Percent Solids (%)																																							
Percent Solids	--	--	--	--	--	--	--	65		0.1	0.1	67		0.1	0.1	69		0.1	0.1	82		0.1	0.1	77		0.1	0.1	80		0.1	0.1	84		0.1	0.1				

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	15B15A-DUP(Dup-3 4/21/2006 0-1			MDL	RL	715B15B 4/21/2006 4-5			MDL	RL	715B15C 4/21/2006 7-8			MDL	RL		
								Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r					
TAL Metals (mg/kg)																								
Aluminum	7429-90-5	40,041	N	7,821	N	102,200	--	15,000		1.6	50			22,000		1.6	50			9,300		1.6	50	
Antimony	7440-36-0	--	--	3.13	N	40.88	13.2	1.4	B,p	0.036	0.5			4.5		0.036	0.5			6.1		0.036	0.5	
Arsenic	7440-38-2	15.8	C	0.426	C	1.91	0.026	15	L,m	0.023	0.4			7.5	L,m	0.023	0.4			19	L,m	0.023	0.4	
Barium	7440-39-3	209	N	1,564	N	20,440	6,015	140		0.1	5			130		0.1	5			250		0.1	5	
Beryllium	7440-41-7	1.02	N	15.64	N	204.4	1,154	0.94	J	0.016	1			0.78	J	0.016	1			0.39	J	0.016	1	
Cadmium	7440-43-9	0.69	N	3.91	N	51.1	27.4	0.3	J	0.0073	1			7.6		0.0073	1			2.8		0.0073	1	
Calcium	7440-70-2	--	--	--	--	--	--	2,500	L,m	10	250			6,400	L,m	10	250			18,000	L,m	10	250	
Chromium ⁽¹⁾	7440-47-3	65.3	N	23.46	N	306.6	42.05	24	L,m	0.57	5			31	L,m	0.57	5			66	L,m	0.57	5	
Cobalt	7440-48-4	72.3	--	--	--	--	--	8	L,m	0.35	1			10	L,m	0.35	1			4.3	L,m	0.35	1	
Copper	7440-50-8	53.5	N	312.86	N	4,088	10,518	67	L,m	0.045	2			500	L,m	0.45	20			52,000	L,m	45	2,000	
Iron	7439-89-6	50,962	N	5,475	N	71,540	--	28,000		23	500			17,000		11	250			8,900		11	250	
Lead ⁽²⁾	7439-92-1	26.8	--	400	--	750	--	31	J,f	0.041	1			55		0.083	2			1,100		1.7	40	
Magnesium	7439-95-4	--	--	--	--	--	--	3,600		3.4	250			4,200		3.4	250			2,600		3.4	250	
Manganese	7439-96-5	2,543	N	156.43	N	2,044	951.92	250		0.14	10			440		0.14	10			170		0.14	10	
Mercury ⁽³⁾	7439-97-6	0.13	N	2.35	N	30.66	--	0.31	B,x	0.0048	0.1			11		0.12	2.5			2		0.024	0.5	
Nickel	7440-02-0	62.8	N	156.43	N	2,044	--	19	J,s	0.027	0.5			33	J,s	0.027	0.5			20	J,s	0.027	0.5	
Potassium	7440-09-7	--	--	--	--	--	--	1,600	J,f	7.5	100			1,700		7.5	100			510		7.5	100	
Selenium	7782-49-2	--	N	39.11	N	511	18.98	0.71	J,L,m	0.063	1			0.48	J,L,m	0.063	1			0.55	J,L,m	0.063	1	
Silver	7440-22-4	--	N	39.11	N	511	31.03	0.12	J	0.017	3			0.24	J	0.017	3			2.7	J	0.017	3	
Sodium	7440-23-5	--	--	--	--	--	--	170	L,m	19	100			1,000	L,m	19	100			1,400	L,m	19	100	
Thallium	7440-28-0	2.11	N	0.548	N	7.15	3.638	0.54		0.0085	0.5			0.34	J	0.0085	0.5			0.27	J	0.0085	0.5	
Vanadium	7440-62-2	108	N	7.82	N	102.2	730.15	37	J,s	0.024	1			33	J,s	0.024	1			23	J,s	0.024	1	
Zinc	7440-66-6	202	N	2,346	N	30,660	13,622	120	L,m	1.7	8			180	L,m	1.7	8			16,000	L,m	170	800	
Pesticides/PCBs (ug/kg)																								
4,4'-DDE	72-55-9	--	C	1.9E+03	C	8.4E+03	3.5E+04	NT						NT						NT				
4,4'-DDT	50-29-3	--	C	1.9E+03	C	8.4E+03	1.2E+03	NT						NT						NT				
Aldrin	309-00-2	--	C	3.8E+01	C	1.7E+02	7.7E+00	NT						NT						NT				
alpha-BHC	319-84-6	--	C	1.0E+02	C	4.5E+02	8.9E-01	NT						NT						NT				
alpha-Chlordane ⁽⁴⁾	5103-71-9	--	C	1.8E+03	C	8.2E+03	--	NT						NT						NT				
beta-BHC	319-85-7	--	C	3.5E+02	C	1.6E+03	3.1E+00	NT						NT						NT				
delta-BHC ⁽⁵⁾	319-86-8	--	C	1.0E+02	C	4.5E+02	--	NT						NT						NT				
Endosulfan Sulfate ⁽⁶⁾	1031-07-8	--	N	4.7E+04	N	6.1E+05	--	NT						NT						NT				
Endrin	72-20-8	--	N	2.3E+03	N	3.1E+04	5.4E+03	NT						NT						NT				
Endrin Ketone ⁽⁷⁾	53494-70-5	--	N	2.3E+03	N	3.1E+04	--	NT						NT						NT				
gamma-BHC (Lindane)	58-89-9	--	C	4.9E+02	C	2.2E+03	4.3E+00	NT						NT						NT				
gamma-Chlordane ⁽⁴⁾	5103-74-2	--	C	1.8E+03	C	8.2E+03	--	NT						NT						NT				
Methoxychlor	72-43-5	--	N	3.9E+04	N	5.1E+05	3.1E+05	NT						NT						NT				
Aroclor 1016 ⁽⁸⁾	12674-11-2	--	N	5.5E+02	N	7.2E+03	4.2E+03	<77	U	5	77			<87	U	5.7	87			<97	U	6.3	97	
Aroclor 1232	11141-16-5	--	C	3.2E+02	C	1.4E+03	--	<77	U	5.2	77			<87	U	5.9	87			<97	U	6.6	97	
Aroclor 1242	53469-21-9	--	C	3.2E+02	C	1.4E+03	--	<38	U	7.2	38			<43	U	8.2	43			<49	U	9.1	49	
Aroclor 1248	12672-29-6	--	C	3.2E+02	C	1.4E+03	--	370	J	4.3	38			210	J,g	4.9	43			280		5.4	49	
Aroclor 1254 ⁽⁹⁾	11097-69-1	--	N	1.6E+02	C	1.4E+03	1.1E+03	210	J,f	7	38			610	J,g	7.9	43			580	J,g	8.8	49	
Aroclor 1260	11096-82-5	--	C	3.2E+02	C	1.4E+03	--	<77	U	5.1	77			<87	U	5.8	87			120		6.5	97	
TCL VOCs (ug/kg)																								
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	--	N	2.3E+08	N	3.1E+09	2.3E+06	NT						NT						NT				
1,1-Dichloroethane	75-34-3	--	N	1.6E+06	N	2.0E+07	5.1E+03	NT						NT						NT				
1,2,4-Trichlorobenzene	120-82-1	--	N	7.8E+04	N	1.0E+06	2.4E+03	NT						NT						NT				
1,2-Dibromo-3-Chloropropane	96-12-8	--	C	2.0E+02	C	3.6E+03	3.7E-03	NT						NT						NT				
1,2-Dichlorobenzene	95-50-1	--	N	7.0E+05	N	9.2E+06	4.6E+03	NT						NT						NT				
1,3-Dichlorobenzene	541-73-1	--	N	2.3E+04	N	3.1E+05	2.9E+02	NT						NT						NT				
1,4-Dichlorobenzene	106-46-7	--	C	2.7E+04	C	1.2E+05	4.2E+00	NT						NT						NT				
2-Butanone	78-93-3	--	N	4.7E+06	N	6.1E+07	2.9E+04	NT						NT						NT				
2-Hexanone	591-78-6	--	--	--	--	--	--	NT						NT						NT				
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	--	NT						NT						NT				
Acetone	67-64-1	--	N	7.0E+06	N	9.2E+07	2.2E+04	NT						NT						NT				
Benzene	71-43-2	--	C	1.2E+04	C	5.2E+04	1.9E+00	NT						NT						NT				
Bromomethane	74-83-9	--	N	1.1E+04	N	1.4E+05	4.1E+01	NT						NT						NT				
Carbon Disulfide	75-15-0	--	N	7.8E+05	N	1.0E+07	1.9E+04	NT						NT						NT				
Chlorobenzene	108-90-7	--	N	1.6E+05	N	2.0E+06	6.8E+02	NT						NT						NT				
Chloromethane	74-87-3	--	--	--	--	--	9.3E+02	NT						NT						NT				
cis-1,2-Dichloroethene	156-59-2	--	N	7.8E+04	N	1.0E+06	--	NT						NT						NT				
Cyclohexane	110-82-7	--	--	--	--	--	--	NT						NT						NT				
Dichlorodifluoromethane	75-71-8	--	N	1.6E+06	N	2.0E+07	1.1E+04	NT						NT						NT				
Ethylbenzene	100-41-4	--	N	7.8E+05	N	1.0E+07	1.5E+04	NT						NT						NT				
Isopropylbenzene	98-82-8	--	N	7.8E+05	N	1.0E+07	6.4E+04	NT						NT						NT				
Methyl Acetate	79-20-9	--	N	7.8E+06	N	1.0E+08	2.5E+04	NT						NT						NT				
Methyl Tert-Butyl Ether	1634-04-4	--	C	1.6E+05	C	7.2E+05	1.2E+01	NT						NT						NT				
Methyl																								

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	15B15A-DUP(Dup-3	MDL	RL	71SB15B	MDL	RL	71SB15C	MDL	RL
								4/21/2006			4/21/2006			4/21/2006		
								0-1			4-5			7-8		
Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r											
Benzene, 1,3-Diethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Benzene, 1-Methyl-4-(1-Methylethyl)-	--	--	--	--	--	--	--	NI			NI			NI		
Benzene, 2-Ethenyl-1,4-Dimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Bicyclo[2.2.1]Heptan-2-One, 1,3,3-Trimet	--	--	--	--	--	--	--	NI			NI			NI		
Bicyclo[2.2.1]Heptan-2-One, 1,7,7-Trimet	--	--	--	--	--	--	--	NI			NI			NI		
Camphene	79-92-5	--	--	--	--	--	--	NI			NI			NI		
Camphor	--	--	--	--	--	--	--	NI			NI			NI		
Cyclohexene, 4-Methyl-1-(1-Methylethyl)-	--	--	--	--	--	--	--	NI			NI			NI		
Cyclotetrasiloxane, Octamethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Dimethyl Sulfide	--	--	--	--	--	--	--	NI			NI			NI		
Ether	--	--	--	--	--	--	--	NI			NI			NI		
Hexanal	--	--	--	--	--	--	--	NI			NI			NI		
Indan, 1-Methyl-	--	--	--	--	--	--	--	NI			NI			NI		
Methanethiol	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 1,2,3,4-Tetrahydro-1-Methyl	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, Decahydro-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, Decahydro-, Trans-	--	--	--	--	--	--	--	NI			NI			NI		
Nonanal	--	--	--	--	--	--	--	NI			NI			NI		
Pentanal	--	--	--	--	--	--	--	NI			NI			NI		
Sulfur Dioxide	--	--	--	--	--	--	--	NI			NI			NI		
TCL SVOCs (ug/kg)																
1,1'-Biphenyl	92-52-4	--	N	3.9E+05	N	5.1E+06	9.6E+04	NT			NT			NT		
2,4-Dinitrotoluene	121-14-2	--	N	1.6E+04	N	2.0E+05	5.7E+02	NT			NT			NT		
2,6-Dinitrotoluene	606-20-2	--	N	7.8E+03	N	1.0E+05	2.5E+02	NT			NT			NT		
2-Methylnaphthalene	91-57-6	--	N	3.1E+04	N	4.1E+05	4.4E+03	NT			NT			NT		
4-Chloro-3-Methylphenol	59-50-7	--	--	--	--	--	--	NT			NT			NT		
4-Methylphenol	106-44-5	--	N	3.9E+04	N	5.1E+05	--	NT			NT			NT		
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT			NT			NT		
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT			NT			NT		
Acetophenone	98-86-2	--	N	7.8E+05	N	1.0E+07	3.2E+03	NT			NT			NT		
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	NT			NT			NT		
Benzaldehyde	100-52-7	--	N	7.8E+05	N	1.0E+07	--	NT			NT			NT		
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT			NT			NT		
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT			NT			NT		
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT			NT			NT		
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	NT			NT			NT		
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT			NT			NT		
Bis(2-ethylhexyl)phthalate	117-81-7	--	C	4.6E+04	C	2.0E+05	2.9E+06	NT			NT			NT		
Butylbenzylphthalate	85-68-7	--	N	1.6E+06	N	2.0E+07	1.7E+07	NT			NT			NT		
Caprolactam	105-60-2	--	N	3.9E+06	N	5.1E+07	--	NT			NT			NT		
Carbazole	86-74-8	--	C	3.2E+04	C	1.4E+05	4.7E+02	NT			NT			NT		
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT			NT			NT		
Di-n-butylphthalate	84-74-2	--	N	7.8E+05	N	1.0E+07	5.0E+06	NT			NT			NT		
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	NT			NT			NT		
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	NT			NT			NT		
Dibenzofuran	132-64-9	--	N	7.8E+03	N	1.0E+05	--	NT			NT			NT		
Diethylphthalate	84-66-2	--	N	6.3E+06	N	8.2E+07	4.5E+05	NT			NT			NT		
Dimethyl phthalate	131-11-3	--	--	--	--	--	--	NT			NT			NT		
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	NT			NT			NT		
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	NT			NT			NT		
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	NT			NT			NT		
n-Nitrosodiphenylamine	86-30-6	--	C	1.3E+05	C	5.8E+05	7.6E+02	NT			NT			NT		
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	NT			NT			NT		
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	NT			NT			NT		
Phenol	108-95-2	--	N	2.3E+06	N	3.1E+07	6.7E+04	NT			NT			NT		
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	NT			NT			NT		
SVOC TICs (ug/kg)																
(-)-Nortrachelogenin	--	--	--	--	--	--	--	NI			NI			NI		
1,2-Benzenedicarboxylic Acid, Decyl Octy	--	--	--	--	--	--	--	NI			NI			NI		
1,2-Benzenedicarboxylic Acid, Diisononyl	28553-12-0	--	--	--	--	--	--	NI			NI			NI		
1-Hexadecanol	--	--	--	--	--	--	--	NI			NI			NI		
1-Iodo-2-Methylundecane	--	--	--	--	--	--	--	NI			NI			NI		
1-Naphthalenamine, n-Phenyl-	--	--	--	--	--	--	--	NI			NI			NI		
1-Phenanthrenecarboxylic Acid, 1,2,3,4,4	--	--	--	--	--	--	--	NI			NI			NI		
11H-Benzo[b]fluorene	--	--	--	--	--	--	--	NI			NI			NI		
2-Naphthalenamine, n-Phenyl-	--	--	--	--	--	--	--	NI			NI			NI		
2-Propenal, 3-Chloro-2,3-Bis(1,3-Benzodi	--	--	--	--	--	--	--	NI			NI			NI		
1H-Idene-1,2,3-Trione	--	--	--	--	--	--	--	NI			NI			NI		
7H-Benz[De]Anthracen-7-One	--	--	--	--	--	--	--	NI			NI			NI		
9,10-Anthracenedione	--	--	--	--	--	--	--	NI			NI			NI		
Benzenamine, 4,4',4''-Methyldynetris[N,	--	--	--	--	--	--	--	NI			NI			NI		
Benzene, (1-Methylethyl)-	--	--	--	--	--	--	--	NI			NI			NI		
Benzene, 1-Methyl-2-(1-Methylethyl)-	--	--	--	--	--	--	--	NI			NI			NI		
Benzo[e]Pyrene	--	--	--	--	--	--	--	NI			NI			NI		
Cyclohexene, 1-Methyl-4-(1-Methylethenyl	--	--	--	--	--	--	--	NI			NI			NI		
Cyclotetradecane	--	--	--	--	--	--	--	NI			NI			NI		
Ethane, 1,1,2,2-Tetrachloro-	--	--	--	--	--	--	--	NI			NI			NI		
Hexadecane	--	--	--	--	--	--	--	NI			NI			NI		
Hexadecanoic Acid	--	--	--	--	--	--	--	NI			NI			NI		
Hexanedioic Acid, Dioctyl Ester	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 1,3-Dimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 1,4,6-Trimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 1,6,7-Trimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 1,7-Dimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 1-Methyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 2,3,6-Trimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 2,3-Dimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphthalene, 2,6-Dimethyl-	--	--	--	--	--	--	--	NI			NI			NI		
Naphtho[1,2,3,4-def]Chrysene	--	--	--	--	--	--	--	NI			NI			NI		

Table 4-1
SWMU 40 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	15B15A-DUP(Dup-3 4/21/2006 0-1		MDL	RL	715B15B 4/21/2006 4-5		MDL	RL	715B15C 4/21/2006 7-8		MDL	RL
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Octadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI			
Oxacyclohexadecan-2-One	--	--	--	--	--	--	--	NI				NI				NI			
Phenanthrene, 2,4,5,7-Tetramethyl-	--	--	--	--	--	--	--	NI				NI				NI			
Pentadecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI			
Phenanthrene, 1-Methyl-7-(1-Methylethyl)	--	--	--	--	--	--	--	NI				NI				NI			
Phenol, 4,4'-(1-Methylethylidene)bis-	--	--	--	--	--	--	--	NI				NI				NI			
Sulfur	--	--	--	--	--	--	--	NI				NI				NI			
Sulfur, Mol. (S8)	10544-50-0	--	--	--	--	--	--	NI				NI				NI			
Testosterone	58-22-0	--	--	--	--	--	--	NI				NI				NI			
Tetradecanoic Acid	--	--	--	--	--	--	--	NI				NI				NI			
TCL PAHs (ug/kg)																			
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT				NT				NT			
Acenaphthylene ^[10]	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT			
Anthracene	120-12-7	--	N	2.3E+06	N	3.1E+07	4.7E+05	NT				NT				NT			
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT				NT				NT			
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT				NT				NT			
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT				NT				NT			
Benzo(g,h,i)perylene ^[10]	191-24-2	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT			
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT				NT				NT			
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT				NT				NT			
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	NT				NT				NT			
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	NT				NT				NT			
Fluorene	86-73-7	--	N	3.1E+05	N	4.1E+06	1.4E+05	NT				NT				NT			
Indeno(1,2,3-cd)pyrene	193-39-5	--	C	2.2E+02	C	3.9E+03	4.2E+03	NT				NT				NT			
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	NT				NT				NT			
Phenanthrene ^[10]	85-01-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT			
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	NT				NT				NT			
Dioxin/Furans (pg/g)																			
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT			
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT			
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT			
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT			
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	--	--	NT				NT				NT			
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT			
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT			
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT			
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT			
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT			
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT			
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT			
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT			
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT			
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT			
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT			
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT			
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT			
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				NT			
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				NT			
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				NT			
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				NT			
Nitroglycerin (mg/kg)																			
Nitroglycerin	55-63-0	--	N	7.8E-01	N	1.0E+01	--	NT				NT				NT			
DRO/GRO (mg/kg)																			
DRO	--	--	--	--	--	--	--	20		0.98	7.8	140		1.1	8.8	850		12	99
GRO	--	--	--	--	--	--	--	<5.8	U,UJ,c	0.91	5.8	8.1		1	6.6	9.7		1.2	7.4
Percent Solids (%)																			
Percent Solids	--	--	--	--	--	--	--	86		0.1	0.1	76		0.1	0.1	68		0.1	0.1

Notes:

CAS = Chemical Abstracts Service
ft bgs = Feet Below Ground Surface
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
pg/g = Picogram Per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
TIC = Tentatively Identified Compound
DRO = Diesel Range Organics
GRO = Gasoline Range Organics
NT = Not Tested
NI = Not Identified
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
RBC = USEPA Region III Risk-Based Concentration

^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Chlordane RBC value was used
^[5] = Alpha-BHC RBC value was used
^[6] = Endosulfan RBC value was used
^[7] = Endrin RBC value was used
^[8] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[9] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[10] = Pyrene RBC value was used

= Concentration Exceeds Adjusted Soil Residential RBC

= Concentration Exceeds Adjusted Soil Industrial RBC

underline = Concentration Exceeds Facility Background Values

bold italic = Concentration Exceeds SSL DAF20

Laboratory Qualifiers

* Sample and associated duplicate are not within control limits.
B Analyte found in associated blank as well as in the sample.
D Discrepancies between the reported concentrations may be due to dilution of the sample or extract.
E Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis.
J Estimated value.
N Presumptive evidence of a compound.
P Greater than 40% difference for detected concentrations between the two GC or HPLC columns.
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.
X Laboratory-defined. Associated PCDF peak(s) has the same retention time as the associated diphenyl ether and that the diphenyl ether contribution to the total PCDF value is greater than 10%.
Z Laboratory-defined. Result reported with sample-specific dilution factor. See DV Reports for additional information.

Validation Qualifiers

B Not detected substantially above the level reported in laboratory or field blanks.
J Analyte present. Reported value may not be accurate or precise.
K Analyte present. Reported value may be biased high. Actual value is expected to be lower.
L Analyte present. Reported value may be biased low. Actual value is expected to be higher.
N Tentative identification. Consider present. Special methods may be needed to confirm its presence or absence in future sampling efforts.
R Unreliable result. Analyte may or may not be present in the sample. Supporting data necessary to confirm result.
U Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ Not detected, quantitation limit may be inaccurate or imprecise.
UL Not detected, quantitation limit is probably higher.

Reason Codes

GC/MS Organics
c Calibration failure; poor (RRF) or unstable (%D) response
d MS/MSD or LCS/LCSD RPD imprecision
h Holding time violation
i LCS recovery failure
l MS/MSD recovery failure
r linearity (%RSD or r) failure in initial calibration
s Surrogate failure
t Tentatively identified Compound
w Identification criteria failure
x Field and/or equipment blank contamination
y Trip blank contamination
z Method blank and/or storage blank contamination

GC and HPLC Organics
c Calibration failure; poor or unstable (%D) response
d MS/MSD or LCS/LCSD RPD imprecision
g Dual column confirmation imprecision
h Holding time violation
i LCS recovery failure
l MS/MSD recovery failure
r Surrogate failure
s No confirmation column
w Field and/or equipment blank contamination
x Trip blank contamination
z Method blank and/or storage blank contamination

Inorganics and Conventional

k Laboratory duplicate imprecision
m MS/MSD recovery failure
o Calibration blank contamination
p Preparation blank contamination
s Serial dilution failure
w Laboratory storage blank contamination
x CRDL standard recovery failure

Note: 1. Source of Data Qualifier Codes: United States Environmental Protection Agency (USEPA) Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses, April 1993.
2. Source of Data Qualifier Codes: United States Environmental Protection Agency (USEPA) Region III Modifications to National Functional Guidelines for Organic Data Review Multimedia, Multi-Concentration (OLMO1.0-OLMO1.9), September 1994.

Table 4-2
SWMU 40 - Summary of Risk Screening Results for Surface Soil/Soil Landfill Cover
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
TAL Metals (mg/kg)														
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	659	28,500	0	0	--	19	19
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.46	1.3	0	0	0	15	18
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	1.3	55	2	2	2	19	19
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	14.6	191	0	0	0	19	19
Beryllium	7440-41-7	1.02	15.64	N	204.40	N	1,154	0.24	1.5	0	0	0	19	19
Cadmium	7440-43-9	0.69	3.911	N	51.10	N	27.45	0.09	0.75	0	0	0	8	19
Calcium	7440-70-2	--	--	--	--	--	--	457	26,300	--	--	--	19	19
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	4.1	37.6	0	0	0	19	19
Cobalt	7440-48-4	72.3	--	--	--	--	--	1.8	13.2	--	--	--	19	19
Copper	7440-50-8	53.5	312.86	N	4,088	N	10,518	2.1	76	0	0	0	18	19
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	1,440	32,000	0	0	--	19	19
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	3.8	110	0	0	--	19	19
Magnesium	7439-95-4	--	--	--	--	--	--	120	24,400	--	--	--	19	19
Manganese	7439-96-5	2,543	156.43	N	2,044	N	951.9	10.7	894	0	0	0	19	19
Mercury ^[3]	7439-97-6	0.13	2.3	N	31	N	--	0.042	2.1	0	0	--	18	19
Nickel	7440-02-0	62.8	156.43	N	2,044	N	--	4.3	20.9	0	0	--	19	19
Potassium	7440-09-7	--	--	--	--	--	--	89.2	5,240	--	--	--	19	19
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.475	3.3	0	0	0	18	19
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.071	0.2	0	0	0	4	19
Sodium	7440-23-5	--	--	--	--	--	--	86.8	370	--	--	--	19	19
Thallium	7440-28-0	2.11	0.548	N	7.15	N	3.64	0.49	1.3	0	0	0	2	14
Vanadium	7440-62-2	108	7.821	N	102.2	N	730.1	5.4	56.9	0	0	0	19	19
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	5.5	148	0	0	0	19	19
Pesticides/PCBs (ug/kg)														
4,4'-DDE	72-55-9	--	1.9E+03	C	8.4E+03	C	3.5E+04	1.8	1.8	0	0	0	1	17
4,4'-DDT	50-29-3	--	1.9E+03	C	8.4E+03	C	1.2E+03	7.7	7.7	0	0	0	1	17
Aldrin	309-00-2	--	3.8E+01	C	1.7E+02	C	7.7E+00	2.1	5.1	0	0	0	2	17
alpha-BHC	319-84-6	--	1.0E+02	C	4.5E+02	C	8.9E-01	ND	ND	0	0	0	0	17
alpha-Chlordane ^[4]	5103-71-9	--	1.8E+03	C	8.2E+03	C	--	0.49	3.2	0	0	--	3	17
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	2.1	12	0	0	4	5	17
delta-BHC ^[5]	319-86-8	--	1.0E+02	C	4.5E+02	C	--	ND	ND	0	0	--	0	17
Endosulfan Sulfate ^[6]	1031-07-8	--	4.7E+04	N	6.1E+05	N	--	29	29	0	0	--	1	17
Endrin	72-20-8	--	2.3E+03	N	3.1E+04	N	5.4E+03	3.9	3.9	0	0	0	1	17
Endrin Ketone ^[7]	53494-70-5	--	2.3E+03	N	3.1E+04	N	--	24	24	0	0	--	1	17
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	0.55	11	0	0	1	2	17
gamma-Chlordane ^[4]	5103-74-2	--	1.8E+03	C	8.2E+03	C	--	7.6	7.6	0	0	--	1	17
Methoxychlor	72-43-5	--	3.9E+04	N	5.1E+05	N	3.1E+05	43	43	0	0	0	1	17
Aroclor 1016 ^[8]	12674-11-2	--	5.5E+02	N	7.2E+00	N	4.2E+03	ND	ND	0	0	0	0	32
Aroclor 1232	11141-16-5	--	3.2E+02	C	1.4E+03	C	--	ND	ND	0	0	--	0	32
Aroclor 1242	53469-21-9	--	3.2E+02	C	1.4E+03	C	--	ND	ND	0	0	--	0	32
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	189.5	189.5	0	0	--	1	32
Aroclor 1254 ^[9]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	20	2,100	9	1	1	28	32
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	12.55	620	1	0	--	11	32
TCL VOCs (ug/kg)														
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	--	2.3E+08	N	3.1E+09	N	2.3E+06	ND	ND	0	0	0	0	17
1,1-Dichloroethane	75-34-3	--	1.6E+06	N	2.0E+07	N	5.1E+03	ND	ND	0	0	0	0	17
1,2,4-Trichlorobenzene	120-82-1	--	7.8E+04	N	1.0E+06	N	2.4E+03	0.7	0.7	0	0	0	1	17
1,2-Dibromo-3-Chloropropane	96-12-8	--	2.0E+02	C	3.6E+03	C	3.7E-03	0.4	0.4	0	0	1	1	17
1,2-Dichlorobenzene	95-50-1	--	7.0E+05	N	9.2E+06	N	4.6E+03	0.4	0.8	0	0	0	2	17
1,3-Dichlorobenzene	541-73-1	--	2.3E+04	N	3.1E+05	N	2.9E+02	0.3	0.9	0	0	0	2	17
1,4-Dichlorobenzene	106-46-7	--	2.7E+04	C	1.2E+05	C	4.2E+00	0.5	1	0	0	0	3	17
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	6	40	0	0	0	8	17
2-Hexanone	591-78-6	--	--	--	--	--	--	2	2	--	--	--	1	17
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	3	31	--	--	0	10	17
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	11	460	0	0	0	16	17
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	0.8	6	0	0	2	3	17
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	3	3	0	0	0	1	17
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	1	4	0	0	0	8	17

Table 4-2
SWMU 40 - Summary of Risk Screening Results for Surface Soil/Soil Landfill Cover
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
Chlorobenzene	108-90-7	--	1.6E+05	N	2.0E+06	N	6.8E+02	0.4	0.4	0	0	0	1	17
Chloromethane	74-87-3	--	--	--	--	--	9.3E+02	1	3	--	--	0	2	17
cis-1,2-Dichloroethene	156-59-2	--	7.8E+04	N	1.0E+06	N	--	ND	ND	0	0	--	0	17
Cyclohexane	110-82-7	--	--	--	--	--	--	3	3	--	--	--	2	17
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	1	3	0	0	0	4	17
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	0.7	17	0	0	0	9	17
Isopropylbenzene	98-82-8	--	7.8E+05	N	1.0E+07	N	6.4E+04	3	3	0	0	0	1	17
Methyl Acetate	79-20-9	--	7.8E+06	N	1.0E+08	N	2.5E+04	14	120	0	0	0	7	17
Methyl Tert-Butyl Ether	1634-04-4	--	1.6E+05	C	7.2E+05	C	1.2E+01	2	2	0	0	0	1	17
Methylcyclohexane	108-87-2	--	--	--	--	--	--	1	27	--	--	--	3	17
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	0.7	14	0	0	0	11	17
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	0.8	2	0	0	0	5	17
Tetrachloroethene	127-18-4	--	1.2E+03	C	5.3E+03	C	4.7E+00	1	1	0	0	0	1	17
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	0.8	19	0	0	0	17	17
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	0.6	22	0	0	16	16	17
Trichlorofluoromethane	75-69-4	--	2.3E+06	N	3.1E+07	N	2.3E+04	ND	ND	0	0	0	0	17
Vinyl Chloride	75-01-4	--	9.0E+01	C	4.0E+03	C	1.2E-01	ND	ND	0	0	0	0	17
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	1	82	0	0	0	16	17
TCL SVOCs (ug/kg)														
1,1'-Biphenyl	92-52-4	--	3.9E+05	N	5.1E+06	N	9.6E+04	ND	ND	0	0	0	0	17
2,4-Dinitrotoluene	121-14-2	--	1.6E+04	N	2.0E+05	N	5.7E+02	35	35	0	0	0	1	17
2,6-Dinitrotoluene	606-20-2	--	7.8E+03	N	1.0E+05	N	2.5E+02	40	40	0	0	0	1	17
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	45	140	0	0	0	3	17
4-Chloro-3-Methylphenol ^[10]	59-50-7	--	3.9E+04	N	5.1E+05	N	--	ND	ND	0	0	--	0	17
4-Methylphenol	106-44-5	--	3.9E+04	N	5.1E+05	N	--	ND	ND	0	0	--	0	17
Acetophenone	98-86-2	--	7.8E+05	N	1.0E+07	N	3.2E+03	ND	ND	0	0	0	0	17
Benzaldehyde	100-52-7	--	7.8E+05	N	1.0E+07	N	--	66	66	0	0	--	1	17
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	38	280	0	0	0	14	17
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	ND	ND	0	0	0	0	17
Caprolactam	105-60-2	--	3.9E+06	N	5.1E+07	N	--	800	800	0	0	--	1	17
Carbazole	86-74-8	--	3.2E+04	C	1.4E+05	C	4.7E+02	47	200	0	0	0	2	17
Di-n-butylphthalate	84-74-2	--	7.8E+05	N	1.0E+07	N	5.0E+06	92	140	0	0	0	2	17
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	26	500	--	--	--	5	17
Dibenzofuran	132-64-9	--	7.8E+03	N	1.0E+05	N	--	52	56	0	0	--	2	17
Diethylphthalate	84-66-2	--	6.3E+06	N	8.2E+07	N	4.5E+05	ND	ND	0	0	0	0	17
Dimethylphthalate	131-11-3	--	--	--	--	--	--	ND	ND	--	--	--	0	17
n-Nitrosodiphenylamine	86-30-6	--	1.3E+05	C	5.8E+05	C	7.6E+02	ND	ND	0	0	0	0	17
Phenol	108-95-2	--	2.3E+06	N	3.1E+07	N	6.7E+04	ND	ND	0	0	0	0	17
TCL PAHs (ug/kg)														
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	21	1,200	0	0	0	7	17
Acenaphthylene ^[11]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	80	220	0	0	--	2	17
Anthracene	120-12-7	--	2.3E+06	N	3.1E+07	N	4.7E+05	120	120	0	0	0	1	17
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	11	390	1	0	0	11	17
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	3.8	300	7	0	1	12	17
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	4.2	570	2	0	0	15	17
Benzo(g,h,i)perylene ^[11]	191-24-2	--	2.3E+05	N	3.1E+06	N	--	10	140	0	0	--	6	17
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	10	370	0	0	0	11	17
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	4.5	680	0	0	0	13	17
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	19	110	3	0	0	4	17
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	20	1,500	0	0	0	15	17
Fluorene	86-73-7	--	3.1E+05	N	4.1E+06	N	1.4E+05	ND	ND	0	0	0	0	17
Indeno(1,2,3-cd)pyrene	193-39-5	--	2.2E+02	C	3.9E+03	C	4.2E+03	6.9	250	1	0	0	10	17
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	26	1,100	0	0	3	6	17
Phenanthrene ^[11]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	14	550	0	0	--	8	17
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	12	810	0	0	0	15	17
Dioxin/Furans (pg/g)														
Total 2,3,7,8-TCDD TEQ ^[12]	--	--	4.3E+00	C	1.9E+01	C	8.6E+00	0.408	7.141	1	0	0	2	2

Table 4-2
SWMU 40 - Summary of Risk Screening Results for Surface Soil/Soil Landfill Cover
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Nitroglycerin (mg/kg)														
Nitroglycerin	55-63-0	--	7.8E-01	N	1.0E+01	N	--	ND	ND	0	0	--	0	17
DRO/GRO (mg/kg) ^[13]														
DRO	--	--	1.0E+02	--	--	--	--	20.5	68	0	--	--	2	2
GRO	--	--	1.0E+02	--	--	--	--	ND	ND	0	--	--	0	2
DRO+GRO	--	--	1.0E+02	--	--	--	--	20.5	68	0	--	--	2	2

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
ug/kg = Microgram per kilogram
pg/g = Picogram per Gram
ND = Not Detected
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20

-- = No screening value available
^[A] = For inorganics, number of samples that exceed background (if available) and screening level
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Chlordane RBC value was used
^[5] = Alpha-BHC RBC value was used
^[6] = Endosulfan RBC value was used
^[7] = Endrin RBC value was used
^[8] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[9] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[10] = 3-Methylphenol RBC value was used
^[11] = Pyrene RBC value was used
^[12] = See Table 6-2 for Total 2,3,7,8-TCDD TEQ Calculations
^[13] = VDEQ TPH Screening Level used

Table 4-3
SWMU 40 - Summary of Risk Screening Results for Landfill Material
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
TAL Metals (mg/kg)														
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	4,950	26,100	0	0	--	16	16
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.31	6.1	2	0	0	13	15
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	2.14	74.6	4	4	4	16	16
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	40.9	250	0	0	0	16	16
Beryllium	7440-41-7	1.02	15.64	N	204.40	N	1,154	0.24	1.4	0	0	0	16	16
Cadmium	7440-43-9	0.69	3.911	N	51.10	N	27.45	0.13	7.6	1	0	0	12	16
Calcium	7440-70-2	--	--	--	--	--	--	1,320	64,000	--	--	--	16	16
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	12.2	234	2	0	2	16	16
Cobalt	7440-48-4	72.3	--	--	--	--	--	4.3	11.9	--	--	--	16	16
Copper	7440-50-8	53.5	312.86	N	4,088	N	10,518	7.6	52,000	2	1	1	15	15
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	8,900	98,100	2	1	--	16	16
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	13.2	1,100	1	1	--	16	16
Magnesium	7439-95-4	--	--	--	--	--	--	1,400	36,800	--	--	--	16	16
Manganese	7439-96-5	2,543	156.43	N	2,044	N	951.9	164.5	538	0	0	0	16	16
Mercury ^[3]	7439-97-6	0.13	2.3	N	31	N	--	0.026	11	3	0	--	16	16
Nickel	7440-02-0	62.8	156.43	N	2,044	N	--	3.6	77.7	0	0	--	16	16
Potassium	7440-09-7	--	--	--	--	--	--	382	3,180	--	--	--	16	16
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.12	7.45	0	0	0	16	16
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.1	2.71	0	0	0	12	16
Sodium	7440-23-5	--	--	--	--	--	--	180	4,110	--	--	--	16	16
Thallium	7440-28-0	2.11	0.548	N	7.15	N	3.64	0.26	0.41	0	0	0	4	10
Vanadium	7440-62-2	108	7.821	N	102.2	N	730.1	9.5	60	0	0	0	16	16
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	15.8	16,000	1	0	1	16	16
Pesticides/PCBs (ug/kg)														
4,4'-DDE	72-55-9	--	1878.61	C	8416.47	C	35220.4	ND	ND	0	0	0	0	4
4,4'-DDT	50-29-3	--	1878.61	C	8416.47	C	1161.4	ND	ND	0	0	0	0	4
Aldrin	309-00-2	--	37.57	C	168.33	C	7.7	ND	ND	0	0	0	0	4
alpha-BHC	319-84-6	--	1.0E+02	C	4.5E+02	C	8.9E-01	1.9	1.9	0	0	1	1	4
alpha-Chlordane ^[4]	5103-71-9	--	1.8E+03	C	8.2E+03	C	--	4.4	4.4	0	0	--	1	4
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	3.8	3.8	0	0	1	1	4
delta-BHC ^[5]	319-86-8	--	1.0E+02	C	4.5E+02	C	--	ND	ND	0	0	--	0	4
Endosulfan Sulfate ^[6]	1031-07-8	--	4.7E+04	N	6.1E+05	N	--	64	64	0	0	--	1	4
Endrin	72-20-8	--	2.3E+03	N	3.1E+04	N	5.4E+03	ND	ND	0	0	0	0	4
Endrin Ketone ^[7]	53494-70-5	--	2.3E+03	N	3.1E+04	N	--	ND	ND	0	0	--	0	4
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	ND	ND	0	0	0	0	4
gamma-Chlordane ^[8]	5103-74-2	--	1.8E+03	C	8.2E+03	C	--	ND	ND	0	0	--	0	4
Methoxychlor	72-43-5	--	3.9E+04	N	5.1E+05	N	3.1E+05	ND	ND	0	0	0	0	4
Aroclor 1016 ^[9]	12674-11-2	--	5.5E+02	N	7.2E+03	N	4.2E+03	128.75	210	0	0	0	3	16
Aroclor 1232	11141-16-5	--	3.2E+02	C	1.4E+03	C	--	ND	ND	0	0	--	0	16
Aroclor 1242	53469-21-9	--	3.2E+02	C	1.4E+03	C	--	17,000	17,000	1	1	--	1	16
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	82	280	0	0	--	3	16
Aroclor 1254 ^[9]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	74	5,000	12	3	4	15	16
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	66	380	2	0	--	8	16
TCL VOCs (ug/kg)														
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	--	2.3E+08	N	3.1E+09	N	2.3E+06	ND	ND	0	0	0	0	12
1,1-Dichloroethane	75-34-3	--	1.6E+06	N	2.0E+07	N	5.1E+03	5	5	0	0	0	1	12
1,2,4-Trichlorobenzene	120-82-1	--	7.8E+04	N	1.0E+06	N	2.4E+03	160.25	160.25	0	0	0	1	12
1,2-Dibromo-3-Chloropropane	96-12-8	--	2.0E+02	C	3.6E+03	C	3.7E-03	ND	ND	0	0	0	0	12
1,2-Dichlorobenzene	95-50-1	--	7.0E+05	N	9.2E+06	N	4.6E+03	ND	ND	0	0	0	0	12
1,3-Dichlorobenzene	541-73-1	--	2.3E+04	N	3.1E+05	N	2.9E+02	46.25	46.25	0	0	0	1	12
1,4-Dichlorobenzene	106-46-7	--	2.7E+04	C	1.2E+05	C	4.2E+00	0.5	885	0	0	3	6	12
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	16	51	0	0	0	5	12
2-Hexanone	591-78-6	--	--	--	--	--	--	ND	ND	--	--	--	0	12
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	4	26.625	--	--	0	4	12
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	35.5	280	0	0	0	11	12
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	0.9	535	0	0	7	12	12
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	3	6	0	0	0	2	12
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	1	185	0	0	0	12	12

Table 4-3
SWMU 40 - Summary of Risk Screening Results for Landfill Material
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
Chlorobenzene	108-90-7	--	1.6E+05	N	2.0E+06	N	6.8E+02	2	11,050	0	0	1	4	12
Chloromethane	74-87-3	--	--	--	--	--	9.3E+02	ND	ND	--	--	0	0	12
cis-1,2-Dichloroethene	156-59-2	--	7.8E+04	N	1.0E+06	N	--	1	1	0	0	--	1	12
Cyclohexane	110-82-7	--	--	--	--	--	--	1.175	145	--	--	--	2	12
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	1	1	0	0	0	1	12
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	0.8	920	0	0	0	11	12
Isopropylbenzene	98-82-8	--	7.8E+05	N	1.0E+07	N	6.4E+04	0.9	155	0	0	0	7	12
Methyl Acetate	79-20-9	--	7.8E+06	N	1.0E+08	N	2.5E+04	4	955	0	0	0	6	12
Methyl Tert-Butyl Ether	1634-04-4	--	1.6E+05	C	7.2E+05	C	1.2E+01	ND	ND	0	0	0	0	12
Methylcyclohexane	108-87-2	--	--	--	--	--	--	0.675	410	--	--	--	6	12
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	1.625	170.5	0	0	1	8	12
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	0.45	1	0	0	0	2	12
Tetrachloroethene	127-18-4	--	1.2E+03	C	5.3E+03	C	4.7E+00	ND	ND	0	0	0	0	12
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	2.5	455	0	0	0	12	12
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	0.9	9	0	0	9	9	12
Trichlorofluoromethane	75-69-4	--	2.3E+06	N	3.1E+07	N	2.3E+04	2.125	2.125	0	0	0	1	12
Vinyl Chloride	75-01-4	--	9.0E+01	--	4.0E+03	--	1.2E-01	2	2	0	0	1	1	12
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	2	2,000	0	0	0	12	12
TCL SVOCs (ug/kg)														
1,1'-Biphenyl	92-52-4	--	3.9E+05	N	5.1E+06	N	9.6E+04	26.5	82.5	0	0	0	6	12
2,4-Dinitrotoluene	121-14-2	--	1.6E+04	N	2.0E+05	N	5.7E+02	25.5	31	0	0	0	2	12
2,6-Dinitrotoluene	606-20-2	--	7.8E+03	N	1.0E+05	N	2.5E+02	ND	ND	0	0	0	0	12
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	51	600	0	0	0	7	12
4-Chloro-3-Methylphenol ^[10]	59-50-7	--	3.9E+04	--	5.1E+05	--	--	82	130	0	0	--	2	12
4-Methylphenol	106-44-5	--	3.9E+04	N	5.1E+05	N	--	61	570	0	0	--	5	12
Acetophenone	98-86-2	--	7.8E+05	N	1.0E+07	N	3.2E+03	35.75	35.75	0	0	0	1	12
Benzaldehyde	100-52-7	--	7.8E+05	N	1.0E+07	N	--	109.75	120	0	0	--	2	12
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	45	3,900	0	0	0	12	12
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	370	5,900	0	0	0	3	12
Caprolactam	105-60-2	--	3.9E+06	N	5.1E+07	N	--	ND	ND	0	0	--	0	12
Carbazole	86-74-8	--	3.2E+04	C	1.4E+05	C	4.7E+02	ND	ND	0	0	0	0	12
Di-n-butylphthalate	84-74-2	--	7.8E+05	N	1.0E+07	N	5.0E+06	32	535	0	0	0	11	12
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	48	1,145	--	--	--	3	12
Dibenzofuran	132-64-9	--	7.8E+03	--	1.0E+05	--	--	44	44	0	0	--	1	12
Diethylphthalate	84-66-2	--	6.3E+06	N	8.2E+07	N	4.5E+05	72	180	0	0	0	6	12
Dimethylphthalate	131-11-3	--	--	--	--	--	--	95	95	--	--	--	1	12
n-Nitrosodiphenylamine	86-30-6	--	1.3E+05	C	5.8E+05	C	7.6E+02	60	3,500	0	0	3	8	12
Phenol	108-95-2	--	2.3E+06	N	3.1E+07	N	6.7E+04	209.5	209.5	0	0	0	1	12
TCL PAHs (ug/kg)														
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	951.45	6,500	0	0	0	5	12
Acenaphthylene ^[11]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	660	4,100	0	0	--	6	12
Anthracene	120-12-7	--	2.3E+06	N	3.1E+07	N	4.7E+05	ND	ND	0	0	0	0	12
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	220	2,260	4	0	3	6	12
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	45	450.4	3	1	2	3	12
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	49.425	464	2	0	0	9	12
Benzo(g,h,i)perylene ^[11]	191-24-2	--	2.3E+05	N	3.1E+06	N	--	92	92	0	0	--	1	12
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	42	521	0	0	0	3	12
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	1212.5	3,350	0	0	0	11	12
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	101.05	101.05	1	0	0	1	12
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	150	1,600	0	0	0	11	12
Fluorene	86-73-7	--	3.1E+05	N	4.1E+06	N	1.4E+05	ND	ND	0	0	0	0	12
Indeno(1,2,3-cd)pyrene	193-39-5	--	2.2E+02	C	3.9E+03	C	4.2E+03	120	326	1	0	0	2	12
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	420	3,095	0	0	3	3	12
Phenanthrene ^[11]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	97.125	500	0	0	--	4	12
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	170	940	0	0	0	12	12
Dioxin/Furans (pg/g)														
Total 2,3,7,8-TCDD TEQ ^[12]	--	--	4.3E+00	--	1.9E+01	--	8.6E+00	9.068	9.068	1	0	1	1	1

Table 4-3
SWMU 40 - Summary of Risk Screening Results for Landfill Material
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Nitroglycerin (mg/kg)														
Nitroglycerin	55-63-0	--	7.8E-01	N	1.0E+01	N	--	130	130	1	1	--	1	12
DRO/GRO (mg/kg) ^[13]														
DRO	--	--	1.0E+02	--	--	--	--	68	850	3	--	--	4	4
GRO	--	--	1.0E+02	--	--	--	--	8.1	13	0	--	--	3	4
DRO+GRO	--	--	1.0E+02	--	--	--	--	68	859.7	3	--	--	4	4

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
ug/kg = Microgram per kilogram
pg/g = Picogram per Gram
ND = Not Detected
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20

-- = No screening value available
^[A] = For inorganics, number of samples that exceed background (if available) and screening level
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Chlordane RBC value was used
^[5] = Alpha-BHC RBC value was used
^[6] = Endosulfan RBC value was used
^[7] = Endrin RBC value was used
^[8] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[9] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[10] = 3-Methylphenol RBC value was used
^[11] = Pyrene RBC value was used
^[12] = See Table 6-2 for Total 2,3,7,8-TCDD TEQ Calculations
^[13] = VDEQ TPH Screening Level used

Table 4-4
SWMU 40 - Summary of Risk Screening Results for Soil Below Landfill Material
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
TAL Metals (mg/kg)														
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	14,400	47,500	1	0	--	24	24
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.46	1.2	0	0	0	15	22
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	2.3	9.7	0	0	0	23	24
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	25.7	94.3	0	0	0	24	24
Beryllium	7440-41-7	1.02	15.64	N	204.40	N	1,154	0.42	3	0	0	0	24	24
Cadmium	7440-43-9	0.69	3.911	N	51.10	N	27.45	0.08	0.42	0	0	0	16	24
Calcium	7440-70-2	--	--	--	--	--	--	426	102,000	--	--	--	24	24
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	21.9	86.3	2	0	2	24	24
Cobalt	7440-48-4	72.3	--	--	--	--	--	3.2	24.85	--	--	--	24	24
Copper	7440-50-8	53.5	312.86	N	4,088	N	10,518	3.5	42	0	0	0	24	24
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	18,500	49,300	0	0	--	24	24
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	2.4	54	0	0	--	24	24
Magnesium	7439-95-4	--	--	--	--	--	--	1,290	66,200	--	--	--	24	24
Manganese	7439-96-5	2543	156.43	N	2,044	N	951.9	132	952	0	0	0	24	24
Mercury ^[3]	7439-97-6	0.13	2.3	N	31	N	--	0.027	0.4	0	0	--	18	24
Nickel	7440-02-0	62.8	156.43	N	2,044	N	--	6.3	47.5	0	0	--	24	24
Potassium	7440-09-7	--	--	--	--	--	--	949	10,100	--	--	--	24	24
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.62	2.8	0	0	0	22	24
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.1	0.11	0	0	0	2	24
Sodium	7440-23-5	--	--	--	--	--	--	121	6,670	--	--	--	22	24
Thallium	7440-28-0	2.11	0.548	N	7.15	N	3.64	0.82	0.82	0	0	0	1	16
Vanadium	7440-62-2	108	7.821	N	102.2	N	730.1	31.6	95.2	0	0	0	24	24
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	30.8	79	0	0	0	24	24
Pesticides/PCBs (ug/kg)														
4,4'-DDE	72-55-9	--	1878.61	C	8416.47	C	35220.4	ND	ND	0	0	0	0	4
4,4'-DDT	50-29-3	--	1878.61	C	8416.47	C	1161.4	ND	ND	0	0	0	0	4
Aldrin	309-00-2	--	37.57	C	168.33	C	7.7	ND	ND	0	0	0	0	4
alpha-BHC	319-84-6	--	1.0E+02	C	4.5E+02	C	8.9E-01	0.95	0.95	0	0	1	1	4
alpha-Chlordane ^[4]	5103-71-9	--	1.8E+03	C	8.2E+03	C	--	ND	ND	0	0	--	0	4
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	1.4	4.2	0	0	1	2	4
delta-BHC ^[5]	319-86-8	--	1.0E+02	C	4.5E+02	C	--	1.4	1.4	0	0	--	1	4
Endosulfan Sulfate ^[6]	1031-07-8	--	4.7E+04	N	6.1E+05	N	--	ND	ND	0	0	--	0	4
Endrin	72-20-8	--	2.3E+03	N	3.1E+04	N	5.4E+03	ND	ND	0	0	0	0	4
Endrin Ketone ^[7]	53494-70-5	--	2.3E+03	N	3.1E+04	N	--	ND	ND	0	0	--	0	4
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	0.55	0.55	0	0	0	1	4
gamma-Chlordane ^[8]	5103-74-2	--	1.8E+03	C	8.2E+03	C	--	ND	ND	0	0	--	0	4
Methoxychlor	72-43-5	--	3.9E+04	N	5.1E+05	N	3.1E+05	ND	ND	0	0	0	0	4
Aroclor 1016 ^[9]	12674-11-2	--	5.5E+02	N	7.2E+03	N	4.2E+03	ND	ND	0	0	0	0	24
Aroclor 1232	11141-16-5	--	3.2E+02	C	1.4E+03	C	--	30	30	0	0	--	1	24
Aroclor 1242	53469-21-9	--	3.2E+02	C	1.4E+03	C	--	ND	ND	0	0	--	0	24
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	ND	ND	0	0	--	0	24
Aroclor 1254 ^[9]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	34	270	1	0	0	2	24
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	660	660	1	0	--	1	24
TCL VOCs (ug/kg)														
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	--	2.3E+08	N	3.1E+09	N	2.3E+06	3	11	0	0	0	4	24
1,1-Dichloroethane	75-34-3	--	1.6E+06	N	2.0E+07	N	5.1E+03	ND	ND	0	0	0	0	24
1,2,4-Trichlorobenzene	120-82-1	--	7.8E+04	N	1.0E+06	N	2.4E+03	ND	ND	0	0	0	0	24
1,2-Dibromo-3-Chloropropane	96-12-8	--	2.0E+02	C	3.6E+03	C	3.7E-03	ND	ND	0	0	0	0	24
1,2-Dichlorobenzene	95-50-1	--	7.0E+05	N	9.2E+06	N	4.6E+03	ND	ND	0	0	0	0	24
1,3-Dichlorobenzene	541-73-1	--	2.3E+04	N	3.1E+05	N	2.9E+02	ND	ND	0	0	0	0	24
1,4-Dichlorobenzene	106-46-7	--	2.7E+04	C	1.2E+05	C	4.2E+00	0.3	0.8	0	0	0	3	24
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	6	74	0	0	0	7	24
2-Hexanone	591-78-6	--	--	--	--	--	--	2	2	--	--	--	1	24
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	5	25	--	--	0	13	24
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	8	440	0	0	0	24	24
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	1	2	0	0	2	3	24
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	2	7	0	0	0	3	24
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	0.6	31	0	0	0	12	24

Table 4-4
SWMU 40 - Summary of Risk Screening Results for Soil Below Landfill Material
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
Chlorobenzene	108-90-7	--	1.6E+05	N	2.0E+06	N	6.8E+02	0.6	3	0	0	0	3	24
Chloromethane	74-87-3	--	--	--	--	--	9.3E+02	2	3	--	--	0	2	24
cis-1,2-Dichloroethene	156-59-2	--	7.8E+04	N	1.0E+06	N	--	1	1	0	0	--	1	24
Cyclohexane	110-82-7	--	--	--	--	--	--	ND	ND	--	--	--	0	24
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	1	2	0	0	0	3	24
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	0.9	6	0	0	0	14	24
Isopropylbenzene	98-82-8	--	7.8E+05	N	1.0E+07	N	6.4E+04	ND	ND	0	0	0	0	24
Methyl Acetate	79-20-9	--	7.8E+06	N	1.0E+08	N	2.5E+04	3	18	0	0	0	4	24
Methyl Tert-Butyl Ether	1634-04-4	--	1.6E+05	C	7.2E+05	C	1.2E+01	ND	ND	0	0	0	0	24
Methylcyclohexane	108-87-2	--	--	--	--	--	--	0.575	0.575	--	--	--	1	24
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	0.675	15	0	0	0	21	24
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	0.6	4	0	0	0	7	24
Tetrachloroethene	127-18-4	--	1.2E+03	C	5.3E+03	C	4.7E+00	ND	ND	0	0	0	0	24
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	1	13	0	0	0	24	24
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	1	21	0	0	23	23	24
Trichlorofluoromethane	75-69-4	--	2.3E+06	N	3.1E+07	N	2.3E+04	6	6	0	0	0	1	24
Vinyl Chloride	75-01-4	--	9.0E+01	--	4.0E+03	--	1.2E-01	ND	ND	0	0	0	0	24
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	1.5	43	0	0	0	24	24
TCL SVOCs (ug/kg)														
1,1'-Biphenyl	92-52-4	--	3.9E+05	N	5.1E+06	N	9.6E+04	ND	ND	0	0	0	0	24
2,4-Dinitrotoluene	121-14-2	--	1.6E+04	N	2.0E+05	N	5.7E+02	ND	ND	0	0	0	0	24
2,6-Dinitrotoluene	606-20-2	--	7.8E+03	N	1.0E+05	N	2.5E+02	ND	ND	0	0	0	0	24
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	33	78	0	0	0	2	24
4-Chloro-3-Methylphenol ^[10]	59-50-7	--	3.9E+04	--	5.1E+05	--	--	ND	ND	0	0	--	0	24
4-Methylphenol	106-44-5	--	3.9E+04	N	5.1E+05	N	--	ND	ND	0	0	--	0	24
Acetophenone	98-86-2	--	7.8E+05	N	1.0E+07	N	3.2E+03	ND	ND	0	0	0	0	24
Benzaldehyde	100-52-7	--	7.8E+05	N	1.0E+07	N	--	ND	ND	0	0	--	0	24
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	51	3,100	0	0	0	13	24
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	ND	ND	0	0	0	0	24
Caprolactam	105-60-2	--	3.9E+06	N	5.1E+07	N	--	ND	ND	0	0	--	0	24
Carbazole	86-74-8	--	3.2E+04	C	1.4E+05	C	4.7E+02	ND	ND	0	0	0	0	24
Di-n-butylphthalate	84-74-2	--	7.8E+05	N	1.0E+07	N	5.0E+06	67	67	0	0	0	1	24
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	63	420	--	--	--	3	24
Dibenzofuran	132-64-9	--	7.8E+03	--	1.0E+05	--	--	ND	ND	0	0	--	0	24
Diethylphthalate	84-66-2	--	6.3E+06	N	8.2E+07	N	4.5E+05	ND	ND	0	0	0	0	24
Dimethylphthalate	131-11-3	--	--	--	--	--	--	ND	ND	--	--	--	0	24
n-Nitrosodiphenylamine	86-30-6	--	1.3E+05	C	5.8E+05	C	7.6E+02	43.75	250	0	0	0	3	24
Phenol	108-95-2	--	2.3E+06	N	3.1E+07	N	6.7E+04	ND	ND	0	0	0	0	24
TCL PAHs (ug/kg)														
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	17	1,500	0	0	0	7	24
Acenaphthylene ^[11]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	12	210	0	0	--	3	24
Anthracene	120-12-7	--	2.3E+06	N	3.1E+07	N	4.7E+05	66.35	130	0	0	0	2	24
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	87.7	540	1	0	1	2	24
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	16	380	4	0	1	5	24
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	8.4	460	1	0	0	8	24
Benzo(g,h,i)perylene ^[11]	191-24-2	--	2.3E+05	N	3.1E+06	N	--	30.9	250	0	0	--	2	24
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	24	570	0	0	0	4	24
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	265	2,100	0	0	0	7	24
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	16	160	1	0	0	2	24
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	7.6	3,200	0	0	0	7	24
Fluorene	86-73-7	--	3.1E+05	N	4.1E+06	N	1.4E+05	160	160	0	0	0	1	24
Indeno(1,2,3-cd)pyrene	193-39-5	--	2.2E+02	C	3.9E+03	C	4.2E+03	395	3,600	2	0	0	2	24
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	1,300	1,300	0	0	1	1	24
Phenanthrene ^[11]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	212.125	1,100	0	0	--	2	24
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	14	1,100	0	0	0	12	24
Dioxin/Furans (pg/g)														
Total 2,3,7,8-TCDD TEQ ^[12]	--	--	4.3E+00	--	1.9E+01	--	8.6E+00	NT	NT	--	--	--	--	--

Table 4-4
SWMU 40 - Summary of Risk Screening Results for Soil Below Landfill Material
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Nitroglycerin (mg/kg)														
Nitroglycerin	55-63-0	--	7.8E-01	N	1.0E+01	N	--	ND	ND	0	0	--	0	24
DRO/GRO (mg/kg) ^[13]														
DRO	--	--	--	--	--	--	--	NT	NT	--	--	--	--	--
GRO	--	--	--	--	--	--	--	NT	NT	--	--	--	--	--
DRO+GRO	--	--	--	--	--	--	--	NT	NT	--	--	--	--	--

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
ug/kg = Microgram per kilogram
pg/g = Picogram per Gram
ND = Not Detected
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20

-- = No screening value available
^[A] = For inorganics, number of samples that exceed background (if available) and screening level
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Chlordane RBC value was used
^[5] = Alpha-BHC RBC value was used
^[6] = Endosulfan RBC value was used
^[7] = Endrin RBC value was used
^[8] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[9] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[10] = 3-Methylphenol RBC value was used
^[11] = Pyrene RBC value was used
^[12] = See Table 6-2 for Total 2,3,7,8-TCDD TEQ Calculations
^[13] = VDEQ TPH Screening Level used

Table 4-5
SWMU 40 - Summary of Risk Screening Results for Total Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
TAL Metals (mg/kg)														
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	659	47,500	1	0	--	59	59
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.31	6.1	2	0	0	43	55
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	1.3	74.6	6	6	6	58	59
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	14.6	250	0	0	0	59	59
Beryllium	7440-41-7	1.02	15.64	N	204.40	N	1,154	0.24	3	0	0	0	59	59
Cadmium	7440-43-9	0.69	3.911	N	51.10	N	27.45	0.08	8	1	0	0	36	59
Calcium	7440-70-2	--	--	--	--	--	--	426	102,000	--	--	--	59	59
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	4.1	234	4	0	4	59	59
Cobalt	7440-48-4	72.3	--	--	--	--	--	1.8	24.85	--	--	--	59	59
Copper	7440-50-8	53.5	312.86	N	4,088	N	10,518	2.1	52,000	2	1	1	57	58
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	1,440	98,100	2	1	--	59	59
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	2.4	1100	1	1	--	59	59
Magnesium	7439-95-4	--	--	--	--	--	--	120	66,200	--	--	--	59	59
Manganese	7439-96-5	2,543	156.43	N	2,044	N	951.9	10.7	952	0	0	0	59	59
Mercury ^[3]	7439-97-6	0.13	2.3	N	31	N	--	0.026	11	3	0	--	52	59
Nickel	7440-02-0	62.8	156.43	N	2,044	N	--	3.6	77.7	0	0	--	59	59
Potassium	7440-09-7	--	--	--	--	--	--	89.2	10,100	--	--	--	59	59
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.12	7.45	0	0	0	56	59
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.071	2.71	0	0	0	18	59
Sodium	7440-23-5	--	--	--	--	--	--	86.8	6,670	--	--	--	57	59
Thallium	7440-28-0	2.11	0.548	N	7.15	N	3.64	0.26	1.3	0	0	0	7	40
Vanadium	7440-62-2	108	7.821	N	102.2	N	730.1	5.4	95.2	0	0	0	59	59
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	5.5	16,000	1	0	1	59	59
Pesticides/PCBs (ug/kg)														
4,4'-DDE	72-55-9	--	1.9E+03	C	8.4E+03	C	3.5E+04	1.8	1.8	0	0	0	1	25
4,4'-DDT	50-29-3	--	1.9E+03	C	8.4E+03	C	1.2E+03	7.7	7.7	0	0	0	1	25
Aldrin	309-00-2	--	3.8E+01	C	1.7E+02	C	7.7E+00	2.1	5.1	0	0	0	2	25
alpha-BHC	319-84-6	--	1.0E+02	C	4.5E+02	C	8.9E-01	0.95	1.9	0	0	2	2	25
alpha-Chlordane ^[4]	5103-71-9	--	1.8E+03	C	8.2E+03	C	--	0.49	4.4	0	0	--	4	25
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	1.4	12	0	0	6	8	25
delta-BHC ^[5]	319-86-8	--	1.0E+02	C	4.5E+02	C	--	1.4	1.4	0	0	--	1	25
Endosulfan Sulfate ^[6]	1031-07-8	--	4.7E+04	N	6.1E+05	N	--	29	64	0	0	--	2	25
Endrin	72-20-8	--	2.3E+03	N	3.1E+04	N	5.4E+03	3.9	3.9	0	0	0	1	25
Endrin Ketone ^[7]	53494-70-5	--	2.3E+03	N	3.1E+04	N	--	24	24	0	0	--	1	25
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	0.55	11	0	0	1	3	25
gamma-Chlordane ^[4]	5103-74-2	--	1.8E+03	C	8.2E+03	C	--	7.6	7.6	0	0	--	1	25
Methoxychlor	72-43-5	--	3.9E+04	N	5.1E+05	N	3.1E+05	43	43	0	0	0	1	25
Aroclor 1016 ^[8]	12674-11-2	--	5.5E+02	N	7.2E+03	N	4.2E+03	128.75	210	0	0	0	3	72
Aroclor 1232	11141-16-5	--	3.2E+02	C	1.4E+03	C	--	30	30	0	0	--	1	72
Aroclor 1242	53469-21-9	--	3.2E+02	C	1.4E+03	C	--	17,000	17,000	1	1	--	1	72
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	82	280	0	0	--	4	72
Aroclor 1254 ^[9]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	20	5,000	22	4	5	45	72
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	12.55	660	4	0	--	20	72
TCL VOCs (ug/kg)														
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	--	2.3E+08	N	3.1E+09	N	2.3E+06	3	11	0	0	0	4	53
1,1-Dichloroethane	75-34-3	--	1.6E+06	N	2.0E+07	N	5.1E+03	5	5	0	0	0	1	53
1,2,4-Trichlorobenzene	120-82-1	--	7.8E+04	N	1.0E+06	N	2.4E+03	0.7	160.25	0	0	0	2	53
1,2-Dibromo-3-Chloropropane	96-12-8	--	2.0E+02	C	3.6E+03	C	3.7E+03	0.4	0.4	0	0	1	1	53
1,2-Dichlorobenzene	95-50-1	--	7.0E+05	N	9.2E+06	N	4.6E+03	0.4	0.8	0	0	0	2	53
1,3-Dichlorobenzene	541-73-1	--	2.3E+04	N	3.1E+05	N	2.9E+02	0.3	46.25	0	0	0	3	53
1,4-Dichlorobenzene	106-46-7	--	2.7E+04	C	1.2E+05	C	4.2E+00	0.3	885	0	0	3	12	53
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	6	74	0	0	0	20	53
2-Hexanone	591-78-6	--	--	--	--	--	--	2	2	--	--	--	2	53
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	3	31	--	--	0	27	53
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	8	460	0	0	0	51	53
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	0.8	535	0	0	11	18	53
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	2	7	0	0	0	6	53
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	0.6	185	0	0	0	32	53

Table 4-5
SWMU 40 - Summary of Risk Screening Results for Total Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^(A)	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
Chlorobenzene	108-90-7	--	1.6E+05	N	2.0E+06	N	6.8E+02	0.4	11,050	0	0	1	8	53
Chloromethane	74-87-3	--	--	--	--	--	9.3E+02	1	3	--	--	0	4	53
cis-1,2-Dichloroethene	156-59-2	--	7.8E+04	N	1.0E+06	N	--	1	1	0	0	--	2	53
Cyclohexane	110-82-7	--	--	--	--	--	--	1.175	145	--	--	--	4	53
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	1	3	0	0	0	8	53
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	0.7	920	0	0	0	34	53
Isopropylbenzene	98-82-8	--	7.8E+05	N	1.0E+07	N	6.4E+04	0.9	155	0	0	0	8	53
Methyl Acetate	79-20-9	--	7.8E+06	N	1.0E+08	N	2.5E+04	3	955	0	0	0	17	53
Methyl Tert-Butyl Ether	1634-04-4	--	1.6E+05	C	7.2E+05	C	1.2E+01	2	2	0	0	0	1	53
Methylcyclohexane	108-87-2	--	--	--	--	--	--	0.575	410	--	--	--	10	53
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	0.675	170.5	0	0	1	40	53
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	0.45	4	0	0	0	14	53
Tetrachloroethene	127-18-4	--	1.2E+03	C	5.3E+03	C	4.7E+00	1	1	0	0	0	1	53
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	0.8	455	0	0	0	53	53
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	0.6	22	0	0	48	48	53
Trichlorofluoromethane	75-69-4	--	2.3E+06	N	3.1E+07	N	2.3E+04	2.125	6	0	0	0	2	53
Vinyl Chloride	75-01-4	--	9.0E+01	--	4.0E+03	--	1.2E-01	2	2	0	0	1	1	53
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	1	2,000	0	0	0	52	53
TCL SVOCs (ug/kg)														
1,1'-Biphenyl	92-52-4	--	3.9E+05	N	5.1E+06	N	9.6E+04	26.5	82.5	0	0	0	6	53
2,4-Dinitrotoluene	121-14-2	--	1.6E+04	N	2.0E+05	N	5.7E+02	25.5	35	0	0	0	3	53
2,6-Dinitrotoluene	606-20-2	--	7.8E+03	N	1.0E+05	N	2.5E+02	40	40	0	0	0	1	53
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	33	600	0	0	0	12	53
4-Chloro-3-Methylphenol ^[10]	59-50-7	--	--	--	--	--	--	82	130	0	0	--	2	53
4-Methylphenol	106-44-5	--	3.9E+04	N	5.1E+05	N	--	61	570	0	0	--	5	53
Acetophenone	98-86-2	--	7.8E+05	N	1.0E+07	N	3.2E+03	35.75	35.75	0	0	0	1	53
Benzaldehyde	100-52-7	--	7.8E+05	N	1.0E+07	N	--	66	120	0	0	--	3	53
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	38	3,900	0	0	0	39	53
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	370	5,900	0	0	0	3	53
Caprolactam	105-60-2	--	3.9E+06	N	5.1E+07	N	--	800	800	0	0	--	1	53
Carbazole	86-74-8	--	3.2E+04	C	1.4E+05	C	4.7E+02	47	200	0	0	0	2	53
Di-n-butylphthalate	84-74-2	--	7.8E+05	N	1.0E+07	N	5.0E+06	32	535	0	0	0	14	53
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	26	1,145	--	--	--	11	53
Dibenzofuran	132-64-9	--	7.8E+03	--	1.0E+05	--	--	44	56	0	0	--	3	53
Diethylphthalate	84-66-2	--	6.3E+06	N	8.2E+07	N	4.5E+05	72	180	0	0	0	6	53
Dimethylphthalate	131-11-3	--	--	--	--	--	--	95	95	--	--	--	1	53
n-Nitrosodiphenylamine	86-30-6	--	1.3E+05	C	5.8E+05	C	7.6E+02	43.75	3,500	0	0	3	11	53
Phenol	108-95-2	--	2.3E+06	N	3.1E+07	N	6.7E+04	209.5	209.5	0	0	0	1	53
TCL PAHs (ug/kg)														
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	17	6,500	0	0	0	19	53
Acenaphthylene ^[11]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	12	4,100	0	0	--	11	53
Anthracene	120-12-7	--	2.3E+06	N	3.1E+07	N	4.7E+05	66.35	130	0	0	0	3	53
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	11	2,260	6	0	4	19	53
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	3.8	450	14	1	4	20	53
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	4.2	570	5	0	0	32	53
Benzo(g,h,i)perylene ^[11]	191-24-2	--	2.3E+05	N	3.1E+06	N	--	10	250	0	0	--	9	53
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	10	570	0	0	0	18	53
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	4.5	3,350	0	0	0	31	53
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	16	160	5	0	0	7	53
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	7.6	3,200	0	0	0	33	53
Fluorene	86-73-7	--	3.1E+05	N	4.1E+06	N	1.4E+05	160	160	0	0	0	1	53
Indeno(1,2,3-cd)pyrene	193-39-5	--	2.2E+02	C	3.9E+03	C	4.2E+03	6.9	3,600	4	0	0	14	53
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	26	3,095	0	0	7	10	53
Phenanthrene ^[11]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	14	1,100	0	0	--	14	53
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	12	1,100	0	0	0	39	53
Dioxin/Furans (pg/g)														
Total 2,3,7,8-TCDD TEQ ^[12]	--	--	4.3E+00	N	1.9E+01	N	8.6E+00	0.408	9.068	2	0	1	3	3

Table 4-5
SWMU 40 - Summary of Risk Screening Results for Total Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Nitroglycerin (mg/kg)														
Nitroglycerin	55-63-0	--	7.8E-01	--	1.0E+01	--	--	130	130	1	1	--	1	53
DRO/GRO (mg/kg) ^[13]														
DRO	--	--	1.0E+02	--	--	--	--	20.5	850	3	--	--	6	6
GRO	--	--	1.0E+02	--	--	--	--	8.1	13	0	--	--	3	6
DRO+GRO	--	--	1.0E+02	--	--	--	--	20.5	859.7	3	--	--	6	6

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
ug/kg = Microgram per kilogram
pg/g = Picogram per Gram
ND = Not Detected
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20

-- = No screening value available
^[A] = For inorganics, number of samples that exceed background (if available) and screening level
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Chlordane RBC value was used
^[5] = Alpha-BHC RBC value was used
^[6] = Endosulfan RBC value was used
^[7] = Endrin RBC value was used
^[8] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[9] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[10] = 3-Methylphenol RBC value was used
^[11] = Pyrene RBC value was used
^[12] = See Table 6-2 for Total 2,3,7,8-TCDD TEQ Calculations
^[13] = VDEQ TPH Screening Level used

Table 4-6
SWMU 71 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	71SS11 11/11/2002 0-1				MDL	RL	71SS11B 4/20/2006 2-3				MDL	RL	71SS11B-DUP(Dup-2) 4/20/2006 2-3				MDL	RL	71SS12 11/11/2002 0-1				MDL	RL	71SS12-DUP(D-1) 11/11/2002 0-1				MDL	RL	71SS12B 4/20/2006 10.2-11.2				MDL	RL	71SS13 11/18/2002 0-1				MDL	RL																																																																																																																																																																																																																																																																																																																																																																													
								Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result

Table 4-6
SWMU 71 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	71SS11 11/11/2002 0-1		MDL	RL	71SS11B 4/20/2006 2-3		MDL	RL	71SS11B-DUP(Dup-2) 4/20/2006 2-3		MDL	RL	71SS12 11/11/2002 0-1		MDL	RL	71SS12-DUP(D-1) 11/11/2002 0-1		MDL	RL	71SS12B 4/20/2006 10.2-11.2		MDL	RL	71SS13 11/18/2002 0-1		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	<46	U	5.9	46	NT				NT					43	J	5.9	49	200	Z	5.9	95	NT				140	P,J,g	5.9	45			
Acenaphthylene ^(B)	208-96-8	--	N	2.3E+05	N	3.1E+06	--	<46	U	5.9	46	NT				NT					<49	U	5.9	49	<48	U	5.9	48	NT				120	P,J,g	5.9	45			
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	<9	U	2.2	9	NT				NT					7.4	JP,J,g	2.2	9.6	44	PZ,J,g	2.2	19	NT				36	P,J,g	2.2	8.8			
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	<9	U	1.6	9	NT				NT					<9.6	U	1.6	9.6	10	JPZ,J,g	1.6	19	NT				20		1.6	8.8			
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	<9	U	1.7	9	NT				NT					<9.6	U	1.7	9.6	20	P,J,g	1.7	9.4	NT				15	J,c	1.7	8.8			
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	<9	U	1.4	9	NT				NT					<9.6	U	1.4	9.6	15		1.4	9.4	NT				17	P,J,c	1.4	8.8			
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	9	JP,J,g	2.4	9	NT				NT					<9.6	U	2.4	9.6	<9.4	U	2.4	9.4	NT				54	P,J,c	2.4	8.8			
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	<9	U	4.2	9	NT				NT					<9.6	U	4.2	9.6	<9.4	U	4.2	9.4	NT				<8.8	U	4.2	8.8			
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	31		2.1	18	NT				NT					59		2.1	20	410	PZ,J,c	2.1	39	NT				82		2.1	18			
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	<46	U	14	46	NT				NT					<49	U	14	49	81	JZ	14	95	NT				120	P,J,g	14	45			
Phenanthrene ^(B)	85-01-8	--	N	2.3E+05	N	3.1E+06	--	<46	U	8.5	46	NT				NT					<49	U	8.5	49	<48	U	8.5	48	NT				67		8.5	45			
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	<18	U	4.3	18	NT				NT					19	JP,J,g	4.3	20	24	JZ	4.3	39	NT				<18	U	4.3	18			
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	438		1.6	10	NT				NT					NT				NT						1,050		1.4	9.9					
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	9.8	J	1.2	10	NT				NT					NT				NT						35.5		1.1	9.9					
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	53.6		1	5	NT				NT					NT				NT						89.9		0.7	5					
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	5.4		0.5	5	NT				NT					NT				NT						10.3		0.3	5					
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	1.2	J	0.5	5	NT				NT					NT				NT						1.5	J	0.3	5					
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	1.3	J	0.3	5	NT				NT					NT				NT						2.3	J	0.2	5					
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	2.3	J	0.6	5	NT				NT					NT				NT						3	J	0.3	5					
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	<5		0.3	5	NT				NT					NT				NT						0.96	J	0.2	5					
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	3.6	J	0.5	5	NT				NT					NT				NT						3.4	J	0.3	5					
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	1.1	J	0.4	5	NT				NT					NT				NT						0.74	J	0.2	5					
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	1.7	MXJ,J,w	0.2	5	NT				NT					NT				NT						<5		0.1	5					
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	0.6	J	0.4	5	NT				NT					NT				NT						0.99	J	0.2	5					
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	0.64	J	0.2	5	NT				NT					NT				NT						0.76	J,J,I	0.1	5					
2,3,7,8-TCDD	1746-01-6	--	C	4.3E+00	C	1.9E+01	8.6E+00	<1		0.3	1	NT				NT					NT				NT						0.37	JB,B,z	0.1	1					
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	0.69	J	0.1	1	NT				NT					NT				NT						0.66	J	0.08	1					
Total HpCDD	37871-00-4	--	--	--	--	--	--	113		1	5	NT				NT					NT				NT						180		0.7	5					
Total HpCDF	38998-75-3	--	--	--	--	--	--	15.2	MX,J,w	0.5	5	NT				NT					NT				NT						38.9	MX,J,w	0.3	5					
Total HxCDD	34465-46-8	--	--	--	--	--	--	29.7	M	0.5	5	NT				NT					NT				NT						32.3	M	0.3	5					
Total HxCDF	55684-94-1	--	--	--	--	--	--	13.1	MX,J,w	0.3	5	NT				NT					NT				NT						33.5	MX,J,w	0.2	5					
Total PeCDD	36088-22-9	--	--	--	--	--	--	9.6	M	0.4	5	NT				NT					NT				NT						5.4	M	0.2	5					
Total PeCDF	30402-15-4	--	--	--	--	--	--	12.1	MX,J,w	0.2	5	NT				NT					NT				NT						24.1	MX,J,w	0.1	5					
Total TCDD	41903-57-5	--	--	--	--	--	--	1.8		0.3	1	NT				NT					NT				NT						6.7	M	0.1	1					
Total TCDF	55722-27-5	--	--	--	--	--	--	8.1	M	0.3	1	NT				NT					NT				NT						19.1	MX	0.08	1					
DRO/GRO (mg/kg)																																							
DRO	--	--	--	--	--	--	--	NT								3.9	J	1.2	9.9					NT							3	J	1.2	9.9	NT				
GRO	--	--	--	--	--	--	--	NT								<7.4	U	1.2	7.4					NT							<7.4	U	1.2	7.4	NT				
Percent Solids (%)																																							
Percent Solids	--	--	--	--	--	--	--	NT								68		0.1	0.1					NT						68		0.1	0.1	NT					

Table 4-6
SWMU 71 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

[illegible]

Table 4-6
SWMU 71 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	71SS13B 4/20/2006 6-7		MDL	RL	71SB11A 11/11/2002 0-1		MDL	RL	71SB11B 11/18/2002 2-4.5		MDL	RL	71SB11C 11/18/2002 6-7		MDL	RL	71SB11F 11/18/2002 1.4-2		MDL	RL	71SB12A 4/20/2006 0-1		MDL	RL	71SB12B 4/20/2006 3-4		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT				<48	U	5.9	48	<58	U	5.9	58	<60	U	5.9	60	<52	U	5.8	52	NT				NT							
Acenaphthylene ^(B)	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT				<48	U	5.9	48	<58	U	5.9	58	<60	U	5.9	60	360	JPZ,J,g	5.9	1000	NT				NT							
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT				<9.4	U	2.2	9.4	<12	U	2.2	12	<12	U	2.2	12	<10	U	2.2	10	NT				NT							
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT				<9.4	U	1.6	9.4	<12	U	1.6	12	<12	U	1.6	12	120	JPZ,J,g	1.6	210	NT				NT							
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT				<9.4	U	1.7	9.4	<12	U	1.7	12	<12	U	1.7	12	56	JPZ,J,g	1.7	210	NT				NT							
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT				<9.4	U	1.4	9.4	<12	U	1.4	12	<12	U	1.4	12	<10	U	1.4	10	NT				NT							
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT				<9.4	U	2.4	9.4	<12	U	2.4	12	<12	U	2.4	12	3,200	PZ,J,g	2.4	210	NT				NT							
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	NT				<9.4	U	4.2	9.4	<12	U	4.2	12	<12	U	4.2	12	210	PZ,J,g	4.2	210	NT				NT							
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	NT				44		2.1	19	<24	U	2.1	24	<24	U	2.1	24	300	P,J,g	2.1	21	NT				NT							
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	NT				<48	U	14	48	<58	U	14	58	<60	U	14	60	<52	U	14	52	NT				NT							
Phenanthrene ^(B)	85-01-8	--	N	2.3E+05	N	3.1E+06	--	NT				<48	U	8.5	48	<58	U	8.5	58	<60	U	8.5	60	<52	U	8.5	52	NT				NT							
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	NT				<19	U	4.3	19	<24	U	4.3	24	<24	U	4.3	24	290	JPZ,J,g	4.3	420	NT				NT							
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				2,470		5.7	9.9	NT				NT							NT								
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				87.6		4.4	9.9	NT				NT							NT								
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				226		3.3	5	NT				NT							NT								
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				34.3		1.5	5	NT				NT							NT								
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				<5		1.3	5	NT				NT							NT								
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				4.3	J	0.8	5	NT				NT							NT								
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				10.1		1.3	5	NT				NT							NT								
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				2.1	J	0.8	5	NT				NT							NT								
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				5.5		1.3	5	NT				NT							NT								
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				<5		0.6	5	NT				NT							NT								
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				<5		0.4	5	NT				NT							NT								
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				1.7	MJ	0.9	5	NT				NT							NT								
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				1.2	J,J,I	0.4	5	NT				NT							NT								
2,3,7,8-TCDD	1746-01-6	--	C	4.3E+00	C	1.9E+01	8.6E+00	NT				NT				0.54	JB,B,z	0.4	1	NT				NT							NT								
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				1	M	0.08	1	NT				NT							NT								
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				442		3.3	5	NT				NT							NT								
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				120	M	1.7	5	NT				NT							NT								
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				73.5	M	1.3	5	NT				NT							NT								
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				72.5	MX,J,w	0.9	5	NT				NT							NT								
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				<5		0.6	5	NT				NT							NT								
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				26.6	MX,J,w	0.4	5	NT				NT							NT								
Total TCDD	41903-57-5	--	--	--	--	--	--	NT				NT				7.2	M	0.4	1	NT				NT							NT								
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				26.8	MX,J,w	0.3	1	NT				NT							NT								
DRO/GRO (mg/kg)																																							
DRO	--	--	--	--	--	--	--	3.2	J	1.2	9.2	NT				NT				NT				NT				4.9	J	1.1	8.9	3	J	1.3	10				
GRO	--	--	--	--	--	--	--	<6.8	U	1.1	6.8	NT				NT				NT				NT				<6.7	U	1	6.7	<7.5	U	1.2	7.5				
Percent Solids (%)																																							
Percent Solids	--	--	--	--	--	--	--	73		0.1	0.1	NT				NT				NT				NT				75		0.1	0.1	67		0.1	0.1				

Table 4-6
SWMU 71 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	71SB12C 4/20/2006 5-6				MDL	RL	71SB13A 4/20/2006 0-1				MDL	RL	71SB13B 4/20/2006 5-6				MDL	RL	71SB13C 4/20/2006 8-9				MDL	RL	71SB16A 4/21/2006 0-1				MDL	RL	71SB16B 4/21/2006 2.5-3.5				MDL	RL	71SB16C 4/21/2006 4-5				MDL	RL																																																																																																																																																																																																																																																																																																																																																																													
								Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result

Table 4-6
SWMU 71 - Summary of Detected Chemicals in Analytical Samples
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Facility-Wide Background Point Estimate ^(A)	C/N	Adjusted Soil RBC (Residential)	C/N	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	71SB12C 4/20/2006 5-6		MDL	RL	71SB13A 4/20/2006 0-1		MDL	RL	71SB13B 4/20/2006 5-6		MDL	RL	71SB13C 4/20/2006 8-9		MDL	RL	71SB16A 4/21/2006 0-1		MDL	RL	71SB16B 4/21/2006 2.5-3.5		MDL	RL	71SB16C 4/21/2006 4-5		MDL	RL				
								Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r	Result	LQ, VQ, r
TCL PAHs (ug/kg)																																							
Acenaphthene	83-32-9	--	N	4.7E+05	N	6.1E+06	1.0E+05	NT				NT				NT				NT				NT						NT									
Acenaphthylene ⁽⁶⁾	208-96-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT						NT									
Benzo(a)anthracene	56-55-3	--	C	2.2E+02	C	3.9E+03	4.8E+02	NT				NT				NT				NT				NT						NT									
Benzo(a)pyrene	50-32-8	--	C	2.2E+01	C	3.9E+02	1.2E+02	NT				NT				NT				NT				NT						NT									
Benzo(b)fluoranthene	205-99-2	--	C	2.2E+02	C	3.9E+03	1.5E+03	NT				NT				NT				NT				NT						NT									
Benzo(k)fluoranthene	207-08-9	--	C	2.2E+03	C	3.9E+04	1.5E+04	NT				NT				NT				NT				NT						NT									
Chrysene	218-01-9	--	C	2.2E+04	C	3.9E+05	4.8E+04	NT				NT				NT				NT				NT						NT									
Dibenz(a,h)anthracene	53-70-3	--	C	2.2E+01	C	3.9E+02	4.6E+02	NT				NT				NT				NT				NT						NT									
Fluoranthene	206-44-0	--	N	3.1E+05	N	4.1E+06	6.3E+06	NT				NT				NT				NT				NT						NT									
Naphthalene	91-20-3	--	N	1.6E+05	N	2.0E+06	1.5E+02	NT				NT				NT				NT				NT						NT									
Phenanthrene ⁽⁶⁾	85-01-8	--	N	2.3E+05	N	3.1E+06	--	NT				NT				NT				NT				NT						NT									
Pyrene	129-00-0	--	N	2.3E+05	N	3.1E+06	6.8E+05	NT				NT				NT				NT				NT						NT									
Dioxin/Furans (pg/g)																																							
1,2,3,4,6,7,8,9-OCDD	3268-87-9	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,4,6,7,8,9-OCDF	39001-02-0	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,7,8,9-HxCDD	19408-74-3	--	C	1.0E+02	C	4.6E+02	--	NT				NT				NT				NT				NT						NT									
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
2,3,7,8-TCDD	1746-01-6	--	C	4.3E+00	C	1.9E+01	8.6E+00	NT				NT				NT				NT				NT						NT									
2,3,7,8-TCDF	51207-31-9	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total HpCDD	37871-00-4	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total HpCDF	38998-75-3	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total HxCDD	34465-46-8	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total HxCDF	55684-94-1	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total PeCDD	36088-22-9	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total PeCDF	30402-15-4	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total TCDD	41903-57-5	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
Total TCDF	55722-27-5	--	--	--	--	--	--	NT				NT				NT				NT				NT						NT									
DRO/GRO (mg/kg)																																							
DRO	--	--	--	--	--	--	--	2.3	J	1.2	9.9	46		1	8.2	3.6	J	1.2	9.2	2.4	J	1.2	9.3	38		0.99	7.9	9.7		1.1	9.1	9.4	J	1.3	10				
GRO	--	--	--	--	--	--	--	<7.4	U	1.2	7.4	<6.1	U	0.95	6.1	<6.8	U	1.1	6.8	<6.9	U	1.1	6.9	<5.9	U	0.92	5.9	<6.8	U	1.1	6.8	<7.7	U,UJ,c	1.2	7.7				
Percent Solids (%)																																							
Percent Solids	--	--	--	--	--	--	--	68		0.1	0.1	82		0.1	0.1	73		0.1	0.1	72		0.1	0.1	85		0.1	0.1	74		0.1	0.1	65		0.1	0.1				

Notes:

CAS = Chemical Abstracts Service
ft bgs = Feet Below Ground Surface
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
pg/g = Picogram Per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
TIC = Tentatively Identified Compound
DRO = Diesel Range Organics
GRO = Gasoline Range Organics
NT = Not Tested
NI = Not Identified
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the October 11, 2007,
RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[5] = Pyrene RBC value was used

= Concentration Exceeds Adjusted Soil Residential RBC

= Concentration Exceeds Adjusted Soil Industrial RBC

underline = Concentration Exceeds Site Background Values

bold italic = Concentration Exceeds SSL DAF20

Laboratory Qualifiers

B Analyte found in associated blank as well as in the sample.
E Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis.
J Estimated value.
N Presumptive evidence of a compound.
P Greater than 40% difference for detected concentrations between the two GC or HPLC columns.
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.
X Laboratory-defined. Associated PCDF peak(s) has the same retention time as the associated diphenyl ether and that the diphenyl ether contribution to the total PCDF value is greater than 10%.
Z Laboratory-defined. Result reported with sample-specific dilution factor. See DV Reports for additional information.

Validation Qualifiers

B Not detected substantially above the level reported in laboratory or field blanks.
N Tentative Identification. Consider present. Special methods may be needed to confirm its presence or absence in future sampling efforts.
J Analyte present. Reported value may not be accurate or precise.
K Analyte present. Reported value may be biased high. Actual value is expected to be lower.
L Analyte present. Reported value may be biased low. Actual value is expected to be higher.
R Unreliable result. Analyte may or may not be present in the sample. Supporting data necessary to confirm result.
U Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ Not detected, quantitation limit may be inaccurate or imprecise.
UL Not detected, quantitation limit is probably higher.

Reason Codes

GC/MS Organics
c Calibration failure; poor (RRF) or unstable (%D) response
l MS/MSD recovery failure
r linearity (%RSD or r) failure in initial calibration
t Tentatively identified Compound
w Identification criteria failure
y Trip blank contamination
z Method blank and/or storage blank contamination

GC and HPLC Organics

c Calibration failure; poor or unstable (%D) response
g Dual column confirmation imprecision
l MS/MSD recovery failure
r Surrogate failure
w Field and/or equipment blank contamination
z Method blank and/or storage blank contamination

Inorganics and Conventionals

f Field duplicate imprecision
k Laboratory duplicate imprecision
m MS/MSD recovery failure
p Preparation blank contamination
s Serial dilution failure
w Laboratory storage blank contamination
x CRDL standard recovery failure

(1.) Source of Data Qualifier Codes: United States Environmental Protection Agency (USEPA) Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses, April 1993.
(2.) Source of Data Qualifier Codes: United States Environmental Protection Agency (USEPA) Region III Modifications to National Functional Guidelines for Organic Data Review Multimedia, Multi-Concentration (OLMO1.0-OLMO1.9), September 1994.

Table 4-7
SWMU 71 - Summary of Risk Screening Results for Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
TAL Metals (mg/kg)														
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	3,460	33,000	0	0	--	7	7
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.2	16.4	1	0	0	7	7
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	4.7	16.1	2	2	2	7	7
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	51.3	180	0	0	0	7	7
Beryllium	7440-41-7	1.02	15.64	N	204.4	N	1,154	0.29	1.6	0	0	0	7	7
Cadmium	7440-43-9	0.69	3.911	N	51.1	N	27.45	0.03	0.31	0	0	0	6	7
Calcium	7440-70-2	--	--	--	--	--	--	2,610	172,000	--	--	--	7	7
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	11	47	0	0	0	7	7
Cobalt	7440-48-4	72.3	--	--	--	--	--	2.65	13	--	--	--	7	7
Copper	7440-50-8	53.5	312.9	N	4,088	N	10,518	15.8	40	0	0	0	7	7
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	6,730	34,000	0	0	--	7	7
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	9.9	366	0	0	--	7	7
Magnesium	7439-95-4	--	--	--	--	--	--	1290	74,800	--	--	--	7	7
Manganese	7439-96-5	2,543	156.4	N	2,044	N	951.92	83.7	550	0	0	0	7	7
Mercury ^[3]	7439-97-6	0.13	2.35	N	30.66	N	--	0.019	0.49	0	0	--	7	7
Nickel	7440-02-0	62.8	156.4	N	2,044	N	--	6.7	33	0	0	--	7	7
Potassium	7440-09-7	--	--	--	--	--	--	378	4,500	--	--	--	7	7
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.25	1.1	0	0	0	5	7
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.12	2.1	0	0	0	5	7
Sodium	7440-23-5	--	--	--	--	--	--	100	358	--	--	--	6	7
Thallium	7440-28-0	2.11	0.548	N	7.154	N	3.638	0.35	0.59	0	0	0	3	6
Vanadium	7440-62-2	108	7.821	N	102.2	N	730.1	11.6	91	0	0	0	7	7
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	24.5	152	0	0	0	7	7
Pesticides/PCBs (ug/kg)														
Aldrin	309-00-2	--	3.8E+01	C	1.7E+02	C	7.7E+00	0.86	1.05	0	0	0	2	4
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	3.4	5.5	0	0	2	2	4
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	0.99	0.99	0	0	0	1	4
Aroclor 1016 ^[4]	12674-11-2	--	5.5E+02	N	7.2E+03	N	4.2E+03	ND	ND	0	0	0	0	7
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	450	450	1	0	--	1	7
Aroclor 1254 ^[5]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	24	460	1	0	0	6	7
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	35	92	0	0	--	2	7
TCL VOCs (ug/kg)														
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	16.5	46	0	0	0	3	4
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	2	16	--	--	0	3	4
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	54	250	0	0	0	4	4
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	1	3,225	0	0	1	2	4
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	2	2	0	0	0	1	4
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	2	7.5	0	0	0	4	4
Cyclohexane	110-82-7	--	--	--	--	--	--	4	4	--	--	--	1	4
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	1	1	0	0	0	1	4
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	5	5	0	0	0	1	4
Methylcyclohexane	108-87-2	--	--	--	--	--	--	26.5	26.5	--	--	--	1	4
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	6	15.5	0	0	0	2	4
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	1	1	0	0	0	1	4
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	1	12.5	0	0	0	4	4
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	1	21	0	0	4	4	4
Vinyl Chloride	75-01-4	--	9.0E+01	C	4.0E+03	C	1.2E-01	ND	ND	0	0	0	0	4
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	2	60.5	0	0	0	4	4
TCL SVOCs (ug/kg)														
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	33	78	0	0	0	3	4
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	47	58	0	0	0	3	4
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	ND	ND	0	0	0	0	4
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	ND	ND	--	--	--	0	4
TCL PAHs (ug/kg)														
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	121.5	140	0	0	0	2	4
Acenaphthylene ^[6]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	120	120	0	0	--	1	4
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	25.7	36	0	0	0	2	4

Table 4-7
SWMU 71 - Summary of Risk Screening Results for Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	5.4	20	0	0	0	2	4
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	10.425	15	0	0	0	2	4
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	7.85	17	0	0	0	2	4
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	9	54	0	0	0	2	4
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	ND	ND	0	0	0	0	4
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	31	234.5	0	0	0	4	4
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	44	120	0	0	0	2	4
Phenanthrene ^[6]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	67	67	0	0	--	1	4
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	21.5	21.5	0	0	0	1	4
Dioxin/Furans (pg/g)														
2,3,7,8-TCDD TEQ ^[7]	--	--	4.3E+00	C	1.9E+01	C	8.6E+00	3.036	3.577	0	0	0	2	2
DRO/GRO (mg/kg) ^[8]														
DRO	--	--	1.0E+02	--	--	--	--	4.9	46	0	--	--	3	3
GRO	--	--	1.0E+02	--	--	--	--	ND	ND	0	--	--	0	3
DRO+GRO	--	--	1.0E+02	--	--	--	--	4.9	46	0	--	--	3	3

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
ug/kg = Microgram per kilogram
pg/g = Picogram per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20
-- = No screening value available

^[A] = For inorganics, number of samples that exceed background (if available) and screening level
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[5] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[6] = Pyrene RBC value was used
^[7] = See Table 6-2 for 2,3,7,8-TCDD TEQ Calculations
^[8] = VDEQ TPH Screening Level used

Table 4-8
SWMU 71 - Summary of Risk Screening Results for Subsurface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
TAL Metals (mg/kg)														
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	18,600	69,000	6	0	--	12	12
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.061	0.24	0	0	0	6	12
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	0.32	9.5	0	0	0	12	12
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	50	139	0	0	0	12	12
Beryllium	7440-41-7	1.02	15.64	N	204.4	N	1,154	0.83	3.2	0	0	0	12	12
Cadmium	7440-43-9	0.69	3,911	N	51.1	N	27.45	0.017	0.43	0	0	0	12	12
Calcium	7440-70-2	--	--	--	--	--	--	1,000	6,200	--	--	--	12	12
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	33.2	66	2	0	2	12	12
Cobalt	7440-48-4	72.3	--	--	--	--	--	7.45	22	--	--	--	12	12
Copper	7440-50-8	53.5	312.9	N	4,088	N	10,518	6.4	39.1	0	0	0	12	12
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	21,600	62,000	3	0	--	12	12
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	1.3	119	0	0	--	12	12
Magnesium	7439-95-4	--	--	--	--	--	--	5,510	55,000	--	--	--	12	12
Manganese	7439-96-5	2,543	156.4	N	2,044	N	951.92	160	500	0	0	0	12	12
Mercury ^[3]	7439-97-6	0.13	2.35	N	30.66	N	--	0.0099	0.16	0	0	--	11	12
Nickel	7440-02-0	62.8	156.4	N	2,044	N	--	23	46	0	0	--	12	12
Potassium	7440-09-7	--	--	--	--	--	--	1820	6,900	--	--	--	12	12
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.15	2	0	0	0	12	12
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.11	1.3	0	0	0	10	12
Sodium	7440-23-5	--	--	--	--	--	--	50	260	--	--	--	5	12
Thallium	7440-28-0	2.11	0.548	N	7.154	N	3.638	0.19	0.43	0	0	0	9	9
Vanadium	7440-62-2	108	7,821	N	102.2	N	730.1	38.8	130	1	1	0	12	12
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	44.7	78	0	0	0	12	12
Pesticides/PCBs (ug/kg)														
Aldrin	309-00-2	--	3.8E+01	C	1.7E+02	C	7.7E+00	ND	ND	0	0	0	0	0
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	ND	ND	0	0	0	0	0
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	ND	ND	0	0	0	0	0
Aroclor 1016 ^[4]	12674-11-2	--	5.5E+02	N	7.2E+03	N	4.2E+03	68	68	0	0	0	1	12
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	ND	ND	0	0	--	0	12
Aroclor 1254 ^[5]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	13	320	1	0	0	3	12
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	73	73	0	0	--	1	12
TCL VOCs (ug/kg)														
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	ND	ND	0	0	0	0	3
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	15	15	--	--	0	1	3
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	24	140	0	0	0	3	3
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	ND	ND	0	0	0	0	3
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	ND	ND	0	0	0	0	3
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	1	14	0	0	0	2	3
Cyclohexane	110-82-7	--	--	--	--	--	ND	ND	ND	--	--	--	0	3
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	ND	ND	0	0	0	0	3
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	0.7	0.7	0	0	0	1	3
Methylcyclohexane	108-87-2	--	--	--	--	--	0.9	0.9	0.9	--	--	--	1	3
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	1	1	0	0	0	2	3
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	0.4	0.5	0	0	0	2	3
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	2	2	0	0	0	3	3
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	2	3	0	0	3	3	3
Vinyl Chloride	75-01-4	--	9.0E+01	C	4.0E+03	C	1.2E-01	66	66	0	0	1	1	3
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	5	5	0	0	0	3	3
TCL SVOCs (ug/kg)														
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	ND	ND	0	0	0	0	3
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	50	94	0	0	0	3	3
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	51	51	0	0	0	1	3
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	140	140	--	--	--	1	3
TCL PAHs (ug/kg)														
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	ND	ND	0	0	0	0	3
Acenaphthylene ^[6]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	360	360	0	0	--	1	3
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	ND	ND	0	0	0	0	3

Table 4-8
SWMU 71 - Summary of Risk Screening Results for Subsurface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. R-RBC ^[A]	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	120	120	1	0	0	1	3
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	56	56	0	0	0	1	3
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	ND	ND	0	0	0	0	3
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	3,200	3,200	0	0	0	1	3
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	210	210	1	0	0	1	3
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	300	300	0	0	0	1	3
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	ND	ND	0	0	0	0	3
Phenanthrene ^[6]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	ND	ND	0	0	--	0	3
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	290	290	0	0	0	1	3
Dioxin/Furans (pg/g)														
2,3,7,8-TCDD TEQ ^[7]	--	--	4.3E+00	C	1.9E+01	C	8.6E+00	6.2	6.2	1	0	0	1	1
DRO/GRO (mg/kg)^[8]														
DRO	--	--	1.0E+02	--	--	--	--	2.3	9.7	0	--	--	9	9
GRO	--	--	1.0E+02	--	--	--	--	ND	ND	0	--	--	0	9
DRO+GRO	--	--	1.0E+02	--	--	--	--	3.4	10.8	0	--	--	9	9

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
ug/kg = Microgram per kilogram
pg/g = Picogram per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20
-- = No screening value available

^[A] = For inorganics, number of samples that exceed background (if available) and screening level

^[1] = Chromium VI RBC value was used

^[2] = Lead criteria are Action Levels; see USEPA Region III guidance

^[3] = Mercuric chloride soil RBC value used

^[4] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening

^[5] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening

^[6] = Pyrene RBC value was used

^[7] = See Table 6-2 for 2,3,7,8-TCDD TEQ Calculations

^[8] = VDEQ TPH Screening Level used

Table 4-9
SWMU 71 - Summary of Risk Screening Results for Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. I-RBC ^(A)	# of Samples that Exceed SSL ^(A)	# of Detections	# of Samples
TAL Metals (mg/kg)													
Aluminum	7429-90-5	40,041	7,821	N	102,200	N	--	3,460	69,000	0	--	19	19
Antimony	7440-36-0	--	3.13	N	40.88	N	13.2	0.061	16.4	0	0	13	19
Arsenic	7440-38-2	15.8	0.426	C	1.91	C	0.026	0.32	16.1	2	2	19	19
Barium	7440-39-3	209	1,564	N	20,440	N	6,015	50	180	0	0	19	19
Beryllium	7440-41-7	1.02	15.64	N	204.4	N	1,154	0.29	3	0	0	19	19
Cadmium	7440-43-9	0.69	3.911	N	51.1	N	27.45	0.017	0	0	0	18	19
Calcium	7440-70-2	--	--	--	--	--	--	1,000	172,000	--	--	19	19
Chromium ^[1]	7440-47-3	65.3	23.46	N	306.6	N	42.05	11	66	0	2	19	19
Cobalt	7440-48-4	72.3	--	--	--	--	--	2.65	22	--	--	19	19
Copper	7440-50-8	53.5	312.9	N	4,088	N	10,518	6.4	40	0	0	19	19
Iron	7439-89-6	50,962	5,475	N	71,540	N	--	6,730	62,000	0	--	19	19
Lead ^[2]	7439-92-1	26.8	400	--	750	--	--	1.3	366	0	--	19	19
Magnesium	7439-95-4	--	--	--	--	--	--	1,290	74,800	--	--	19	19
Manganese	7439-96-5	2,543	156.4	N	2,044	N	951.92	83.7	550	0	0	19	19
Mercury ^[3]	7439-97-6	0.13	2.35	N	30.66	N	--	0.0099	0.49	0	--	18	19
Nickel	7440-02-0	62.8	156.4	N	2,044	N	--	6.7	46	0	--	19	19
Potassium	7440-09-7	--	--	--	--	--	--	378	6,900	--	--	19	19
Selenium	7782-49-2	--	39.11	N	511	N	18.98	0.15	2	0	0	17	19
Silver	7440-22-4	--	39.11	N	511	N	31.03	0.11	2.1	0	0	15	19
Sodium	7440-23-5	--	--	--	--	--	--	50	358	--	--	11	19
Thallium	7440-28-0	2.11	0.548	N	7.154	N	3.638	0.19	0.59	0	0	12	15
Vanadium	7440-62-2	108	7,821	N	102.2	N	730.1	11.6	130	1	0	19	19
Zinc	7440-66-6	202	2,346	N	30,660	N	13,622	24.5	152	0	0	19	19
Pesticides/PCBs (ug/kg)													
Aldrin	309-00-2	--	3.8E+01	C	1.7E+02	C	7.7E+00	0.86	1.05	0	0	2	4
beta-BHC	319-85-7	--	3.5E+02	C	1.6E+03	C	3.1E+00	3.4	5.5	0	2	2	4
gamma-BHC (Lindane)	58-89-9	--	4.9E+02	C	2.2E+03	C	4.3E+00	0.99	0.99	0	0	1	4
Aroclor 1016 ^[4]	12674-11-2	--	5.5E+02	N	7.2E+03	N	4.2E+03	68	68	0	0	1	19
Aroclor 1248	12672-29-6	--	3.2E+02	C	1.4E+03	C	--	450	450	0	--	1	19
Aroclor 1254 ^[5]	11097-69-1	--	1.6E+02	N	1.4E+03	C	1.1E+03	13	460	0	0	9	19
Aroclor 1260	11096-82-5	--	3.2E+02	C	1.4E+03	C	--	35	92	0	--	3	19
TCL VOCs (ug/kg)													
2-Butanone	78-93-3	--	4.7E+06	N	6.1E+07	N	2.9E+04	16.5	46	0	0	3	7
4-Methyl-2-Pentanone	108-10-1	--	--	--	--	--	5.9E+04	2	16	--	0	4	7
Acetone	67-64-1	--	7.0E+06	N	9.2E+07	N	2.2E+04	24	250	0	0	7	7
Benzene	71-43-2	--	1.2E+04	C	5.2E+04	C	1.9E+00	1	3,225	0	1	2	7
Bromomethane	74-83-9	--	1.1E+04	N	1.4E+05	N	4.1E+01	2	2	0	0	1	7
Carbon Disulfide	75-15-0	--	7.8E+05	N	1.0E+07	N	1.9E+04	1	14	0	0	6	7
Cyclohexane	110-82-7	--	--	--	--	--	--	4	4	--	--	1	7
Dichlorodifluoromethane	75-71-8	--	1.6E+06	N	2.0E+07	N	1.1E+04	1	1	0	0	1	7
Ethylbenzene	100-41-4	--	7.8E+05	N	1.0E+07	N	1.5E+04	0.7	5	0	0	2	7
Methylcyclohexane	108-87-2	--	--	--	--	--	--	0.9	26.5	--	--	2	7
Methylene Chloride	75-09-2	--	8.5E+04	C	3.8E+05	C	1.9E+01	1	15.5	0	0	4	7
Styrene	100-42-5	--	1.6E+06	N	2.0E+07	N	5.7E+04	0.4	1	0	0	3	7
Toluene	108-88-3	--	6.3E+05	N	8.2E+06	N	2.7E+04	1	12.5	0	0	7	7
Trichloroethene	79-01-6	--	1.6E+03	C	7.2E+03	C	2.6E-01	1	21	0	7	7	7
Vinyl Chloride	75-01-4	--	9.0E+01	C	4.0E+03	C	1.2E-01	66	66	0	1	1	7
Xylenes (Total)	1330-20-7	--	1.6E+06	N	2.0E+07	N	3.0E+03	2	60.5	0	0	7	7
TCL SVOCs (ug/kg)													
2-Methylnaphthalene	91-57-6	--	3.1E+04	N	4.1E+05	N	4.4E+03	33	78	0	0	3	7
Bis(2-ethylhexyl)phthalate	117-81-7	--	4.6E+04	C	2.0E+05	C	2.9E+06	47	94	0	0	6	7
Butylbenzylphthalate	85-68-7	--	1.6E+06	N	2.0E+07	N	1.7E+07	51	51	0	0	1	7
Di-n-octylphthalate	117-84-0	--	--	--	--	--	--	140	140	--	--	1	7
TCL PAHs (ug/kg)													
Acenaphthene	83-32-9	--	4.7E+05	N	6.1E+06	N	1.0E+05	121.5	140	0	0	2	7
Acenaphthylene ^[6]	208-96-8	--	2.3E+05	N	3.1E+06	N	--	120	360	0	--	2	7
Benzo(a)anthracene	56-55-3	--	2.2E+02	C	3.9E+03	C	4.8E+02	25.7	36	0	0	2	7

Table 4-9
SWMU 71 - Summary of Risk Screening Results for Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	Facility Background	Adjusted R-RBC	C/N	Adjusted I-RBC	C/N	SSL DAF20	Minimum Detected Concentration	Maximum Detected Concentration	# of Samples that Exceed Adj. I-RBC ^[A]	# of Samples that Exceed SSL ^[A]	# of Detections	# of Samples
Benzo(a)pyrene	50-32-8	--	2.2E+01	C	3.9E+02	C	1.2E+02	5.4	120	0	0	3	7
Benzo(b)fluoranthene	205-99-2	--	2.2E+02	C	3.9E+03	C	1.5E+03	10.425	56	0	0	3	7
Benzo(k)fluoranthene	207-08-9	--	2.2E+03	C	3.9E+04	C	1.5E+04	7.85	17	0	0	2	7
Chrysene	218-01-9	--	2.2E+04	C	3.9E+05	C	4.8E+04	9	3,200	0	0	3	7
Dibenz(a,h)anthracene	53-70-3	--	2.2E+01	C	3.9E+02	C	4.6E+02	210	210	0	0	1	7
Fluoranthene	206-44-0	--	3.1E+05	N	4.1E+06	N	6.3E+06	31	300	0	0	5	7
Naphthalene	91-20-3	--	1.6E+05	N	2.0E+06	N	1.5E+02	44	120	0	0	2	7
Phenanthrene ^[6]	85-01-8	--	2.3E+05	N	3.1E+06	N	--	67	67	0	--	1	7
Pyrene	129-00-0	--	2.3E+05	N	3.1E+06	N	6.8E+05	21.5	290	0	0	2	7
Dioxin/Furans (pg/g)													
2,3,7,8-TCDD TEQ ^[7]	--	--	4.3E+00	C	1.9E+01	C	8.6E+00	3.036	6.2	0	0	3	3
DRO/GRO (mg/kg)^[8]													
DRO	--	--	1.0E+02	--	--	--	--	2.3	46	--	--	12	12
GRO	--	--	1.0E+02	--	--	--	--	ND	ND	--	--	0	12
DRO+GRO	--	--	1.0E+02	--	--	--	--	3.4	10.8	--	--	12	12

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
µg/kg = Microgram per kilogram
pg/g = Picogram per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Facility Background = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)
R-RBC = Adjusted Residential RBC
I-RBC = Adjusted Industrial RBC
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20
-- = No screening value available

^[A] = For inorganics, number of samples that exceed background (if available) and screening level
^[1] = Chromium VI RBC value was used
^[2] = Lead criteria are Action Levels; see USEPA Region III guidance
^[3] = Mercuric chloride soil RBC value used
^[4] = Noncarcinogenic Industrial RBC value for Aroclor 1016 was used for screening
^[5] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
^[6] = Pyrene RBC value was used
^[7] = See Table 6-2 for 2,3,7,8-TCDD TEQ Calculations
^[8] = VDEQ TPH Screening Level used

Table 4-10
Detected Analytes in Groundwater
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date	CAS #	C/N	Adjusted Tap Water RBC	MCL	17MW3 8/13/2007			MDL	RL	40MW3 8/14/2007			MDL	RL	40MW5 8/15/2007			MDL	RL	40MW5-DUP(DUP-1) 8/15/2007			MDL	RL	40MW6 8/14/2007			MDL	RL
					Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r				Result	LQ, VQ, r			
Perchlorate (ug/L)																													
Perchlorate	14797-73-0	N	2.56	--	5.2			0.08	0.2	0.52			0.08	0.2	0.64			0.08	0.2	0.67			0.08	0.2	0.52			0.08	0.2
TAL Metals (ug/L)																													
Antimony, Total	7440-36-0	N	1.46	--	0.56	J,B,o	0.44	3	<3	U	0.44	3	<3	U	0.44	3	0.64	J,B,o	0.44	3	<3	U	0.44	3	<3	U	0.44	3	
Barium, Dissolved	7440-39-3	N	730	2,000	150		0.52	2	29		0.52	2	46		0.52	2	46		0.52	2	39		0.52	2	39		0.52	2	
Barium, Total	7440-39-3	N	730	2,000	150		0.52	2	29		0.52	2	45		0.52	2	42		0.52	2	39		0.52	2	39		0.52	2	
Calcium, Dissolved	7440-70-2	--	--	--	100,000		40	500	53,000		40	500	69,000		200	2,500	71,000		40	500	68,000		40	500	68,000		40	500	
Calcium, Total	7440-70-2	--	--	--	100,000		40	500	52,000		40	500	69,000		40	500	69,000		40	500	71,000		40	500	71,000		40	500	
Chromium, Dissolved ^[1]	7440-47-3	N	10.95	100	1.7	J,B,p	0.31	2	1.2	J,B,p	0.31	2	1.4	J,B,p	0.31	2	1.8	J,B,p	0.31	2	1.3	J,B,p	0.31	2	1.3	J,B,p	0.31	2	
Chromium, Total ^[1]	7440-47-3	N	10.95	100	5.3	B,x	0.31	2	1.7	J,B,x	0.31	2	1.9	J,B,x	0.31	2	0.83	J,B,x	0.31	2	5	B,x	0.31	2	5	B,x	0.31	2	
Cobalt, Dissolved	7440-48-4	--	--	--	0.45	J	0.096	1	0.3	J	0.096	1	0.31	J	0.096	1	0.59	J	0.096	1	0.3	J	0.096	1	0.3	J	0.096	1	
Cobalt, Total	7440-48-4	--	--	--	0.42	J	0.096	1	0.16	J	0.096	1	0.13	J	0.096	1	0.12	J	0.096	1	0.3	J	0.096	1	0.3	J	0.096	1	
Copper, Dissolved	7440-50-8	N	146	1,300	1.9		0.33	1	0.86	J	0.33	1	0.98	J	0.33	1	0.78	J	0.33	1	0.91	J	0.33	1	0.91	J	0.33	1	
Copper, Total	7440-50-8	N	146	1,300	2.5		0.33	1	1.3		0.33	1	0.79	J	0.33	1	0.79	J	0.33	1	1		0.33	1	1		0.33	1	
Iron, Dissolved	7439-89-6	N	2,555	--	17	J	5.7	20	17	J	5.7	20	10	J	5.7	20	9.7	J	5.7	20	15	J	5.7	20	15	J	5.7	20	
Iron, Total	7439-89-6	N	2,555	--	36		5.7	20	21	J,B,p	5.7	20	14	J,B,p	5.7	20	11	J,B,p	5.7	20	28	J,B,p	5.7	20	28	J,B,p	5.7	20	
Lead, Total ^[2]	7439-92-1	--	15	--	<1	U	0.33	1	0.51	J,B,x	0.33	1	<1	U	0.33	1	<1	U	0.33	1	<1	U	0.33	1	<1	U	0.33	1	
Manganese, Dissolved	7439-96-5	N	73	--	0.69	J	0.43	3	<3	U	0.43	3	<3	U	0.43	3	0.75	J	0.43	3	<3	U	0.43	3	<3	U	0.43	3	
Manganese, Total	7439-96-5	N	73	--	1.2	J,B,x	0.43	3	0.48	J,B,x	0.43	3	<3	U	0.43	3	<3	U	0.43	3	<3	U	0.43	3	<3	U	0.43	3	
Magnesium, Dissolved	7439-95-4	--	--	--	36,000		38	500	18,000		38	500	22,000		38	500	22,000		38	500	21,000		38	500	21,000		38	500	
Magnesium, Total	7439-95-4	--	--	--	37,000		38	500	18,000		38	500	22,000		38	500	21,000		38	500	22,000		38	500	22,000		38	500	
Mercury, Total ^[3]	7439-97-6	--	0.37	2	<0.2	U	0.039	0.2	0.04	J	0.039	0.2	<0.2	U	0.039	0.2	<0.2	U	0.039	0.2	<0.2	U	0.039	0.2	<0.2	U	0.039	0.2	
Nickel, Dissolved	7440-02-0	N	73	--	1.9	J	0.28	2	1.3	J	0.28	2	0.49	J	0.28	2	1.8	J	0.28	2	1.8	J	0.28	2	1.8	J	0.28	2	
Nickel, Total	7440-02-0	N	73	--	2.8		0.28	2	1.8	J	0.28	2	1	J	0.28	2	0.87	J	0.28	2	2.1		0.28	2	2.1		0.28	2	
Potassium, Dissolved	7440-09-7	--	--	--	2,400		54	200	1,200		54	200	1,000		54	200	1,000		54	200	1,100		54	200	1,100		54	200	
Potassium, Total	7440-09-7	--	--	--	2,300		54	200	1,200		54	200	1,000		54	200	1,000		54	200	1,200		54	200	1,200		54	200	
Selenium, Dissolved	7782-49-2	N	18.25	50	<3	U	0.92	3	1.3	J,B,o	0.92	3	<3	U	0.92	3	<3	U	0.92	3	1.1	J,B,o	0.92	3	1.1	J,B,o	0.92	3	
Selenium, Total	7782-49-2	N	18.25	50	<3	U	0.92	3	<3	U	0.92	3	1.4	J,B,o	0.92	3	<3	U	0.92	3	<3	U	0.92	3	<3	U	0.92	3	
Sodium, Dissolved	7440-23-5	--	--	--	16,000		84	500	7,800		84	500	7,000		84	500	6,700		84	500	7,000		84	500	7,000		84	500	
Sodium, Total	7440-23-5	--	--	--	16,000		84	500	7,600		84	500	7,000		84	500	6,900		84	500	7,300		84	500	7,300		84	500	
Vanadium, Dissolved	7440-62-2	N	3.65	--	<3	U	0.83	3	<3	U	0.83	3	<3	U	0.83	3	1.9	J	0.83	3	<3	U	0.83	3	<3	U	0.83	3	
Zinc, Dissolved	7440-66-6	N	1,095	--	7.5	J,B,B,p	0.84	10	4.5	J,B,B,p	0.84	10	3.3	J,B,B,p	0.84	10	2.9	J,B,B,p	0.84	10	4.7	J,B,B,p	0.84	10	4.7	J,B,B,p	0.84	10	
Zinc, Total	7440-66-6	N	1,095	--	30	J,B,x	0.84	10	15	J,B,x	0.84	10	11	J,B,x	0.84	10	10	J,B,x	0.84	10	15	J,B,x	0.84	10	15	J,B,x	0.84	10	
Pesticides (ug/L)																													
gamma-BHC (Lindane)	58-89-9	C	0.0515	--	0.0085	J,J,g	0.0018	0.05	<0.05	U	0.0018	0.05	<0.05	U	0.0018	0.05	<0.05	U	0.0018	0.05	0.0098	J,J,g	0.0018	0.05	0.0098	J,J,g	0.0018	0.05	
gamma-Chlordane ^[4]	5103-74-2	C	0.191	--	0.0057	J	0.0021	0.05	<0.05	U	0.0021	0.05	<0.05	U	0.0021	0.05	<0.05	U	0.0021	0.05	<0.05	U	0.0021	0.05	<0.05	U	0.0021	0.05	
TCL VOCs (ug/L)																													
Acetone	67-64-1	N	547.5	--	<20	U	1.2	20	<20	U	1.2	20	<20	U	1.2	20	<20	U	1.2	20	<20	U	1.2	20	1.6	U,B,z	1.2	20	
Chloroform	67-66-3	C	0.15	80	<1	U	0.061	1	19		0.061	1	23		0.061	1	23		0.061	1	24		0.061	1	24		0.061	1	
Toluene	108-88-3	N	227.11	--	<1	U	0.072	1	<1	U	0.072	1	0.09	J,B,y	0.072	1	0.09	J,B,y	0.072	1	<1	U	0.072	1	<1	U	0.072	1	
TCL SVOCs (ug/L)																													
1,1'-Biphenyl	92-52-4	N	30.42	--	<5	U	0.015	5	<5	U	0.015	5	0.028	J	0.015	5	0.038	J	0.015	5	<5	U	0.015	5	<5	U	0.015	5	
2-Methylnaphthalene	91-57-6	N	2,433	--	<5	U	0.015	5	<5	U	0.015	5	0.094	J	0.015	5	0.11	J	0.015	5	<5	U	0.015	5	<5	U	0.015	5	
Butylbenzylphthalate	85-68-7	N	730	--	0.057	J,B,z	0.029	5	0.057	J,B,z	0.029	5	<5	U	0.029	5	<5	U	0.029	5	0.038	J,B,z	0.029	5	0.038	J,B,z	0.029	5	
Diethylphthalate	84-66-2	N	2,920	--	0.057	J,B,x	0.034	5	0.038	J,B,x	0.034	5	<5	U	0.034	5	0.038	J,B,x	0.034	5	<5	U	0.034	5	<5	U	0.034	5	
Dimethylphthalate	131-11-3	--	--	--	0.019	J	0.016	5	<5	U	0.016	5	<5	U	0.016	5	<5	U	0.016	5	<5	U	0.016	5	<5	U	0.016	5	
Naphthalene	91-20-3	N	0.6511	--	<5	U	0.023	5	<5	U	0.023	5	0.094	J	0.023	5	0.1	J	0.023	5	<5	U	0.023	5	<5	U	0.023	5	
Field Parameters																													
Dissolved Oxygen (mg/L)	--	--	--	--	5.65					8.41			6.5				6.5				6.5				6.5				
Oxidation Reduction Potential (mV)	--	--	--	--	67					58			93				93				99				99				
pH (SU)	--	--	--	--	6.41					6.77			6.67				6.67				6.61				6.61				
Conductivity (mS)	--	--	--	--	1.03					0.543			0.697				0.697				0.667				0.667				
Temperature (°C)	--	--	--	--	17.16					17.34			15.13				15.13				16.36				16.36				
Turbidity (NTU)	--	--	--	--	3.41					1.79			0.55				0.55				0.48				0.48				

Table 4-11
Summary of Risk Screening Results for Groundwater
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

	CAS #	C/N	Adjusted T-RBC	MCL	Minimum Detected Concentration	Maximum Detected Concentration	# Samples that Exceed Adj. T-RBC	# Samples that Exceed MCL	# of Detections	# of Samples
Perchlorate (ug/L)										
Perchlorate	14797-73-0	N	2.56	--	0.52	5.2	1	0	4	4
TAL Metals (ug/L)										
Antimony, Total	7440-36-0	N	1.46	--	0.43	0.56	0	--	2	4
Barium, Dissolved	7440-39-3	N	730	2,000	29	150	0	0	4	4
Barium, Total	7440-39-3	N	730	2,000	29	150	0	0	4	4
Calcium, Dissolved	7440-70-2	--	--	--	53,000	100,000	--	--	4	4
Calcium, Total	7440-70-2	--	--	--	52,000	100,000	--	--	4	4
Chromium, Dissolved ^[1]	7440-47-3	N	10.95	100	1.2	1.7	0	0	4	4
Chromium, Total ^[1]	7440-47-3	N	10.95	100	1.365	5.3	0	0	4	4
Cobalt, Dissolved	7440-48-4	--	--	--	0.3	0.45	--	--	4	4
Cobalt, Total	7440-48-4	--	--	--	0.125	0.42	--	--	4	4
Copper, Dissolved	7440-50-8	N	146	1,300	0.86	1.9	0	0	4	4
Copper, Total	7440-50-8	N	146	1,300	0.79	2.5	0	0	4	4
Iron, Dissolved	7439-89-6	N	2,555	--	9.85	17	0	--	4	4
Iron, Total	7439-89-6	N	2,555	--	12.5	36	0	--	4	4
Lead, Total ^[2]	7439-92-1	--	15	--	0.51	0.51	0	--	1	4
Manganese, Dissolved	7439-96-5	N	73	--	0.4825	0.69	0	--	2	4
Manganese, Total	7439-96-5	N	73	--	0.48	1.2	0	--	2	4
Magnesium, Dissolved	7439-95-4	--	--	--	18,000	36,000	--	--	4	4
Magnesium, Total	7439-95-4	--	--	--	18,000	37,000	--	--	4	4
Mercury, Total ^[3]	7439-97-6	--	0.37	2	0.04	0.04	0	0	1	4
Nickel, Dissolved	7440-02-0	N	73	--	1.145	1.9	0	--	4	4
Nickel, Total	7440-02-0	N	73	--	0.935	2.8	0	--	4	4
Potassium, Dissolved	7440-09-7	--	--	--	1,000	2,400	--	--	4	4
Potassium, Total	7440-09-7	--	--	--	1,000	2,300	--	--	4	4
Selenium, Dissolved	7782-49-2	N	18.25	50	1.1	1.3	0	0	2	4
Selenium, Total	7782-49-2	N	18.25	50	0.93	0.93	0	0	1	4
Sodium, Dissolved	7440-23-5	--	--	--	6,850	16,000	--	--	4	4
Sodium, Total	7440-23-5	--	--	--	6,950	16,000	--	--	4	4
Vanadium, Dissolved	7440-62-2	N	3.65	--	1.1575	1.1575	0	--	1	4
Zinc, Dissolved	7440-66-6	N	1,095	--	3.1	7.5	0	--	4	4
Zinc, Total	7440-66-6	N	1,095	--	10.5	30	0	--	4	4
Pesticides (ug/L)										
gamma-BHC (Lindane)	58-89-9	C	0.052	--	0.0085	0.0098	0	--	2	4
gamma-Chlordane ^[4]	5103-74-2	C	0.191	--	0.0057	0.0057	0	--	1	4
TCL VOCs (ug/L)										
Acetone	67-64-1	N	547.5	--	1.6	1.6	0	--	1	4
Chloroform	67-66-3	C	0.155	80	19	24	3	0	3	4
Toluene	108-88-3	N	227.1	--	0.09	0.09	0	--	1	4
TCL SVOCs (ug/L)										
1,1'-Biphenyl	92-52-4	N	30.42	--	0.033	0.033	0	--	1	4
2-Methylnaphthalene	91-57-6	N	2.433	--	0.102	0.102	0	--	1	4
Butylbenzylphthalate	85-68-7	N	730	--	0.038	0.057	0	--	3	4
Diethylphthalate	84-66-2	N	2,920	--	0.0275	0.057	0	--	3	4
Dimethylphthalate	131-11-3	--	--	--	0.019	0.019	--	--	1	4
Naphthalene	91-20-3	N	0.651	--	0.097	0.097	0	--	1	4

Notes:

CAS = Chemical Abstract Service

TAL = Target Analyte List

ug/L = Microgram Per Liter

VOC = Volatile Organic Compound

SVOC = Semi-volatile Organic Compound

T-RBC = Adjusted Tap Water RBC

RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007,

RBC Table and October 11, 2007, Alternate RBC Table

Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)

MCL = Maximum Contaminant Level

^[1] = Chromium VI RBC value was used

^[2] = USEPA Action Level used for screening

^[3] = Methylmercury RBC used for screening

^[4] = Chlordane RBC used for screening

5.0 CONTAMINANT FATE AND TRANSPORT

This section discusses the fate and transport of site-related COPCs identified in the nature and extent assessment. Primary fate and transport mechanisms occurring at the site are discussed. The objective of the fate and transport analysis is to identify the primary mechanisms affecting the distribution and migration of COPCs and their ultimate fate. COPCs identified at the site are summarized in the following table.

Site COPCs for Nature and Extent Assessment

Soil – Human Health	Site-Specific Soil SSL DAF20	Groundwater
Aluminum	Arsenic	Chloroform
Arsenic	Chromium	Perchlorate*
Antimony	Copper	
Cadmium	Zinc	
Chromium	1,2-Dibromo-3-Chloropropane	
Copper	1,4-Dichlorobenzene	
Iron	Benzene	
Lead	Chlorobenzene	
Mercury	Methylene Chloride	
Vanadium	Trichloroethene	
Zinc	Vinyl Chloride	
Aroclor 1242	Naphthalene	
Aroclor 1248	2,3,7,8-TCDD TEQ	
Aroclor 1254		
Aroclor 1260		
Benzo(a)pyrene		
Dibenz(a,h)anthracene		
Nitroglycerin		
2,3,7,8-TCDD TEQ		

*COPC when including data from well located crossgradient from site.

The potential for transport of chemicals in environmental media is largely controlled by the physiochemical properties of the chemicals and the matrix through which they travel or migrate. Table 5-1a describes the physiochemical properties of chemicals that affect their fate in environmental media. Table 5-1b describes the fate processes affecting metals including: ion exchange, chemical speciation, and oxidation-reduction potential. Table 5-1c describes the fate processes affecting organic chemicals including: sorption, volatilization, hydrolysis, and abiotic and biotic degradation. Chemicals can be transported with little attenuation or retardation due to these fate processes or they can be delayed or transformed so that minimal migration occurs. The physical and chemical properties of organic COPCs detected in soil and/or groundwater are summarized in Table 5-2.

Primary fate and transport mechanisms for COPCs potentially present at the site include the following:

- Volatilization of chemicals from soil and groundwater;
- Erosion of particulate-bound chemicals from soil;
- Degradation of chemicals in soil and groundwater;
- Leaching of chemicals from soil with infiltrating water; and
- Transport of chemicals with groundwater flow.

Fate and transport processes for site media are discussed in the following sections

5.1 FATE AND TRANSPORT - SOIL

Fate and transport processes for soil are discussed in the following sections including volatilization, erosion and mass transport, and degradation of chemicals in soil, and leaching of chemical from soil with infiltrating water.

5.1.1 Volatilization

Volatilization can significantly affect the distribution of a chemical in the environment. This process will result in the mass and concentration of a chemical in soil and/or groundwater as the chemical volatilizes to soil gas and ultimately discharges to the atmosphere. Volatilization reactions are most significant in surface soil that is in direct (or near-direct) contact with the atmosphere. These reactions may also occur in groundwater with VOCs. Chemical volatility is typically quantified by a chemical's Henry's constant, which may be calculated from the chemical's vapor pressure, molecular weight, and solubility. The lower the Henry's constant, the less volatile the chemical. Values of Henry's constant for soil COPCs are summarized in Table 5-2.

Several VOCs were identified as COPCs for the soil-to-groundwater migration pathway based on detections in one or more samples above calculated site-specific SSLs. Low concentrations of these COPCs have been detected in surface soil and therefore, volatilization is not expected to be a significant influence on the fate of these compounds in soil. Other COPCs at the site are characterized by low Henry's constants (i.e., < 0.01) and are not VOCs, and therefore, volatilization is not expected to be a significant influence on the fate of these compounds at the site.

5.1.2 Erosion Processes in Soil

Erosion processes can substantially affect the distribution of soil-bound particulates in the environment and thus influence the distribution of constituents in soil. High winds can scour fine particles from the soil surface and redistribute these particles downwind. Mass transport from surface water runoff during heavy precipitation events can also scour fine soil particles from surface soil, eventually depositing the particles during sedimentation downstream. These erosion processes often represent the primary mechanism for transport of otherwise immobile chemicals such as PCBs and dioxins.

Surface water runoff has cut several distinct gullies and swales into the northern edge/slope of the landfill. Overland flow has deposited material at the base of the landfill slope containing PCBs and PAHs. Surface soil samples collected at the base of the western part of the landfill had the highest PCB concentrations (Figure 4-4). One sample (40SS1) collected from the base of one of the gullies had an Aroclor 1254 concentration (2,100 $\mu\text{g/kg}$) above its I-RBC. PCB concentrations in the other 16 samples collected north of the landfill had PCB concentrations below I-RBCs; three of these samples had PCB concentrations above R-RBCs. Detected concentrations of PAH compounds benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene in surface soil were above R-RBCs but below I-RBCs in one or more samples.

5.1.3 Degradation of Chemicals in Soil

Many organic chemicals that are found in the environment are subject to naturally occurring biotic (biologically based) and abiotic (non-biologically based) transformation reactions. These reactions result in degradation of the chemical. Biodegradation reactions can occur under aerobic (in the presence of oxygen) and anaerobic (in the absence of oxygen) conditions. During biodegradation, naturally occurring microorganisms in the subsurface transform a chemical to another state as a direct or indirect consequence of their metabolic processes. In many cases, biodegradation reactions break down organic chemicals to less toxic forms.

Several naturally occurring abiotic reactions can significantly affect the fate of chemicals in the environment. Common abiotic reactions include photodegradation and hydrolysis. Photodegradation is the process of decomposition of a chemical upon exposure to radiant energy such as the action of light,

and is most significant to chemicals in surface soil that are in direct contact with sunlight. Hydrolysis is the degradation reaction of the chemical with components of water (e.g., hydroxyl and hydronium ions) and is therefore most important in saturated environments.

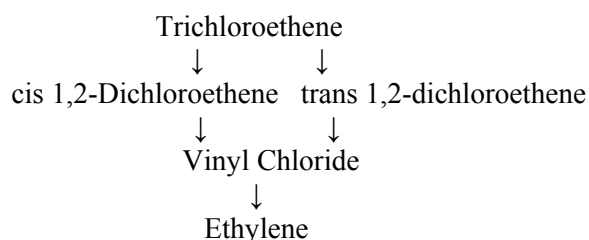
5.1.3.1 VOCs

VOCs were detected low concentrations in soil at the site. COPCs identified for the soil-to-groundwater migration pathway were primarily benzene compounds and derivatives (benzene, chlorobenzene, and 1,4-dichlorobenzene), and halogenated compounds (methylene chloride, TCE, and vinyl chloride) along with 1,2-dibromo-3-chloropropane in one surface soil sample.

Benzene, Chlorobenzene, and 1,4-Dichlorobenzene: Benzene was the second most frequently detected VOC in soil with detected levels at estimated concentrations near or below the laboratory method reporting limits, with the exception of one landfill material sample. Benzene can undergo degradation in soil via an aerobic or anaerobic pathway. The aerobic pathway is the most important with the formation of catechol as an end-product (HSDB 2007). Benzene can be mineralized under anaerobic conditions; although this pathway more frequently occurs in sediment and groundwater. Chlorobenzene was detected in one landfill sample at a concentration above its site-specific SSL. It can undergo some degradation in soil but not at a substantial rate unless microorganisms present are already growing on another hydrocarbon source. Chlorobenzene can be mineralized by bacteria with 2-chlorophenol and 4-chlorophenol as products (HSDB 2007). 1,4-Dichlorobenzene (detected in one landfill material sample at a concentration above its site-specific SSL) is resistant to degradation in soil.

TCE and Vinyl Chloride: TCE was the most frequency detected VOC with detected levels at estimated concentrations near or below the laboratory method reporting limits. TCE is resistant to aerobic degradation in soil although biodegradation may proceed co-metabolically. Under anaerobic conditions, TCE is slowly biodegraded through reductive dechlorination, with the extent and rate of degradation dependant on the degree of the reducing environment. The reductive dechlorination pathway for TCE is shown below. Vinyl chloride is an intermediate degradation by product in this pathway as shown below; this compound has been detected in one sample at an estimated concentration slightly above the laboratory detection limit. Ethylene is an end- product of this degradation process.

TCE Degradation Pathway – Reductive Dechlorination



Methylene Chloride (Dichloromethane): Methylene chloride can undergo biodegradation in soil to formaldehyde. It can also be formed as part of a bacteria and reductive dechlorination pathway from carbon tetrachloride to chloroform (intermediate) to methylene chloride (end-product) (UM 2007). Carbon tetrachloride and chloroform have not been detected in soil samples; however, chloroform has been detected in two groundwater samples at concentrations above its T-RBC.

1,2-Dibromo-3-Chloropropane: this compound was detected in one surface soil sample at an estimated concentration below the laboratory reporting limit. 1,2-Dibromo-3-chloropropane compound can undergo biodegradation in soil but at much slower rates relative to volatilization or leaching processes (HSDB 2007).

5.1.3.2 Metals

Metal COPCs, such as aluminum, arsenic, antimony, cadmium, chromium, copper, iron, lead, mercury, vanadium, and zinc copper, and zinc, will not be influenced by degradation processes in soil.

5.1.3.3 Nitroglycerin

Nitroglycerin undergoes rapid biodegradation using batch reactors and digestors but its rate of biodegradation in soil is unknown. Hydrolysis of nitroglycerin in soil may be important under alkaline conditions but is not expected to be an operable degradation process at the site due to the neutral pH of the soil (HSDB 2007).

5.1.3.4 PCBs

PCBs are very persistent in the environment and are extremely resistant to oxidation and hydrolysis. PCBs are resistant to chemical degradation by oxidation or hydrolysis (HSDB 2007). Aroclors are PCB mixtures of more than 90 different congeners of chlorobiphenyl. The most frequently detected Aroclors at the site have a high degree of chlorination (54% for 1254 and 60% for 1260), which contain higher proportions of the more heavily chlorinated congeners. The persistence of PCBs generally increases with an increase in the degree of chlorination. Aroclor 1254 and 1260 are generally resistant to biodegradation in soil, with limited degradation involving anaerobic reactions, which result in reductive dechlorination to lower chlorinated PCBs; however, this degradation does not necessarily lead to a reduction in toxicity (HSDB 2007). Some biodegradation of lower chlorinated PCBs can occur under aerobic conditions through biotic degradation by microorganisms. Lower chlorinated PCBs tend to degrade more readily than higher chlorinated PCBs.

Two PCB samples collected from the site were analyzed for both Aroclors by SW-846 Method 8082 and for PCB congeners by EPA Method 1668. A comparison of the test results is presented in the following table.

Comparison of Aroclor and PCB Congener Testing

Sample	Location	Sample Results (µg/kg)					Congener Pattern Detected (Congener # and % by Weight)
		Aroclor 1248	Aroclor 1254	Aroclor 1260	Total Aroclors	Total PCB Congeners VDEQ List	
40SS9	SWMU 40	<5.4	40	12.55	52.5	91.39	Aroclors 1254 and 1260
71SS12B	SWMU 71	<5.4	<8.8	<6.5	ND	0.28	Aroclor 1254 and 1260

Note: µg/kg = micrograms per kilogram.

The results of the congener testing indicated slightly higher total PCB concentrations than the Aroclor results. Both congener mixtures detected were consistent with a mixture of Aroclor 1254 and 1260, which were detectable in sample 40SS9 but not in sample 71SS12B. Congener testing does not indicate significant weathering of Aroclors detected. This is consistent with the higher proportions of the heavily chlorinated congeners detected and tendency for these mixtures to be resistant to degradation.

5.1.3.5 Dioxins

Dioxins are highly stable in soil under most environmental conditions. Photodegradation is the primary degradation mechanism affecting the fate of dioxins in soil (ATSDR 1998). This process is limited to the uppermost layer of surface soil and therefore, is unlikely to influence the overall occurrence of dioxins at the site due to their occurrence both at the surface and subsurface and the nature of vegetative cover.

5.1.3.6 PAHs

PAHs identified as COPCs in soil at the site consisted of high molecular weight compounds benzo(a)pyrene, and dibenz(a,h)anthracene, and low molecular weight compound naphthalene. Microbial

metabolism is the primary process for degradation of PAHs in soil. Hydrolysis, oxidation reduction, and photodegradation are not considered important processes for the degradation of PAHs in soil. The higher molecular weight PAHs that are COPCs at the site will tend to have lower rates and degrees of degradation than middle to lower molecular weight PAHs. The rate and extent of biodegradation of PAHs in soil is also influenced by soil properties such as organic content, structure, particle size, pH, temperature, and oxygen content, and the characteristics of microbial populations in the soil. The presence of metals in soil that are toxic to microorganisms will impede degradation (ATSDR 1995).

Experimentally reported half-lives for high molecular weight PAHs in soil are typically in the range of 1 to 1.5 years but will vary depending soil and site characteristics. Specific information on the relative degradation rates of PAHs in site soil is not available; it is possible that some degradation of PAHs has occurred at the site given the low concentrations of high molecular weight compounds detected.

5.1.4 Leaching of Chemicals from Soil to Groundwater

Chemicals in soils have the potential to migrate to greater depths with infiltrating water. As precipitation infiltrates, chemicals may be leached from the soil and carried to greater depths and potentially to groundwater. Factors affecting leaching are discussed below followed by specific assessments for COPCs identified in Section 4.0 for the soil-to-groundwater migration pathway based on comparisons to site-specific SSLs. The degree to which a chemical is leached is strongly influenced by the chemical's tendency to partition to the solid or aqueous phases, which is largely a function of the chemical's solubility and particle affinity.

Water Solubility

Water solubility of a chemical is the mass of chemical that will dissolve in a unit volume of water at a specific temperature. Chemicals with a high solubility can often be readily dissolved in water and therefore are susceptible to being mobilized from the soil matrix with infiltrating water and migrating downward to groundwater. Chemicals with a low solubility tend to partition to soil.

The solubility of organic chemicals is typically a function of the hydrophobic nature of the chemical. Many organic chemicals are non-polar and therefore do not dissolve readily into water, which is a polar solution. Several of the COPCs identified in soil at the site, such as dioxins, PAHs, and PCBs have low water solubility. Water solubility data for COPCs are summarized in Table 5-2.

Adsorption

The aqueous concentration of chemicals in soil systems can also be substantially influenced by adsorption reaction to the soil matrix. Adsorption is the ability of a substance to bind to the surface of soil particles from reactions that occur between the chemical and the soil particle surface. Organic compounds are frequently non-polar, and therefore, tend to interact with organic matter commonly associated with the soil matrix. The tendency for a chemical to be adsorbed to the organic fraction of soil (or sediment) can be measured by the chemical's organic carbon partition coefficient (K_{oc}). The lower the K_{oc} values the more leaching potential from soil to water as summarized below. Organic compounds with a K_{oc} less than 100 liters per kilogram (L/kg), such as TCE, have a high potential to leach from soil or sediment to water, while K_{oc} values in the range of 100 to 500 L/kg, such as benzene and chlorobenzene, indicate a moderate leaching potential. Progressively higher values of K_{oc} greater than 500 L/kg indicate lower leaching potential. Organic compounds with K_{oc} values in the range of $1E+04$ to $1E+06$ L/kg, such as PCBs, high molecular weight PAHs, and dioxins, are generally immobile or nearly immobile in soil. Values of K_{oc} for COPCs are summarized in Table 5-2.

Site-specific distribution coefficients (K_d) can be estimated for each organic COPC, as the product of the K_{oc} of the chemical and the fraction of the organic carbon (f_{oc}) in the soil matrix. The distribution coefficient is a measure of the ratio of chemical mass that partitions to the solid and liquid phases under equilibrium conditions. The fraction of organic carbon in site soil is estimated as 1% based on typical

levels observed in soil at RFAAP. Calculated K_d values are presented in Table 5-2. The relatively mobility of site COPCs for the soil-to-groundwater migration pathway have been estimated in the following table based on solubility, K_{oc} and K_d values.

Relative Mobility of COPCs in Soil for the Soil-to-Groundwater Migration Pathway

Immobile	Slight	Low	Moderate	High	Very High
High-molecular weight PAHs Dioxins PCBs Lead	Aluminum Arsenic Chromium Copper Iron Mercury Zinc	1,4- Dichlorobenzene Naphthalene	Chlorobenzene Nitroglycerin TCE	Benzene Methylene Chloride Vinyl Chloride	Chloroform*

*Groundwater COPC, detected only in groundwater.

COPCs classified as immobile, slightly mobile, or low are unlikely to leach from soil to groundwater at levels of potential concern. Other factors that will influence the degree of leaching for COPCs with a higher mobility include: source area size, concentrations detected, and soil type and permeability.

5.1.4.1 Metals

Arsenic, chromium, copper, and zinc were detected in one or more samples at concentrations above their DAF20 soil-to-groundwater SSLs and facility-wide background point estimates. Metals detected above facility background without soil-to-groundwater SSLs included: aluminum, iron, lead, and mercury.

Aluminum: Aluminum compounds generally exist in soil in the form of silicates, hydroxides, and oxides. During soil acidification, aluminum ions are released from silicates (i.e., solubilized). At pH values above 5, aluminum ions become strongly bound to soil and exist predominantly in an undissolved form such as gibbsite (HSDB 2007 and ATSDR 1999). The adsorption of aluminum to clay surfaces is a major factor in controlling aluminum mobility and has been observed to be very rapid (ATSDR 1999). Aluminum is expected to be strongly adsorbed to soil at the site due to its neutral pH (above 5.5) and clay content. Aluminum was not detected in groundwater samples collected at the site.

Arsenic: Arsenic is strongly adsorbed by soil particles (e.g., clays, metal oxides, and organic matter). Arsenic binds to soil much more strongly than other divalent cations, and the distribution of arsenic in the soil solution is less affected by pH than other inorganic compounds such as chromium. Conditions at the site are conducive to the immobilization of arsenic in soil due to the presence of low permeability clay soil, neutral pH, and the presence of organic matter (2.8 to 5.5%). Arsenic was not detected in groundwater samples collected at the site.

Chromium: The fate of chromium in soil is dependent on the speciation of chromium, which is a function of oxidation reduction potential and pH of the soil. Chromium is typically found in the III valence state, which has very low solubility and low reactivity resulting in low mobility in the environment. Conditions at the site are conducive to the immobilization of chromium in soil due to the presence of low permeability clay soil, neutral pH, and the presence of organic matter (2.8 to 5%). Chromium was detected at low concentrations in groundwater below its adjusted T-RBC.

Copper and Zinc: The solubility and mobility of copper and zinc in soil are strongly dependent on the soil pH and type. Conditions at the site are conducive to the adsorption and immobilization of copper and zinc in soil due to a neutral soil pH, the presence of low permeability clay soil and soil organic matter (2.8 to 5.5%). Copper and zinc were detected at low concentrations in groundwater at below their adjusted T-RBCs.

Lead: Most lead is retained strongly in soil and very little leaches to groundwater. Conditions at the site are conducive to the immobilization of lead in soil due to the neutral soil pH, the presence of low permeability clay soil and soil organic matter (2.8 to 5.5%). Dissolved lead was not detected in site groundwater.

Iron: Adsorption of iron is dependent on soil pH and organic matter, with an increase in either of these parameters resulting in increased adsorption. Mobility is also influenced by oxidation reduction potential, with iron becoming more mobile under oxidizing conditions (HSDB 2007). Conditions at the site are conducive to the adsorption and immobilization of iron in soil due to a neutral pH, the presence of low permeability soil and soil organic matter (2.8 to 5.5%). Iron was detected at low concentrations in site groundwater below its adjusted T-RBC.

Mercury: Mercury compounds released to soil tend to be strongly adsorbed to soil and typically do not significantly leach. Adsorption of mercury increases with the percent of organic matter in the soil. In contrast to most other metals, acidification of soils does not increase the solubility of mercury compounds. Inorganic mercury compounds can be methylated by microorganisms that are indigenous to the soil environment. This process is mediated by various microbial populations under both aerobic and anaerobic conditions. Sulfur-reducing bacteria are responsible for most of the mercury methylation in the environment; however, yeast populations are also able to methylate mercury (HSDB 2007). Mercury is expected to have low mobility in site soil given its properties, and the presence of low permeability soil and soil organic matter (2.8 to 5.5%). Dissolved mercury was not detected in site groundwater.

5.1.4.2 VOCs

COPCs identified for the soil-to-groundwater migration pathway were primarily benzene and derivatives (benzene, chlorobenzene, and 1,4-dichlorobenzene), and halogenated compounds (methylene chloride, TCE, and vinyl chloride) along with 1,2-dibromo-3-chloropropane in one surface soil sample. These compounds have moderate to high solubilities, lower K_{oc} values, and moderate to high mobility in subsurface, with the exception of 1,4-dichlorobenzene, which has lower mobility in the subsurface (Table 5-2).

VOCs were not detected in soil samples collected below the landfill material at concentrations above their site-specific SSLs, with the exception of TCE. TCE was detected in these samples at low-level concentrations at or near the laboratory reporting limit. TCE and other VOCs identified for the soil-to-groundwater migration pathway have not been detected in site groundwater samples. These COPCs are not considered at potential concern for the soil-to-groundwater migration pathway based on the low concentrations detected, presence of the low permeability clay soil, and lack of detections in site groundwater.

One VOC not detected in site soil, chloroform, has been detected in site groundwater at concentrations above its T-RBC.

5.1.4.3 SVOCs and PAHs

Other than PAHs, SVOCs have not been identified as COPCs for the soil-to-groundwater migration pathway based on comparisons to calculated site-specific SSLs with the exception of naphthalene. Naphthalene, a lower molecular weight PAH identified as a COPC in soil, has lower solubility and its mobility in soil is low. Naphthalene is not considered a potential concern for the soil-to-groundwater migration pathway given their low mobility in soil, the low permeability of clay soil at the site, and the lack of detections of naphthalene in site groundwater at concentrations above adjusted T-RBCs.

5.1.4.4 Pesticides

Pesticides have low mobility in the subsurface due their lower solubility and higher K_{oc} values and therefore will tend to remain absorbed to soil (Table 5-2). Levels of pesticides detected at the site were below site-specific SSLs. Pesticides are not considered a potential concern for the soil-to-groundwater

migration pathway given their low mobility in soil, the lack of detections above site-specific SSLs, the low permeability of clay soil at the site, and the lack of detections of pesticides in site groundwater at concentrations above adjusted T-RBCs.

5.1.4.5 PCBs

PCBs have a low solubility in water and high K_{oc} values, and will tend to be immobile in the environment and remain adsorbed to soil (Table 5-2). Detected concentrations of PCBs were below site-specific SSLs. PCBs are not considered a potential concern for the soil-to-groundwater migration pathway given their immobile nature, the lack of detected concentrations above site-specific SSLs, the low permeability of clay soil underlying landfill material at the site, and the lack of detections in site groundwater.

5.1.4.6 Dioxins

Dioxins have a low solubility in water and high K_{oc} values, and will tend to be immobile in the environment and remain adsorbed to soil (Table 5-2). Dioxins are not considered a potential concern for the soil-to-groundwater migration pathway given their immobile nature and low permeability of clay soil at the site.

5.2 FATE AND TRANSPORT - GROUNDWATER

Fate and transport processes for site-related COPCs in groundwater are discussed in the following sections. COPCs identified in groundwater include: perchlorate and chloroform.

5.2.1 Volatilization

Volatilization of a chemical from groundwater will result in a reduction of its mass and concentration as the chemical volatilizes to soil gas and ultimately discharges to the atmosphere. This process may also occur in groundwater with VOCs. Some volatilization of chloroform may occur in site groundwater under ambient conditions due to its higher Henry's constant and volatility, and therefore, may have some influence on the fate of this compound in the subsurface. Perchlorate is not a VOC and therefore, volatilization will not influence the fate of this compound.

5.2.2 Degradation of Chemicals in Groundwater

Groundwater COPCs explosives and perchlorate can be subjected to transformation and degradation in groundwater, which will reduce their concentrations over time.

5.2.2.1 Chloroform

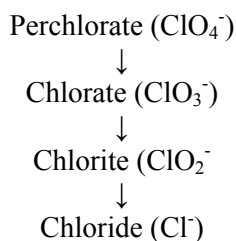
Chloroform will tend to persist in groundwater under aerobic conditions, where dissolved oxygen levels are greater than 0.5%. Degradation of chloroform may occur in groundwater under anaerobic conditions if appropriate microbial bacteria are present (USGS 2006). In this case, chloroform (trichloromethane) would be transformed to dichloromethane (methylene chloride) by reductive dechlorination (dehalogenation). Aerobic conditions in site groundwater appear to be unfavorable for natural degradation of chloroform.

5.2.2.2 Perchlorate

Perchlorate occurs as ammonium, potassium, magnesium, or sodium salts. The perchlorate anion (ClO_4^-) consists of a tetrahedral of oxygen atoms around a central chlorine atom. Perchlorate is a strong oxidizer due to its +7 valence. Under typical groundwater conditions, perchlorate can persist in the environment due to high solubility, limited tendency to absorb to soil surfaces, and its resistance to reactions with other available constituents in the subsurface.

Biological degradation of perchlorate can occur by microorganisms via an anaerobic pathway if an electron donor is present to complete microbial degradation process, such as a carbon substrate or other source. The biological degradation pathway for perchlorate is shown below.

Perchlorate Degradation Pathway¹ (from Borden 2006)



Note: ¹ from Borden 1996

Aerobic conditions in site groundwater appear to be unfavorable for natural degradation of perchlorate. In most natural groundwater systems, dispersion is considered the most important process influencing fate and transport of perchlorate.

5.2.3 Dispersion Processes in Groundwater

As contaminated water flows through a porous medium it will mix with non-contaminated water and as a result it will dilute (mechanical dispersion). Mixing that occurs along the direction of groundwater flow is called longitudinal dispersion and mixing that occurs perpendicular to the direction of groundwater is called lateral dispersion. Longitudinal dispersion is influenced by pore size, flow path length through the porous media, and the friction in the pore. Lateral dispersion occurs due to the splitting and branching of water as it flow paths through porous media.

Dispersion processes are likely an important process influencing the fate and transport of dissolved phase constituents in site groundwater given the variety of interconnections that can exist in bedrock ranging from very small fractures to larger karst cavities caused by dissolution of the rock. Dispersion can also occur through the matrix of the rock.

As discussed in Section 2.8.4, a preferential flow path for groundwater was identified during the dye-trace study conducted at SWMU 17. This flow path extends from the sink hole located east of SWMU 40 approximately 4,800 ft west-northwest to spring SPG3 paralleling an identified fracture trace. The identified flow path is likely present beneath or in close proximity to the site. Migration pathways were not identified from the SWMU 17 sinkhole to monitoring wells 17MW3 and 40MW3 located north and south of the site, respectively.

5.2.4 Adsorption and Retardation

The migration rate of chemicals in groundwater can be slowed relative to groundwater flow due to attenuation reactions such as adsorption, particularly when flowing through porous media. In porous media, the effect of adsorption reaction on chemical migration rates is typically quantified by using a retardation factor (R), which may be estimated from the chemical-specific distribution coefficient (K_d) in liters per kilogram, soil bulk density in kilograms per liter (ρ_b) and porosity (n). However, the rates of retardation in fractured and karst bedrock aquifers are difficult to quantify and therefore, have not been estimated for site groundwater. Based on the chemical and physical properties of the chloroform and perchlorate, lower rates of adsorption and retardation are expected for these constituents in site groundwater.

5.3 FATE AND TRANSPORT SUMMARY

The fate and transport assessment identified mass transport and erosion from the northern edge/slope of the landfill area at SWMU 40 due to the detection of PCBs in surface soil deposited at the base of the landfill slope. Surface water runoff has several distinct gullies and swales into the northern edge/slope of the landfill in this area.

Groundwater samples collected from the landfill area indicated apparent leaching of chloroform from the landfill area to groundwater at levels above its T-RBC. Extensive source characterization was conducted at SWMUs 40 and 71 including the collection of 91 soil samples many of which were collected from landfill material and soil below the landfill material at SWMU 40. Chloroform was not detected in these samples. The lack of any detections and absence of other volatiles in groundwater samples suggests a potential alternate source for chloroform in groundwater. Studies and groundwater investigations have shown the presence of chloroform in most groundwater samples collected at the facility regardless of location. The concentrations of chloroform detected in monitoring wells at SWMUs 40 and 71 are within the range of chloroform levels present in the water transmitted through water lines at the facility. The landfill area is located downgradient of developed areas containing water lines that could be leaking, which may have been the source of chloroform. Based on the historical use of SWMU 40 (i.e., sanitary landfill), chloroform could be a potential site-related groundwater COPC, but it should be noted that no source of chloroform has been identified within the landfill material or soil beneath the landfill material at SWMU 40. Low concentrations of other organic and inorganic constituents below adjusted T-RBCs were detected in the two monitoring wells installed adjacent to the landfill area. Perchlorate was detected in the two monitoring wells located adjacent to the landfill at concentrations below the adjusted T-RBC. However, samples collected upgradient of the site at SWMU 17 (wells LFMW01, 17MW2, and 17PZ1) and crossgradient from the site (well 17MW3) had higher perchlorate concentrations above the adjusted T-RBC. These sample results suggested an alternative source of perchlorate than the site.

Table 5-1a
Chemical Properties Affecting Fate and Transport
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Property	Description
Specific Gravity	Specific gravity is the ratio of the density of a chemical to the density of water and its tendency to float (specific gravity <1) or sink (specific gravity >1) in water. Chemicals that are immiscible in water can exist as non-aqueous phase liquids and are referred to as light non-aqueous phase liquid if their specific gravity is less than one, or dense non-aqueous phase liquid if their specific gravity is greater than one.
Water Solubility	Water solubility of a chemical is the mass of chemical that will dissolve in a unit volume of water at a specific temperature. Chemicals with a high solubility tend to remain dissolved in water rather than partition to soil or sediment are less likely to volatilize, and more likely to biodegrade. Chemicals with a low solubility tend to partition to soil or sediment, are more likely to volatilize and less likely to biodegrade.
Vapor Pressure	Vapor pressure of a chemical is how readily it will volatilize to the atmosphere. Volatilization from water is dependent upon vapor pressure and Henry's law constant. Vapor pressures in their pure state range from 0.001 to 760 millimeters mercury (mm Hg) for liquids to less than 1E-10 mm Hg for solids.
Henry's Law Constant	Henry's law constant of a chemical is a measure of how a chemical will partition between air and water at equilibrium. It is the ratio of the vapor pressure to the water solubility (atm-m ³ /mole) and can be used to calculate the rate of volatilization of a chemical from water. Chemicals with a high Henry's law constant more readily volatilize from water.
Organic Carbon Partition Coefficient (K _{oc})	K _{oc} is a measure of the tendency for a chemical to be sorbed to the organic fraction of soil and sediment. The lower the K _{oc} values the more leaching potential from soil or sediment to water. Chemicals with a K _{oc} less than 100 milliliters per gram (mL/g) have a high potential to leach from soil or sediment to water, while K _{oc} values in the range of 100 to 500 mL/g indicate a moderate leaching potential.
Octanol-Water Partition Coefficient (K _{ow})	K _{ow} describes the partitioning of an organic chemical between a polar phase (water) and a relatively nonpolar phase (1-octanol). It is equated to the partitioning (sorption) in an aquifer of a chemical between the water and the porous media organic content. A chemical with a high K _{ow} is hydrophobic and may be relatively immobile in an aqueous system but may be mobilized in the presence of an organic solvent.

Table 5-1b
Fate Processes Affecting Metals
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Process	Description
Ion Exchange	Ion exchange is a specific category of adsorption due to an affinity of the solid surface for the chemical. Ion exchange occurs when the adsorbent charge deficiency can be neutralized more efficiently by ions in solution than by those ions currently adsorbed. As an example, if sodium ions (monovalent) have accumulated at the interface and suddenly calcium ions (divalent) appear, the surface excess can be more efficiently neutralized by the calcium ions than by the sodium ions; thus, the sodium ions will desorb and the calcium ions will adsorb and an exchange of ions will occur. Clay minerals are frequently the dominant source of ion exchange in the subsurface. The surface charge of clays and many other mineral surfaces is a function of pH. At low pH (excess hydrogen ions), the surface can exhibit a positive net charge while at higher pH (excess hydroxyl ions) the surface can exhibit a negative charge (Knox et al 1993). The surface area of the exchange site significantly influences the level of adsorption; this parameter is typically discussed in terms of the cation exchange capacity (CEC) of the medium and is expressed in units of milliequivalents of exchanging cations per 100 grams of solids (meq/100 g). CEC values indicate the likely type of clay present; the higher the CEC value the greater the absorption potential.
Chemical Speciation	Most metals occur in more than one ionic form (species) in solid and aqueous media. These species form from hydrolysis, oxidation reduction reactions, and complexation reactions, which may have different valences and mobilities in soil water, groundwater, and surface water due to different affinities for adsorption and different solubility controls. Simple ionic species frequently combine ligands to form ionic or neutral-charge aqueous complexes. Environmental conditions that affect speciation of metals include pH, redox potential, and organic ligands.
Oxidation Reduction Potential (ORP)	Redox refers to the transfer of electrons and resultant species change of ions or compounds. Oxidation is the loss of electrons and reduction is the gain of electrons. Redox can cause changes in the mobility of many metals, such as site COPCs iron, manganese, and arsenic. The ability of a redox reaction to occur is a function of the redox potential. Redox potential is typically defined in terms of the negative logarithm of the free-electron activity (pE). The redox potential can also be expressed in terms of volts (Eh). Low values of pE indicate high electron activity and favor electron-rich species (reduced). High values of pE indicate low electron activity and favor electron-poor species (oxidized) (Knox et al 1993).

Table 5-1c
Fate Processes Affecting Organics
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Process	Description
Sorption	Sorption includes the processes of adsorption and absorption. Adsorption is a mass transfer process where a substance is transferred from a phase to the surface of a medium (e.g. soil or sediment) where it is bounded by chemical or physical forces. Absorption is the partitioning between two phases (Knox et al. 1993). Sorption reactions are either sorbent or solvent-motivated. Sorbent-motivated reactions occur when there is an attraction between the sorbent and the solute and the chemical accumulates at the surface due to the affinity of the surface for the chemical. Solvent-motivated reactions occur when the chemical is hydrophobic, such as nonionic organics, where the chemical will accumulate at an interface or partition into a nonionic phase (associate with the organic content of the medium). For nonionic organics, the fraction of organic content (foc) of the subsurface material is the dominant soil characteristic affecting sorption (Knox et al. 1993). Primary indicators of the partitioning of a chemical are the organic carbon water partition coefficient (Koc), soil/water distribution coefficient (Kd), the octanol water partitioning coefficient (Kow), and the calculated retardation factor.
Hydrolysis	Hydrolysis is the degradation process via chemical reactions (oxidation, reduction, hydrolysis) without the participation of organisms. Hydrolysis is a chemical decomposition process that uses water to split chemical bonds of substances. There are two types of hydrolysis, acid and enzymatic. Hydrolysis is limited to chemical that contain hydrolyzable groups and is effected by the contaminants hydrolysis half life.
Volatilization	Volatilization is the process by which a contaminant changes from a liquid phase to a gas phase. This process applies to organic comtaminants migrating from the soil or surface water. Volatile organic chemicals are a class of chemicals that easily evaporate or mix with the atmosphere. The potential volatilization of a chemical is affected by the compounds vapor pressure, solubility, organic carbon partitioning coefficient, and the temperature.
Abiotic Degradation	Abiotic degradation includes degradation processes in which organisms do not participate. Photolysis describes the abiotic degradation process via photochemical reactions such as photooxidation, photomineralisation without the participation of organisms. As described above, hydrolysis is an additional process of abiotic degradation.
Biotic Degradation	Biotic degradations the process in which chemical degradation of a contaminant is aided by soil organisms. Biotic degradation can be either aerobic or anaerobic. The rate of metabolism/cometabolism is affected by the contaminant's biochemical oxygen demand, chemical oxygen demand, degree of halogenation, etc. Reactions include but are not limited to oxidation/reduction and hydrolysis, as described above.

Table 5-2
Chemical Properties Affecting Fate and Transport
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Chemical	CAS #	Molecular Weight (g/mol)	Henry's Law Constant (atm·m ³ /mol)	Unitless Henry's Law Constant	Organic Carbon Partition Coef. (K _{oc}) (L/kg)	Site-Specific Soil-Water Partition Coef. (K _d)	Log of Octanol-Water Partition Coef. (log K _{ow})	Octanol-Water Partition Coef. (K _{ow}) (L/kg)	Water Solubility (mg/L)	Vapor Pressure (mm Hg)
Aroclor 1242	53469219	291.99	3.41E-04	1.40E-02	4.48E+04	448.0	6.29	1.95E+06	2.77E-01	8.63E-05
Aroclor 1248	12672296	291.99	4.39E-04	1.80E-02	4.39E+04	439.0	6.34	2.19E+06	5.32E-02	4.94E-04
Aroclor 1254	11097691	326.44	2.83E-04	1.16E-02	8.10E+05	8,100	6.79	6.17E+06	3.40E-03	6.53E-06
Aroclor 1260	11096825	395.33	3.34E-04	1.37E-02	2.07E+05	2,070	8.27	1.86E+08	2.84E-04	4.05E-05
Benzene	71432	78.11	5.54E-03	2.27E-01	3.10E+01	0.3	2.13	1.35E+02	1.79E+03	9.48E+01
Benzo[a]pyrene	50328	252.32	1.13E-06	4.63E-05	1.02E+06	10,200	6.13	1.35E+06	1.62E-03	5.49E-09
Chlorobenzene	108907	112.56	3.71E-03	1.52E-01	8.20E+01	0.8	2.84	6.92E+02	4.98E+02	1.18E+01
Chloroform	67663	119.38	3.66E-03	1.50E-01	3.50E+01	0.4	1.97	9.33E+01	7.95E+03	1.97E+02
Dibenz[a,h]anthracene	53703	278.36	1.23E-07	5.03E-06	2.62E+06	26,200	6.54	3.47E+06	1.03E-03	1.39E-11
1,2-Dibromo-3-chloropropane	96128	236.33	1.47E-04	6.03E-03	3.60E+02	4	2.96	9.12E+02	1.23E+03	8.00E-01
1,4-Dichlorobenzene	106467	147.0	2.40E-03	9.84E-02	2.73E+02	2.7	3.44	2.75E+03	8.13E+01	1.74E+00
Methylene Chloride	75092	84.93	2.19E-03	8.98E-02	1.20E+01	0.1	1.25	1.78E+01	1.30E+04	4.35E+02
Naphthalene	91203	128.18	4.83E-04	1.98E-02	4.90E+02	4.9	3.3	2.00E+03	3.10E+01	8.50E-02
Nitroglycerin	55630	227.09	2.54E-09	1.04E-07	1.31E+02	1.3	1.62	4.17E+01	1.38E+03	4.00E-02
Trichloroethene	79016	131.39	1.03E-02	4.22E-01	1.30E+02	1.3	2.42	2.63E+02	1.28E+03	6.90E+01
TCDD, 2,3,7,8-	1746016	321.98	4.98E-05	2.04E-03	4.60E+06	46,000	6.8	6.31E+06	2.00E-04	1.50E-09
Vinyl Chloride	75014	62.5	2.70E-02	1.11E+00	5.60E+01	0.6	1.62	4.17E+01	8.80E+03	2.98E+03

Notes:

CAS = Chemical Abstract System
g/mol = Grams per mole
atm·m³/mol = Cubic meters atmosphere per mole
L/kg = Liters per kilogram
mg/L = Milligrams per liter
mm Hg = Millimeters Mercury

6.0 HUMAN HEALTH RISK ASSESSMENT

This HHRA evaluates the probability and magnitude of potential adverse effects on human health associated with exposure to site-related chemicals in soil and groundwater. SWMUs 40 and 71 are evaluated separately given their different disposal histories. Refer to Section 2.0 for additional information regarding the site background. The HHRAs were conducted for the sites consistent with guidance included in EPA's *Interim Final Risk Assessment Guidance for Superfund* (RAGS), as well as other USEPA guidance (USEPA 1989a,b; 1991a; 1997a; 2001; 2002c; and 2004). Guidance documents are also noted on the RAGS Part D tables provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71).

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 screening levels 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 gathered 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 1989b) are discussed; and
- **Section 6.6: Summary and Conclusions:** The results of the HHRA are summarized.

As previously stated, 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 Appendices E.1 (SWMU 40) and E.2 (SWMU 71).

6.1 DATA SUMMARY AND SELECTION OF COPCS

6.1.1 Data Summary

Table 6-1 identifies the samples used in the SWMU 40 and SWMU 71 COPC screening for soil. Note that as presented in Section 2.8 soil data have been collected at SWMUs 40 and 71 since 1992, but only data collected from the 2002 and 2006 investigations have been used for estimates of risk and hazard at these sites. Prior to this RFI, historical soil analytical data (1992 and 1994) were limited to SWMU 71 for metals, explosives, and total petroleum hydrocarbons. These data were considered screening level data and excluded from the risk assessment given the age of the data, the use of non SW-846 analytical methods, the lack of available data validation reports/information, and the availability of sufficient newer validated RFI data to more appropriately characterize current conditions in this small area. Data from the groundwater samples collected from 40MW3, 40MW5, and 40MW6 were used in the COPC screening for groundwater. Refer to Section 4 for complete data tables for detected analytes for each media and disposal area. Additional information regarding the data used in the HHRAs is summarized below:

- Though several dioxins are known to be toxic, toxicity criteria are limited to 2,3,7,8-TCDD. Therefore, the HHRA uses the method outlined in Interim Procedures for Estimating Risks

Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs) (USEPA 1989a and WHO 2005) to assess risks due to exposure to dioxins and/or furans. Each congener is assigned a TEF, which corresponds to its toxicity relative to 2,3,7,8-TCDD. Each congener detection is multiplied by its corresponding TEF; the adjusted concentrations are then summed to derive one total 2,3,7,8-TCDD equivalent concentration for each sample. This concentration is then compared with toxicity criteria for 2,3,7,8-TCDD to calculate risks. TEFs are presented and total 2,3,7,8-TCDD equivalents are calculated for SWMU 40 and SWMU 71 in Table 6-2.

- If a constituent was measured by two methods, results from the more sensitive analytical method were used. For example PAHs were analyzed as part of the SVOC method, as well as, by a PAH specific method. Results from the specific method were used;
- J-flagged data (estimated concentration) and B-flagged data (detected in an associated blank) are considered detections and are used without modification;
- Chemicals that were not detected in at least one sample were considered as uncertain analytes in the evaluation of risk;
- Rejected results (R-flagged) are not used; and
- 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 specific soil and groundwater samples used in the HHRA is provided in Sections 6.1.1.1 and 6.1.1.2.

6.1.1.1 Surface Soil and Total Soil

Soil samples collected during sampling events completed in 2002 and 2006 for the RFI were used for the COPC screenings. As presented in Table 6-1, the soil samples for SWMU 40 and SWMU 71 were segregated and used for the SWMU 40 and SWMU 71 HHRA, respectively. Note that borings 71SB14 and 71SB15 are not located in SWMU 71 but rather located in SWMU 40; therefore, these samples are used in the HHRA for SWMU 40. In Table 6-1, the soil samples for each area have also been divided into surface soil (0 to 1 ft bgs) and subsurface soil (1 to 15 ft bgs). The two soil data groupings used for COPC screening and the HHRA are surface soil (0 to 1 ft bgs) and total soil (0 to 15 ft bgs). Total soil data grouping consists of combining surface and subsurface soil to address mixing of potential soil contamination during construction or land development activities. Soil samples collected a depth of greater than 15 ft bgs were excluded from the HHRA since it is unlikely soil below this depth would be disturbed and mixed with surface soil during excavation. A total of 32 surface soil samples and 32 subsurface soil samples were used for the HHRA for SWMU 40 and a total of 7 surface soil samples and 12 subsurface soil samples were used for the HHRA for SWMU 71.

6.1.1.2 Groundwater

Groundwater samples collected from 40MW3, 40MW5, and 40MW6 during the sampling event completed in 2007 for the RFI were used for the COPC screening.

6.1.2 Identification of COPCs

COPCs were identified for the sites by comparing the maximum detected concentration (MDC) to the following screening levels for each media: USEPA Region III R-RBCs and I-RBCs (surface soil and total soil) and USEPA T-RBCs (groundwater) as presented in the October 2007 USEPA Region III RBC and Alternate RBC Tables (USEPA 2007a). In accordance with USEPA Region III guidance, RBCs for non-carcinogenic chemicals were adjusted downward to a HQ of 0.1 to ensure that chemicals with additive effects were not prematurely eliminated during screening.

For nutrients detected in soil (calcium, potassium, magnesium, and sodium) that have no available RBC, the MDC was compared to the recommended daily allowance (RDA)-derived soil ingestion screening criteria. Table 6-3 presents the equation, exposure parameters, and RDAs used, as well as the calculated screening criteria for the adult resident and child resident receptors. The lowest screening criterion for each nutrient (e.g., the screening criteria for the child resident) was selected as the screening criterion.

In addition, lead ALs of 400 mg/kg for residential receptors and 750 mg/kg for industrial receptors were used in the COPC identification since toxicity criteria were not available for lead (USEPA 1994c).

Analytes detected at a maximum concentration greater than the corresponding adjusted RBC or screening values identified above (or those for which no screening criteria exists) were selected as COPCs. COPC screening tables for each SWMU are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-2.1 (COPC Determination Detects-Surface Soil), E.1-2.2 (COPC Determination Detects-Total Soil), E.1-2.3 (Non-Detect Screening-Soil), E.1-2.4 (COPC Determination Detects-Groundwater), and E.1-2.5 (Non-Detect Screening-Groundwater) for SWMU 40 and Tables E.2-2.1 (COPC Determination Detects-Surface Soil), E.2-2.2 (COPC Determination Detects-Total Soil), E.2-2.3 (Non-Detect Screening-Soil), E.2-2.4 (COPC Determination Detects-Groundwater), and E.2-2.5 (Non-Detect Screening-Groundwater) for SWMU 71. A summary of the results of the human health COPC screenings for the sites are presented in the table below.

Human Health COPCs Identified

Chemical	SWMU 40 Soil		SWMU 71 Soil		Groundwater
	Surface	Total	Surface	Total	
Aluminum	X	X	X	X	
Antimony		X	X	X	
Arsenic	X	X	X	X	
Cadmium		X			
Chromium	X	X	X	X	
Cobalt*	X	X	X	X	
Copper		X			
Iron	X	X	X	X	
Lead		X			
Manganese	X	X	X	X	
Mercury		X			
Thallium	X	X	X	X	
Vanadium	X	X	X	X	
Zinc		X			
Aroclor 1242		X			
Aroclor 1248			X	X	
Aroclor 1254	X	X	X	X	
Aroclor 1260	X	X			
2-Hexanone*	X	X			
4-Methyl-2-Pentanone*	X	X	X	X	
Chloroform					X
Chloromethane*	X	X			
Cyclohexane*	X	X	X	X	

Chemical	SWMU 40		SWMU 71		Groundwater
	Surface	Total	Surface	Total	
Methylcyclohexane*	X	X	X	X	
Di-n-octylphthalate*	X	X		X	
Dimethylphthalate*		X			
Benzo(a)anthracene	X	X			
Benzo(a)pyrene	X	X		X	
Benzo(b)fluoranthene	X	X			
Dibenz(a,h)anthracene	X	X		X	
Indeno(1,2,3-cd)pyrene	X	X			
2,3,7,8-TCDD TEQ	X	X		X	
Nitroglycerin		X			
DRO/GRO		X			

Note: * denotes COPC identified due to no screening value available

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 1989b). 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 conceptual site models (CSMs) for SWMUs 40 and 71 are presented on Figure 6-1. The site is located with a portion of the MMA that is characterized by gently to steeply sloping ridges, the presence of landforms indicative of karst topography (e.g., sinkholes), and a general downward slope toward the northwest. SWMUs 40 and 71 are situated topographically lower than areas to the east, south, and west, and topographically higher than areas to the north. Ground surface topography at the site slopes gently toward the northwest from approximately 1908 ft mean sea level (msl) at SWMU 71 to approximately 1,884 ft msl at the northern edge of the landfill at SWMU 40. At the northern edge of the landfill, the ground surface drops approximately 10 ft along a 1:3 grass covered slope.

Subsurface geology consists of four different strata that were identified, as presented in Section 2.6, including soil fill, landfill material, soil weathered in place from bedrock, and bedrock. Groundwater is present in the underlying bedrock (approximately 90 ft bgs). As previously discussed in Section 2.7.2, monitoring well data indicates that groundwater flow in the site area is to the west toward the New River. Groundwater potentially impacted by the study areas is not currently used as drinking water. Potentially affected media include surface soil, subsurface soil, and groundwater at the sites.

The area surrounding the MMA of RFAAP is not highly developed and land use near the Facility is mostly rural with less rugged areas being used for agriculture. Residential and recreational areas are located adjacent to the RFAAP (IT 2001). It is unlikely, however, that the land use within the MMA will change significantly in the foreseeable future. The MMA contains many buildings and facilities, and is likely to remain industrial in nature.

Neither SWMU is currently active; therefore, maintenance workers are the most likely receptors under current site conditions. Due to installation security, it is unlikely that trespassers could gain access to the SWMUs; however, risks associated with the maintenance worker are considered protective of the limited exposure experienced by the trespasser. Under future site conditions, maintenance workers continue to be receptors and although the development of the areas is unlikely due to the use of the site as a landfill, construction workers and commercial workers may be hypothetical receptors if the area is developed.

RFAAP is likely to remain a military installation; therefore, a residential scenario is considered unlikely. However, the residential scenario was evaluated for both SWMUs to assess clean closure requirements under RCRA.

6.2.2 Identification of Exposure Pathways

The potential receptors identified for the sites include current/future maintenance workers, hypothetical future commercial workers, hypothetical future construction workers, hypothetical future child residents, hypothetical future adult residents, and hypothetical future lifetime residents. Carcinogenic risk is assessed for the hypothetical lifetime resident to account for cumulative lifetime risk. The exposure duration for the lifetime resident scenario is assumed to be 30 years total; therefore, for carcinogens, exposures are combined for hypothetical child resident (6 years) and adult resident (24 years). In Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-1 and E.2-1 summarize the selection of exposure pathways for each SWMU and receptor listing the rationale for the inclusion or exclusion of each pathway. A conceptual site diagram presenting the sources, release mechanisms, pathways, and receptors are presented on Figure 6-2 for SMWU 40 and SWMU 71. The table below summarizes the exposure pathways and media evaluated for each of the potential receptor populations.

Media/Exposure Pathways	Exposure Scenarios			
	Current/Future	Future		
	Maintenance Worker	Commercial Worker	Construction Worker	Resident
Surface Soil				
Ingestion	X			
Dermal Absorption	X			
Inhalation of Fugitive Dust	X			
Inhalation of Outdoor Vapors	X			
Total Soil ⁽¹⁾				
Ingestion	X	X	X	X
Dermal Absorption	X	X	X	X
Inhalation of Fugitive Dust	X	X	X	X
Inhalation of Outdoor Vapors	X	X	X	X
Inhalation of Indoor Vapors		X		X
Groundwater				
Ingestion		X		X
Dermal Absorption		X		X
Inhalation of Outdoor Vapors			X	
Inhalation of Indoor Vapors		X		X
Inhalation of Vapors while Showering ⁽²⁾				X

X = Quantitative Evaluation

⁽¹⁾ The evaluation of total soil assumes that construction, excavation, or other activities “mix” the surface and subsurface soil

⁽²⁾ Inhalation of vapors while showering is evaluated using the adult resident only.

6.2.2.1 Current/Future Land Use Scenario

One receptor, the maintenance worker, was identified under the current land use scenario. The current maintenance worker is assumed to contact surface soil. It is assumed that the maintenance worker scenario is likely to exist in the future; therefore, exposure to total soil is possible if excavation activities occur in the future.

6.2.2.2 Future Land Use Scenario Only

In the event that construction occurs at the sites, soil that was previously found at depth may be brought to the surface and become available to receptors. Therefore, the future hypothetical industrial use scenarios of the construction worker and commercial worker are assumed to come into contact with total soil at the sites. In addition, potential future exposures to groundwater are evaluated in the HHRA. It is assumed that the commercial worker is exposed to groundwater via tap water. The construction worker is only exposed to vapors emanating to ambient air from groundwater beneath excavation trenches.

Although the sites are assumed to remain industrial in nature, the residential scenario is evaluated in this HHRA to meet clean closure requirements under RCRA. Future hypothetical resident is assumed to come into contact with total soil and groundwater.

6.2.3 Calculation of EPCs

To calculate intakes, the mean concentration of each COPC is estimated and is referred to as the EPC. To account for uncertainty when estimating EPCs from sample data, the 95% upper confidence limit of the mean (95% UCL) is used instead of the mean itself (USEPA 1989b). Methods used to calculate 95% UCLs are based on guidance provided in the following documents *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002b) and *On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations* (USEPA 2006).

In general, the method used to calculate a 95% UCL depends on: 1) the number of samples, 2) the prevalence of non-detects, and 3) the data distribution (e.g., normal or lognormal). 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 make for COPCs with a high rate of non-detects. ProUCL 4.0 (USEPA 2007c) is used to calculate EPCs for the sites with the exception of data sets with less than 5% detects for which the MDC was used in the risk assessment. EPCs for soil COPCs are presented in Tables E.1-3.1 and E.1-3.2 of Appendix E.1 (SWMU 40) and Tables E.2-3.1 and E.2-3.2 of Appendix E.2 (SWMU 71). EPC calculations for the sites are included in Appendix C.9. EPCs were not calculated for groundwater; therefore, the MDC for COPCs identified for groundwater were used in the risk assessment.

To address the inhalation of fugitive dust from soil exposure pathway, particulate emission factors (PEFs) were used to derive ambient air EPCs for non-volatile soil COPCs. PEFs were calculated in accordance with the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002c). The PEF calculations are provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.4 and E.2-4.4. To address the inhalation of vapors in outdoor air from soil, a volatilization factor was used to derive ambient air EPC for volatile soil COPCs. The VFs were calculated in accordance with the Supplemental Guidance for Soil Developing Soil Screening Levels for Superfund Sites (USEPA 2002c). The equations used to calculate the volatilization factor to ambient air for VOCs in soil are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.3 and E.2-4.3.

To evaluate inhalation of VOCs from soil and groundwater, EPCs were calculated for VOCs in air using the models as summarized below. The Johnson and Ettinger model (Johnson et al 1991 – updated 2004) was used to estimate indoor air concentrations of volatiles migrating from the soil and into a structure. Spreadsheets for this model were used to estimate air concentrations of VOCs in office buildings and

residences for this HHRA. The spreadsheets are provided in Appendix E.4 and the results provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.5 and E.2-4.5. The Johnson and Ettinger model (Johnson et al 1991 – updated 2004) was also used to estimate indoor air concentrations of volatiles migrating from groundwater through the soil and into a structure. Spreadsheets for this model were used to estimate air concentrations of VOCs in office buildings and residences for this HHRA. The spreadsheet is found in Appendix E.4 and the results provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.7 and E.2-4.7.

EPCs of VOCs in air due to volatilization from groundwater were estimated for a showering scenario, applicable to the adult resident, using the Foster-Chrostowski (1987) shower room model. The model is provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.8 and E.2-4.8.

In the event that excavation work is performed on site, the worker may be exposed to volatile emissions from groundwater below the bottom of the trench. While USEPA does not have a standardized model for estimating concentrations of airborne VOCs in a trench or a pit, the VDEQ provides such a model on their Voluntary Remediation Program (VRP) web site (<http://www.deq.state.va.us/vrprisk/>). The equation and parameters are given in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.9 and E.2-4.9.

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 1989b). 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 1989b).

Intake formulas, exposure parameters, and chemical-specific parameters are provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-4.1 through E.1-4.9 and Tables E.2-4.1 through E.2-4.9. The results of the CDI calculations are presented for each receptor in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-7.1 through E.1-7.7 and Tables E.2-7.1 through E.2-7.7.

6.3 TOXICITY ASSESSMENT

The methodology used for classifying health effects from exposure to chemicals is recommended by USEPA and considers chronic exposures. The chronic toxicity criteria were obtained from the October 2007 USEPA Region III RBC Table (available at <http://www.epa.gov/reg3hwmd/risk/>), which utilizes the following hierarchy:

- Tier 1 – USEPA’s Integrated Risk Information System (IRIS);
- 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;
- Tier 3 - other sources of toxicological reference values that include those from Cal EPA, MRLs from ATSDR, and finally the HEAST toxicity values.

Toxicity criteria used to quantify non-carcinogenic hazards (risk reference doses – RfDs) and carcinogenic risks (e.g., slope factors – CSFs) are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-5.1, E.1-5.2, E.1-6.1, and E.1-6-2 for SWMU 40 and Tables E.2-5.1, E.2-5.2, E.2-6.1, and E.2-6-2 for SWMU 71.

6.3.1 Health Effects Classification and Criteria Development

According to USEPA's science policy, there are two primary approaches to developing toxicity values or health effects criteria. The non-threshold approach is based on USEPA's scientific policy position that a

small number of molecular events can evoke changes in a single cell or a small number of cells. This is described as a non-threshold initiator mechanism because there is essentially no level of exposure (i.e., a threshold) to a constituent that will not result in some finite possibility of causing an adverse effect. Another assumption stemming from USEPA's science policy is that the dose-response curve is linear at low doses. For most carcinogens, toxicity criteria are based on the non-threshold approach.

The threshold approach is based on the assumption that organisms have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before the adverse effect is manifested. For example, an organ can have a large number of cells performing the same or similar functions that must be significantly depleted before the effect on the organ is realized. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable risk of adverse effects. Toxicity criteria for non-carcinogens are based on the threshold approach. Furthermore, as additional information regarding the mechanisms of toxicity becomes available, the threshold approach may also apply to some carcinogens (e.g., chloroform).

6.3.1.1 Cancer Slope Factors

For carcinogens, USEPA estimates the excess lifetime cancer risks associated with various levels of exposure by developing cancer slope factors (CSFs) and unit risks. CSFs are expressed in terms of reciprocal dose, as units of: $(\text{mg chemical/kg body weight} \cdot \text{day})^{-1}$, and describe the upper-bound increase in an individual's risk of developing cancer over a 70-year lifetime per unit of exposure. Unit risks are expressed either as a reciprocal air concentration, in units of micrograms per meter cubed $(\mu\text{g}/\text{m}^3)^{-1}$ or as a reciprocal drinking water concentration, in units of micrograms per liter $(\mu\text{g}/\text{L})^{-1}$. Similarly, they are defined as the probability of an individual developing cancer over a 70-year lifetime from exposure to one unit of concentration in air or water. Because regulatory efforts are geared to be protective of public health, including even the most sensitive members of the population, the CSFs are derived using conservative assumptions.

CSFs and unit risks are derived from the results of human epidemiological studies or chronic animal bioassays. Animal studies usually must be conducted using relatively high doses to detect possible adverse effects. Because humans are expected to be exposed to doses lower than doses used in the animal studies, the potential cancer risks at lower doses are estimated by using mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response relationship. In general, after the data are fit to the dose-response model, the 95% UCL of the slope of the resulting dose-response relationship at low doses is calculated. This upper-bound limit is subjected to various adjustments and an interspecies scaling factor is applied to derive the slope factor or unit risk for humans. Thus, the actual risks associated with a given intake of a potential carcinogen quantitatively evaluated based on animal data are generally regarded as not likely to exceed the risks estimated using these CSFs or unit risks and they may be as low as zero (USEPA 1986b). Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. CSFs and unit risks based on human epidemiological data are derived using conservative assumptions and are unlikely to underestimate risks for a given level of exposure.

Weight-of-evidence categories represent an assessment of the amount and quality of the data, which support the finding that specific chemicals and elements can cause cancer in humans. Although USEPA's guideline for carcinogen risk assessment (USEPA 1996) proposes a weight-of-evidence narrative, IRIS currently uses the original alphanumeric classification. Under the existing guidelines (USEPA 1986a), chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A includes those substances for which high-quality studies have demonstrated a relationship between the exposure to the substance in question and the development of cancer in human populations. Groups B1, B2, and C represent chemicals with limited (B1) or insufficient (B2) human evidence of carcinogenicity, and sufficient (B1, B2) or insufficient (C) animal data. Group D substances are those for which there is

insufficient evidence or not evidence of carcinogenicity in humans or animals and Group E substances are those not having evidence of carcinogenicity available in adequate human or animal studies.

6.3.1.2 Reference Doses and Reference Concentrations

Toxicity criteria for non-carcinogens are generally developed using verified risk reference doses (RfDs) and reference concentrations (RfCs). These are developed by USEPA and listed in IRIS or can be obtained from HEAST (USEPA 1997c) and supplements. RfDs are expressed in units of dose (mg chemical/kg body weight-day) and are usually derived either from human studies involving workplace exposures or from animal studies. In addition, RfDs are estimates (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is used as a reference point for gauging the potential effects of exposures. Usually, exposures (as chemical intakes or doses) that are less than the RfD are not likely to be associated with adverse health effects.

RfDs are developed for both chronic and sub-chronic exposures. Chronic RfDs are presented in IRIS or HEAST and are intended for use in evaluating exposures of durations greater than seven years. Sub-chronic RfDs are developed by USEPA's NCEA and are used to characterize the potential for the occurrence of non-carcinogenic effects associated with short-term exposures [two weeks to seven years as defined by USEPA (1989b)]. The sub-chronic RfDs are developed similarly to chronic RfDs and are typically equal to chronic RfDs or are an order of magnitude greater (less stringent). Sub-chronic RfDs are presented in HEAST but are no longer being reviewed and updated in the same manner as IRIS. Because there is greater uncertainty associated with the sub-chronic RfDs, chronic RfDs have been used in this HHRA.

RfDs are derived using uncertainty factors that reflect scientific judgment regarding the various types of data used to estimate the RfD. RfDs are typically estimated from no observable adverse effect levels (NOAELs) or lowest observable adverse effect levels (LOAELs) in human or animal studies. Uncertainty factors, generally 10-fold factors, are intended to account for:

- The variation in sensitivity among members of the human population;
- The uncertainty in extrapolating animal data to the case of humans;
- The uncertainty in extrapolating from data obtained in a study that is less-than-lifetime exposure;
- The uncertainty in using LOAEL data, when necessary, rather than NOAEL data; and
- The inability of a single study to adequately address every possible adverse outcome in humans.

To derive RfDs, NOAELs or LOAELs are divided by one or more uncertainty factors, as appropriate. When taken together, these uncertainty factors may confer an extra margin of safety of up to a factor of 10,000 below a LOAEL. In some cases, modifying factors are also applied to RfDs to take into account other uncertainties in the toxicity database and reflect the professional judgment of those reviewing the database. The net result is that RfDs are generally considered to provide a conservative estimate of the likelihood of adverse non-carcinogenic effects.

6.3.1.3 Adjustment for Dermal Absorption

Toxicity criteria have not been developed by USEPA specifically for dermal absorption; instead, oral toxicity criteria are adjusted to assess this pathway. In order to have a meaningful comparison between the dermal absorption dose estimates, which represent internal (or absorbed) doses, and oral toxicity criteria, which typically represent potential (or administered) doses, toxicity criteria are modified to represent absorbed doses. The method for modifying toxicity criteria involves calculation of an absolute oral absorption factor for each chemical and use of this value to increase the chemical's CSF or to decrease the chemical's RfD, as shown in the following equations:

- Adjusted Dermal CSF = CSF/Absolute oral absorption factor
- Adjusted Dermal RfD = RfD x Absolute oral absorption factor

The absolute oral absorption factors should reflect the specific conditions under which the toxicological study was conducted (e.g., method of administration such as gavage, water or diet, and vehicle of administration such as solvent or solution). The absolute oral absorption factors and adjusted toxicity criteria for the COPCs used when evaluating dermal absorption are presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-5.1 and E.1-6.1 and Tables E.2-5.1 and E.2-6.1, respectively. The adjusted CSFs and RfDs presented in these tables were used to evaluate potential risks associated with dermal absorption.

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 (1989b).

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. In addition, carcinogenic risk for the residential scenario for carcinogens that act via a mutagenic mode of action (i.e., benzo(a)pyrene) as identified in the October 2007 Region III RBC table were evaluated utilizing default age-dependant adjustment factors in accordance with the Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (USEPA 2005a).

Non-carcinogenic adverse health effects are calculated by dividing the CDI of each COPC by its RfD, forming a HQ. HQs greater than one (1) 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 a Hazard Index (HI). As with HQs, HIs that are greater than 1 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 child and adult residents independently.

Excess lifetime cancer risks derived in this report are compared to USEPA's target risk range for Superfund sites of 1E-06 to 1E-04 (USEPA 1989b). 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 1E-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 presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71) in Tables E.1-7.1 – E.1-7.7 and E.2-7.1 – E.2-7.7. A refinement of the HIs based on target organs is conducted. As shown in Appendices E.1 (SWMU 40) and E.2 (SWMU 71) in Tables E.1-9.1 – E.1-9.7 and E.2-9.1 – E.2-9.7, the refinement consists of calculating HIs based on a target organ-specific basis. In addition in Appendices E.1 (SWMU 40) and E.2 (SWMU 71), Tables E.1-10.1 – E.1-10.2 and E.2-10.1 – E.2-10.2 summarize risks and hazards for risk/HI drivers (i.e., those COPCs contributing to a total risk greater than 1E-04 or a total target organ hazard greater than 1).

Risks and hazards presented in Appendices E.1 (SWMU 40) and E.2 (SWMU 71) in Tables E.1-9.1 – E.1-9.7 and E.2-9.1 – E.2-9.7 are summarized in the tables below.

SWMU 40 – Summary of Risks and Hazards

Timeframe/Receptor	Risk	HI	Risk Drivers	Target Organ Segregation HI>1
Current/Future Maintenance Worker (Surface Soil)	3.E-06	0.08	None	None
Hypothetical Future Maintenance Worker (Total Soil)	4.E-06	0.4	None	None
Hypothetical Future Commercial Worker	1.E-05	1	None	None
Hypothetical Future Construction Worker	9.E-06	15	None	Vascular (HI=5) – Soil (As – Ing (0.2), Nitroglycerin – Ing (4.3)) CNS (HI=9) – Soil (Al – Inh (4), Mn – Inh (5))
Hypothetical Future Adult Resident	See Lifetime Resident	4	NA	Vascular (HI=2) – Soil (Nitroglycerin – Ing (2))
Hypothetical Future Child Resident	See Lifetime Resident	26	NA	GI Tract (HI=4) – Soil (Cr-Ing/Derm (0.5), Cu-Ing (2.5), Fe-Ing (0.7)) Vascular (HI=18) – Soil (As - Ing (1), Nitroglycerin – Ing (17)) Kidney (HI=2) – Soil (V – Ing/Derm (1)) (Methylcyclohexane – Inh (1))
Hypothetical Lifetime Resident	3.E-04	NA	Soil – Arsenic and PCBs Groundwater - Chloroform	NA

Note: NA = Not Applicable

HI = Hazard Index

CNS = Central Nervous System

Bold = Exceeds USEPA Risk or Hazard Range

Al = Aluminum, As = Arsenic, Cr – Chromium, Cu = Copper, Fe = Iron, Mn = Manganese, V = Vanadium,

Ing = Ingestion, Inh = Inhalation, Derm = Dermal

SWMU 71 – Summary of Risks and Hazards

Timeframe/Receptor	Risk	HI	Risk Drivers	Target Organ Segregation HI>1
Current/Future Maintenance Worker (Surface Soil)	2.E-06	0.07	None	None
Hypothetical Future Maintenance Worker (Total Soil)	1.E-06	0.08	None	None
Hypothetical Future Commercial Worker	4.E-06	0.3	None	None
Hypothetical Future Construction Worker	4.E-06	5	None	CNS (HI=4) – Soil (Al – Inh (2), Mn – Inh (2))
Hypothetical Future Adult Resident	See Lifetime Resident	1	NA	None
Hypothetical Future Child Resident	See Lifetime Resident	5	NA	Liver (HI=2) – Soil (Cr – Ing/Derm (0.6), Fe - Ing (0.7), Tl - Ing (0.07)) Groundwater – Chloroform – Ing (0.2)) Kidney (HI=2) – Soil (V - Ing/Derm (2))
Hypothetical Lifetime Resident	2.E-04	NA	Groundwater - Chloroform	NA

Note: NA = Not Applicable

HI = Hazard Index

CNS = Central Nervous System

Bold = Exceeds USEPA Risk or Hazard Range

Al = Aluminum, Cr = Chromium, Fe = Iron, Mn = Manganese, Tl = Thallium, V=Vanadium

Ing = Ingestion, Inh = Inhalation

6.4.1 Lead Exposure Assessment

The MDCs for lead in surface soil and total soil for SWMU 40 were above the lead screening level of 400 mg/kg, and therefore, the potential hazard associated with lead was evaluated using the Integrated Exposure Uptake Biokinetic (IEUBK) model for the child resident scenario (USEPA 2007d) and the EPA Adult Lead Model (USEPA 2005b) for adult workers. Lead concentrations in surface and total soil for SWMU 71 were below the lead screening level of 400 mg/kg; therefore, additional lead modeling was not completed for the site.

Site-specific lead exposures were evaluated for residential exposures at SWMU 40 using the IEUBK model. This calculation was based on the site-specific mean concentration of lead detected in total soil (54.8 mg/kg) and the maximum detected lead concentration in groundwater (0.51 µg/L). The results of the model are presented in Appendix E.1. The corresponding input parameters and distribution probability plot are also provided in the Appendix E.1. The results of the modeling presented in Appendix E.1 predict the probability of children expected to have blood levels of 10 gram per deciliter (g/dL) or greater. The lead risks are considered unacceptable if the child-blood lead level for more than 5% of children is estimated to equal or exceed the Center for Disease Control and Prevention (CDCP) concern threshold of 10 g/dL.

USEPA developed a physiologically-based pharmacokinetic adult lead model (ALM) (version 05/19/2003) that can be applied to adult worker receptors. The ALM is currently the accepted and standard model to assess adult non-residential exposures to lead in soil and indoor dust. The model uses a simplified representation of lead biokinetics to predict quasi steady-state blood level concentrations among adults who have relatively steady patterns of site exposures. The methodology focuses on estimating fetal blood lead concentrations in female workers. All of the equations in the model are used to calculate target concentrations based on the probability of exceeding a blood lead level of 10 g/dL for a fetus. Lead risks are considered unacceptable for a non-residential (worker) receptor if the fetal blood lead level for more than 5% of fetuses of adult female workers is estimated to equal or exceed the CDCP concern threshold of 10 g/dL. The ALM is used to evaluate risks of lead exposure to the fetus of pregnant female industrial workers, construction workers, and other workers that are identified as relevant receptors at a site.

6.4.1.1 Lead Exposure Assessment - SWMU 40

Default parameters were utilized for the ALM model with the following ingestion rates and exposure frequencies: maintenance worker – ingestion rate (100 mg/day) and exposure frequency (219 days), commercial worker – ingestion rate (50 mg/day) and exposure frequency (250 days), and construction worker – ingestion rate (330 mg/day) and exposure frequency (250 days). Default parameters were used for the IEUBK model. The arithmetic means for lead in surface soil (27.5 mg/kg) and total soil (54.8 mg/kg) were used in the models for the maintenance worker and the arithmetic mean for lead in total soil (54.8 mg/kg) was used in the models for the remaining potential receptors. The lead modeling predicts the probability of the receptors to have blood levels of 10 microgram per deciliter or greater. This probability is then compared to an established threshold of 5%. The results of the modeling for SWMU 40 is presented in Appendix E.1 and summarized below:

- Current/Future Maintenance Worker (Surface Soil): 1.4% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Maintenance Worker (Total Soil): 1.6% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Construction Worker: 2.9% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Commercial Worker: 1.4% probability that fetal blood levels would exceed 10 g/dL (<5%);
- Hypothetical Future Child resident: 0.014% probability that child blood levels would exceed 10 g/dL (<5%).

The results of the lead modeling predicted the probability of the receptors for SWMU 40 expected to have blood levels of 10 microgram per deciliter or greater were below the established threshold of 5%.

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 both SWMU 40 and SWMU 71, a “margin of exposure evaluation” was conducted for the sites. This evaluation consists of a comparison of estimated intake of iron to the RDA and concentrations known to cause adverse health effects in children (USEPA 2001).

For the margin of exposure evaluation, the estimated iron intakes at the sites for a future resident child scenario for surface soil and total soil are calculated using the assumptions and equations provided in Appendices E.1 (SWMU 40) and E.2 (SWMU 71). These estimated iron intake levels are then compared to the RDA for children (6 months to 10 years old) of 10 mg/day (NCEA 2006). In addition, using an average child weight of 15 kg (USEPA 1989b), the child intakes for surface soil and total soil are

calculated and compared to the calculated provisional (risk reference dose) RfD of 0.7 mg/kg-day. The results of the margin of exposure evaluation are summarized in the table below.

Results of Iron Margin of Exposure Evaluation

	Iron EPC (mg/kg)	RDA Evaluation			Provisional Risk Reference Dose (RfD) Evaluation		
		Child Daily Intake Estimate (mg/day)	RDA (mg/day)	Result	Child Daily Intake (mg/kg-day)	Calculated Provisional RfD (mg/kg-day)	Result
SWMU 40 - Total Soil	37,114	7.1	10	<RDA	0.48	0.7	<RfD
SWMU 71 -Total Soil	39,796	7.6	10	<RDA	0.51	0.7	<RfD

The iron exposure assessment results for the hypothetical future child resident were below the applicable iron margin of exposure screening criteria for both SWMU 40 and SWMU 71.

6.4.3 Background

Statistical evaluations were conducted to compare metals concentrations in soil at SWMUs 40 and 71 to 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 2002a) and included distribution testing and comparisons of site data to background using ProUCL 4.0. At SWMUs 40 and 71, if the distribution testing showed that either site data sets and background data sets in each case were not normal, consistent with Section 4.1 of the above referenced USEPA guidance, comparisons of site to background were conducted using non-parametric testing to evaluate whether site concentrations were consistently higher or lower than the background data set. If the distribution of the site and background data sets were both distributed normally, a paired t-test was conducted to evaluate whether site concentrations were consistently higher or lower than the background data set. Appendix C.10 presents results of the statistical evaluations.

Based on the background evaluations presented in Appendix C.10, COPCs identified for SWMU 40 that exceed background include aluminum for surface soil and aluminum, arsenic, cadmium, and zinc for total soil. The COPC identified for SWMU 71 that exceeds background is arsenic for surface soil. Note that background comparisons could not be conducted for antimony, mercury, and thallium due to the number of detections in the background data set.

6.4.4 SWMUs 40 and 71 HHRA Summary

6.4.4.1 SWMU 40 HHRA Summary

The total risk for each receptor is below or within USEPA's target risk range for Superfund sites (1E-06 to 1E-04, USEPA 1989b) with the exception of the hypothetical future lifetime resident due primarily to arsenic and PCBs in soil and chloroform in groundwater. The iron exposure assessment results for the hypothetical future child resident were below the applicable iron margin of exposure screening criteria for SWMU 40. The results of the lead modeling predicted the probability of the receptors for SWMU 40 expected to have blood levels of 10 microgram per deciliter or greater were below the established threshold of 5%. The total HIs after target organ segregation for all receptors are equal to or below the USEPA reference HI of 1E+00 with the exception of the hypothetical future construction worker (Central Nervous System (CNS) and vascular), the hypothetical future adult resident (vascular), and the

hypothetical future child resident (GI tract, vascular, and kidney). The site-related hazards are further characterized as follows:

Hypothetical Future Construction Worker

The vascular HI of 5 for the hypothetical future construction worker is primarily due to nitroglycerin (HQ=4.3) in soil which was detected 1 of 53 samples. Due to the frequency of detection of nitroglycerin (<2% detects) and the concentration of the detection 130 mg/kg, nitroglycerin is not considered a COC for the site.

The site-related CNS HI for the hypothetical future construction worker, when excluding metal hazard drivers below background (manganese), is 4E+00 with aluminum as the remaining hazard driver for this target organ.

Hypothetical Future Adult Resident

The vascular HI of 2 for the hypothetical future adult resident is primarily due to nitroglycerin (HQ=2) in soil which was detected 1 of 53 samples. Due to the frequency of detection of nitroglycerin (<2% detects) and the concentration of the detection 130 mg/kg, nitroglycerin is not considered a COC for the site.

Hypothetical Future Child Resident

The primary hazard drivers for the elevated target organ specific GI tract HI for the hypothetical future child resident are chromium, copper, and iron in total soil, but these chemicals are below background; therefore, the hazard is not considered site-related.

The vascular HI of 18 for the hypothetical future child resident is primarily due to nitroglycerin (HQ=17) in soil which was detected 1 of 53 samples. Due to the frequency of detection of nitroglycerin (<2% detects) and the concentration of the detection 130 mg/kg, nitroglycerin is not considered a COC for the site. The site-related vascular HI, when excluding nitroglycerin, is 1E+00 which is equal to the USEPA reference HI of 1E+00.

The site-related kidney HI for child resident, when excluding metals hazard drivers detected below background (vanadium), is 1E+00 primarily due to methylcyclohexane in soil which is equal to the USEPA reference HI of 1E+00.

6.4.4.2 SWMU 71 HHRA Summary

As presented in Section 6.4, the total risk for each receptor is below or within USEPA's target risk range for Superfund sites (1E-06 to 1E-04, USEPA 1989b) with the exception of the hypothetical future lifetime resident due primarily to chloroform in groundwater. The iron exposure assessment results for the hypothetical future child resident were below the applicable iron margin of exposure screening criteria for SWMU 71. Lead concentrations in surface and total soil for SWMU 71 were below the lead screening level of 400 mg/kg; therefore, additional lead modeling was not completed for the site. The total HIs after target organ segregation for all receptors except for the hypothetical future construction worker (CNS) and hypothetical future child resident (liver and kidney) are equal to or below the USEPA reference HI of 1E+00. The site-related hazards are further characterized as follows:

Hypothetical Future Construction Worker

The primary hazard drivers for the elevated target organ specific CNS HI for the hypothetical future construction worker were aluminum and manganese in total soil, but both these chemicals were below background; therefore, the hazard is not considered site-related.

Hypothetical Future Child Resident

The site-related liver HI for hypothetical future child resident, when excluding metals hazard drivers detected below background (chromium and iron), is 3E-01, which is below the USEPA reference HI of 1E+00.

The primary hazard drivers for the elevated target organ specific kidney HI for the hypothetical future child resident was vanadium in total soil, but this chemical was below background; therefore, the hazard is not considered site-related.

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 SWMU 40 and SWMU 71, 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 at the SWMUs. 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. These data were retained in the HHRA without modification. The inclusion of "B" qualified data in the risk assessment may overestimate risk.

Another uncertainty associated with sampling and analysis concerns the inclusion of chemicals that are potentially present in the environment due to anthropogenic sources. For example, PAHs are considered ubiquitous in soil from anthropogenic sources, such as the burning of fossil fuels, forest fires, and airborne particulates eroded from roadways and automobile tires. If such chemicals are not site-related, the risks associated with the site may be overestimated. This uncertainty may have a low-to-moderate effect on overestimating risks.

6.5.2 Selection of Chemicals for Evaluation

A comparison of maximum detected chemical concentrations to USEPA Region III RBCs was conducted for both surface and total soil. Chemicals whose maximum concentrations were below their respective RBCs 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 RBCs. 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 exceed their respective RBCs) and the cumulative risk estimates would not be expected to be significantly greater. As presented on the non-detect MDL screening tables in Appendices E.1 (SWMU 40), Tables E.1-2.3 and E.1-2.5, and E.2 (SWMU 71), Tables E.2-2.3 and E.2-2.5 (SWMU 71), the maximum MDL exceeded the adjusted RBCs for several chemical in soil and groundwater; therefore, the site-related risks and hazards could be underestimated for the risk assessments due to inadequate detection limits.

Background concentrations of metals in soil at RFAAP have been characterized and are used in statistical comparisons to site soil to evaluate whether concentrations of metals detected at SWMU 40 and SWMU 71 are consistently higher or lower than background. Uncertainties associated with the use of these data may lead to a low-to-moderate overestimation or underestimation of surface and total soil risks due to metals.

Screening criteria are derived from RDAs for essential human dietary minerals, trace elements, and electrolytes that are toxic at very high doses (i.e., calcium, magnesium, potassium, and sodium). 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 exposure point concentrations, 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.

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 over estimate risks, depending 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, one half of the MDL was sometimes used for non-detect samples in the calculation of the 95% UCL of the mean. Approaches which substitutes 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. The uncertainty of the exposure point concentration will increase as the number of non-detects in a data set increases and the uncertainty could result in either the overestimation or underestimation of EPCs.

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 (e.g., exposures were assumed to occur for 25 years for workers). In addition, many USEPA (1991a) 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% bioavailable; this assumes that ingested chemicals present in a soil matrix are absorbed through the gastrointestinal (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 *Risk Assessment Guidance for Superfund (RAGS): Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA 2004). 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 1999b) indicates cadmium is not known to result in human health effects by dermal absorption because virtually zero cadmium 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 (ATSDR 1999a). Therefore, using the dermal absorption factors to evaluate dermal absorption exposures to soil may result in an overestimation of risks.

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 1986a), 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% 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. More refined modeling in the area of dose response calculation (e.g., using maximum likelihood dose response values rather than the 95% 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. This HHRA does not use oral-based toxicity criteria to estimate risks from inhalation exposure because of the following uncertainties 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). For example, orally administered benzo(a)pyrene is associated with benign and malignant tumors in the gut mucosa (Neal and Rigdon 1967), but inhaled benzo(a)pyrene produces an increased incidence of upper respiratory tract tumors (Thyssen et al. 1981). Therefore, quantitative risk estimates based on these two administration routes are dissimilar;
- 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 (μm) 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;
- Because highly soluble gases (e.g., chloroform) are more rapidly absorbed into the blood than poorly soluble gases (e.g., ethylene), they take much longer to reach equilibrium. Thus, the inhalation absorption rate of a gas is more dependent on blood solubility than the oral absorption rate of the same substance administered as a liquid; and
- 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 fore 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.

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; and
- 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 Integrated Risk Information System (IRIS) toxicity criteria, provisional toxicity criteria were used where available (Appendices E.1 and E.2 - Tables E.1-5.1 through E.1-6.2 and Tables E.2-5.1 through E.2-6.2). Provisional toxicity criteria present a source of uncertainty, since USEPA has evaluated the compound, but consensus has not been established on the toxicity criteria. Provisional oral toxicity values were used for aluminum, antimony, arsenic, chromium, cobalt, copper, iron, thallium, vanadium, zinc, Aroclor 1254, chloroform, 2-hexanone, di-n-octylphthalate, nitroglycerin, and 2,3,7,8-TCDD equivalents. For this assessment, use of provisional toxicity criteria was preferable to not evaluating the chemical in order to limit data gaps. However, because these toxicity criteria have not been formally accepted by USEPA, there is uncertainty with these values and, therefore, with the risks calculated using these toxicity criteria.

Some detected constituents (cobalt, 2-hexanone, 4-methyl-2-pentanone, chloromethane, cyclohexane, methylcyclohexane, di-n-octylphthalate, and dimethylphthalate) do not have USEPA Region III RBCs and were therefore carried forward as COPCs into the HHRA. Provisional/surrogate toxicity values were researched for these COPCs and cancer risk/non-cancer hazard calculations were derived. It is undetermined if the uncertainty is biased high or low for these COPCs because of the provisional nature of the toxicity data used. However, these COPCs are addressed quantitatively in the HHRA using what little toxicity data are available to reduce the level of uncertainty associated with the risk assessment results.

For some chemicals, toxicity criteria were unavailable (Appendices E.1 and E.2 - Tables E.1-5.1 through E.1-6.2 and Tables E.2-5.1 through E.2-6.2).

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 causes minor differences between summed risk and hazard values, depending on how the summing is performed. For example, RAGS Table 7s in Appendix E presents risks and hazards that are summed for exposure route, exposure point, exposure medium, and medium total. Only for the first (exposure route) are the individual chemical-specific risks and hazards summed to derive 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 minor rounding-related differences between the 'same' values presented in RAGS Table 9s and 10s in Appendix E.

6.6 HHRA CONCLUSIONS

This HHRA was performed to evaluate the potential human health effects associated with previous activities at the SWMUs. Receptors evaluated for both areas included: current/future maintenance worker, hypothetical future construction worker, hypothetical future commercial worker, hypothetical future adult resident, hypothetical future child resident, and hypothetical future lifetime resident.

6.6.1 SWMU 40 HHRA Conclusions

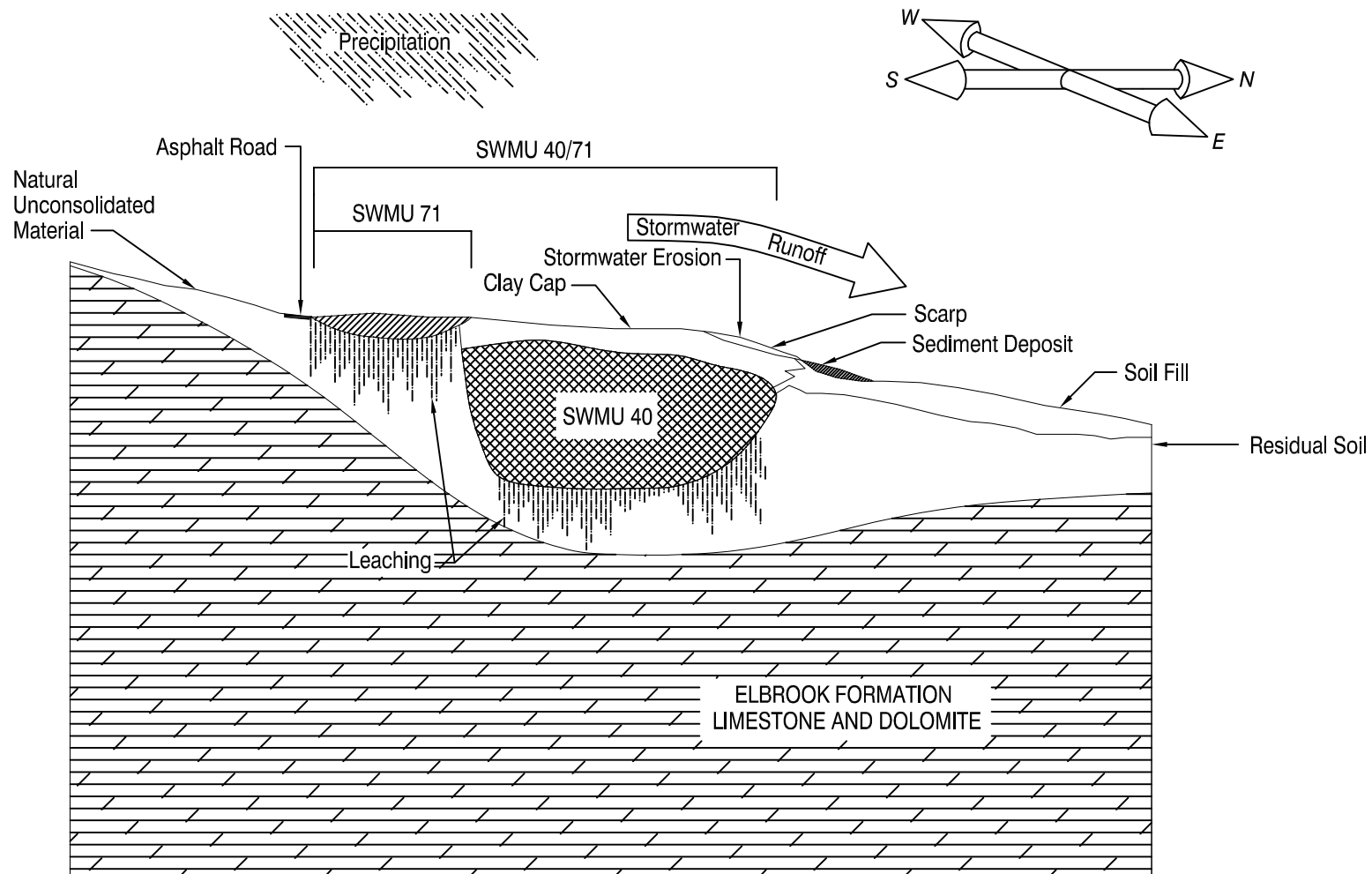
In summary for SWMU 40, the results of the risk assessment indicate that the calculated cancer risks and hazards (when taking target organs and background into consideration) are within USEPA target ranges for each of the receptors evaluated with the exception of cumulative risk for the hypothetical future lifetime resident due primarily to arsenic and PCBs in soil and chloroform in groundwater and hazard for

the hypothetical future construction worker (CNS due to aluminum in soil via the inhalation pathway). Extensive source characterization was conducted at SWMUs 40 and 71 including the collection of 91 soil samples many of which were collected from landfill material and soil below the landfill material at SWMU 40. Chloroform was not detected in these samples. The lack of any detections and absence of other volatiles in groundwater samples suggests a potential alternate source for chloroform in groundwater. Studies and groundwater investigations have shown the presence of chloroform in most groundwater samples collected at the facility regardless of location. The concentrations of chloroform detected in monitoring wells at SWMUs 40 and 71 are within the range of chloroform levels present in the water transmitted through water lines at the facility. The landfill area is located downgradient of developed areas containing water lines that could be leaking, which may have been the source of chloroform. Based on the historical use of SWMU 40 (i.e., sanitary landfill), chloroform could be a potential site-related groundwater COPC, but it should be noted that no source of chloroform has been identified within the landfill material or soil beneath the landfill material at SWMU 40.

6.6.2 SWMU 71 HHRA Conclusions

In summary for SWMU 71, the results of the risk assessment indicate that the calculated site-related cancer risks and hazards (when taking target organs and background into consideration) are within USEPA target ranges for each of the receptors evaluated with the exception of the hypothetical future lifetime resident due primarily to chloroform in groundwater. Based on the historical use of SWMU 71 (i.e., flash and burn area), the site-related soil COPCs identified (metals), and the small size of the site, chloroform is not considered a site-related COPC in groundwater for SWMU 71.

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CONCEPTUAL DRAWING - NO SCALE IMPLIED

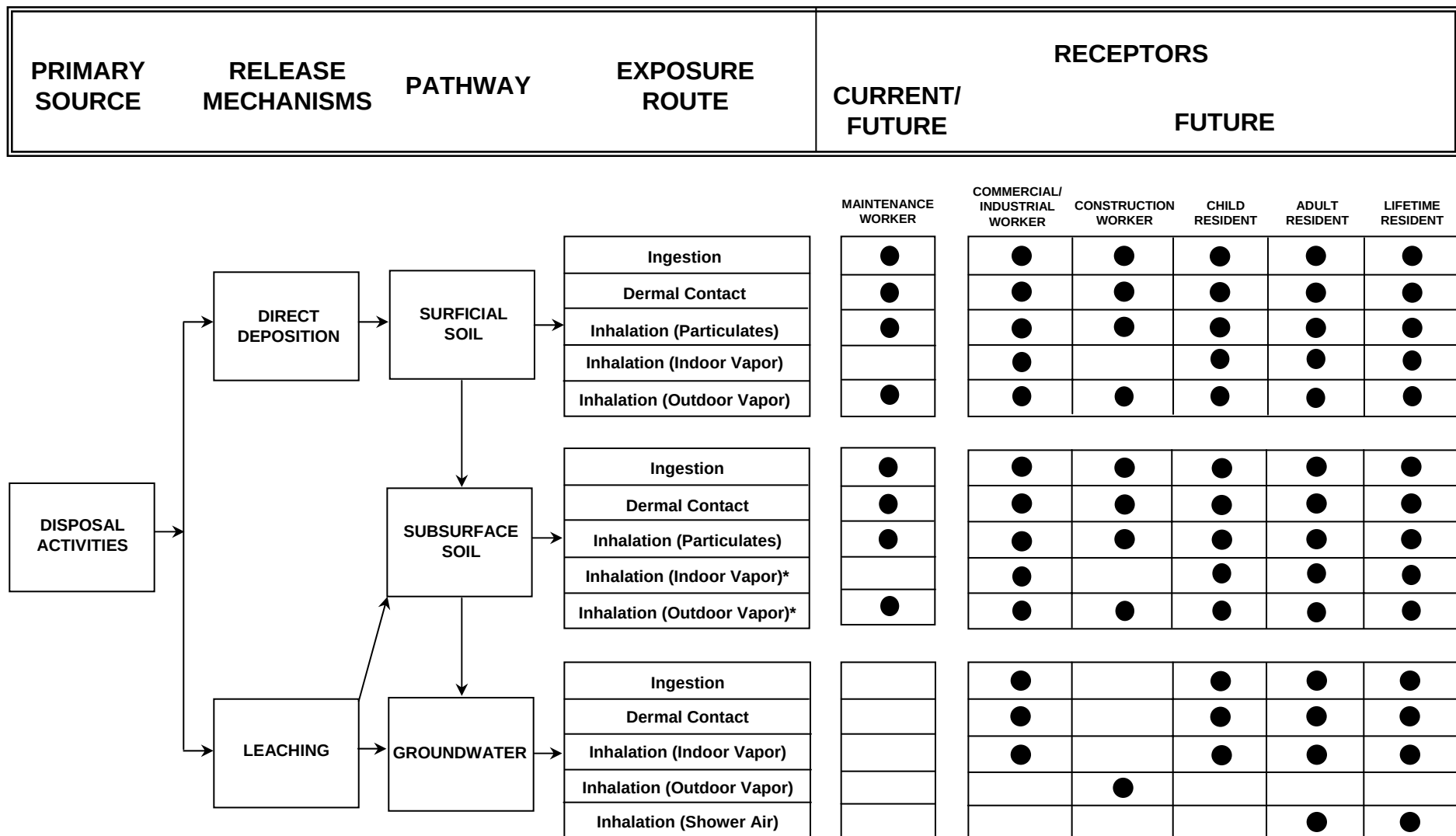
FIGURE 6-1
Conceptual Site Model

SWMU's 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia

Date: February 2008	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: Not to Scale	File Name: Fig. 6-1 CSM



URS Group, Inc.
5540 Falmouth Street
Suite 201
Richmond, Virginia 23230



● Potentially complete pathway assessed quantitatively

FIGURE 6-2
Conceptual Site Diagram

Date: January 2009	URS Project#: 11656351
Prepared by: CLD	Approved by: JOS
Scale: Not to Scale	File Name: Fig.6-2 CSD

SWMUs 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia



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Richmond, VA 23230

Table 6-1
Sample Assemblages for Soil COPC Screening
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

SWMU 40				
Surface Soil				
40SB1A	40SB8A	40SS3	40SS10	40SS17
40SB2A	40SB9A	40SS4	40SS11	40SS18
40SB3A	40SB10A	40SS5	40SS12	71SB14A
40SB4A	40SB12A	40SS6	40SS13	71SB15A
40SB5A	40SB13A	40SS7	40SS14	
40SB6A	40SS1	40SS8	40SS15	
40SB7A	40SS2	40SS9	40SS16	
Subsurface Soil				
40SB1B	40SB4F	40SB10B	TESTPIT1F	
40SB1C	40SB5C	40SB10C	TESTPIT1F2	
40SB1F	40SB5F	40SB10F	TESTPIT2BP	
40SB2B	40SB6C	40SB11B	TESTPIT2F	
40SB2C	40SB6F	40SB11F	71SB14B	
40SB2F	40SB7F	40SB12B	71SB14C	
40SB3B	40SB8F	40SB13B	71SB15B	
40SB3C	40SB9F	40SB13C	71SB15C	
Samples Collected at a Depth >15' Excluded from HHRA				
40SB4B	40SB12C			
40SB4C				
40SB7B				
40SB7C				
40SB8C				
40SB9C				
40SB11C				
SWMU 71				
Surface Soil				
71SS11				
71SS12				
71SS13				
71SB11A				
71SB12A				
71SB13A				
71SB16A				
Subsurface Soil				
71SS11B	71SB16B			
71SS12B	71SB16C			
71SS13B				
71SB11B				
71SB11C				
71SB11F				
71SB12B				
71SB12C				
71SB13B				
71SB13C				
Samples Collected at a Depth >15' Excluded from HHRA				
NONE				

Table 6-2
Dioxin/Furan 2,3,7,8-TCDD Equivalents Calculation - Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	C/N	Adjusted Soil RBC (Residential)	Adjusted Soil RBC (Industrial)	Soil to Groundwater SSL (DAF 20)	TEF	40SS4 11/11/2002 0-1		40SS5 11/11/2002 0-1		TESTPIT2F 11/11/2002 6		71SS11 11/11/2002 0-1		71SB11B 11/11/2002 13-16		71SS13 11/11/2002 0-1	
							Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r	Result	LQ, VQ, r
Dioxin/Furans (pg/g)																		
1,2,3,4,6,7,8,9-OCDD (OCDD)	3268-87-9	--	--	--	--	0.0003	1,640		248		7250	E,J,q	438		2,470		1,050	
1,2,3,4,6,7,8,9-OCDF (OCDF)	39001-02-0	--	--	--	--	0.0003	151		13.6		124		9.8	J	87.6		35.5	
1,2,3,4,6,7,8-HpCDD	35822-39-4	--	--	--	--	0.01	218		26.6		431		53.6		226		89.9	
1,2,3,4,6,7,8-HpCDF	67562-39-4	--	--	--	--	0.01	48.2		4	J	44.3		5.4		34.3		10.3	
1,2,3,4,7,8,9-HpCDF	55673-89-7	--	--	--	--	0.01	4.6	J	<5		2.9	J	<5		<5		<5	
1,2,3,4,7,8-HxCDD	39227-28-6	--	--	--	--	0.1	2.1	MJ	<5		1.3	J	1.2	J	<5		1.5	J
1,2,3,4,7,8-HxCDF	70648-26-9	--	--	--	--	0.1	2.4	MJ	<5		2.3	JB	1.3	J	4.3	J	2.3	J
1,2,3,6,7,8-HxCDD	57653-85-7	--	--	--	--	0.1	6.3		<5		10.6		2.3	J	10.1		3	J
1,2,3,6,7,8-HxCDF	57117-44-9	--	--	--	--	0.1	2	J	<5		1.1	J	<5		2.1	J	0.96	J
1,2,3,7,8,9-HxCDD	19408-74-3	C	1.0E+02	4.6E+02	--	0.1	5.5		<5		3.9	J	3.6	J	5.5		3.4	J
1,2,3,7,8,9-HxCDF	72918-21-9	--	--	--	--	0.1	<5		<5		<4.9		<5		<5		<5	
1,2,3,7,8-PeCDD	40321-76-4	--	--	--	--	1	1.3	MJ	<5		<4.9		1.1	J	<5		0.74	J
1,2,3,7,8-PeCDF	57117-41-6	--	--	--	--	0.03	11.5	MX,J,w	0.79	MX,J,w	<4.9		1.7	MX,J,w	<5		<5	
2,3,4,6,7,8-HxCDF	60851-34-5	--	--	--	--	0.1	3.1	J	<5		1.2	MJ	0.6	J	1.7	MJ	0.99	J
2,3,4,7,8-PeCDF	57117-31-4	--	--	--	--	0.3	0.37	J	<5		0.38	MJ	0.64	J	1.2	J,J,I	0.76	J,J,I
2,3,7,8-TCDD	1746-01-6	C	4.3E+00	1.9E+01	8.6E+00	1	<1		<1		<1		0.54	JB,B,z	0.37	JB,B,z	0.37	JB,B,z
2,3,7,8-TCDF	51207-31-9	--	--	--	--	0.1	<1		<1		1.5	M	0.69	J	1	M	0.66	J
Total 2,3,7,8-TCDD Equivalents			4.3E+00	1.9E+01	8.6		7.141		0.408		9.068		3.036		6.200		3.577	

Notes:

CAS = Chemical Abstracts Service

pg/g = Picogram per gram

TEF = Toxicity Equivalency Factor

TEF from World Health Organization (WHO). 2005.

LQ = Laboratory Qualifier

VQ = Validation Qualifier

r = Reason Code

RBC = USEPA Region III Risk-Based Concentration

(RBC) values from the October 11, 2007,

RBC Table and October 11, 2007, Alternate RBC Table

C = Carcinogenic per EPA RBC Table (October 2007)

N = Noncarcinogenic per EPA RBC Table (October 2007)

Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

C/N = Carcinogenic/Noncarcinogenic per EPA RBC Table (October 2007)

SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20

from USEPA Region III Risk-Based Concentration Table (October 11, 2007)

Total 2,3,7,8-TCDD Equivalents are calculated by summing

the detected concentration times the TEF for each chemical.

Non-detects, R-flagged data, and B-flagged data are

excluded from summed total.

OCDD = octachlorodibenzodioxin

OCDF = octachlorodibenzofuran

HpCDD = heptachlorodibenzodioxin

HpCDF = heptachlorodibenzofuran

HxCDD = hexachlorodibenzodioxin

HxCDF = hexachlorodibenzofuran

PeCDD = pentachlorodibenzodioxin

PeCDF = pentachlorodibenzofuran

TCDD = tetrachlorodibenzo-p-dioxin

TCDF = tetrachlorodibenzofuran

 = Concentration Exceeds Adjusted Soil Residential RBC

 = Concentration Exceeds Adjusted Soil Industrial RBC

bold italic = Concentration Exceeds SSL DAF20

Data Qualifiers:

B = Not detected substantially above the level reported in laboratory or field blanks.

E = Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis.

For TICs, compound not present in calibration standard, calculated using total peak areas ion chromatographs and response factor of 1.

J = Analyte present. Reported value may not be accurate or precise.

M = Estimate Maximum Possible Concentration (EMPC) value.

X = Laboratory-defined. Associated PCDF peak(s) has the same retention time as the associated diphenyl ether and that the diphenyl ether contribution to the total PCDF value is greater than 10%.

I = LCS recovery failure

q = Linearity (%RSD or r) failure in initial calibration

w = Laboratory storage blank contamination

z = Method blank and/or storage blank contamination

Table 6-3
RDA-based Screening Criteria Calculations
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

SOIL AND GROUNDWATER CRITERIA		Parameter Definition	Value	Units
Soil Screening = Criteria (mg/kg)	$\frac{\text{RDA/AI}}{(\text{IR}_S \times \text{EF} \times \text{ED} \times 10^{-6} \text{ kg/mg} \times \text{year}/365 \text{ days}) / \text{AT}}$	RDA/AI = Recommended Daily Allowance/Adequate Intake	nutrient-specific	mg/day
		IR _S = Soil Ingestion Rate		
		- adult resident	100	mg soil/day
		- child resident	200	mg soil/day
		IR _W = Tap water ingestion rate		
		- adult resident	2	L water/day
Groundwater Screening = Criteria (µg/L)	$\frac{\text{RDA/AI} \times 1000 \text{ µg/mg}}{(\text{IR}_W \times \text{EF} \times \text{ED} \times \text{year}/365 \text{ days}) / \text{AT}}$	EF = Exposure frequency		
		- residential	350	days/year
		ED = Exposure duration		
		- adult resident	24	years
		- child resident	6	years
		AT = Averaging time		
		- adult resident	24	years
		- child resident	6	years

	Reference	CAS	Soil Screening Criteria (mg/kg)					Groundwater Screening Criteria (µg/L)		
			RDA/AI ^(c,d) (mg/day)		Adult Resident	Child Resident	Selected Criteria (Minimum)	Adult Resident	Child Resident	Selected Criteria (Minimum)
			Adult	Child						
Calcium	(a)	7440-70-2	800	210	8.3E+06	1.1E+06	1.1E+06	4.2E+05	2.2E+05	2.2E+05
Magnesium	(a)	7439-95-4	130	30	1.4E+06	1.6E+05	1.6E+05	6.8E+04	3.1E+04	3.1E+04
Potassium	(b)	2023-69-5	1600	500	1.7E+07	2.6E+06	2.6E+06	8.3E+05	5.2E+05	5.2E+05
Sodium	(b)	7440-23-5	400	120	4.2E+06	6.3E+05	6.3E+05	2.1E+05	1.3E+05	1.3E+05

- (a) Recommended Dietary Allowances, 10th edition ©1989 by the National Academy of Sciences (National Academy Press, Washington, D.C.)
- (b) Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride, ©1997 by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board, Institute of Medicine (National Academy Press, Washington, D.C.)
- (c) RDA/AIs for calcium and magnesium represent the lower end of the RDA/AI for persons 7 years old and over (adults) and 6 years old and under (children).
- (d) RDA/AIs for potassium and sodium represent the lower end of the minimum requirement for healthy persons 7 years old and over (adults) and 6 years old and under (children).

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7.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

7.1 ECOLOGICAL RISK SCREENING PROCESS

The purpose of the ecological risk screening is to provide conclusions and recommendations regarding potential ecological risk associated with SWMU 40 and SWMU 71. SLERAs were performed in accordance with the Ecological Risk Assessment Guidance for Superfund (ERAGS): Process for Designing and Conducting Ecological Risk Assessments (USEPA 1997). The SLERA process is summarized below in Sections 7.1.1 through 7.1.7. Refer to Appendix F.1 for a detailed description of the SLERA process and example sample calculations utilized for the evaluations of SWMU 40 and SWMU 71. A summary of the SLERA results are provided in Section 7.2 (SWMU 40) and Section 7.3 (SWMU 71) and the complete tables for the SLERA are provided in Appendices F.2 (SWMU 40) and F.3 (SWMU 71).

7.1.1 Scope of Work

The SLERA includes Steps 1, 2, and 3a of ERAGS (USEPA 1997). Step 1 includes a screening-level problem formulation and ecological effects evaluation. Step 2 includes a preliminary exposure estimate and risk calculation. Step 3a reviews and refines the conservative assumptions used in the risk calculation (Step 2). The addition of Step 3a focuses the outcome of the SLERA, streamlines the review process, and functions as the initial basis for ecological risk management decision making.

The objectives of the ecological risk screening are to:

- Identify potentially complete exposure pathways between chemicals of potential ecological concern (COPECs) and receptors;
- Assess whether the COPECs exceed toxicological screening values that are considered to be protective of ecological receptors;
- Identify uncertainty and/or data gaps in the ecological risk screening; and
- Identify an appropriate scientific management decision point (SMDP) for each site area based on the ecological risk screening results.

7.1.1.1 Ecological Site Characterization

An overview of the site physiography, water resources, geology, and soil for SWMUs 40 and 71 is presented in Section 2.0. The site is located within the south-central portion of the MMA and consists of the approximate 2-acre landfill area (SWMU 40) and the approximate 2,240 ft² flash burn area (SWMU 71), which is conterminous with the southwest corner of the landfill.

The SWMU 40 area is grasslands without unique habitat features. Consequently, grasses provide the cover type and shrub or tree species are not established. The area is bordered to the east by hardwoods. 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). The SWMU 71 area is primarily gravel with small patches of weeds. Observations made during the site reconnaissance indicate the vegetation community at the Landfill appears healthy and vigorous (See photographic logs, Appendix A). Indications of chemical vegetative stress were not observed.

In addition to the information contained in Section 2.0, additional site characterization is required for the ecological risk screening, which includes local ecological receptors (threatened and endangered species) and ecological resources. A discussion of potential biota likely to use the site areas, are included in this section. During a site reconnaissance performed on July 21, 2005, wildlife species were not observed at the site. During subsequent site visits, wildlife species were observed at the site such as squirrels, deer, and red foxes.

The Virginia Department of Conservation, Division of Natural Heritage and U.S. Fish and Wildlife Service were contacted to gather information regarding the potential for threatened or endangered species to utilize the RFAAP. Results of these inquiries are provided in Appendix F.4.

In addition, the Virginia Department of Game and Inland Fisheries Installation-Wide Biological Survey (1999) recorded various species associated with the grassland communities at RFAAP. Based on their survey of the grassland habitats, the invertebrates (approximately 250 species) and birds (83 species) accounted for the majority of species observations at RFAAP. Potential species utilizing the grassland areas of the site include common passerine birds (e.g., American robin) and small mammals (e.g., short-tailed shrew). Larger mammals (e.g., white-tailed deer and red fox) and raptors (e.g., red-tailed hawk) may potentially utilize the grassland habitat for foraging. Animals such as the mallard duck, belted kingfisher, and raccoon could be expected to forage in the New River.

The Virginia Department of Game and Inland Fisheries survey identified three threatened wildlife species and two rare plant species associated with RFAAP grassland communities (currently not on the 2002 Plant Watch List; <http://www.dcr.state.va.us/dnh/plantlist02.pdf>). They include:

- Regal Fritillary Butterfly (*Speyeria idalia*);
- Henslow's Sparrow (*Ammodramus henslowii*);
- Loggerhead Shrike (*Lanius ludovicianus*);
- Midland Sedge (*Carex mesochorea*); and
- Shaggy False Gromwell (*Onosmodium hispidissimum*).

Threatened wildlife observations in 1999 at RFAAP included the Regal Fritillary Butterfly (VDGIF 1999). The Regal Fritillary Butterfly was documented in the east-central and eastern edges of the MMA. No threatened wildlife species or rare plant species were observed at the site.

7.1.2 Identification of Chemicals of Potential Ecological Concern

SWMUs 40 and 71 are evaluated separately in the SLERA for soil given that these areas have different waste disposal histories and characteristics. Although the sites are assessed separately, due to the proximity of the sites an area use factor for the refined exposure assessment and risk characterization was calculated as the ratio of the sum of the site areas to the average home range of the receptor (see Section 7.1.6.2). The medium of concern with respect to the SLERA is surface soil.

7.1.2.1 Approach

Soil samples were collected from 0 to 1 ft bgs below organic layers at the surface. This layer contains the zone of highest biological activity of soil organisms and the soil that is most frequently contacted by terrestrial biota. Although fossorial wildlife may be in contact with soil below 1 ft bgs, the preys of these animals are primarily associated with surficial soil. Furthermore, incidental exposure to the soil below 1 ft bgs is likely to be insignificant relative to surface soil exposure.

Terrestrial grassland surficial soil (0 to 1 ft bgs) represents the potential exposure media to ecological receptors. The following sections describe the process used to evaluate soil, the selection of COPECs evaluated in the SLERA, and the uncertainties associated with COPEC selection.

7.1.2.2 Summary of COPEC Selection

As outlined in Section 7.1.5, for the soil direct contact COPEC screening, the MDCs for detected chemicals were compared to established TRVs. Direct contact COPECs were selected for further consideration in the SLERA if the MDC exceeded the available screening value. Chemicals for which no screening values are available are considered uncertainties and not carried through the risk assessment. For food chain, COPECs were selected for further consideration in the preliminary risk calculations of the

SLERA if the detected chemical was bioaccumulative as listed on Table 4-2 in *Bioaccumulative Testing and Interpretation for the Purpose of Sediment Quality Assessment, Status and Needs* (USEPA 2000c).

7.1.2.3 Terrestrial

Potential ecological receptors at SWMUs 40 and 71 may be exposed to COPECs in soil through the following exposure routes:

- Direct contact/absorption from soil;
- Direct ingestion of soil;
- Incidental ingestion of soil; and
- Direct ingestion of biota with accumulated COPECs.

Although receptors may be exposed to COPECs through inhalation or drinking surface water, sufficient literature regarding toxicity due to these pathways is lacking to quantitatively evaluate such exposure routes. Given the potential mobility of COPECs between food web trophic levels, a number of terrestrial categories were selected. Individual receptor species were selected to represent five wildlife receptor categories and these species possess the following characteristics that are essential for assessing COPEC mobility within the food web:

- Highly likely to occur at the site in relatively high abundance;
- Limited home range;
- Important role in the local food web; and
- Sufficient toxicological information is available in the literature.

Receptor categories and the species selected to represent the wildlife categories include:

- Plant communities;
- Soil invertebrate/microbial communities;
- Omnivorous birds: American Robin (*Turdus migratorius*);
- Carnivorous birds: Red-tailed Hawk (*Buteo jamaicensis*);
- Herbivorous animals: Meadow Vole (*Microtus pennsylvanicus*);
- Omnivorous mammals: Red Fox (*Vulpes vulpes*); and
- Carnivorous mammals: Short-tailed Shrew (*Blarina brevicauda*).

Potential wildlife utilizing the site includes passerine bird and small mammalian species common to RFAAP grasslands (VDGIF 1999). During site visits, wildlife species were observed at the site such as squirrels, deer, and red foxes.

7.1.3 Identification of Exposure Pathways and Potential Receptors Analysis

7.1.3.1 Data Organization

The following table identifies the soil samples used for the SLERA. Each of these samples were selectively analyzed for TCL VOCs, TCL SVOCs, PAHs, explosives (including nitroglycerin and Pentaerythritol tetranitrate (PETN)), TAL metals and cyanide, TCL pesticides, TCL PCBs, TCL dioxin/furans, and DRO/GRO. Refer to Table 3-1 for a detailed list of samples and analytes.

Soil Samples Evaluated for SLERA

Soil - SWMU 40	Soil - SWMU 71
40SB1A, 40SB2A, 40SB3A, 40SB4A, 40SB5A, 40SB6A, 40SB7A, 40SB8A, 40SB9A, 40SB10A, 40SB12A, 40SB13A, 40SS1, 40SS2, 40SS3, 40SS4, 40SS5, 40SS6, 40SS7, 40SS8, 40SS9, 40SS10, 40SS11, 40SS12, 40SS13, 40SS14, 40SS15, 40SS16, 40SS17, 40SS18, 71SB14A, 71SB15A	71SS11, 71SS12, 71SS13, 71SB11A, 71SB12A, 71SB13A, 71SB16A

Detected chemical occurrence and distribution tables are presented in Tables 7-1 (SWMU 40) and 7-2 (SWMU 71). Refer to Section 4, Tables 4-1 (SWMU 40) and 4-6 (SWMU 71) for a complete list of results for detected analytes. In addition, to evaluate the adequate sensitivity of the MDL for the necessary screening levels, Tables 7-3 and 7-4 provide a screening of the maximum MDL versus available ecological screening values for non-detected chemicals in surface soil in SWMU 40 and SWMU 71, respectively. Additional information regarding the data used in the SLERA is summarized below:

- Flagged data such as J-flagged data (estimated concentration) and B-flagged data (detected in an associated blank) are considered detections and are used without modification;
- Rejected results (R-flagged) are not used; and
- 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.
- Chemicals that were not detected in at least one sample were considered as uncertain analytes in the evaluation of risk. Other qualified analytical data were retained in the assessment, with the exception of tentatively identified compounds (TICs) identified by the laboratory qualifier “NJ.” TICs were not evaluated quantitatively in the risk assessment.
- In cases where chemicals were analyzed using multiple laboratory methods, the analytical results for the method with the lowest MDL were retained for the risk assessment. For example, concentrations of PAHs were assessed using Method 8310 rather than the SVOC Method 8270. Eliminating the method having the higher detection limit did not result in exclusion of samples with higher detected concentrations.

7.1.3.2 Ecological Conceptual Site Model (ECSM)

The terrestrial ECSM is presented on Figure 7-1. Surface soil is a potential exposure medium of concern based on historical activities at the site. Based on the site characterization and data, the terrestrial receptor exposure to surface soil pathway exists.

7.1.4 Identification of Assessment and Measurement Endpoints

Assessment endpoints are explicit statements of ecological resources (entities) and attributes of those entities that are important to protect (USEPA 1998). Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to ecological resources chosen as assessment endpoints. Assessment and measurement endpoints for the resources in the terrestrial sites are outlined below.

7.1.4.1 Terrestrial

Assessment and measurement endpoints for terrestrial receptors are as follows:

Assessment Endpoints	Measurement Endpoints
Survival, growth, and reproduction of terrestrial plants	MDCs for chemicals detected in surface soil will be compared to concentrations representing no adverse effects thresholds to the survival of plants communities reported in the scientific literature
Survival, growth, and reproduction of soil invertebrates and microbial communities	MDCs for chemicals detected in surface soil will be compared to concentrations representing no adverse effects thresholds to the survival of soil invertebrates or microbial communities reported in the scientific literature
Survival, growth, and reproduction of terrestrial wildlife (birds and mammals) populations and communities	- MDCs for detected bioaccumulative chemicals in soil (non-dioxin/furan) will be compared to no observable adverse effects levels (NOAELs) and lowest observable adverse effects levels (LOAELs) associated with effects on growth, reproduction, or survival of terrestrial wildlife - Comparison of the maximum additive dose of dioxin/furan congeners ingested from soil and food to NOAEL and LOAEL doses associated with effects on growth, reproduction, or survival of terrestrial wildlife

7.1.5 Preliminary Exposure Estimate and Ecological Effects Evaluation

The preliminary exposure estimate and ecological effects evaluation considers the most conservative risk scenario. Highly conservative assumptions are used to estimate COPEC exposure to terrestrial receptors for pathways to be quantitatively evaluated. Conservative toxicity reference values (TRVs) are used to evaluate the ecological effects of exposure using the two approaches discussed below.

Risk is assessed by comparing the preliminary exposure estimate (MDC) of each detected chemical to the established TRV (detailed in Appendix F.1, Section 2.1). The preliminary risk is characterized in terms of a HQ, which is expressed as:

$$HQ = MDC/TRV$$

where:

- HQ** = Hazard Quotient for the contaminant (unitless)
MDC = Maximum Detected Concentration for contaminant (mg/kg)
TRV = Screening Level for contaminant (mg/kg)

An HQ of less than 1 indicates no or negligible risk. The potential for risk increases as the HQ increases above unity. However, this result should be considered in the context of other characteristics of the exposure area. Results of the preliminary exposure assessment are presented in Appendices F.2 (SWMU 40) and F.3 (SWMU 71).

7.1.5.1 Direct Contact Approach

The maximum soil concentrations for detected chemicals are used as the preliminary exposure estimate concentrations to develop a conservative risk scenario for the direct contact pathway to soil invertebrates and terrestrial plants. To assess the potential impact of PCBs on plants, the sum detected PCBs is compared to the available BTAG screening level for total PCBs (Appendix F.2, Table F.2-3c and Appendix F.3, Table F.3-3c). In addition to assess the potential impact of PAHs on invertebrates, the sum of high molecular weight and low molecular weight PAHs are compared to the available EcoSSLs for these compound groups (Appendix F.2, Table F.2-3b and Appendix F.3, Table F.3-3b).

Although there are no dioxin or furan benchmarks available for soil invertebrates or plants, plant and invertebrate receptors are much more tolerant of TCDD than fish, birds, and mammals. Dioxins are aryl hydrocarbon receptor agonists, which cause a wide spectrum of adverse toxic effects in many vertebrate species. The observed lack of sensitivity of plants and invertebrates to TCDD is consistent with the view that the aryl hydrocarbon receptor is not present in invertebrates or plants (Gatehouse 2004). Therefore, the calculated risks associated with mammalian and avian receptors, Section 7.1.5.2, are considered protective of plants and invertebrates.

7.1.5.2 Dose Rate Modeling Approach

Preliminary risk characterization for wildlife receptors uses the conservative preliminary exposure estimate and ecological effects evaluation to characterize risk to potential terrestrial receptors. Risk is assessed by comparing the preliminary exposure estimate of each detected bioaccumulative chemical, as defined in Table 4-2 in Bioaccumulative Testing and Interpretation for the Purpose of Sediment Quality Assessment, Status, and Needs, EPA-823-R-00-001, to the TRV developed in the ecological effects evaluation. An example calculation for dose rate modeling is provided in Appendix F.1., Section 4.1, utilizing the equation below.

$$C_{TRV} = \frac{ADD \cdot BW}{(IR_{food} (BAF_{food} \cdot DF) + IR_s) AF}$$

where:

C_{TRV} = NOAEL or LOAEL-based screening level (mg chemical/kg soil)

ADD = NOAEL or LOAEL (mg COPC/kg body weight-day)

BW = Minimum Body Weight of the receptor (kg)

IR_{food} = Maximum Ingestion Rate of food (kg food ingested per day, dry weight)

BAF_{food} = BAF of most contaminated dietary component used, specific to prey type and COPC (ratio of mg of COPC/kg fauna, wet weight to mg COPC/ kg substrate, dry weight)

DF = Dietary Fraction (most contaminated dietary component assumed to be 100% of diet)

IR_s = Maximum Incidental Ingestion Rate of soil (kg substrate ingested per day, dry weight)

AF = 100% Area Use Factor

In the preliminary dose rate modeling approach, the maximum COPEC concentrations for detected bioaccumulative chemicals, along with assumptions of maximum ingestion rate, minimum body weight, 100% area use, and 100% bioavailability are used in the conservative risk scenario as the preliminary exposure estimate for soil and compared to the calculated TRVs. Preliminary receptor-specific exposure parameters are presented on Table F.2-9 for SWMU 40 (Appendix F.2) and Table F.3-9 for SWMU 71 (Appendix F.3).

An equivalency method for dioxin/furan congeners was used to evaluate whether surface soil concentrations pose a threat to terrestrial wildlife. Though several dioxins are known to be toxic, toxicity

criteria are limited to 2,3,7,8- TCDD. Each congener is assigned a TEF for avian and mammalian receptors respectively (WHO 2005), which corresponds to its toxicity relative to 2,3,7,8-TCDD. Each congener detection is multiplied by its corresponding TEF; the adjusted concentrations are then summed to derive one total 2,3,7,8-TCDD equivalent concentration for each sample. This concentration is then compared with toxicity criteria for 2,3,7,8-TCDD to calculate risks.

7.1.6 Refined Exposure Estimate and Risk Characterization

Refined exposure estimates and ecological effects are developed for two major receptor categories having complete exposure pathways to be quantitatively evaluated: 1) direct contact to plants and invertebrates, and 2) wildlife ingestion (i.e., omnivorous birds and mammals, carnivorous birds and mammals, and herbivorous mammals). The refined exposure and risk characterization, Step 3a of ERAGS, reviews and refines the conservative assumptions used in the risk calculation (USEPA 1997). In Step 3a, conservative assumptions used in the preliminary exposure and risk characterization are replaced with more environmentally realistic assumptions to evaluate risk posed by constituents identified in the preliminary risk characterization. The addition of Step 3a focuses the outcome of the SLERA, streamlines the review process, and functions as the initial basis for ecological risk management decision-making.

As noted below for the refined exposure estimate and risk characterization, (95% UCL) is used as the exposure concentration rather than the MDC. Methods used to calculate 95% UCLs are based on guidance provided in the following documents *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002b) and *On the Computation of a 95% Upper Confidence Limit of the Unknown Population Mean Based Upon Data Sets with Below Detection Limit Observations* (USEPA 2006).

In general, the method used to calculate a 95% UCL depends on: 1) the prevalence of non-detects, and 2) the data distribution (e.g., normal or lognormal). 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 make for COPCs with a high rate of non-detects. ProUCL 4.0 is used to calculate EPCs for the sites with the exception of data sets with less than 5% detects for which MDCs were used for the SLERA. EPCs for soil COPECs are presented in Table F.2-4 of Appendix F.2 (SWMU 40) and Table F.3-4 of Appendix F.3 (SWMU 71).

For the refined evaluation, risk is assessed by comparing the EPC (95% UCL) of each detected chemical to the TRV. The refined risk HQ is expressed as:

$$\text{HQ} = \text{EPC}/\text{TRV}$$

where:

HQ = Hazard Quotient for the contaminant (unitless)
EPC = Calculated Exposure Point Concentration for chemical (mg/kg)
TRV = Screening Level for chemical (mg/kg)

An HQ of less than 1 indicates no or negligible risk. The potential for risk increases as the HQ increases above unity. However, this result should be considered in the context of other characteristics of the exposure area. Results of the refined exposure assessment are presented in Appendices F.2 (SWMU 40) and F.3 (SWMU 71).

7.1.6.1 Direct Contact Approach

The refined exposure estimate for the direct contact pathway to soil invertebrate and microbial communities incorporates the 95% UCL as the exposure concentration for evaluating the COPECs using a conservative yet more realistic exposure assumption than MDCs.

7.1.6.2 Dose Rate Modeling Approach

The conservative assumptions used in the preliminary exposure estimate and ecological effects evaluation were replaced with more environmentally realistic assumptions resulting in a more realistic estimate of potential risk. An example calculation for dose rate modeling is provided in Appendix F.1, Section 4.4, utilizing the equation below.

$$C_{TRV} = \frac{ADD \cdot BW}{(IR_{food} \sum (BAF_{food} \cdot DF) + IR_s) AF}$$

where:

C_{TRV} = NOAEL or LOAEL-based screening level (mg chemical/kg soil)

ADD = NOAEL or LOAEL (mg COPC/kg body weight-day)

BW = Average Body Weight of the receptor (kg)

IR_{food} = Average Ingestion Rate of food (kg food ingested per day, dry weight)

BAF_{food} = BAF of dietary component used, specific to prey type and COPC (ratio of mg of COPC/kg fauna, wet weight to mg COPC/ kg substrate, dry weight)

DF = Dietary Fraction

IR_s = Average Incidental Ingestion Rate of soil (kg substrate ingested per day, dry weight)

$AF_{refined}$ = Refined Area Use Factor (detailed below)

The refined exposure estimates and ecological effects are developed for wildlife receptors having complete exposure pathways to be quantitatively evaluated (i.e., omnivorous birds, and carnivorous and herbivorous mammals). In the refined model, an average body weight, average ingestion rate, and a 95% UCL as the EPC are used. Refined receptor-specific exposure parameters are presented on Table F.2-9 for SWMU 40 (Appendix F.2) and Table F.3-9 for SWU 71 (Appendix F.3). In addition, a realistic area use factor ($AF_{refined}$) was calculated as the ratio of the site study area to the average home range of the receptor which is also presented in Table F.2-9 and Table F.3-9. Note that due to the proximity of the sites an area use factor for the refined exposure assessment and risk characterization was calculated as the ratio of the sum of the site areas (0.67 hectares) to the average home range of the receptor.

7.1.7 Risk Management – Scientific Management Decision Point

The findings of the ecological risk screen including site characterization and risk calculations are used as input to risk management decision-making for the site. The SMDP reached from the ecological risk screening concludes that one of the following statements is true:

- There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site 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; or
- The information collected and presented indicates that a more thorough assessment is warranted.

7.2 SLERA RESULTS – SWMU 40

7.2.1 Preliminary Risk Characterization

The complete preliminary risk characterization tables are provided in Appendix F.2 and summarized below.

7.2.1.1 Terrestrial Plants

Preliminary direct contact HQs calculated for plants are presented in Table 7-5 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of aluminum, arsenic, calcium, chromium, cobalt, copper, manganese, mercury, selenium, and vanadium resulted in HQ values that were greater than 1.

7.2.1.2 Soil Invertebrates and Microbial Communities

Preliminary direct contact HQs calculated for invertebrates are presented in Table 7-6 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of chromium, iron, manganese, mercury, vanadium, and zinc resulted in HQ values that were greater than 1.

7.2.1.3 Terrestrial Wildlife

Quantitative risk characterization for terrestrial wildlife is limited to direct ingestion of biota and incidental ingestion of soil. The calculated total 2,3,7,8-TCDD equivalents used in the screening for SWMU 40 are provided in Table 7-7. The preliminary risks for detected bioaccumulative chemicals are summarized in Table 7-8 for each terrestrial wildlife receptor and the chemicals with HQs greater than 1 are characterized as follows:

Receptor	NOAEL Only Exceedances	NOAEL and LOAEL Exceedances
Meadow Vole	copper, lead	arsenic, selenium
Short-tailed Shrew	cadmium, chromium, lead, zinc	arsenic, selenium, 2,3,7,8-TCDD TEQ (dioxin/furans), Aroclor 1254, Aroclor 1260
Red Fox	cadmium, chromium, lead	arsenic, copper, selenium, zinc, 2,3,7,8-TCDD TEQ (dioxin/furans), Aroclor 1254, Aroclor 1260
American Robin	cadmium, 2,3,7,8-TCDD TEQ (dioxin/furans), Aroclor 1260, acenaphthene, phenanthrene	arsenic, chromium, lead, mercury, selenium, zinc, 4,4'-DDT, Aroclor 1254
Red-tailed Hawk	lead, zinc	none

7.2.2 Refined Risk Characterization – SWMU 40

The complete refined risk characterization tables are provided in Appendix F.2 and summarized below.

7.2.2.1 Terrestrial Plants

Refined direct contact HQs calculated for plants are presented in Table 7-5 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of aluminum, arsenic, calcium, chromium, manganese, mercury, selenium, and vanadium resulted in refined HQ values that were greater than 1.

7.2.2.2 Soil Invertebrates and Microbial Communities

Refined direct contact HQs calculated for invertebrates are presented in Table 7-6 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of chromium, iron, mercury, and vanadium resulted in refined HQ values that were greater than 1.

7.2.2.3 Terrestrial Wildlife

The refined risk characterization results are presented in Table 7-8 and summarized below for each of the receptors with chemical HQs greater than 1:

Receptor	NOAEL Only Exceedances	NOAEL and LOAEL Exceedances
Meadow Vole	arsenic (2.8)	none
Short-tailed Shrew	arsenic (4.3), 2,3,7,8-TCDD TEQ (dioxin/furans) (10), Aroclor 1254 (5)	none
Red Fox	none	none
American Robin	lead (2.2), zinc (2.4)	none
Red-tailed Hawk	none	none

*Note: (2.8) = NOAEL-based HQ

7.2.3 Risk Management – Scientific Management Decision Point

Terrestrial plant COPECs with refined HQs greater than 1 included: aluminum, arsenic, calcium, chromium, manganese, mercury, selenium, and vanadium. Although the refined aluminum HQ exceeds 1, the average pH in the soil is greater than 5.5 (see Appendix C.1); therefore, aluminum is not considered a COPEC. Arsenic, chromium, manganese, and vanadium are consistently below background (see Appendix C.10); therefore, these chemicals are not considered site related. Even though refined HQs for mercury (3.1) and selenium (1.7) are greater than 1 and a means comparison to background concentrations cannot be conducted due to the number of detection in the background data, these risks present low to moderate risk to terrestrial plants at the site. A discussion of the methodology of site versus background comparison is provided in Section 6.4.3.

Soil invertebrates and microbial processes COPECs with refined HQs greater than 1 include chromium, iron, mercury, and vanadium. Chromium, iron, and vanadium are consistently below background; therefore, these chemicals are not considered site related. Even though the refined HQ for mercury (9.3) is greater than 1 and a means comparison to background concentrations cannot be conducted due to the number of detection in the background data, these risks present low to moderate risk to soil invertebrates at the site.

The refined risk characterization for wildlife resulted in the identification of no chemicals with a LOAEL-based HQ greater than 1.

After consideration of spatial distribution of data at the site, the results of the SLERA, background concentrations, and the isolated nature of the landfill material in place at the site, the SMDP is the following:

There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site on the basis of ecological risk.

7.3 SLERA RESULTS – SWMU 71

7.3.1 Preliminary Risk Characterization

The complete preliminary risk characterization tables are provided in Appendix F.3 and summarized below.

7.3.1.1 Terrestrial Plants

Direct contact HQs calculated for plants are presented in Table 7-9 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of aluminum, antimony, calcium, chromium, lead, manganese, mercury, selenium, and vanadium resulted in HQ values greater than 1.

7.3.1.2 Soil Invertebrates and Microbial Communities

Direct contact HQs calculated for invertebrates are presented in Table 7-10 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of chromium, iron, manganese, mercury, vanadium, and zinc resulted in HQ values that were greater than 1.

7.3.1.3 Terrestrial Wildlife

Quantitative risk characterization for terrestrial wildlife is limited to direct ingestion of biota and incidental ingestion of soil. The calculated total 2,3,7,8-TCDD equivalents used in the screening for SWMU 71 are provided in Table 7-11. The risk for detected bioaccumulative chemicals are summarized in Table 7-12 for each terrestrial wildlife receptor and the chemicals with HQs great than 1 are characterized as follows:

Receptor	NOAEL Only Exceedances	NOAEL and LOAEL Exceedances
Meadow Vole	lead	arsenic, selenium
Short-tailed Shrew	cadmium, chromium, lead, zinc, Aroclor 1260	arsenic, selenium, 2,3,7,8-TCDD TEQ (dioxin/furans), Aroclor 1254
Red Fox	cadmium, Aroclor 1260	arsenic, chromium, lead, selenium, zinc, 2,3,7,8-TCDD TEQ (dioxin/furans), Aroclor 1254
American Robin	arsenic, cadmium, 2,3,7,8-TCDD TEQ (dioxin/furans), Aroclor 1254, Aroclor 1260	chromium, lead, mercury, selenium, zinc
Red-tailed Hawk	lead, zinc	none

7.3.2 Refined Risk Characterization

The complete refined risk characterization tables are provided in Appendix F.3 and summarized below.

7.3.2.1 Terrestrial Plants

Direct contact HQs calculated for plants are presented in Table 7-9 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of aluminum, antimony, calcium, chromium, lead, manganese, and vanadium resulted in HQ values greater than 1.

7.3.2.2 Soil Invertebrates and Microbial Communities

Direct contact HQs calculated for invertebrates are presented in Table 7-10 for detected chemicals. Of the detected chemicals for which screening values were available, the concentrations of chromium, iron, manganese, mercury, and vanadium resulted in HQ values that were greater than 1.

7.3.2.3 Terrestrial Wildlife

The refined risk characterization results are presented in Table 7-12 and summarized below for each of the receptors with chemical HQs greater than 1:

Receptor	NOAEL Only Exceedances	NOAEL and LOAEL Exceedances
Meadow Vole	arsenic (1.6)	none
Short-tailed Shrew	arsenic (2.6), 2,3,7,8-TCDD TEQ (dioxin/furans) (10.3), Aroclor 1254 (3.7)	none
Red Fox	none	none
American Robin	chromium (1.2), lead (7.5), zinc (2.8)	none
Red-tailed Hawk	none	none

*Note: (1.6) = NOAEL-based HQ

7.3.3 Risk Management - Scientific Management Decision Point

Terrestrial plant COPECs with refined HQs greater than 1 included: aluminum, antimony, calcium, chromium, lead, manganese, and vanadium. Although the refined aluminum HQ exceeds 1, the average pH in the soil is greater than 5.5 (see Appendix C.1); therefore, aluminum is not considered a COPEC. Chromium, lead, manganese, and vanadium are consistently below background (see Appendix C.10); therefore, these chemicals are not considered site related. Even though refined HQ for antimony (2.4) is greater than 1 and a means comparison to background concentrations cannot be conducted due to the number of detection in the background data, these risks present low to moderate risk to terrestrial plants at the site. A discussion of the methodology of site versus background comparison is provided in Section 6.4.3.

Soil invertebrates and microbial processes COPECs with refined HQs greater than 1 include chromium, iron, manganese, mercury, and vanadium. Chromium, iron, manganese, and vanadium are consistently below background; therefore, these chemicals are not considered site related. Even though refined HQ for mercury (2.9) is greater than 1 and a means comparison to background concentrations cannot be conducted due to the number of detection in the background data, these risks present low to moderate risk to invertebrates at the site.

The refined risk characterization for wildlife resulted in the identification of no chemicals with a LOAEL-based HQ greater than 1.

After consideration of spatial distribution of data at the site, the results of the SLERA, background concentrations, and site characteristics, the SMDP is the following:

There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the site on the basis of ecological risk.

7.4 EXPOSURE AND RISK UNCERTAINTY ANALYSIS

Based on this assessment, while factors such as lack of TSV and wildlife profile assumptions may create limited uncertainty, the overall result of the conservative nature of the process has produced a conservative assessment of potential ecological risks associated with the site.

Assumptions and other factors that tend to overestimate, underestimate, or have an unknown effect on the findings of the ecological risk screening are presented below with a discussion of their uncertainty.

7.4.1 Data Quality

Insufficient sampling density or the analyte list may not provide a representative estimate of exposure to COPECs. Misrepresentation of exposure results in uncertainty and may lead to an overestimation or underestimation of risk. Ten or more sampling locations at each of the sites under consideration reduce this uncertainty. Moreover, the extensive list of constituents analyzed reduces the likelihood of failing to

identify a COPEC. Therefore, the uncertainty in the ecological risk screening results associated with data quality is likely minimal.

7.4.2 COPEC Bioavailability

Chemical analyses of exposure media measured the total levels of the COPECs rather than the more bioavailable toxic forms. The availability of the total concentrations alone assumes that the entire fraction is bioavailable and toxic. This is likely to be a very conservative assumption that varies from constituent to constituent. It was also assumed that no geochemical factors limited receptor exposure to, or the potential for toxic expression of COPECs. It is likely that COPECs may, to some degree, adsorb to fine-grained particles and/or complex with chemical complexing agents and organic ligands in the exposure media. Such actions may change the chemical speciation of the COPECs to a less toxic form, or reduce the concentrations of bioavailable chemicals and subsequent uptake by receptors. Therefore, risk is likely to be overestimated.

7.4.3 Wildlife Profile Assumptions

Dose rate models require a number of assumptions, which could result in either an overestimation or underestimation of risk to receptors. For example, body weights and ingestion rates are estimated from limited information. In addition, receptors are assumed to feed on specified food sources, although some such as the Red Fox may feed opportunistically on a greater variety of food types.

Area use factor (AF) was estimated based on the size of the study area relative to the home ranges of the receptors. However, the foraging of birds and mammals is not assessed simply by size, but rather a function of habitat suitability, habitat productivity, and species-specific foraging behaviors. Therefore, because habitat quality is not accounted for in estimating AF, the risk to terrestrial receptors in this assessment is likely to be overestimated.

7.4.4 Lack of Toxicological Data

The evaluation of ecological effects was limited in the direct contact and wildlife ingestion pathways due to limited toxicological data of the COPECs. The effects of many COPECs evaluated for the direct contact pathway to invertebrates and microbial communities were not quantified due to the lack of invertebrate derived TRVs. In addition, NOAEL and LOAEL TRVs were not available for receptors exposed to multiple COPECs. Therefore, due to the lack of toxicological data, the risk to potential receptors may be underestimated or unknown.

7.4.5 TRVs

NOAEL and LOAEL TRVs identified for wildlife receptors represent the most conservative application of toxicity test results identified from the literature. High uncertainty factors were used to provide TRVs representative of chronic exposure and sub-lethal effects. This approach is likely to overestimate the sensitivity of many ecological receptors and likely overestimates risk to potential receptors.

7.4.6 Hazard Quotients

Uncertainties in characterizing risks are primarily associated with the assumption that an HQ greater than 1 is an adequate indicator of the potential for ecological risks of individual chemicals. Given the use of conservative and realistic exposure and effects assumptions previously discussed, there is minimal uncertainty that the potential for ecological risks of individual chemicals are not identified in the ecological risk screening of the sites. Conversely, there is a strong possibility for false positive identification of ecological risks for some individual chemicals.

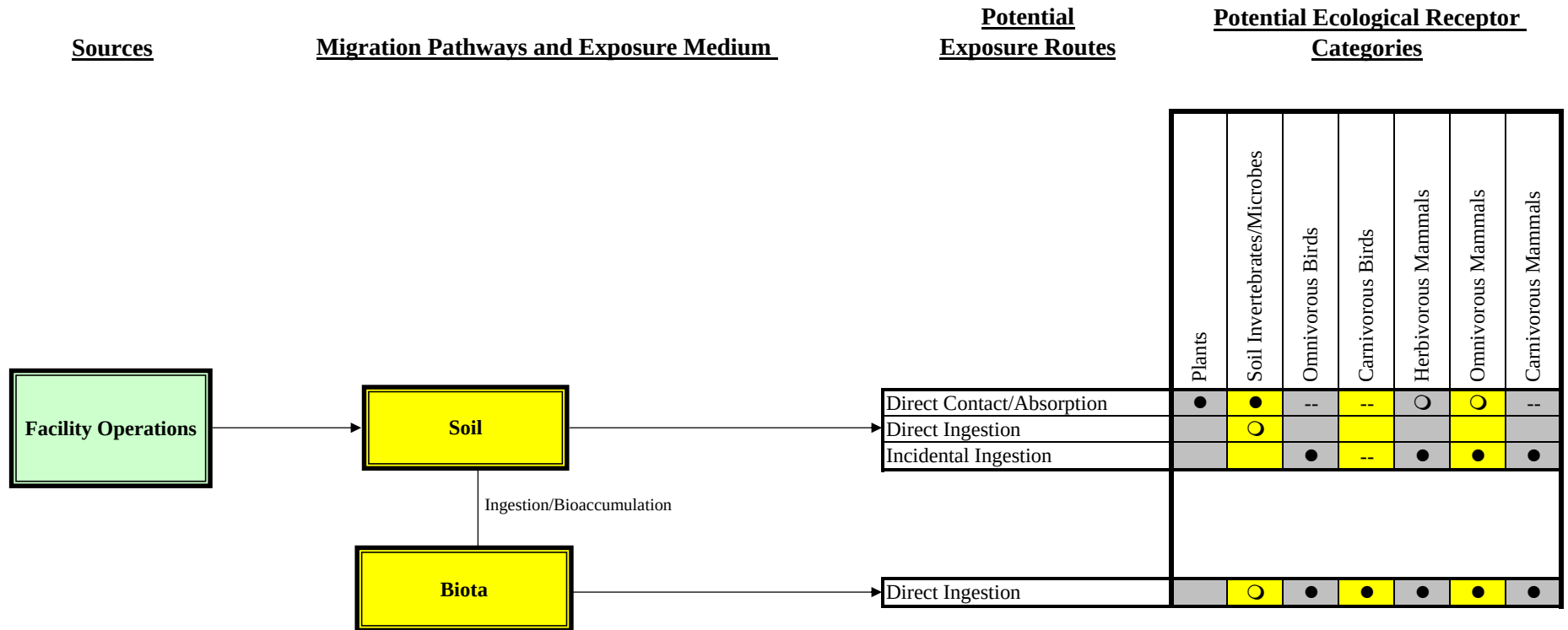
7.4.7 Exposure and Risk Uncertainty Conclusions

While factors such as lack of TSV and wildlife profile assumptions may create limited uncertainty, the very small size and negligible habitat quality of the site in combination with these limited uncertainties has produced a conservative assessment of potential ecological risks associated with SWMUs 40 and 71.

7.5 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the SLERA and risk management considerations, it is recommended that no further action is necessary at SWMU 40 and SWMU 71 due to ecological risk.

Figure 7-1
Terrestrial Ecological Conceptual Site Model
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia



NOTES:

- = POTENTIALLY COMPLETE PATHWAY EVALUATED QUANTITATIVELY
- = COMPLETE PATHWAY EVALUATED QUALITATIVELY
- = PATHWAY IS INSIGNIFICANT
- BLANK = INCOMPLETE PATHWAY

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Table 7-1
SLERA Occurrence/Distribution - SWMU 40 Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Chemical	CAS #	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits
TAL Metals (mg/kg)							
Aluminum	7429-90-5	659	28,500	mg/kg	40SB4A	19/19	1.6 - 11.3
Antimony	7440-36-0	0.46	1.3	mg/kg	71SB14A	15/18	0.036 - 1.1
Arsenic	7440-38-2	1.3	55	mg/kg	71SB14A	19/19	0.023 - 1.1
Barium	7440-39-3	14.6	191	mg/kg	40SB3A	19/19	0.02 - 1.1
Beryllium	7440-41-7	0.24	1.5	mg/kg	40SB4A	19/19	0.01 - 0.57
Cadmium	7440-43-9	0.09	0.75	mg/kg	40SB1A	8/19	0.0073 - 0.57
Calcium	7440-70-2	457	26,300	mg/kg	40SB10A	19/19	1.1 - 113
Chromium	7440-47-3	4.1	37.6	mg/kg	40SS3	19/19	0.07 - 0.57
Cobalt	7440-48-4	1.8	13.2	mg/kg	40SB3A	19/19	0.07 - 0.57
Copper	7440-50-8	2.1	76	mg/kg	71SB14A	18/19	0.045 - 0.57
Iron	7439-89-6	1,440	32,000	mg/kg	40SB1A	19/19	1.4 - 23
Lead	7439-92-1	3.8	110	mg/kg	71SB14A	19/19	0.041 - 0.34
Magnesium	7439-95-4	120	24,400	mg/kg	40SB4A	19/19	0.69 - 113
Manganese	7439-96-5	10.7	894	mg/kg	40SS1	19/19	0.02 - 1.1
Mercury	7439-97-6	0.042	2.1	mg/kg	40SB1A	18/19	0.0048 - 0.039
Nickel	7440-02-0	4.3	20.9	mg/kg	40SB4A	19/19	0.027 - 0.57
Potassium	7440-09-7	89.2	5240	mg/kg	40SB4A	19/19	4.5 - 113
Selenium	7782-49-2	0.475	3.3	mg/kg	40SB1A	18/19	0.063 - 0.57
Silver	7440-22-4	0.071	0.2	mg/kg	40SB1A	4/19	0.017 - 0.57
Sodium	7440-23-5	86.8	370	mg/kg	71SB14A	19/19	19 - 226
Thallium	7440-28-0	0	1.3	mg/kg	71SB14A	2/14	0.0085 - 1.1
Vanadium	7440-62-2	5.4	56.9	mg/kg	40SB9A	19/19	0.024 - 2.3
Zinc	7440-66-6	5.5	148	mg/kg	40SB1A	19/19	0.11 - 2.3
Pesticides/PCBs (ug/kg)							
4,4'-DDE	72-55-9	1.8E+00	1.8E+00	ug/kg	40SB10A	1/17	0.4 - 2.1
4,4'-DDT	50-29-3	7.7E+00	7.7E+00	ug/kg	40SS4	1/17	0.39 - 6.2
Aldrin	309-00-2	2.1E+00	5.1E+00	ug/kg	40SS4	2/17	0.17 - 1
alpha-Chlordane	5103-71-9	4.9E-01	3.2E+00	ug/kg	40SB10A	3/17	0.22 - 2.1
beta-BHC	319-85-7	2.1E+00	1.2E+01	ug/kg	40SB12A	5/17	0.28 - 2.1
Endosulfan Sulfate	1031-07-8	2.9E+01	2.9E+01	ug/kg	40SS4	1/17	0.4 - 4.1
Endrin	72-20-8	3.9E+00	3.9E+00	ug/kg	40SS4	1/17	0.35 - 4.1
Endrin Ketone	53494-70-5	2.4E+01	2.4E+01	ug/kg	40SS4	1/17	0.39 - 10
gamma-BHC (Lindane)	58-89-9	5.5E-01	1.1E+01	ug/kg	40SS4	2/17	0.22 - 1
gamma-Chlordane	5103-74-2	7.6E+00	7.6E+00	ug/kg	40SS4	1/17	0.35 - 1
Methoxychlor	72-43-5	4.3E+01	4.3E+01	ug/kg	40SS4	1/17	1.4 - 10
Aroclor 1248	12672-29-6	1.9E+02	1.9E+02	ug/kg	71SB15A DUP AVG	1/32	5.2 - 56
Aroclor 1254	11097-69-1	2.0E+01	2.1E+03	ug/kg	40SS1	28/32	5.5 - 56
Aroclor 1260	11096-82-5	1.3E+01	6.2E+02	ug/kg	40SS7	11/32	6.2 - 80
TCL VOCs (ug/kg)							
1,2,4-Trichlorobenzene	120-82-1	7.0E-01	7.0E-01	ug/kg	40SB12A	1/17	0.4 - 15
1,2-Dibromo-3-Chloropropane	96-12-8	4.0E-01	4.0E-01	ug/kg	40SB12A	1/17	0.2 - 15
1,2-Dichlorobenzene	95-50-1	4.0E-01	8.0E-01	ug/kg	40SS5	2/17	0.2 - 15
1,3-Dichlorobenzene	541-73-1	3.0E-01	9.0E-01	ug/kg	40SS5	2/17	0.2 - 15
1,4-Dichlorobenzene	106-46-7	5.0E-01	1.0E+00	ug/kg	40SS5	3/17	0.2 - 15
2-Butanone	78-93-3	6.0E+00	4.0E+01	ug/kg	40SS3	8/17	1 - 39
2-Hexanone	591-78-6	2.0E+00	2.0E+00	ug/kg	40SB12A	1/17	0.5 - 39
4-Methyl-2-Pentanone	108-10-1	3.0E+00	3.1E+01	ug/kg	40SB10A	10/17	0.5 - 39
Acetone	67-64-1	1.1E+01	4.6E+02	ug/kg	40SS3	16/17	0.9 - 39
Benzene	71-43-2	8.0E-01	6.0E+00	ug/kg	40SB10A	3/17	0.4 - 15
Bromomethane	74-83-9	3.0E+00	3.0E+00	ug/kg	40SB12A	1/17	0.9 - 15
Carbon Disulfide	75-15-0	1.0E+00	4.0E+00	ug/kg	40SS2	8/17	0.5 - 15
Chlorobenzene	108-90-7	4.0E-01	4.0E-01	ug/kg	40SB5A	1/17	0.2 - 15
Chloromethane	74-87-3	1.0E+00	3.0E+00	ug/kg	40SS5	2/17	0.9 - 15
Cyclohexane	110-82-7	3.0E+00	3.0E+00	ug/kg	40SB10A	2/17	0.4 - 15
Dichlorodifluoromethane	75-71-8	1.0E+00	3.0E+00	ug/kg	40SS5	4/17	0.4 - 15
Ethylbenzene	100-41-4	7.0E-01	1.7E+01	ug/kg	40SB10A	9/17	0.4 - 15
Isopropylbenzene	98-82-8	3.0E+00	3.0E+00	ug/kg	40SB10A	1/17	6 - 17
Methyl Acetate	79-20-9	1.4E+01	1.2E+02	ug/kg	40SS3	7/17	0.5 - 15
Methyl Tert-Butyl Ether	1634-04-4	2.0E+00	2.0E+00	ug/kg	40SB10A	1/17	6 - 17
Methylcyclohexane	108-87-2	1.0E+00	2.7E+01	ug/kg	40SS4	3/17	0.4 - 15
Methylene Chloride	75-09-2	7.0E-01	1.4E+01	ug/kg	40SS2	11/17	0.5 - 15
Styrene	100-42-5	8.0E-01	2.0E+00	ug/kg	40SS3	5/17	0.2 - 15
Tetrachloroethene	127-18-4	1.0E+00	1.0E+00	ug/kg	40SB12A	1/17	0.3 - 15
Toluene	108-88-3	8.0E-01	1.9E+01	ug/kg	40SS4	17/17	0.4 - 15
Trichloroethene	79-01-6	6.0E-01	2.2E+01	ug/kg	40SS2	16/17	0.4 - 15
Xylenes (Total)	1330-20-7	1.0E+00	8.2E+01	ug/kg	40SS4	16/17	1 - 46

Table 7-1
SLERA Occurrence/Distribution - SWMU 40 Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Chemical	CAS #	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits
TCL SVOCs (ug/kg)							
2-Methylnaphthalene	91-57-6	4.5E+01	1.4E+02	µg/kg	40SS5	3/17	24 - 410
Benzaldehyde	100-52-7	6.6E+01	6.6E+01	µg/kg	40SB1A	1/17	39 - 410
Bis(2-ethylhexyl)phthalate	117-81-7	3.8E+01	2.8E+02	µg/kg	40SS3	14/17	32 - 410
Caprolactam	105-60-2	8.0E+02	8.0E+02	µg/kg	40SS2	1/17	62 - 410
Carbazole	86-74-8	4.7E+01	2.0E+02	µg/kg	40SS4	2/17	29 - 410
Di-n-butylphthalate	84-74-2	9.2E+01	1.4E+02	µg/kg	40SB6A	2/17	27 - 570
Di-n-octylphthalate	117-84-0	2.6E+01	5.0E+02	µg/kg	40SS3	5/17	21 - 570
Dibenzofuran	132-64-9	5.2E+01	5.6E+01	µg/kg	40SS5	2/17	24 - 410
TCL PAHs (ug/kg)							
Acenaphthene	83-32-9	2.1E+01	1.2E+03	µg/kg	40SB1A	7/17	5.8 - 52
Acenaphthylene	208-96-8	8.0E+01	2.2E+02	µg/kg	40SS4	2/17	5.9 - 52
Anthracene	120-12-7	1.2E+02	1.2E+02	µg/kg	40SS2	1/17	5.4 - 52
Benzo(a)anthracene	56-55-3	1.1E+01	3.9E+02	µg/kg	40SS4	11/17	2.2 - 10
Benzo(a)pyrene	50-32-8	3.8E+00	3.0E+02	µg/kg	40SS2	12/17	1.6 - 10
Benzo(b)fluoranthene	205-99-2	4.2E+00	5.7E+02	µg/kg	40SS4	15/17	1.7 - 10
Benzo(g,h,i)perylene	191-24-2	1.0E+01	1.4E+02	µg/kg	40SS2	6/17	3.6 - 10
Benzo(k)fluoranthene	207-08-9	1.0E+01	3.7E+02	µg/kg	40SS2	11/17	1.4 - 10
Chrysene	218-01-9	4.5E+00	6.8E+02	µg/kg	40SB1A	13/17	2.4 - 10
Dibenz(a,h)anthracene	53-70-3	1.9E+01	1.1E+02	µg/kg	40SS5	4/17	4.2 - 10
Fluoranthene	206-44-0	2.0E+01	1.5E+03	µg/kg	40SS2	15/17	2.1 - 21
Indeno(1,2,3-cd)pyrene	193-39-5	6.9E+00	2.5E+02	µg/kg	40SS2	10/17	2.5 - 10
Naphthalene	91-20-3	2.6E+01	1.1E+03	µg/kg	40SS4	6/17	14 - 52
Phenanthrene	85-01-8	1.4E+01	5.5E+02	µg/kg	40SS2	8/17	8.5 - 52
Pyrene	129-00-0	1.2E+01	8.1E+02	µg/kg	40SS4	15/17	4.3 - 21
Dioxin/Furans (pg/g)							
2,3,7,8-TCDD TEQ (mammalian)	--	4.1E-01	7.1E+00	pg/g	40SS4	2/2	--
2,3,7,8-TCDD TEQ (avian)	--	4.8E+00	1.7E-01	pg/g	40SS4	2/2	--
DRO/GRO (mg/kg)							
DRO	--	2.1E+01	6.8E+01	mg/kg	71SB14A	2/2	1 - 1

Notes:

CAS = Chemical Abstracts Service
COPEC = Chemical of Potential Ecological Concern
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
pg/g = Picogram Per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
TEQ = Toxicity Equivalent
DRO = Diesel Range Organics
GRO = Gasoline Range Organics

Table 7-2
SLERA Occurrence/Distribution - SWMU 71 Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Chemical	CAS #	Minimum Concentration	Maximum Concentration	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits
TAL Metals (mg/kg)							
Aluminum	7429-90-5	3,460	33,000	mg/kg	71SB12A	7/7	1.6 - 79
Antimony	7440-36-0	0.2	16.4	mg/kg	71SS13	7/7	0.036 - 0.37
Arsenic	7440-38-2	4.7	16.1	mg/kg	71SS12 DUP AVG	7/7	0.023 - 0.35
Barium	7440-39-3	51.3	180	mg/kg	71SB16A	7/7	0.02 - 0.1
Beryllium	7440-41-7	0.29	1.6	mg/kg	71SB12A	7/7	0.01 - 0.02
Cadmium	7440-43-9	0.03	0.31	mg/kg	71SS12 DUP AVG	6/7	0.0073 - 0.04
Calcium	7440-70-2	2,610	172,000	mg/kg	71SS12 DUP AVG	7/7	0.96 - 10
Chromium	7440-47-3	11	47	mg/kg	71SB12A	7/7	0.06 - 0.57
Cobalt	7440-48-4	2.65	13	mg/kg	71SB12A	7/7	0.06 - 0.35
Copper	7440-50-8	15.8	40	mg/kg	71SB16A	7/7	0.022 - 0.17
Iron	7439-89-6	6,730	34,000	mg/kg	71SB12A	7/7	1.3 - 23
Lead	7439-92-1	9.9	366	mg/kg	71SS13	7/7	0.041 - 0.23
Magnesium	7439-95-4	1290	74,800	mg/kg	71SS11	7/7	0.61 - 170
Manganese	7439-96-5	83.7	550	mg/kg	71SB12A	7/7	0.02 - 0.14
Mercury	7439-97-6	0.019	0.49	mg/kg	71SB13A	7/7	0.0048 - 0.018
Nickel	7440-02-0	6.7	33	mg/kg	71SB12A	7/7	0.027 - 0.12
Potassium	7440-09-7	378	4,500	mg/kg	71SB12A	7/7	4.2 - 11.9
Selenium	7782-49-2	0.25	1.1	mg/kg	71SS13	5/7	0.063 - 0.35
Silver	7440-22-4	0.12	2.1	mg/kg	71SS12 DUP AVG	5/7	0.017 - 0.09
Sodium	7440-23-5	100	358	mg/kg	71SS13	6/7	19 - 35.2
Thallium	7440-28-0	0.35	0.59	mg/kg	71SB14A	3/6	0.0085 - 0.28
Vanadium	7440-62-2	11.6	91	mg/kg	71SB12A	7/7	0.024 - 0.08
Zinc	7440-66-6	24.5	152	mg/kg	71SS13	7/7	0.1 - 1.7
Pesticides/PCBs (ug/kg)							
Aldrin	309-00-2	8.6E-01	1.1E+00	µg/kg	71SS12 DUP AVG	2/4	0.17 - 0.17
beta-BHC	319-85-7	3.4E+00	5.5E+00	µg/kg	71SB11A	2/4	0.28 - 0.28
gamma-BHC (Lindane)	58-89-9	9.9E-01	9.9E-01	µg/kg	71SB11A	1/4	0.22 - 0.22
Aroclor 1254	11097-69-1	2.4E+01	4.6E+02	µg/kg	71SB13A	6/9	7.1 - 9
Aroclor 1260	11096-82-5	3.5E+01	9.2E+01	µg/kg	71SB13A	2/9	5.2 - 9.2
TCL VOCs (ug/kg)							
2-Butanone	78-93-3	1.7E+01	4.6E+01	µg/kg	71SB11A	3/4	1 - 4
4-Methyl-2-Pentanone	108-10-1	2.0E+00	1.6E+01	µg/kg	71SS12 DUP AVG	3/4	0.6 - 2
Acetone	67-64-1	5.4E+01	2.5E+02	µg/kg	71SB11A	4/4	1 - 3
Benzene	71-43-2	1.0E+00	3.2E+00	µg/kg	71SS12 DUP AVG	2/4	0.4 - 1
Bromomethane	74-83-9	2.0E+00	2.0E+00	µg/kg	71SS13	1/4	1 - 3
Carbon Disulfide	75-15-0	2.0E+00	7.5E+00	µg/kg	71SS12 DUP AVG	4/4	0.5 - 2
Cyclohexane	110-82-7	4.0E+00	4.0E+00	µg/kg	71SS12 DUP AVG	1/4	0.5 - 1
Dichlorodifluoromethane	75-71-8	1.0E+00	1.0E+00	µg/kg	71SB11A	1/4	0.5 - 1
Ethylbenzene	100-41-4	5.0E+00	5.0E+00	µg/kg	71SS12 DUP AVG	1/4	0.4 - 1
Methylcyclohexane	108-87-2	2.7E+01	2.7E+01	µg/kg	71SS12 DUP AVG	1/4	0.5 - 1
Methylene Chloride	75-09-2	6.0E+00	1.6E+01	µg/kg	71SS12 DUP AVG	2/4	0.5 - 2
Styrene	100-42-5	1.0E+00	1.0E+00	µg/kg	71SB11A	1/4	0.3 - 0.8
Toluene	108-88-3	1.0E+00	1.3E+01	µg/kg	71SS12 DUP AVG	4/4	0.4 - 1
Trichloroethene	79-01-6	1.0E+00	2.1E+01	µg/kg	71SS12 DUP AVG	4/4	0.4 - 1
Xylenes (Total)	1330-20-7	2.0E+00	6.1E+01	µg/kg	71SS12 DUP AVG	4/4	1 - 4
TCL SVOCs (ug/kg)							
2-Methylnaphthalene	91-57-6	3.3E+01	7.8E+01	µg/kg	71SS13	3/4	24 - 24
Bis(2-ethylhexyl)phthalate	117-81-7	4.7E+01	5.8E+01	µg/kg	71SS12 DUP AVG	3/4	32 - 32
TCL PAHs (ug/kg)							
Acenaphthene	83-32-9	1.2E+02	1.4E+02	µg/kg	71SS13	2/4	5.9 - 5.9
Acenaphthylene	208-96-8	1.2E+02	1.2E+02	µg/kg	71SS13	1/4	5.9 - 5.9
Benzo(a)anthracene	56-55-3	2.6E+01	3.6E+01	µg/kg	71SS13	2/4	2.2 - 2.2
Benzo(a)pyrene	50-32-8	5.4E+00	2.0E+01	µg/kg	71SS13	2/4	1.6 - 1.6
Benzo(b)fluoranthene	205-99-2	1.0E+01	1.5E+01	µg/kg	71SS13	2/4	1.7 - 1.7
Benzo(k)fluoranthene	207-08-9	7.9E+00	1.7E+01	µg/kg	71SS13	2/4	1.4 - 1.4
Chrysene	218-01-9	9.0E+00	5.4E+01	µg/kg	71SS13	2/4	2.4 - 2.4
Fluoranthene	206-44-0	3.1E+01	2.3E+02	µg/kg	71SS12 DUP AVG	4/4	2.1 - 2.1
Naphthalene	91-20-3	4.4E+01	1.2E+02	µg/kg	71SS13	2/4	14 - 14
Phenanthrene	85-01-8	6.7E+01	6.7E+01	µg/kg	71SS13	1/4	8.5 - 8.5
Pyrene	129-00-0	2.2E+01	2.2E+01	µg/kg	71SS12 DUP AVG	1/4	4.3 - 4.3
Dioxin/Furans (pg/g)							
2,3,7,8-TCDD TEQ (mammalian)	--	3.0E+00	3.6E+00	pg/g	71SS13	2/2	--
2,3,7,8-TCDD TEQ (avian)	--	2.7E+00	3.3E+00	pg/g	71SS13	2/2	--
DRO/GRO (mg/kg)							
DRO	--	4.9E+00	4.6E+01	mg/kg	71SB13A	3/3	0.99 - 1.1

Notes:

CAS = Chemical Abstracts Service

COPEC = Chemical of Potential Ecological Concern

TAL = Target Analyte List

TCL = Target Compound List

PCB = Polychlorinated Biphenyl

VOC = Volatile Organic Compound

SVOC = Semi-volatile Organic Compound

PAH = Polynuclear Aromatic Hydrocarbon

mg/kg = Milligram Per Kilogram

µg/kg = Microgram Per Kilogram

Table 7-3
Non-detected Chemicals MDL Screening for SWMU 40 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
Gasoline Range Organics																		
GRO	--	mg/kg	2	2	0.93	0.95	--	--	NS	--	--	NS	--	--	NS	--	--	NS
TAL Metals																		
Antimony	7440-36-0	mg/kg	3	18	0.17	0.47	5	F	N	78	A	N	--	--	NS	0.27	A	Y
Cadmium	7440-43-9	mg/kg	11	19	0.03	0.59	32	A	N	140	A	N	0.77	A	N	0.36	A	Y
Copper	7440-50-8	mg/kg	1	19	0.16	0.16	70	A	N	80	A	N	28	A	N	49	A	N
Mercury	7439-97-6	mg/kg	1	19	0.023	0.023	0.3	F	N	0.1	B	N	--	--	NS	--	--	NS
Selenium	7782-49-2	mg/kg	1	19	0.42	0.42	0.52	A	N	4.1	A	N	1.2	A	N	0.63	A	N
Silver	7440-22-4	mg/kg	15	19	0.08	0.13	560	A	N	50	E	N	4.2	A	N	14	A	N
Thallium	7440-28-0	mg/kg	12	14	0.27	0.64	1	F	N	--	--	NS	--	--	NS	--	--	NS
Pesticides/PCBs																		
4,4'-DDD	72-54-8	ug/kg	17	17	0.32	3.9	100	G	N	100	C	N	--	--	NS	--	--	NS
4,4'-DDE	72-55-9	ug/kg	16	17	0.4	2	100	G	N	100	C	N	--	--	NS	--	--	NS
4,4'-DDT	50-29-3	ug/kg	16	17	0.39	5.9	100	G	N	100	C	N	93	A	N	21	A	N
Aldrin	309-00-2	ug/kg	15	17	0.17	0.98	100	G	N	100	C	N	--	--	NS	--	--	NS
alpha-BHC	319-84-6	ug/kg	17	17	0.26	0.98	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
alpha-Chlordane	5103-71-9	ug/kg	14	17	0.22	2	100	G	N	100	C	N	--	--	NS	--	--	NS
beta-BHC	319-85-7	ug/kg	12	17	0.28	2	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
delta-BHC	319-86-8	ug/kg	17	17	0.15	0.98	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
Dieldrin	60-57-1	ug/kg	17	17	0.43	2	100	G	N	100	C	N	22	A	N	4.9	A	N
Endosulfan I	959-98-8	ug/kg	17	17	0.43	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Endosulfan II	33213-65-9	ug/kg	17	17	0.58	3.9	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Endosulfan Sulfate	1031-07-8	ug/kg	16	17	0.4	3.9	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Endrin	72-20-8	ug/kg	16	17	0.35	3.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Endrin Aldehyde	7421-93-4	ug/kg	17	17	0.35	3.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Endrin Ketone	53494-70-5	ug/kg	16	17	0.39	9.8	100	G	N	100	C	N	--	--	NS	--	--	NS
gamma-BHC (Lindane)	58-89-9	ug/kg	15	17	0.22	0.98	100	G	N	100	C	N	--	--	NS	--	--	NS
gamma-Chlordane	5103-74-2	ug/kg	16	17	0.35	0.98	100	G	N	100	C	N	--	--	NS	--	--	NS
Heptachlor	76-44-8	ug/kg	17	17	0.34	0.98	100	G	N	100	C	N	--	--	NS	--	--	NS
Heptachlor Epoxide	1024-57-3	ug/kg	17	17	0.26	0.98	100	G	N	100	C	N	--	--	NS	--	--	NS
Methoxychlor	72-43-5	ug/kg	16	17	1.4	9.8	100	G	N	100	C	N	--	--	NS	--	--	NS
Toxaphene	8001-35-2	ug/kg	17	17	18	98	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Aroclor 1016	12674-11-2	ug/kg	32	32	5.2	76	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1221	11104-28-2	ug/kg	32	32	14	100	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1232	11141-16-5	ug/kg	32	32	5.4	76	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1242	53469-21-9	ug/kg	32	32	7.6	53	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1248	12672-29-6	ug/kg	31	32	4.5	53	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1254	11097-69-1	ug/kg	4	32	8.5	9	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1260	11096-82-5	ug/kg	21	32	5.4	76	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
TCL VOCs																		
1,1,1-Trichloroethane	71-55-6	ug/kg	17	17	0.5	1	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1,2,2-Tetrachloroethane	79-34-5	ug/kg	17	17	0.2	0.4	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	ug/kg	16	17	6	17	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,1,2-Trichloroethane	79-00-5	ug/kg	17	17	0.1	0.4	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1-Dichloroethane	75-34-3	ug/kg	17	17	0.3	0.8	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1-Dichloroethene	75-35-4	ug/kg	17	17	0.6	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,4-Trichlorobenzene	120-82-1	ug/kg	16	17	0.4	1	100	G	N	100	C	N	--	--	NS	--	--	NS
1,2-Dibromo-3-chloropropane	96-12-8	ug/kg	16	17	0.2	0.7	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2-Dibromoethane	106-93-4	ug/kg	17	17	0.2	0.5	--	--	NS	5,000	C	N	--	--	NS	--	--	NS
1,2-Dichlorobenzene	95-50-1	ug/kg	15	17	0.2	0.4	100	G	N	100	C	N	--	--	NS	--	--	NS
1,2-Dichloroethane	107-06-2	ug/kg	17	17	0.3	0.8	870,000	G	N	--	--	NS	--	--	NS	--	--	NS
1,2-Dichloropropane	78-87-5	ug/kg	17	17	0.2	0.5	300	G	N	300	C	N	--	--	NS	--	--	NS
1,3-Dichlorobenzene	541-73-1	ug/kg	15	17	0.2	0.6	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,4-Dichlorobenzene	106-46-7	ug/kg	14	17	0.2	0.6	100	G	N	20,000	B	N	--	--	NS	--	--	NS
2-Butanone	78-93-3	ug/kg	9	17	1	3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Hexanone	591-78-6	ug/kg	16	17	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS

Table 7-3
Non-detected Chemicals MDL Screening for SWMU 40 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
4-Methyl-2-Pentanone	108-10-1	ug/kg	7	17	0.5	0.8	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
Acetone	67-64-1	ug/kg	1	17	1	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Benzene	71-43-2	ug/kg	14	17	0.4	1	100	G	N	100	C	N	--	--	NS	--	--	NS
Bromodichloromethane	75-27-4	ug/kg	17	17	0.2	0.5	450,000	G	N	--	--	NS	--	--	NS	--	--	NS
Bromoform	75-25-2	ug/kg	17	17	0.2	0.6	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Bromomethane	74-83-9	ug/kg	16	17	0.9	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Carbon Disulfide	75-15-0	ug/kg	9	17	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Carbon Tetrachloride	56-23-5	ug/kg	17	17	0.5	1	300	G	N	300	C	N	--	--	NS	--	--	NS
Chlorobenzene	108-90-7	ug/kg	16	17	0.2	0.6	100	G	N	40,000	B	N	--	--	NS	--	--	NS
Chloroethane	75-00-3	ug/kg	17	17	0.4	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Chloroform	67-66-3	ug/kg	17	17	0.4	0.9	300	G	N	300	C	N	--	--	NS	--	--	NS
Chloromethane	74-87-3	ug/kg	15	17	0.9	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
cis-1,2-Dichloroethene	156-59-2	ug/kg	17	17	0.3	0.9	300	G	N	300	C	N	--	--	NS	--	--	NS
cis-1,3-Dichloropropene	10061-01-5	ug/kg	17	17	0.3	0.8	300	G	N	300	C	N	--	--	NS	--	--	NS
Cyclohexane	110-82-7	ug/kg	15	17	0.4	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dibromochloromethane	124-48-1	ug/kg	17	17	0.2	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dichlorodifluoromethane	75-71-8	ug/kg	13	17	0.4	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Ethylbenzene	100-41-4	ug/kg	8	17	0.4	0.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Isopropylbenzene	98-82-8	ug/kg	16	17	6	17	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methyl Acetate	79-20-9	ug/kg	10	17	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methyl-t-butyl Ether	1634-04-4	ug/kg	16	17	6	17	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methylcyclohexane	108-87-2	ug/kg	14	17	0.4	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methylene Chloride	75-09-2	ug/kg	6	17	0.5	1	300	G	N	300	C	N	--	--	NS	--	--	NS
Styrene	100-42-5	ug/kg	12	17	0.2	0.6	300,000	F	N	100	C	N	--	--	NS	--	--	NS
Tetrachloroethene	127-18-4	ug/kg	16	17	0.3	0.9	300	G	N	300	C	N	--	--	NS	--	--	NS
trans-1,2-Dichloroethene	156-60-5	ug/kg	17	17	0.4	0.9	300	G	N	300	C	N	--	--	NS	--	--	NS
trans-1,3-Dichloropropene	10061-02-6	ug/kg	17	17	0.2	0.5	300	G	N	300	C	N	--	--	NS	--	--	NS
Trichloroethene	79-01-6	ug/kg	1	17	0.9	0.9	300	G	N	300	C	N	--	--	NS	--	--	NS
Trichlorofluoromethane	75-69-4	ug/kg	17	17	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Vinyl Chloride	75-01-4	ug/kg	17	17	0.4	1	300	G	N	300	C	N	--	--	NS	--	--	NS
Xylene (Total)	1330-20-7	ug/kg	1	17	1	1	100	G	N	--	--	NS	--	--	NS	--	--	NS
TCL SVOCs																		
1,1'-Biphenyl	92-52-4	ug/kg	17	17	22	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,2'-oxybis(1-chloropropane)	108-60-1	ug/kg	17	17	30	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,4,5-Trichlorophenol	95-95-4	ug/kg	17	17	49	390	4,000	F	N	9,000	B	N	--	--	NS	--	--	NS
2,4,6-Trichlorophenol	88-06-2	ug/kg	17	17	50	390	100	G	Y	10,000	B	N	--	--	NS	--	--	NS
2,4-Dichlorophenol	120-83-2	ug/kg	17	17	22	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
2,4-Dimethylphenol	105-67-9	ug/kg	17	17	30	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
2,4-Dinitrophenol	51-28-5	ug/kg	17	17	170	2,000	20,000	F	N	100	C	Y	--	--	NS	--	--	NS
2,4-Dinitrotoluene	121-14-2	ug/kg	16	17	20	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,6-Dinitrotoluene	606-20-2	ug/kg	16	17	21	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Chloronaphthalene	91-58-7	ug/kg	17	17	22	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Chlorophenol	95-57-8	ug/kg	17	17	18	390	7,000	F	N	10,000	B	N	--	--	NS	--	--	NS
2-Methylnaphthalene	91-57-6	ug/kg	14	17	24	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Methylphenol	95-48-7	ug/kg	17	17	27	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
2-Nitroaniline	88-74-4	ug/kg	17	17	29	780	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Nitrophenol	88-75-5	ug/kg	17	17	26	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
3,3'-Dichlorobenzidine	91-94-1	ug/kg	17	17	29	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
3-Nitroaniline	99-09-2	ug/kg	17	17	34	780	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4,6-Dinitro-2-Methylphenol	534-52-1	ug/kg	17	17	35	780	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Bromophenyl Phenyl Ether	101-55-3	ug/kg	17	17	390	570	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Chloro-3-Methylphenol	59-50-7	ug/kg	17	17	29	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Chloroaniline	106-47-8	ug/kg	17	17	16	390	20,000	F	N	--	--	NS	--	--	NS	--	--	NS
4-Chlorophenyl Phenyl Ether	7005-72-3	ug/kg	17	17	390	570	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Methylphenol	106-44-5	ug/kg	17	17	48	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
4-Nitroaniline	100-01-6	ug/kg	17	17	39	780	--	--	NS	--	--	NS	--	--	NS	--	--	NS

Table 7-3
Non-detected Chemicals MDL Screening for SWMU 40 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
4-Nitrophenol	100-02-7	ug/kg	17	17	75	780	100	G	Y	7,000	B	N	--	--	NS	--	--	NS
Acenaphthene	83-32-9	ug/kg	17	17	31	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Acenaphthylene	208-96-8	ug/kg	15	17	17	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Acetophenone	98-86-2	ug/kg	17	17	23	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Anthracene	120-12-7	ug/kg	14	17	25	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Atrazine	1912-24-9	ug/kg	17	17	16	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Benzaldehyde	100-52-7	ug/kg	16	17	39	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Benzo(a)pyrene	50-32-8	ug/kg	11	17	23	390	100	G	Y	--	--	NS	--	--	NS	--	--	NS
Benzo(a)anthracene	56-55-3	ug/kg	12	17	29	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Benzo(b)fluoranthene	205-99-2	ug/kg	11	17	36	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Benzo(g,h,i)perylene	191-24-2	ug/kg	12	17	23	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Benzo(k)fluoranthene	207-08-9	ug/kg	11	17	29	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
bis(2-Chloroethoxy)methane	111-91-1	ug/kg	17	17	21	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
bis(2-Chloroethyl)ether	111-44-4	ug/kg	17	17	18	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
bis(2-ethylhexyl)phthalate	117-81-7	ug/kg	3	17	32	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Butylbenzylphthalate	85-68-7	ug/kg	17	17	390	570	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Caprolactam	105-60-2	ug/kg	16	17	62	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Carbazole	86-74-8	ug/kg	15	17	29	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Chrysene	218-01-9	ug/kg	10	17	28	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Di-n-butylphthalate	84-74-2	ug/kg	15	17	390	570	200,000	F	N	--	--	NS	--	--	NS	--	--	NS
Di-n-octylphthalate	117-84-0	ug/kg	12	17	390	570	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dibenzo(a,h)anthracene	53-70-3	ug/kg	14	17	21	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Dibenzofuran	132-64-9	ug/kg	15	17	24	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Diethylphthalate	84-66-2	ug/kg	17	17	390	570	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dimethylphthalate	131-11-3	ug/kg	17	17	390	570	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Fluoranthene	206-44-0	ug/kg	9	17	18	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Fluorene	86-73-7	ug/kg	16	17	18	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Hexachlorobenzene	118-74-1	ug/kg	17	17	22	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Hexachlorobutadiene	87-68-3	ug/kg	17	17	24	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Hexachlorocyclopentadiene	77-47-4	ug/kg	17	17	67	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Hexachloroethane	67-72-1	ug/kg	17	17	17	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Indeno(1,2,3-cd)pyrene	193-39-5	ug/kg	11	17	20	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Isophorone	78-59-1	ug/kg	17	17	28	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
n-Nitroso-di-n-Propylamine	621-64-7	ug/kg	17	17	21	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
n-Nitrosodiphenylamine	86-30-6	ug/kg	17	17	390	1,100	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Naphthalene	91-20-3	ug/kg	15	17	21	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Nitrobenzene	98-95-3	ug/kg	17	17	28	390	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Pentachlorophenol	87-86-5	ug/kg	17	17	46	390	5,000	A	N	31,000	A	N	2,100	A	N	2,800	A	N
Phenol	108-95-2	ug/kg	17	17	34	390	100	G	Y	30,000	B	N	--	--	NS	--	--	NS
Phenanthrene	85-01-8	ug/kg	11	17	24	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Pyrene	129-00-0	ug/kg	10	17	24	390	100	G	Y	100	C	Y	--	--	NS	--	--	NS
Dioxin/Furans (pg/g)																		
1,2,3,4,7,8,9-HpCDF	55673-89-7	pg/g	1	2	0.6	0.6	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,4,7,8-HxCDD	39227-28-6	pg/g	1	2	0.5	0.5	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,4,7,8-HxCDF	70648-26-9	pg/g	1	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,6,7,8-HxCDD	57653-85-7	pg/g	1	2	0.6	0.6	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,6,7,8-HxCDF	57117-44-9	pg/g	1	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,7,8,9-HxCDD	19408-74-3	pg/g	1	2	0.5	0.5	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,7,8,9-HxCDF	72918-21-9	pg/g	2	2	0.4	0.5	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,7,8-PeCDD	40321-76-4	pg/g	1	2	0.4	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,3,4,6,7,8-HxCDF	60851-34-5	pg/g	1	2	0.4	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,3,4,7,8-PeCDF	57117-31-4	pg/g	1	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,3,7,8-TCDD	1746-01-6	pg/g	2	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,3,7,8-TCDF	51207-31-9	pg/g	2	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Total PeCDD	36088-22-9	pg/g	1	2	0.4	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Total TCDD	41903-57-5	pg/g	2	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Total TCDF	55722-27-5	pg/g	1	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS

Table 7-3
Non-detected Chemicals MDL Screening for SWMU 40 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
PAHs																		
Acenaphthene	83-32-9	ug/kg	10	17	5.8	5.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Acenaphthylene	208-96-8	ug/kg	15	17	5.9	5.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Anthracene	120-12-7	ug/kg	16	17	5.4	5.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(a)pyrene	50-32-8	ug/kg	5	17	1.6	1.6	100	G	N	--	--	NS	--	--	NS	--	--	NS
Benzo(a)anthracene	56-55-3	ug/kg	6	17	2.2	2.2	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(b)fluoranthene	205-99-2	ug/kg	2	17	1.7	1.7	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(k)fluoranthene	207-08-9	ug/kg	6	17	1.4	1.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(g,h,i)perylene	191-24-2	ug/kg	11	17	3.6	3.6	100	G	N	100	C	N	--	--	NS	--	--	NS
Chrysene	218-01-9	ug/kg	4	17	2.4	2.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Dibenzo(a,h)anthracene	53-70-3	ug/kg	13	17	4.2	4.2	100	G	N	100	C	N	--	--	NS	--	--	NS
Fluoranthene	206-44-0	ug/kg	2	17	2.1	2.1	100	G	N	100	C	N	--	--	NS	--	--	NS
Fluorene	86-73-7	ug/kg	17	17	14	14	100	G	N	100	C	N	--	--	NS	--	--	NS
Indeno(1,2,3-cd)pyrene	193-39-5	ug/kg	7	17	2.5	2.5	100	G	N	100	C	N	--	--	NS	--	--	NS
Naphthalene	91-20-3	ug/kg	11	17	14	14	100	G	N	100	C	N	--	--	NS	--	--	NS
Phenanthrene	85-01-8	ug/kg	9	17	8.5	8.5	100	G	N	100	C	N	--	--	NS	--	--	NS
Pyrene	129-00-0	ug/kg	2	17	4.3	4.3	100	G	N	100	C	N	--	--	NS	--	--	NS
Explosives																		
1,3,5-Trinitrobenzene	99-35-4	mg/kg	17	17	0.079	0.079	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,3-Dinitrobenzene	99-65-0	mg/kg	17	17	0.097	0.097	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,4,6-Trinitrotoluene	118-96-7	mg/kg	17	17	0.16	0.16	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,4-Dinitrotoluene	121-14-2	mg/kg	17	17	0.12	0.12	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,6-Dinitrotoluene	606-20-2	mg/kg	17	17	0.19	0.19	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Amino-4,6-Dinitrotoluene	35572-78-2	mg/kg	17	17	0.1	0.1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Nitrotoluene	88-72-2	mg/kg	17	17	0.16	0.16	--	--	NS	--	--	NS	--	--	NS	--	--	NS
3-Nitrotoluene	99-08-1	mg/kg	17	17	0.11	0.11	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Amino-2,6-Dinitrotoluene	1946-51-0	mg/kg	17	17	0.095	0.095	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Nitrotoluene	99-99-0	mg/kg	17	17	0.27	0.27	--	--	NS	--	--	NS	--	--	NS	--	--	NS
HMX	2691-41-0	mg/kg	17	17	0.1	0.1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Nitrobenzene	98-95-3	mg/kg	17	17	0.17	0.17	--	--	NS	--	--	NS	--	--	NS	--	--	NS
RDX	121-82-4	mg/kg	17	17	0.28	0.28	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Tetryl	479-45-8	mg/kg	17	17	0.4	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Nitroglycerin																		
Nitroglycerin	55-63-0	mg/kg	17	17	1	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS

Notes:

CAS = Chemical Abstracts Service
mg/kg = Milligram Per Kilogram
ug/kg = Microgram Per Kilogram
pg/g = Picogram Per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
MDL = Method Detection Limit
SL = Screening Level
Eco SSL = Ecological Soil Screening Level

Sources:

A = USEPA Eco SSL - Soil Invertebrates, Plants, Avian, Mammalian (<http://www.epa.gov/ecotox/ecossl>)
B = ORNL - Earthworms - (Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision, Efromson et al.)
C = BTAG - Fauna - (Region III Biological Technical Assistance Group - Draft Screening Levels - 1995)
E = ORNL - Microbial Processes - (Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision, Efromson et al.)
F = ORNL - Plants - Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision Efromson et al.)
G = BTAG - Flora - (Region III Biological Technical Assistance Group - Draft Screening Levels - 1995)

Y = MDL exceeds screening level
N = MDL does not exceed screening level
NS = No screening level available

Table 7-4
Non-detected Chemicals MDL Screening for SWMU 71 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
Gasoline Range Organics																		
GRO	--	mg/kg	3	3	0.95	1.1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
TAL Metals																		
Cadmium	7440-43-9	mg/kg	1	7	0.03	0.03	32	A	N	140	A	N	0.77	A	N	0.36	A	N
Selenium	7782-49-2	mg/kg	2	7	0.31	0.32	0.52	A	N	4.1	A	N	1.2	A	N	0.63	A	N
Silver	7440-22-4	mg/kg	2	7	0.08	0.09	560	A	N	50	E	N	4.2	A	N	14	A	N
Sodium	7440-23-5	mg/kg	1	7	19	19	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Thallium	7440-28-0	mg/kg	3	6	0.25	0.28	1	F	N	--	--	NS	--	--	NS	--	--	NS
Pesticides/PCBs																		
4,4'-DDD	72-54-8	ug/kg	4	4	0.32	0.32	100	G	N	100	C	N	--	--	NS	--	--	NS
4,4'-DDE	72-55-9	ug/kg	4	4	0.4	0.4	100	G	N	100	C	N	--	--	NS	--	--	NS
4,4'-DDT	50-29-3	ug/kg	4	4	0.39	0.39	100	G	N	100	C	N	93	A	N	21	A	N
Aldrin	309-00-2	ug/kg	2	4	0.17	0.17	100	G	N	100	C	N	--	--	NS	--	--	NS
alpha-BHC	319-84-6	ug/kg	4	4	0.26	0.26	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
alpha-Chlordane	5103-71-9	ug/kg	4	4	0.22	0.22	100	G	N	100	C	N	--	--	NS	--	--	NS
beta-BHC	319-85-7	ug/kg	2	4	0.28	0.28	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
delta-BHC	319-86-8	ug/kg	4	4	0.15	0.15	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
Dieldrin	60-57-1	ug/kg	4	4	0.43	0.43	100	G	N	100	C	N	22	A	N	4.9	A	N
Endosulfan I	959-98-8	ug/kg	4	4	0.43	0.43	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Endosulfan II	33213-65-9	ug/kg	4	4	0.58	0.58	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Endosulfan Sulfate	1031-07-8	ug/kg	4	4	0.4	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Endrin	72-20-8	ug/kg	4	4	0.35	0.35	100	G	N	100	C	N	--	--	NS	--	--	NS
Endrin Aldehyde	7421-93-4	ug/kg	4	4	0.35	0.35	100	G	N	100	C	N	--	--	NS	--	--	NS
Endrin Ketone	53494-70-5	ug/kg	4	4	0.39	0.39	100	G	N	100	C	N	--	--	NS	--	--	NS
gamma-BHC (Lindane)	58-89-9	ug/kg	3	4	0.22	0.22	100	G	N	100	C	N	--	--	NS	--	--	NS
gamma-Chlordane	5103-74-2	ug/kg	4	4	0.35	0.35	100	G	N	100	C	N	--	--	NS	--	--	NS
Heptachlor	76-44-8	ug/kg	4	4	0.34	0.34	100	G	N	100	C	N	--	--	NS	--	--	NS
Heptachlor Epoxide	1024-57-3	ug/kg	4	4	0.26	0.26	100	G	N	100	C	N	--	--	NS	--	--	NS
Methoxychlor	72-43-5	ug/kg	4	4	1.4	1.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Toxaphene	8001-35-2	ug/kg	4	4	18	18	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Aroclor 1016	12674-11-2	ug/kg	7	7	5.1	15	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1221	11104-28-2	ug/kg	7	7	14	16	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1232	11141-16-5	ug/kg	7	7	5.3	6	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1242	53469-21-9	ug/kg	7	7	7.3	10	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1248	12672-29-6	ug/kg	6	7	4.4	9.1	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1254	11097-69-1	ug/kg	1	7	8	8	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
Aroclor 1260	11096-82-5	ug/kg	5	7	5.2	9.2	40,000	--	N	--	--	NS	--	--	NS	--	--	NS
TCL VOCs																		
1,1,1-Trichloroethane	71-55-6	ug/kg	4	4	0.5	2	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1,2,2-Tetrachloroethane	79-34-5	ug/kg	4	4	0.2	0.5	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	ug/kg	4	4	6	18	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,1,2-Trichloroethane	79-00-5	ug/kg	4	4	0.2	0.5	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1-Dichloroethane	75-34-3	ug/kg	4	4	0.3	1	300	G	N	300	C	N	--	--	NS	--	--	NS
1,1-Dichloroethene	75-35-4	ug/kg	4	4	0.7	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,4-Trichlorobenzene	120-82-1	ug/kg	4	4	0.4	1	100	G	N	100	C	N	--	--	NS	--	--	NS
1,2-Dibromo-3-chloropropane	96-12-8	ug/kg	4	4	0.3	0.8	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2-Dibromoethane	106-93-4	ug/kg	4	4	0.2	0.6	--	--	NS	5,000	C	N	--	--	NS	--	--	NS
1,2-Dichlorobenzene	95-50-1	ug/kg	4	4	0.2	0.5	100	G	N	100	C	N	--	--	NS	--	--	NS
1,2-Dichloroethane	107-06-2	ug/kg	4	4	0.3	1	870,000	G	N	--	--	NS	--	--	NS	--	--	NS
1,2-Dichloropropane	78-87-5	ug/kg	4	4	0.2	0.6	300	G	N	300	C	N	--	--	NS	--	--	NS
1,3-Dichlorobenzene	541-73-1	ug/kg	4	4	0.3	0.8	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,4-Dichlorobenzene	106-46-7	ug/kg	4	4	0.3	0.7	100	G	N	20,000	B	N	--	--	NS	--	--	NS
2-Butanone	78-93-3	ug/kg	1	4	1	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Hexanone	591-78-6	ug/kg	4	4	0.6	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Methyl-2-Pentanone	108-10-1	ug/kg	1	4	0.6	0.6	100,000	G	N	--	--	NS	--	--	NS	--	--	NS
Benzene	71-43-2	ug/kg	2	4	0.4	0.6	100	G	N	100	C	N	--	--	NS	--	--	NS
Bromodichloromethane	75-27-4	ug/kg	4	4	0.2	0.6	450,000	G	N	--	--	NS	--	--	NS	--	--	NS

Table 7-4
Non-detected Chemicals MDL Screening for SWMU 71 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
Bromoform	75-25-2	ug/kg	4	4	0.3	0.8	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Bromomethane	74-83-9	ug/kg	3	4	1	3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Carbon Tetrachloride	56-23-5	ug/kg	4	4	0.5	2	300	G	N	300	C	N	--	--	NS	--	--	NS
Chlorobenzene	108-90-7	ug/kg	4	4	0.3	0.7	100	G	N	40,000	B	N	--	--	NS	--	--	NS
Chloroethane	75-00-3	ug/kg	4	4	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Chloroform	67-66-3	ug/kg	4	4	0.4	1	300	G	N	300	C	N	--	--	NS	--	--	NS
Chloromethane	74-87-3	ug/kg	4	4	1	3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
cis-1,2-Dichloroethene	156-59-2	ug/kg	4	4	0.4	1	300	G	N	300	C	N	--	--	NS	--	--	NS
cis-1,3-Dichloropropene	10061-01-5	ug/kg	4	4	0.3	0.9	300	G	N	300	C	N	--	--	NS	--	--	NS
Cyclohexane	110-82-7	ug/kg	3	4	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dibromochloromethane	124-48-1	ug/kg	4	4	0.2	0.5	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dichlorodifluoromethane	75-71-8	ug/kg	3	4	0.5	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Ethylbenzene	100-41-4	ug/kg	3	4	0.4	0.8	100	G	N	100	C	N	--	--	NS	--	--	NS
Isopropylbenzene	98-82-8	ug/kg	4	4	6	18	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methyl Acetate	79-20-9	ug/kg	4	4	0.6	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methyl-t-butyl Ether	1634-04-4	ug/kg	4	4	6	18	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methylcyclohexane	108-87-2	ug/kg	3	4	0.5	0.9	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Methylene Chloride	75-09-2	ug/kg	2	4	0.5	0.7	300	G	N	300	C	N	--	--	NS	--	--	NS
Styrene	100-42-5	ug/kg	3	4	0.3	0.8	300,000	F	N	100	C	N	--	--	NS	--	--	NS
Tetrachloroethene	127-18-4	ug/kg	4	4	0.4	1	300	G	N	300	C	N	--	--	NS	--	--	NS
trans-1,2-Dichloroethene	156-60-5	ug/kg	4	4	0.4	1	300	G	N	300	C	N	--	--	NS	--	--	NS
trans-1,3-Dichloropropene	10061-02-6	ug/kg	4	4	0.2	0.7	300	G	N	300	C	N	--	--	NS	--	--	NS
Trichlorofluoromethane	75-69-4	ug/kg	4	4	0.6	2	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Vinyl Chloride	75-01-4	ug/kg	4	4	0.5	1	300	G	N	300	C	N	--	--	NS	--	--	NS
TCL SVOCs																		
1,1'-Biphenyl	92-52-4	ug/kg	4	4	22	22	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,2'-oxybis(1-chloropropane)	108-60-1	ug/kg	4	4	30	30	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,4,5-Trichlorophenol	95-95-4	ug/kg	4	4	49	49	4,000	F	N	9,000	B	N	--	--	NS	--	--	NS
2,4,6-Trichlorophenol	88-06-2	ug/kg	4	4	50	50	100	G	N	10,000	B	N	--	--	NS	--	--	NS
2,4-Dichlorophenol	120-83-2	ug/kg	4	4	22	22	100	G	N	100	C	N	--	--	NS	--	--	NS
2,4-Dimethylphenol	105-67-9	ug/kg	4	4	30	30	100	G	N	100	C	N	--	--	NS	--	--	NS
2,4-Dinitrophenol	51-28-5	ug/kg	4	4	170	170	20,000	F	N	100	C	Y	--	--	NS	--	--	NS
2,4-Dinitrotoluene	121-14-2	ug/kg	4	4	20	20	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,6-Dinitrotoluene	606-20-2	ug/kg	4	4	21	21	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Chloronaphthalene	91-58-7	ug/kg	4	4	22	22	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Chlorophenol	95-57-8	ug/kg	4	4	18	18	7,000	F	N	10,000	B	N	--	--	NS	--	--	NS
2-Methylnaphthalene	91-57-6	ug/kg	1	4	24	24	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Methylphenol	95-48-7	ug/kg	4	4	27	27	100	G	N	100	C	N	--	--	NS	--	--	NS
2-Nitroaniline	88-74-4	ug/kg	4	4	29	29	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Nitrophenol	88-75-5	ug/kg	4	4	26	26	--	--	NS	--	--	NS	--	--	NS	--	--	NS
3,3'-Dichlorobenzidine	91-94-1	ug/kg	4	4	29	29	--	--	NS	--	--	NS	--	--	NS	--	--	NS
3-Nitroaniline	99-09-2	ug/kg	4	4	34	34	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4,6-Dinitro-2-Methylphenol	534-52-1	ug/kg	4	4	35	35	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Bromophenyl Phenyl Ether	101-55-3	ug/kg	4	4	350	380	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Chloro-3-Methylphenol	59-50-7	ug/kg	4	4	29	29	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Chloroaniline	106-47-8	ug/kg	4	4	16	16	20,000	F	N	--	--	NS	--	--	NS	--	--	NS
4-Chlorophenyl Phenyl Ether	7005-72-3	ug/kg	4	4	350	380	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Methylphenol	106-44-5	ug/kg	4	4	48	48	100	G	N	100	C	N	--	--	NS	--	--	NS
4-Nitroaniline	100-01-6	ug/kg	4	4	39	39	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Nitrophenol	100-02-7	ug/kg	4	4	75	75	100	G	N	7,000	B	N	--	--	NS	--	--	NS
Acenaphthene	83-32-9	ug/kg	4	4	31	31	100	G	N	100	C	N	--	--	NS	--	--	NS
Acenaphthylene	208-96-8	ug/kg	4	4	17	17	100	G	N	100	C	N	--	--	NS	--	--	NS
Acetophenone	98-86-2	ug/kg	4	4	23	23	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Anthracene	120-12-7	ug/kg	4	4	25	25	100	G	N	100	C	N	--	--	NS	--	--	NS
Atrazine	1912-24-9	ug/kg	4	4	16	16	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Benzaldehyde	100-52-7	ug/kg	4	4	39	39	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Benzo(a)anthracene	50-32-8	ug/kg	4	4	29	29	100	G	N	--	--	NS	--	--	NS	--	--	NS

Table 7-4
Non-detected Chemicals MDL Screening for SWMU 71 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
Benzo(a)pyrene	56-55-3	ug/kg	4	4	23	23	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(b)fluoranthene	205-99-2	ug/kg	4	4	36	36	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(g,h,i)perylene	191-24-2	ug/kg	4	4	23	23	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(k)fluoranthene	207-08-9	ug/kg	4	4	29	29	100	G	N	100	C	N	--	--	NS	--	--	NS
bis(2-Chloroethoxy)methane	111-91-1	ug/kg	4	4	21	21	--	--	NS	--	--	NS	--	--	NS	--	--	NS
bis(2-Chloroethyl)ether	111-44-4	ug/kg	4	4	18	18	--	--	NS	--	--	NS	--	--	NS	--	--	NS
bis(2-ethylhexyl)phthalate	117-81-7	ug/kg	1	4	32	32	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Butylbenzylphthalate	85-68-7	ug/kg	4	4	350	380	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Caprolactam	105-60-2	ug/kg	4	4	62	62	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Carbazole	86-74-8	ug/kg	4	4	29	29	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Chrysene	218-01-9	ug/kg	4	4	28	28	100	G	N	100	C	N	--	--	NS	--	--	NS
Di-n-butylphthalate	84-74-2	ug/kg	4	4	350	380	200,000	F	N	--	--	NS	--	--	NS	--	--	NS
Di-n-octylphthalate	117-84-0	ug/kg	4	4	350	380	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dibenzo(a,h)anthracene	53-70-3	ug/kg	4	4	21	21	100	G	N	100	C	N	--	--	NS	--	--	NS
Dibenzofuran	132-64-9	ug/kg	4	4	24	24	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Diethylphthalate	84-66-2	ug/kg	4	4	350	380	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Dimethylphthalate	131-11-3	ug/kg	4	4	350	380	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Fluoranthene	206-44-0	ug/kg	1	4	18	18	100	G	N	100	C	N	--	--	NS	--	--	NS
Fluorene	86-73-7	ug/kg	4	4	18	18	100	G	N	100	C	N	--	--	NS	--	--	NS
Hexachlorobenzene	118-74-1	ug/kg	4	4	22	22	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Hexachlorobutadiene	87-68-3	ug/kg	4	4	24	24	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Hexachlorocyclopentadiene	77-47-4	ug/kg	4	4	67	67	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Hexachloroethane	67-72-1	ug/kg	4	4	17	17	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Indeno(1,2,3-cd)pyrene	193-39-5	ug/kg	4	4	20	20	100	G	N	100	C	N	--	--	NS	--	--	NS
Isophorone	78-59-1	ug/kg	4	4	28	28	--	--	NS	--	--	NS	--	--	NS	--	--	NS
n-Nitroso-di-n-Propylamine	621-64-7	ug/kg	4	4	21	21	--	--	NS	--	--	NS	--	--	NS	--	--	NS
n-Nitrosodiphenylamine	86-30-6	ug/kg	4	4	350	770	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Naphthalene	91-20-3	ug/kg	3	4	21	21	100	G	N	100	C	N	--	--	NS	--	--	NS
Nitrobenzene	98-95-3	ug/kg	4	4	28	28	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Pentachlorophenol	87-86-5	ug/kg	4	4	46	46	5,000	A	N	31,000	A	N	2,100	A	N	2,800	A	N
Phenanthrene	85-01-8	ug/kg	1	4	24	24	100	G	N	100	C	N	--	--	NS	--	--	NS
Phenol	108-95-2	ug/kg	4	4	34	34	100	G	N	30,000	B	N	--	--	NS	--	--	NS
Pyrene	129-00-0	ug/kg	2	4	24	24	100	G	N	100	C	N	--	--	NS	--	--	NS
Dioxin/Furans																		
1,2,3,4,7,8,9-HpCDF	55673-89-7	pg/g	2	2	0.4	0.6	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,6,7,8-HxCDF	57117-44-9	pg/g	1	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,7,8,9-HxCDF	72918-21-9	pg/g	2	2	0.2	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
1,2,3,7,8-PeCDF	57117-41-6	pg/g	1	2	0.1	0.1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,3,7,8-TCDD	1746-01-6	pg/g	1	2	0.3	0.3	--	--	NS	--	--	NS	--	--	NS	--	--	NS
PAHs																		
Acenaphthene	83-32-9	ug/kg	2	4	5.9	5.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Acenaphthylene	208-96-8	ug/kg	3	4	5.9	5.9	100	G	N	100	C	N	--	--	NS	--	--	NS
Anthracene	120-12-7	ug/kg	4	4	5.4	5.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(a)anthracene	50-32-8	ug/kg	2	4	2.2	2.2	100	G	N	--	--	NS	--	--	NS	--	--	NS
Benzo(a)pyrene	56-55-3	ug/kg	2	4	1.6	1.6	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(b)fluoranthene	205-99-2	ug/kg	2	4	1.7	1.7	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(g,h,i)perylene	207-08-9	ug/kg	4	4	3.6	3.6	100	G	N	100	C	N	--	--	NS	--	--	NS
Benzo(k)fluoranthene	191-24-2	ug/kg	2	4	1.4	1.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Chrysene	218-01-9	ug/kg	2	4	2.4	2.4	100	G	N	100	C	N	--	--	NS	--	--	NS
Dibenzo(a,h)anthracene	53-70-3	ug/kg	4	4	4.2	4.2	100	G	N	100	C	N	--	--	NS	--	--	NS
Fluorene	86-73-7	ug/kg	4	4	14	14	100	G	N	100	C	N	--	--	NS	--	--	NS
Indeno(1,2,3-cd)pyrene	193-39-5	ug/kg	4	4	2.5	2.5	100	G	N	100	C	N	--	--	NS	--	--	NS
Naphthalene	91-20-3	ug/kg	2	4	14	14	100	G	N	100	C	N	--	--	NS	--	--	NS
Phenanthrene	85-01-8	ug/kg	3	4	8.5	8.5	100	G	N	100	C	N	--	--	NS	--	--	NS
Pyrene	129-00-0	ug/kg	3	4	4.3	4.3	100	G	N	100	C	N	--	--	NS	--	--	NS
Explosives																		
1,3,5-Trinitrobenzene	99-35-4	mg/kg	4	4	0.079	0.079	--	--	NS	--	--	NS	--	--	NS	--	--	NS

Table 7-4
Non-detected Chemicals MDL Screening for SWMU 71 - Surface Soil
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Parameter Name	CAS #	Units	Number of Non-Detects	Number of Samples	Minimum MDL	Maximum MDL	Plant SL	Source	Maximum MDL Exceeds SL	Invertebrate SL	Source	Maximum MDL Exceeds SL	Avian ECO SSL	Source	Maximum MDL Exceeds SL	Mammalian ECO SSL	Source	Maximum MDL Exceeds SL
1,3-Dinitrobenzene	99-65-0	mg/kg	4	4	0.097	0.097	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,4,6-Trinitrotoluene	118-96-7	mg/kg	4	4	0.16	0.16	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,4-Dinitrotoluene	121-14-2	mg/kg	4	4	0.12	0.12	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2,6-Dinitrotoluene	606-20-2	mg/kg	4	4	0.19	0.19	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Amino-4,6-Dinitrotoluene	35572-78-2	mg/kg	4	4	0.1	0.1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
2-Nitrotoluene	88-72-2	mg/kg	4	4	0.16	0.16	--	--	NS	--	--	NS	--	--	NS	--	--	NS
3-Nitrotoluene	99-08-1	mg/kg	4	4	0.11	0.11	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Amino-2,6-Dinitrotoluene	1946-51-0	mg/kg	4	4	0.095	0.095	--	--	NS	--	--	NS	--	--	NS	--	--	NS
4-Nitrotoluene	99-99-0	mg/kg	4	4	0.27	0.27	--	--	NS	--	--	NS	--	--	NS	--	--	NS
HMX	2691-41-0	mg/kg	4	4	0.1	0.1	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Nitrobenzene	98-95-3	mg/kg	4	4	0.17	0.17	--	--	NS	--	--	NS	--	--	NS	--	--	NS
RDX	121-82-4	mg/kg	4	4	0.28	0.28	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Tetryl	479-45-8	mg/kg	4	4	0.4	0.4	--	--	NS	--	--	NS	--	--	NS	--	--	NS
Nitroglycerin																		
Nitroglycerin	55-63-0	mg/kg	4	4	1	1	--	--	NS	--	--	NS	--	--	NS	--	--	NS

Notes:

CAS = Chemical Abstracts Service
mg/kg = Milligram Per Kilogram
ug/kg = Microgram Per Kilogram
pg/g = Picogram Per Gram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
MDL = Method Detection Limit
SL = Screening Level
ECO SSL = Ecological Soil Screening Level

Sources:

A = USEPA Eco SSL - Soil Invertebrates, Plants, Avian, Mammalian (<http://www.epa.gov/ecotox/ecoss/>)
B = ORNL - Earthworms - (Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision, Efromymson et al.)
C = BTAG - Fauna - (Region III Biological Technical Assistance Group - Draft Screening Levels - 1995)
E = ORNL - Microbial Processes - (Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision, Efromymson et al.)
F = ORNL - Plants - Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision Efromymson et al.)
G = BTAG - Flora - (Region III Biological Technical Assistance Group - Draft Screening Levels - 1995)

Y = MDL exceeds screening level
N = MDL does not exceed screening level
NS = No screening level available

Table 7-5
Plant Screening - Soil
Screening Level Ecological Risk Assessment - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Constituent of Potential Ecological Concern	CAS #	Maximum Soil Concentration (mg/kg)	Screening Level (mg/kg)	Hazard Quotient (unitless)	EPC (mg/kg)	EPC Hazard Quotient (unitless)
Inorganics						
Aluminum	7429-90-5	28,500	50	5.7E+02	16,945	3.4E+02
Antimony	7440-36-0	1.3	5	2.6E-01	NC	NC
Arsenic	7440-38-2	55	18	3.1E+00	25.61	1.4E+00
Barium	7440-39-3	191	500	3.8E-01	NC	NC
Beryllium	7440-41-7	1.5	10	1.5E-01	NC	NC
Cadmium	7440-43-9	0.75	32	2.3E-02	NC	NC
Calcium	7440-70-2	26,300	4	6.6E+03	9,550	2.4E+03
Chromium	7440-47-3	37.6	1	3.8E+01	25.95	2.6E+01
Cobalt	7440-48-4	13.2	13	1.0E+00	7.819	6.0E-01
Copper	7440-50-8	76	70	1.1E+00	39.1	5.6E-01
Iron	7439-89-6	32,000	NV	NC	NC	NC
Lead	7439-92-1	110	120	9.2E-01	NC	NC
Magnesium	7439-95-4	24,400	NV	NC	NC	NC
Manganese	7439-96-5	894	220	4.1E+00	416.2	1.9E+00
Mercury	7439-97-6	2.1	0.3	7.0E+00	0.933	3.1E+00
Nickel	7440-02-0	20.9	38	5.5E-01	NC	NC
Potassium	7440-09-7	5,240	NV	NC	NC	NC
Selenium	7782-49-2	3	0.52	6.3E+00	1.657	3.2E+00
Silver	7440-22-4	0.2	560	3.6E-04	NC	NC
Sodium	7440-23-5	370	NV	NC	NC	NC
Vanadium	7440-62-2	56.9	2	2.8E+01	55.35	2.8E+01
Zinc	7440-66-6	148	160	9.3E-01	NC	NC
Pesticides/PCBs						
4,4'-DDE	72-55-9	0.0018	0.1	1.8E-02	NC	NC
4,4'-DDT	50-29-3	0.0077	0.1	7.7E-02	NC	NC
Aldrin	309-00-2	0.0051	0.1	5.1E-02	NC	NC
alpha-Chlordane	5103-71-9	0.0032	0.1	3.2E-02	NC	NC
beta-BHC	319-85-7	0.012	100	1.2E-04	NC	NC
Endosulfan Sulfate	1031-07-8	0.029	NV	NC	NC	NC
Endrin	72-20-8	0.0039	0.1	3.9E-02	NC	NC
Endrin Ketone	53494-70-5	0.024	0.1	2.4E-01	NC	NC
gamma-BHC (Lindane)	58-89-9	0.011	0.1	1.1E-01	NC	NC
gamma-Chlordane	5103-74-2	0.0076	0.1	7.6E-02	NC	NC
Methoxychlor	72-43-5	0.043	0.1	4.3E-01	NC	NC
PCBs (Total)	--	2.1	40	5.3E-02	NC	NC
TCL VOCs						
1,2,4-Trichlorobenzene	120-82-1	0.0007	0.1	7.0E-03	NC	NC
1,2-Dibromo-3-Chloropropane	96-12-8	0.0004	NV	NC	NC	NC
1,2-Dichlorobenzene	95-50-1	0.0008	0.1	8.0E-03	NC	NC
1,3-Dichlorobenzene	541-73-1	0.0009	NV	NC	NC	NC
1,4-Dichlorobenzene	106-46-7	0.001	0.1	1.0E-02	NC	NC
2-Butanone	78-93-3	0.04	NV	NC	NC	NC
2-Hexanone	591-78-6	0.002	NV	NC	NC	NC
4-Methyl-2-Pentanone	108-10-1	0.031	100	3.1E-04	NC	NC
Acetone	67-64-1	0.46	NV	NC	NC	NC
Benzene	71-43-2	0.006	0.1	6.0E-02	NC	NC
Bromomethane	74-83-9	0.003	NV	NC	NC	NC
Carbon Disulfide	75-15-0	0.004	NV	NC	NC	NC
Chlorobenzene	108-90-7	0.0004	0.1	4.0E-03	NC	NC
Chloromethane	74-87-3	0.003	NV	NC	NC	NC
Cyclohexane	110-82-7	0.003	NV	NC	NC	NC
Dichlorodifluoromethane	75-71-8	0.003	NV	NC	NC	NC
Ethylbenzene	100-41-4	0.017	0.1	1.7E-01	NC	NC
Isopropylbenzene	98-82-8	0.003	NV	NC	NC	NC
Methyl Acetate	79-20-9	0.12	NV	NC	NC	NC
Methyl Tert-Butyl Ether	1634-04-4	0.002	NV	NC	NC	NC
Methylcyclohexane	108-87-2	0.027	NV	NC	NC	NC
Methylene Chloride	75-09-2	0.014	0.3	4.7E-02	NC	NC
Styrene	100-42-5	0.002	300	6.7E-06	NC	NC
Tetrachloroethene	127-18-4	0.001	0.3	3.3E-03	NC	NC
Toluene	108-88-3	0.019	200	9.5E-05	NC	NC
Trichloroethene	79-01-6	0.022	0.3	7.3E-02	NC	NC
Xylenes (Total)	1330-20-7	0.082	0.1	8.2E-01	NC	NC

Table 7-5
Plant Screening - Soil
Screening Level Ecological Risk Assessment - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Constituent of Potential Ecological Concern	CAS #	Maximum Soil Concentration (mg/kg)	Screening Level (mg/kg)	Hazard Quotient (unitless)	EPC (mg/kg)	EPC Hazard Quotient (unitless)
TCL SVOCs						
2,4-Dinitrotoluene	121-14-2	0.035	NV	NC	NC	NC
2,6-Dinitrotoluene	606-20-2	0.04	NV	NC	NC	NC
2-Methylnaphthalene	91-57-6	0.14	NV	NC	NC	NC
Benzaldehyde	100-52-7	0.066	NV	NC	NC	NC
Bis(2-ethylhexyl)phthalate	117-81-7	0.28	NV	NC	NC	NC
Caprolactam	105-60-2	0.8	NV	NC	NC	NC
Carbazole	86-74-8	0.2	NV	NC	NC	NC
Di-n-butylphthalate	84-74-2	0.14	200	7.0E-04	NC	NC
Di-n-octylphthalate	117-84-0	0.5	NV	NC	NC	NC
Dibenzofuran	132-64-9	0.056	NV	NC	NC	NC
TCL PAHs						
Low Molecular Weight PAHs	--	2.32	NV	NC	NC	NC
High Molecular Weight PAHs	--	4.26	NV	NC	NC	NC

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon

NV = No Value Available
NC = Not Calculated
Hazard Quotient = Soil Concentration/Screening Level
EPC = Exposure Point Concentration
See Table F.2-3b for Total Low and High Molecular Weight PAHs
See Table F.2-3c for Total PCBs

Table 7-6
Invertebrate and Microbial Screening - Soil
Screening Level Ecological Risk Assessment - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Constituent of Potential Ecological Concern	CAS #	Maximum Soil Concentration (mg/kg)	Screening Level (mg/kg)	Hazard Quotient (unitless)	EPC (mg/kg)	EPC Hazard Quotient (unitless)
Inorganics						
Aluminum	7429-90-5	28,500	NV	NC	NC	NC
Antimony	7440-36-0	1.3	78	1.7E-02	NC	NC
Arsenic	7440-38-2	55	60	9.2E-01	NC	NC
Barium	7440-39-3	191	330	5.8E-01	NC	NC
Beryllium	7440-41-7	1.5	40	3.8E-02	NC	NC
Cadmium	7440-43-9	0.75	140	5.4E-03	NC	NC
Calcium	7440-70-2	26,300	NV	NC	NC	NC
Chromium	7440-47-3	37.6	0.4	9.4E+01	25.95	6.5E+01
Cobalt	7440-48-4	13.2	200	6.6E-02	NC	NC
Copper	7440-50-8	76	80	9.5E-01	NC	NC
Iron	7439-89-6	32,000	200	1.6E+02	30,115	1.5E+02
Lead	7439-92-1	110	1,700	6.5E-02	NC	NC
Magnesium	7439-95-4	24,400	NV	NC	NC	NC
Manganese	7439-96-5	894	450	2.0E+00	416.2	9.2E-01
Mercury	7439-97-6	2.1	0.1	2.1E+01	0.933	9.3E+00
Nickel	7440-02-0	20.9	280	7.5E-02	NC	NC
Potassium	7440-09-7	5,240	NV	NC	NC	NC
Selenium	7782-49-2	3.3	4.1	8.0E-01	NC	NC
Silver	7440-22-4	0.2	50	4.0E-03	NC	NC
Sodium	7440-23-5	370	NV	NC	NC	NC
Vanadium	7440-62-2	56.9	20	2.8E+00	55.35	2.8E+00
Zinc	7440-66-6	148	120	1.2E+00	75.97	6.3E-01
Pesticides/PCBs						
4,4'-DDE	72-55-9	0.0018	0.1	1.8E-02	NC	NC
4,4'-DDT	50-29-3	0.0077	0.1	7.7E-02	NC	NC
Aldrin	309-00-2	0.0051	0.1	5.1E-02	NC	NC
alpha-Chlordane	5103-71-9	0.0032	0.1	3.2E-02	NC	NC
beta-BHC	319-85-7	0.012	NV	NC	NC	NC
Endosulfan Sulfate	1031-07-8	0.029	NV	NC	NC	NC
Endrin	72-20-8	0.0039	0.1	3.9E-02	NC	NC
Endrin Ketone	53494-70-5	0.024	0.1	2.4E-01	NC	NC
gamma-BHC (Lindane)	58-89-9	0.011	0.1	1.1E-01	NC	NC
gamma-Chlordane	5103-74-2	0.0076	0.1	7.6E-02	NC	NC
Methoxychlor	72-43-5	0.043	0.1	4.3E-01	NC	NC
Aroclor 1254	11097-69-1	2.1	NV	NC	NC	NC
Aroclor 1260	11096-82-5	0.62	NV	NC	NC	NC
TCL VOCs						
1,2,4-Trichlorobenzene	120-82-1	0.0007	0.1	7.0E-03	NC	NC
1,2-Dibromo-3-Chloropropane	96-12-8	0.0004	NV	NC	NC	NC
1,2-Dichlorobenzene	95-50-1	0.0008	0.1	8.0E-03	NC	NC
1,3-Dichlorobenzene	541-73-1	0.0009	NV	NC	NC	NC
1,4-Dichlorobenzene	106-46-7	0.001	20.0	5.0E-05	NC	NC
2-Butanone	78-93-3	0.04	NV	NC	NC	NC
2-Hexanone	591-78-6	0.002	NV	NC	NC	NC
4-Methyl-2-Pentanone	108-10-1	0.031	NV	NC	NC	NC
Acetone	67-64-1	0.46	NV	NC	NC	NC
Benzene	71-43-2	0.006	0.1	6.0E-02	NC	NC
Bromomethane	74-83-9	0.003	NV	NC	NC	NC
Carbon Disulfide	75-15-0	0.004	NV	NC	NC	NC
Chlorobenzene	108-90-7	0.0004	40.0	1.0E-05	NC	NC
Chloromethane	74-87-3	0.003	NV	NC	NC	NC
Cyclohexane	110-82-7	0.003	NV	NC	NC	NC
Dichlorodifluoromethane	75-71-8	0.003	NV	NC	NC	NC
Ethylbenzene	100-41-4	0.017	0.1	1.7E-01	NC	NC
Isopropylbenzene	98-82-8	0.003	NV	NC	NC	NC
Methyl Acetate	79-20-9	0.12	NV	NC	NC	NC
Methyl Tert-Butyl Ether	1634-04-4	0.002	NV	NC	NC	NC
Methylcyclohexane	108-87-2	0.027	NV	NC	NC	NC

Table 7-6
Invertebrate and Microbial Screening - Soil
Screening Level Ecological Risk Assessment - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Constituent of Potential Ecological Concern	CAS #	Maximum Soil Concentration (mg/kg)	Screening Level (mg/kg)	Hazard Quotient (unitless)	EPC (mg/kg)	EPC Hazard Quotient (unitless)
Methylene Chloride	75-09-2	0.014	0.3	4.7E-02	NC	NC
Styrene	100-42-5	0.002	0.1	2.0E-02	NC	NC
Tetrachloroethene	127-18-4	0.001	0.3	3.3E-03	NC	NC
Toluene	108-88-3	0.019	0.1	1.9E-01	NC	NC
Trichloroethene	79-01-6	0.022	0.3	7.3E-02	NC	NC
Xylenes (Total)	1330-20-7	0.082	NV	NC	NC	NC
TCL SVOCs						
2,4-Dinitrotoluene	121-14-2	0.035	NV	NC	NC	NC
2,6-Dinitrotoluene	606-20-2	0.04	NV	NC	NC	NC
2-Methylnaphthalene	91-57-6	0.14	NV	NC	NC	NC
Benzaldehyde	100-52-7	0.066	NV	NC	NC	NC
Bis(2-ethylhexyl)phthalate	117-81-7	0.28	NV	NC	NC	NC
Caprolactam	105-60-2	0.8	NV	NC	NC	NC
Carbazole	86-74-8	0.2	NV	NC	NC	NC
Di-n-butylphthalate	84-74-2	0.14	NV	NC	NC	NC
Di-n-octylphthalate	117-84-0	0.5	NV	NC	NC	NC
Dibenzofuran	132-64-9	0.056	NV	NC	NC	NC
TCL PAHs						
Low Molecular Weight PAHs	--	2.32	29	8.0E-02	NC	NC
High Molecular Weight PAHs	--	4.26	18	2.4E-01	NC	NC

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon

NV = No Value Available
NC = Not Calculated
Hazard Quotient = Soil Concentration/Screening Level
EPC = Exposure Point Concentration
See Table F.2-3b for Total Low and High Molecular Weight PAHs

Table 7-7
Dioxin/Furan Equivalent Calculation - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Mammalian TEF	Avian TEF	40SS4 11/11/2002 0-1		40SS5 11/11/2002 0-1	
				Result	LQ, VQ, r	Result	LQ, VQ, r
Dioxin/Furans (pg/g)							
1,2,3,4,6,7,8,9-OCDD (OCDD)	3268-87-9	0.0003	0.0001	1,640		248	
1,2,3,4,6,7,8,9-OCDF (OCDD)	39001-02-0	0.0003	0.0001	151		13.6	
1,2,3,4,6,7,8-HpCDD	35822-39-4	0.01	0.001	218		26.6	
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01	48.2		4	J
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01	4.6	J	<5	
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05	2.1	MJ	<5	
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	0.1	2.4	MJ	<5	
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01	6.3		<5	
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1	2	J	<5	
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1	5.5		<5	
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1	<5		<5	
1,2,3,7,8-PeCDD	40321-76-4	1	1	1.3	MJ	<5	
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1	11.5	MX,J,w	0.79	MXJ,J,w
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1	3.1	J	<5	
2,3,4,7,8-PeCDF	57117-31-4	0.3	1	0.37	J	<5	
2,3,7,8-TCDD	1746-01-6	1	1	<1		<1	
2,3,7,8-TCDF	51207-31-9	0.1	1	<1		<1	
Total 2,3,7,8-TCDD Equivalents (Mammalian)				7.141		0.408	
Total 2,3,7,8-TCDD Equivalents (Avian)				4.843		0.172	

Notes:

pg/g = Picogram Per Gram
ft bgs = Feet Below Ground Surface
TEF = Toxicity Equivalency Factor
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

Total 2,3,7,8-TCDD Equivalents are calculated by summing the detected concentration times the TEF for each chemical. Non-detects, R-flagged data, and B-flagged data are excluded from summed total.

Qualifiers:

J Analyte present. Reported value may not be accurate or precise.
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.
X Associated PCDF peak(s) has the same retention time as the associated diphenyl ether and the diphenyl ether contribution is greater than 10%.
w Retention time failure.

Table 7-8
Wildlife Summary
Screening Level Ecological Risk Assessment - SWMU 40
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Chemical	CAS#	Meadow Vole					Short-tailed Shrew					Red Fox					American Robin					Red-tailed Hawk				
		Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ
Inorganics																										
Arsenic	7440-38-2	3.0E+02	3.0E+01	1.4E+02	2.8E+00	2.8E-01	1.1E+02	1.1E+01	5.1E+01	4.9E+00	4.9E-01	2.0E+02	2.0E+01	9.3E+01	1.3E-02	1.3E-03	3.9E+00	1.6E+00	1.8E+00	1.1E-01	4.5E-02	1.0E-02	4.2E-03	NC	NC	NC
Cadmium	7440-43-9	8.6E-01	8.6E-02	NC	NC	NC	3.5E+00	3.5E-01	1.1E+00	1.4E-01	1.4E-02	7.0E+00	7.0E-01	2.1E+00	2.3E-04	2.3E-05	6.6E+00	4.8E-01	2.0E+00	1.7E-01	1.2E-02	1.4E-01	9.9E-03	NC	NC	NC
Chromium	7440-47-3	4.2E-01	4.2E-02	NC	NC	NC	4.1E+00	4.1E-01	2.8E+00	1.9E-01	1.9E-02	8.0E+00	8.0E-01	5.5E+00	8.2E-04	8.2E-05	3.8E+01	7.6E+00	2.6E+01	1.0E+00	2.0E-01	8.2E-01	1.6E-01	NC	NC	NC
Copper	7440-50-8	1.1E+00	8.3E-01	5.6E-01	7.5E-02	5.7E-02	9.1E-01	6.9E-01	NC	NC	NC	1.7E+00	1.3E+00	8.8E-01	7.5E-04	5.7E-04	8.1E-01	6.1E-01	NC	NC	NC	1.1E-01	8.5E-02	NC	NC	NC
Lead	7439-92-1	2.3E+00	2.3E-01	1.1E+00	5.8E-02	5.8E-03	2.5E+00	2.5E-01	1.2E+00	1.9E-01	1.9E-02	4.7E+00	4.7E-01	2.3E+00	8.1E-04	8.1E-05	4.8E+01	4.8E+00	2.4E+01	2.2E+00	2.2E-01	1.8E+00	1.8E-01	9.0E-01	9.4E-04	9.4E-05
Mercury	7439-97-6	2.1E-01	2.1E-02	NC	NC	NC	2.8E-01	2.8E-02	NC	NC	NC	5.6E-01	5.6E-02	NC	NC	NC	3.0E+01	1.5E+01	1.4E+01	4.0E-01	2.0E-01	5.9E-02	2.9E-02	NC	NC	NC
Nickel	7440-02-0	2.5E-01	1.3E-01	NC	NC	NC	2.8E-01	1.4E-01	NC	NC	NC	5.5E-01	2.7E-01	NC	NC	NC	4.1E-01	2.9E-01	NC	NC	NC	1.0E-02	7.6E-03	NC	NC	NC
Selenium	7782-49-2	1.7E+01	1.0E+01	8.4E+00	5.7E-01	3.5E-01	5.7E+00	3.4E+00	2.8E+00	4.5E-01	2.7E-01	1.1E+01	6.7E+00	5.5E+00	3.7E-03	2.2E-03	8.0E+00	4.0E+00	4.0E+00	5.9E-01	3.0E-01	6.4E-01	3.2E-01	NC	NC	NC
Silver	7440-22-4	1.8E-04	1.8E-05	NC	NC	NC	1.5E-02	1.5E-03	NC	NC	NC	3.0E-02	3.0E-03	NC	NC	NC	5.8E-02	7.8E-03	NC	NC	NC	4.0E-04	5.3E-05	NC	NC	NC
Zinc	7440-66-6	5.7E-01	2.9E-01	NC	NC	NC	1.3E+00	6.6E-01	6.7E-01	1.2E-01	6.1E-02	2.6E+00	1.3E+00	1.3E+00	5.7E-04	2.9E-04	4.2E+01	4.6E+00	2.1E+01	2.4E+00	2.7E-01	1.8E+00	2.0E-01	9.3E-01	1.2E-03	1.4E-04
Dioxin/Furans																										
Total 2,3,7,8-TCDD Equivalents	1746-01-6	1.4E-01	1.4E-02	NC	NC	NC	3.2E+01	3.2E+00	4.3E+01	1.0E+01	1.0E+00	6.5E+01	6.5E+00	8.7E+01	1.5E-02	1.5E-03	2.4E+00	2.4E-01	5.8E+00	7.3E-01	7.3E-02	5.0E-02	5.0E-03	NC	NC	NC
Pesticides/PCBs																										
4,4'-DDE	72-55-9	2.7E-06	2.7E-07	NC	NC	NC	1.7E-04	1.7E-05	NC	NC	NC	3.5E-04	3.5E-05	NC	NC	NC	2.0E-01	2.0E-02	NC	NC	NC	2.0E-03	2.0E-04	NC	NC	NC
4,4'-DDT	50-29-3	2.1E-03	4.2E-04	NC	NC	NC	3.1E-02	6.2E-03	NC	NC	NC	6.2E-02	1.2E-02	NC	NC	NC	2.6E+01	2.6E+00	2.6E+01	3.1E+00	3.1E-01	1.8E-01	1.8E-02	NC	NC	NC
Aldrin	309-00-2	8.8E-03	1.8E-03	NC	NC	NC	9.6E-03	1.9E-03	NC	NC	NC	1.9E-02	3.7E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
alpha-Chlordane	5103-71-9	5.2E-03	5.2E-04	NC	NC	NC	6.8E-03	6.8E-04	NC	NC	NC	1.3E-02	1.3E-03	NC	NC	NC	1.9E-03	3.8E-04	NC	NC	NC	9.8E-05	2.0E-05	NC	NC	NC
beta-BHC	319-85-7	1.0E-02	2.1E-03	NC	NC	NC	6.6E-03	1.3E-03	NC	NC	NC	1.3E-02	2.5E-03	NC	NC	NC	1.3E-02	3.3E-03	NC	NC	NC	1.4E-03	3.5E-04	NC	NC	NC
Endosulfan Sulfate	1031-07-8	3.8E-01	3.8E-02	NC	NC	NC	2.9E-01	2.9E-02	NC	NC	NC	5.5E-01	5.5E-02	NC	NC	NC	2.1E-03	2.1E-04	NC	NC	NC	1.9E-04	1.9E-05	NC	NC	NC
Endrin	72-20-8	2.7E-02	2.7E-03	NC	NC	NC	3.2E-02	3.2E-03	NC	NC	NC	6.3E-02	6.3E-03	NC	NC	NC	1.6E-01	2.6E-02	NC	NC	NC	9.2E-03	1.5E-03	NC	NC	NC
Endrin Ketone	53494-70-5	1.7E-01	1.7E-02	NC	NC	NC	2.0E-01	2.0E-02	NC	NC	NC	3.8E-01	3.8E-02	NC	NC	NC	9.9E-01	1.6E-01	NC	NC	NC	5.6E-02	9.3E-03	NC	NC	NC
gamma-BHC (Lindane)	58-89-9	4.7E-04	4.7E-05	NC	NC	NC	1.3E-03	1.3E-04	NC	NC	NC	2.6E-03	2.6E-04	NC	NC	NC	1.5E-02	1.5E-03	NC	NC	NC	3.6E-04	3.6E-05	NC	NC	NC
gamma-Chlordane	5103-74-2	1.2E-02	1.2E-03	NC	NC	NC	1.6E-02	1.6E-03	NC	NC	NC	3.2E-02	3.2E-03	NC	NC	NC	4.5E-03	9.1E-04	NC	NC	NC	2.3E-04	4.7E-05	NC	NC	NC
Methoxychlor	72-43-5	3.7E-03	1.8E-03	NC	NC	NC	4.2E-03	2.1E-03	NC	NC	NC	8.2E-03	4.1E-03	NC	NC	NC	3.2E-03	3.2E-04	NC	NC	NC	2.0E-04	2.0E-05	NC	NC	NC
Aroclor 1254	11097-69-1	5.9E-01	5.9E-02	NC	NC	NC	1.0E+02	1.0E+01	2.5E+01	5.1E+00	5.1E-01	2.0E+02	2.0E+01	5.0E+01	1.3E-02	1.3E-03	2.6E+01	2.6E+00	6.4E+00	6.8E-01	6.8E-02	3.4E-01	3.4E-02	NC	NC	NC
Aroclor 1260	11096-82-5	1.6E-01	1.6E-02	NC	NC	NC	2.9E+01	2.9E+00	2.6E+00	5.3E-01	5.3E-02	5.9E+01	5.9E+00	5.2E+00	1.3E-03	1.3E-04	7.6E+00	7.6E-01	6.7E-01	7.1E-02	7.1E-03	1.0E-01	1.0E-02	NC	NC	NC
TCL PAHs																										
Acenaphthene	83-32-9	2.0E-01	3.9E-02	NC	NC	NC	6.5E-02	1.3E-02	NC	NC	NC	1.3E-01	2.6E-02	NC	NC	NC	1.7E+00	3.5E-01	4.8E-01	2.7E-02	5.4E-03	7.8E-02	1.6E-02	NC	NC	NC
Acenaphthylene	208-96-8	3.4E-03	6.8E-04	NC	NC	NC	3.3E-03	6.5E-04	NC	NC	NC	6.5E-03	1.3E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Anthracene	120-12-7	6.8E-04	6.8E-05	NC	NC	NC	2.3E-04	2.3E-05	NC	NC	NC	4.5E-04	4.5E-05	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(a)anthracene	56-55-3	4.5E-01	4.5E-02	NC	NC	NC	3.2E-01	3.2E-02	NC	NC	NC	5.9E-01	5.9E-02	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(a)pyrene	50-32-8	6.2E-01	6.2E-02	NC	NC	NC	2.1E-01	2.1E-02	NC	NC	NC	4.1E-01	4.1E-02	NC	NC	NC	6.3E-01	1.3E-01	NC	NC	NC	3.9E-02	7.9E-03	NC	NC	NC
Benzo(b)fluoranthene	205-99-2	1.8E-01	1.8E-02	NC	NC	NC	2.8E-01	2.8E-02	NC	NC	NC	5.3E-01	5.3E-02	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(g,h,i)perylene	191-24-2	2.8E-01	5.6E-02	NC	NC	NC	2.0E-01	4.1E-02	NC	NC	NC	4.0E-01	8.0E-02	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(k)fluoranthene	207-08-9	2.1E-02	2.1E-03	NC	NC	NC	1.3E-02	1.3E-03	NC	NC	NC	2.4E-02	2.4E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Chrysene	218-01-9	3.0E-02	3.0E-03	NC	NC	NC	1.6E-02	1.6E-03	NC	NC	NC	3.0E-02	3.0E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Dibenz(a,h)anthracene	53-70-3	8.5E-03	8.5E-04	NC	NC	NC	2.3E-02	2.3E-03	NC	NC	NC	4.4E-02	4.4E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Fluoranthene	206-44-0	1.8E-01	3.7E-02	NC	NC	NC	6.1E-02	1.2E-02	NC	NC	NC	1.2E-01	2.4E-02	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Indeno(1,2,3-cd)pyrene	193-39-5	2.4E-03	2.4E-04	NC	NC	NC	1.1E-02	1.1E-03	NC	NC	NC	2.1E-02	2.1E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Phenanthrene	85-01-8	5.4E-01	1.1E-01	NC	NC	NC	1.8E-01	3.5E-02	NC	NC	NC	3.5E-01	7.0E-02	NC	NC	NC	1.7E+00	3.4E-01	4.5E-01	4.1E-02	8.2E-03	3.2E-02	6.4E-03	NC	NC	NC
Pyrene	129-00-0	2.3E-01	4.7E-02	NC	NC	NC	7.9E-02	1.6E-02	NC	NC	NC	1.5E-01	3.1E-02	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

Notes:
CAS = Chemical Abstract Services
NC = Not Calculated
NOAEL = No observable adverse effects level
LOAEL = Lowest observable adverse effects level
HQ = Hazard Quotient
EPC = Exposure Point Concentration

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Table 7-9
Plant Screening - Soil
Screening Level Ecological Risk Assessment - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Constituent of Potential Ecological Concern	CAS #	Maximum Soil Concentration (mg/kg)	Screening Level (mg/kg)	Hazard Quotient (unitless)	EPC (mg/kg)	EPC Hazard Quotient (unitless)
Inorganics						
Aluminum	7429-90-5	33,000	50	6.6E+02	21,462	4.3E+02
Antimony	7440-36-0	16.4	5	3.3E+00	11.94	2.4E+00
Arsenic	7440-38-2	16.1	18	8.9E-01	NC	NC
Barium	7440-39-3	180	500	3.6E-01	NC	NC
Beryllium	7440-41-7	1.6	10	1.6E-01	NC	NC
Cadmium	7440-43-9	0.31	32	9.7E-03	NC	NC
Calcium	7440-70-2	172,000	4	4.3E+04	172,000	4.3E+04
Chromium	7440-47-3	47	1	4.7E+01	30.95	3.1E+01
Cobalt	7440-48-4	13	13	1.0E+00	NC	NC
Copper	7440-50-8	40	70	5.7E-01	NC	NC
Iron	7439-89-6	34,000	NV	NC	NC	NC
Lead	7439-92-1	366	120	3.1E+00	241.3	2.0E+00
Magnesium	7439-95-4	74,800	NV	NC	NC	NC
Manganese	7439-96-5	550	220	2.5E+00	461.3	2.1E+00
Mercury	7439-97-6	0.49	0.3	1.6E+00	0.289	9.6E-01
Nickel	7440-02-0	33	38	8.7E-01	NC	NC
Potassium	7440-09-7	4,500	NV	NC	NC	NC
Selenium	7782-49-2	1	0.52	2.1E+00	0.764	1.5E+00
Silver	7440-22-4	2.1	560	3.8E-03	NC	NC
Sodium	7440-23-5	358	NV	NC	NC	NC
Thallium	7440-28-0	0.59	1	5.9E-01	NC	NC
Vanadium	7440-62-2	91	2	4.6E+01	54.94	2.7E+01
Zinc	7440-66-6	152	160	9.5E-01	NC	NC
Pesticides/PCBs						
Aldrin	309-00-2	0.00105	0.1	1.1E-02	NC	NC
beta-BHC	319-85-7	0.0055	100	5.5E-05	NC	NC
gamma-BHC (Lindane)	58-89-9	0.00099	0.1	9.9E-03	NC	NC
Aroclor 1254	11097-69-1	0.46	NV	NC	NC	NC
Aroclor 1260	11096-82-5	0.092	NV	NC	NC	NC
PCBs (Total)	--	1.0	40	2.5E-02	NC	NC
TCL VOCs						
2-Butanone	78-93-3	0.046	NV	NC	NC	NC
4-Methyl-2-Pentanone	108-10-1	0.016	100	1.6E-04	NC	NC
Acetone	67-64-1	0.25	NV	NC	NC	NC
Benzene	71-43-2	0.003225	0.1	3.2E-02	NC	NC
Bromomethane	74-83-9	0.002	NV	NC	NC	NC
Carbon Disulfide	75-15-0	0.0075	NV	NC	NC	NC
Cyclohexane	110-82-7	0.004	NV	NC	NC	NC
Dichlorodifluoromethane	75-71-8	0.001	NV	NC	NC	NC
Ethylbenzene	100-41-4	0.005	0.1	5.0E-02	NC	NC
Methylcyclohexane	108-87-2	0.0265	NV	NC	NC	NC
Methylene Chloride	75-09-2	0.0155	0.3	5.2E-02	NC	NC
Styrene	100-42-5	0.001	300	3.3E-06	NC	NC
Toluene	108-88-3	0.0125	200	6.3E-05	NC	NC
Trichloroethene	79-01-6	0.021	0.3	7.0E-02	NC	NC
Xylenes (Total)	1330-20-7	0.0605	0.1	6.1E-01	NC	NC
TCL SVOCs						
2-Methylnaphthalene	91-57-6	0.078	NV	NC	NC	NC
Bis(2-ethylhexyl)phthalate	117-81-7	0.058	NV	NC	NC	NC
TCL PAHs						
Low Molecular Weight PAHs	--	0.447	NV	NC	NC	NC
High Molecular Weight PAHs	--	0.738	NV	NC	NC	NC

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram per Kilogram
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semi-volatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon

NV = No Value Available
NC = Not Calculated
Hazard Quotient = Soil Concentration/Screening Level
EPC = Exposure Point Concentration
See Table F.3-3b for Total Low and High Molecular Weight PAHs
See Table F.3-3c for Total PCBs

Table 7-10
Invertebrate and Microbial Screening - Soil
Screening Level Ecological Risk Assessment - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Constituent of Potential Ecological Concern	CAS #	Maximum Soil Concentration (mg/kg)	Screening Level (mg/kg)	Hazard Quotient (unitless)	EPC (mg/kg)	EPC Hazard Quotient (unitless)
Inorganics						
Aluminum	7429-90-5	33,000	NV	NC	NC	NC
Antimony	7440-36-0	16.4	78	2.1E-01	NC	NC
Arsenic	7440-38-2	16.1	60	2.7E-01	NC	NC
Barium	7440-39-3	180	330	5.5E-01	NC	NC
Beryllium	7440-41-7	1.6	40	4.0E-02	NC	NC
Cadmium	7440-43-9	0.31	140	2.2E-03	NC	NC
Calcium	7440-70-2	172,000	NV	NC	NC	NC
Chromium	7440-47-3	47	0.4	1.2E+02	30.95	7.7E+01
Cobalt	7440-48-4	13	200	6.5E-02	NC	NC
Copper	7440-50-8	40	80	5.0E-01	NC	NC
Iron	7439-89-6	34,000	200	1.7E+02	25,860	1.3E+02
Lead	7439-92-1	366	1,700	2.2E-01	NC	NC
Magnesium	7439-95-4	74,800	NV	NC	NC	NC
Manganese	7439-96-5	550	450	1.2E+00	461.3	1.0E+00
Mercury	7439-97-6	0.49	0.100	4.9E+00	0.289	2.9E+00
Nickel	7440-02-0	33	280	1.2E-01	NC	NC
Potassium	7440-09-7	4,500	NV	NC	NC	NC
Selenium	7782-49-2	1.1	4	2.7E-01	NC	NC
Silver	7440-22-4	2.1	50	4.2E-02	NC	NC
Sodium	7440-23-5	358	NV	NC	NC	NC
Thallium	7440-28-0	0.59	NV	NC	NC	NC
Vanadium	7440-62-2	91	20	4.6E+00	54.94	2.7E+00
Zinc	7440-66-6	152	120	1.3E+00	106.4	8.9E-01
Pesticides/PCBs						
Aldrin	309-00-2	0.00105	0.1	1.1E-02	NC	NC
beta-BHC	319-85-7	0.0055	NV	NC	NC	NC
gamma-BHC (Lindane)	58-89-9	0.00099	0.1	9.9E-03	NC	NC
Aroclor 1254	11097-69-1	0.46	NV	NC	NC	NC
Aroclor 1260	11096-82-5	0.092	NV	NC	NC	NC
TCL VOCs						
2-Butanone	78-93-3	0.046	NV	NC	NC	NC
4-Methyl-2-Pentanone	108-10-1	0.016	NV	NC	NC	NC
Acetone	67-64-1	0.25	NV	NC	NC	NC
Benzene	71-43-2	0.003225	0.1	3.2E-02	NC	NC
Bromomethane	74-83-9	0.002	NV	NC	NC	NC
Carbon Disulfide	75-15-0	0.0075	NV	NC	NC	NC
Cyclohexane	110-82-7	0.004	NV	NC	NC	NC
Dichlorodifluoromethane	75-71-8	0.001	NV	NC	NC	NC
Ethylbenzene	100-41-4	0.005	0.1	5.0E-02	NC	NC
Methylcyclohexane	108-87-2	0.0265	NV	NC	NC	NC
Methylene Chloride	75-09-2	0.0155	0.3	5.2E-02	NC	NC
Styrene	100-42-5	0.001	0.1	1.0E-02	NC	NC
Toluene	108-88-3	0.0125	0.1	1.3E-01	NC	NC
Trichloroethene	79-01-6	0.021	0.3	7.0E-02	NC	NC
Xylenes (Total)	1330-20-7	0.0605	NV	NC	NC	NC
TCL SVOCs						
2-Methylnaphthalene	91-57-6	0.078	NV	NC	NC	NC
Bis(2-ethylhexyl)phthalate	117-81-7	0.058	NV	NC	NC	NC
TCL PAHs						
Low Molecular Weight PAHs	--	0.447	29	1.5E-02	NC	NC
High Molecular Weight PAHs	--	0.738	18	4.1E-02	NC	NC

Notes:

CAS = Chemical Abstract Service

mg/kg = Milligram per Kilogram

TCL = Target Compound List

PCB = Polychlorinated Biphenyl

VOC = Volatile Organic Compound

SVOC = Semi-volatile Organic Compound

PAH = Polynuclear Aromatic Hydrocarbon

NV = No Value Available

NC = Not Calculated

Hazard Quotient = Soil Concentration/Screening Level

EPC = Exposure Point Concentration

See Table F.3-3b for Total Low and High Molecular Weight PAHs

Table 7-11
Dioxin/Furan Equivalent Calculation - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Sample Date Sample Depth (ft bgs)	CAS #	Mammalian TEF	Avian TEF	71SS11 11/11/2002 0-1		71SS13 11/11/2002 0-1	
				Result	LQ, VQ, r	Result	LQ, VQ, r
Dioxin/Furans (pg/g)							
1,2,3,4,6,7,8,9-OCDD (OCDD)	3268-87-9	0.0003	0.0001	438		1,050	
1,2,3,4,6,7,8,9-OCDF (OCDF)	39001-02-0	0.0003	0.0001	9.8	J	35.5	
1,2,3,4,6,7,8-HpCDD	35822-39-4	0.01	0.001	53.6		89.9	
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.01	0.01	5.4		10.3	
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.01	0.01	<5		<5	
1,2,3,4,7,8-HxCDD	39227-28-6	0.1	0.05	1.2	J	1.5	J
1,2,3,4,7,8-HxCDF	70648-26-9	0.1	0.1	1.3	J	2.3	J
1,2,3,6,7,8-HxCDD	57653-85-7	0.1	0.01	2.3	J	3	J
1,2,3,6,7,8-HxCDF	57117-44-9	0.1	0.1	<5		0.96	J
1,2,3,7,8,9-HxCDD	19408-74-3	0.1	0.1	3.6	J	3.4	J
1,2,3,7,8,9-HxCDF	72918-21-9	0.1	0.1	<5		<5	
1,2,3,7,8-PeCDD	40321-76-4	1	1	1.1	J	0.74	J
1,2,3,7,8-PeCDF	57117-41-6	0.03	0.1	1.7	MXJ,J,w	<5	
2,3,4,6,7,8-HxCDF	60851-34-5	0.1	0.1	0.6	J	0.99	J
2,3,4,7,8-PeCDF	57117-31-4	0.3	1	0.64	J	0.76	J,J,l
2,3,7,8-TCDD	1746-01-6	1	1	<1		0.37	JB,B,z
2,3,7,8-TCDF	51207-31-9	0.1	1	0.69	J	0.66	J
Total 2,3,7,8-TCDD Equivalents (Mammalian)				3.036		3.577	
Total 2,3,7,8-TCDD Equivalents (Avian)				2.745		3.331	

Notes:

pg/g = Picogram Per Gram
ft bgs = Feet Below Ground Surface
TEF = Toxicity Equivalency Factor
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

Total 2,3,7,8-TCDD Equivalents are calculated by summing the detected concentration times the TEF for each chemical. Non-detects, R-flagged data, and B-flagged data are excluded from summed total.

Qualifiers:

B Not detected substantially above the level reported in laboratory or field blanks.
J Analyte present. Reported value may not be accurate or precise.
X Associated PCDF peak(s) has the same retention time as the associated diphenyl ether and the diphenyl ether contribution is greater than 10%.
l LCS recovery failure.
w Retention time failure.
z Method blank contamination.

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Table 7-12
Wildlife Summary
Screening Level Ecological Risk Assessment - SWMU 71
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Chemical	CAS#	Meadow Vole					Short-tailed Shrew					Red Fox					American Robin					Red-tailed Hawk				
		Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ	Preliminary NOAEL-based HQ	Preliminary LOAEL-based HQ	Preliminary EPC NOAEL HQ	Refined NOAEL-based HQ	Refined LOAEL-based HQ
Inorganics																										
Arsenic	7440-38-2	8.9E+01	8.9E+00	7.9E+01	1.6E+00	1.6E-01	3.1E+01	3.1E+00	2.8E+01	2.6E+00	2.6E-01	5.9E+01	5.9E+00	5.2E+01	7.5E-03	7.5E-04	1.1E+00	4.6E-01	1.0E+00	6.6E-02	2.6E-02	3.1E-03	1.2E-03	NC	NC	NC
Cadmium	7440-43-9	3.5E-01	3.5E-02	NC	NC	NC	1.4E+00	1.4E-01	1.0E+00	1.4E-01	1.4E-02	2.9E+00	2.9E-01	2.0E+00	2.3E-04	2.3E-05	2.7E+00	2.0E-01	1.9E+00	1.6E-01	1.2E-02	5.6E-02	4.1E-03	NC	NC	NC
Chromium	7440-47-3	5.2E-01	5.2E-02	NC	NC	NC	5.1E+00	5.1E-01	3.4E+00	2.1E-01	2.1E-02	1.0E+01	1.0E+00	6.6E+00	9.6E-04	9.6E-05	4.8E+01	9.5E+00	3.1E+01	1.2E+00	2.5E-01	1.0E+00	2.0E-01	NC	NC	NC
Copper	7440-50-8	5.7E-01	4.3E-01	NC	NC	NC	4.7E-01	3.6E-01	NC	NC	NC	9.0E-01	6.8E-01	NC	NC	NC	4.2E-01	3.2E-01	NC	NC	NC	5.9E-02	4.5E-02	NC	NC	NC
Lead	7439-92-1	7.5E+00	7.5E-01	5.0E+00	1.8E-01	1.8E-02	8.1E+00	8.1E-01	5.4E+00	6.4E-01	6.4E-02	1.6E+01	1.6E+00	1.0E+01	2.1E-03	2.1E-04	1.6E+02	1.6E+01	1.1E+02	7.5E+00	7.5E-01	6.1E+00	6.1E-01	4.0E+00	1.8E-03	1.8E-04
Mercury	7439-97-6	4.8E-02	4.8E-03	NC	NC	NC	6.5E-02	6.5E-03	NC	NC	NC	1.3E-01	1.3E-02	NC	NC	NC	7.1E+00	3.5E+00	4.2E+00	1.5E-01	7.3E-02	1.4E-02	6.9E-03	NC	NC	NC
Nickel	7440-02-0	4.0E-01	2.0E-01	NC	NC	NC	4.4E-01	2.2E-01	NC	NC	NC	8.6E-01	4.3E-01	NC	NC	NC	6.4E-01	4.6E-01	NC	NC	NC	1.7E-02	1.2E-02	NC	NC	NC
Selenium	7782-49-2	5.6E+00	3.4E+00	3.9E+00	2.4E-01	1.5E-01	1.9E+00	1.1E+00	1.3E+00	2.4E-01	1.4E-01	3.7E+00	2.2E+00	2.6E+00	2.5E-03	1.5E-03	2.7E+00	1.3E+00	1.8E+00	2.9E-01	1.5E-01	2.1E-01	1.1E-01	NC	NC	NC
Silver	7440-22-4	1.9E-03	1.9E-04	NC	NC	NC	1.6E-01	1.6E-02	NC	NC	NC	3.2E-01	3.2E-02	NC	NC	NC	6.1E-01	8.2E-02	NC	NC	NC	4.2E-03	5.6E-04	NC	NC	NC
Zinc	7440-66-6	5.9E-01	2.9E-01	NC	NC	NC	1.3E+00	6.7E-01	9.4E-01	1.4E-01	6.8E-02	2.7E+00	1.3E+00	1.9E+00	6.1E-04	3.0E-04	4.3E+01	4.7E+00	3.0E+01	2.8E+00	3.1E-01	1.9E+00	2.1E-01	1.3E+00	1.3E-03	1.4E-04
Dioxin/Furans																										
Total 2,3,7,8-TCDD Equivalents	1746-01-6	7.0E-02	7.0E-03	NC	NC	NC	1.6E+01	1.6E+00	4.3E+01	1.0E+01	1.0E+00	3.2E+01	3.2E+00	8.7E+01	1.5E-02	1.5E-03	1.7E+00	1.7E-01	5.8E+00	7.3E-01	7.3E-02	3.4E-02	3.4E-03	NC	NC	NC
Pesticides/PCBs																										
Aldrin	309-00-2	1.8E-03	3.6E-04	NC	NC	NC	2.0E-03	3.9E-04	NC	NC	NC	3.8E-03	7.7E-04	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
beta-BHC	319-85-7	4.7E-03	9.4E-04	NC	NC	NC	4.5E-03	8.9E-04	NC	NC	NC	8.8E-03	1.8E-03	NC	NC	NC	9.0E-03	2.3E-03	NC	NC	NC	6.5E-04	1.6E-04	NC	NC	NC
gamma-BHC (Lindane)	58-89-9	4.3E-05	4.3E-06	NC	NC	NC	1.7E-04	1.7E-05	NC	NC	NC	3.5E-04	3.5E-05	NC	NC	NC	2.0E-03	2.0E-04	NC	NC	NC	3.3E-05	3.3E-06	NC	NC	NC
Aroclor 1254	11097-69-1	1.3E-01	1.3E-02	NC	NC	NC	2.2E+01	2.2E+00	1.8E+01	3.7E+00	3.7E-01	4.4E+01	4.4E+00	3.7E+01	9.5E-03	9.5E-04	5.6E+00	5.6E-01	4.7E+00	5.0E-01	5.0E-02	7.4E-02	7.4E-03	NC	NC	NC
Aroclor 1260	11096-82-5	2.4E-02	2.4E-03	NC	NC	NC	4.4E+00	4.4E-01	3.0E+00	6.2E-01	6.2E-02	8.8E+00	8.8E-01	6.1E+00	1.6E-03	1.6E-04	1.1E+00	1.1E-01	7.8E-01	8.3E-02	8.3E-03	1.5E-02	1.5E-03	NC	NC	NC
TCL PAHs																										
Acenaphthene	83-32-9	2.3E-02	4.6E-03	NC	NC	NC	7.6E-03	1.5E-03	NC	NC	NC	1.5E-02	3.0E-03	NC	NC	NC	2.0E-01	4.1E-02	NC	NC	NC	9.1E-03	1.8E-03	NC	NC	NC
Acenaphthylene	208-96-8	1.9E-03	3.7E-04	NC	NC	NC	2.7E-03	5.4E-04	NC	NC	NC	5.4E-03	1.1E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(a)anthracene	56-55-3	4.1E-02	4.1E-03	NC	NC	NC	4.3E-02	4.3E-03	NC	NC	NC	8.2E-02	8.2E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(a)pyrene	50-32-8	4.1E-02	4.1E-03	NC	NC	NC	1.4E-02	1.4E-03	NC	NC	NC	2.7E-02	2.7E-03	NC	NC	NC	4.2E-02	8.4E-03	NC	NC	NC	2.6E-03	5.3E-04	NC	NC	NC
Benzo(b)fluoranthene	205-99-2	4.7E-03	4.7E-04	NC	NC	NC	1.1E-02	1.1E-03	NC	NC	NC	2.1E-02	2.1E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Benzo(k)fluoranthene	207-08-9	9.8E-04	9.8E-05	NC	NC	NC	8.6E-04	8.6E-05	NC	NC	NC	1.7E-03	1.7E-04	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Chrysene	218-01-9	2.4E-03	2.4E-04	NC	NC	NC	1.8E-03	1.8E-04	NC	NC	NC	3.6E-03	3.6E-04	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Fluoranthene	206-44-0	2.9E-02	5.7E-03	NC	NC	NC	1.0E-02	2.1E-03	NC	NC	NC	2.0E-02	4.1E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Phenanthrene	85-01-8	6.5E-02	1.3E-02	NC	NC	NC	2.1E-02	4.3E-03	NC	NC	NC	4.3E-02	8.6E-03	NC	NC	NC	2.1E-01	4.1E-02	NC	NC	NC	3.9E-03	7.8E-04	NC	NC	NC
Pyrene	129-00-0	6.2E-03	1.2E-03	NC	NC	NC	3.1E-03	6.2E-04	NC	NC	NC	6.2E-03	1.2E-03	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

Notes:
CAS = Chemical Abstract Services
NC = Not Calculated
NOAEL = No observable adverse effects level
LOAEL = Lowest observable adverse effects level
HQ = Hazard Quotient
EPC = Exposure Point Concentration

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8.0 ESTABLISHMENT OF CORRECTIVE MEASURE OBJECTIVES

This section identifies the corrective measures objectives (CMOs) for the COCs, and media of interest identified by the site, risk, and fate and transport assessments conducted for the RFI. CMOs are cleanup objectives developed to protect human health and the environment and provide the basis for identification, detailed analysis, and selection of corrective measures alternatives.

8.1 SUMMARY OF RFI RESULTS

8.1.1 SWMU 40

As indicated in Section 6.0, the current land use of the site (closed landfill) is unlikely to change in the future due to the presence of a closed landfill with approximately 18,700 bank cubic yards (BCY) of solid landfill material contained in place by a surface cap and cover. The results of the risk assessment indicated that the calculated risk (3E-06) and hazard (8E-02) for the maintenance worker receptor associated with the current and most likely future land use at the site (closed landfill) were at the lower end of USEPA's target risk range (1E-06 to 1E-04) and hazard range (1E+00 or less) for Superfund sites (USEPA 1989b).

The risk assessment indicated that under an unlikely future hypothetical scenario, where the land use of the site would change from closed landfill to developed commercial/industrial property, the calculated hazard for future hypothetical construction worker would be above target hazard of 1E+00, when considering target organs and background, primarily due to inhalation of aluminum. Calculated risks and hazards for future hypothetical commercial industrial worker were within USEPA's target risk and hazard ranges. Potential risks could be posed to human health and the environment under a hypothetical residential scenario where land use changed and landfill material did not remain contained and in place. Calculated risk for a lifetime resident under such a scenario (3E-04) is above USEPA's target range.

The site assessment and fate and transport assessment identified some localized erosion of the landfill cover along the northern edge/slope as evidenced by distinct gullies and swales, and by some metal debris. Localized mass transport of soil has occurred from the landfill area, which resulted in a limited area of surface soil (one sample) at the base of the landfill containing PCBs at concentrations above I-RBCs.

As previously discussed in Section 4.3, groundwater investigations conducted at the site indicated possible leaching of chloroform from the landfill area to groundwater at concentrations above its T-RBC but below the USEPA MCL of 80 µg/L for total halomethanes. Based on the historical use of SWMU 40 (i.e., sanitary landfill), chloroform could be a potential site-related groundwater COPC, but it should be noted that no source of chloroform has been identified within the landfill material or soil beneath the landfill material at SWMU 40. Significant leaching of other COCs to clay soil present below the landfill or to groundwater at the site was not apparent from the data collection. Groundwater data collected upgradient of the landfill at SWMU 17 indicated an apparent source of perchlorate upgradient of the SWMU 40 landfill site, with low-level perchlorate concentrations detected in the two monitoring wells located adjacent to the landfill at concentrations below adjusted T-RBCs (Figure 4-8).

8.1.2 SWMU 71

As indicated in Section 6.0, the current land use of the site (gravel covered undeveloped area) is unlikely to change in the future due to its small size (2,250 ft²) and location directly adjacent to the landfill. The results of the risk assessment indicated that the calculated risk (2E-06) and hazard (7E-02) for the maintenance worker receptor associated with the current and most likely future land use at the site (undeveloped) were at the lower end of USEPA's target risk range (1E-06 to 1E-04) and hazard range (1E+00 or less) for Superfund sites (USEPA 1989b). Calculated risks also were within the USEPA target risk range for evaluated receptors associated with hypothetical future industrial and residential land uses with the exception of the hypothetical future lifetime resident with a calculated risk of 2E-04 due to

chloroform in groundwater but at concentrations below the USEPA MCL of 80 µg/L. Based on the historical use of SWMU 71 (i.e., flash and burn area), the site-related soil COPCs identified (metals), and the small size of the site, chloroform is not considered a site-related COPC in groundwater for SWMU 71. When considering background and target organs, calculated hazards for evaluated receptors associated with hypothetical future industrial and residential land uses were below the target hazard of 1E+00.

8.2 CORRECTIVE MEASURES OBJECTIVES

CMOs have been developed for the COCs and media of interest at SWMU 40 and SWMU 71 with consideration of the following:

- Current land use of the site is undeveloped industrial consisting of a 2-acre closed landfill (SWMU 40) and immediately adjacent gravel area (SWMU 71) with an area of approximately 2,250 ft².
- Land use of the site is unlikely to change in the future (e.g., industrial with no development) due to the presence of a closed landfill with more than 18,700 BCY of landfill material contained in place by a surface cap and cover.
- Potential site-related COCs in groundwater are limited to chloroform, which has been detected at concentrations below the Federal drinking water standard (MCL) of 80 µg/L for THMs.
- Site, risk, and fate and transport assessment results for SWMU 71 did not indicate a requirement for implementation of corrective measures based on current and future scenarios evaluated.

The residential exposure pathway also will be evaluated in the CMS to assess the remedial effort that would be required to achieve clean closure at SWMU 40 with unrestricted future land use without controls or long-term monitoring (LTM) requirements.

8.2.1 SWMU 40

The following CMOs have been developed for SWMU 40 based on the results of the site, risk, and fate and transport assessments:

- Maintain containment of the landfill material at the site and implement necessary controls to prevent future uncontrolled human exposure to this landfill material.
- Implement any necessary measures to stabilize and repair the landfill cover at the northern edge of the landfill area to prevent any further mass transport of soil material in this area.

8.2.2 SWMU 71

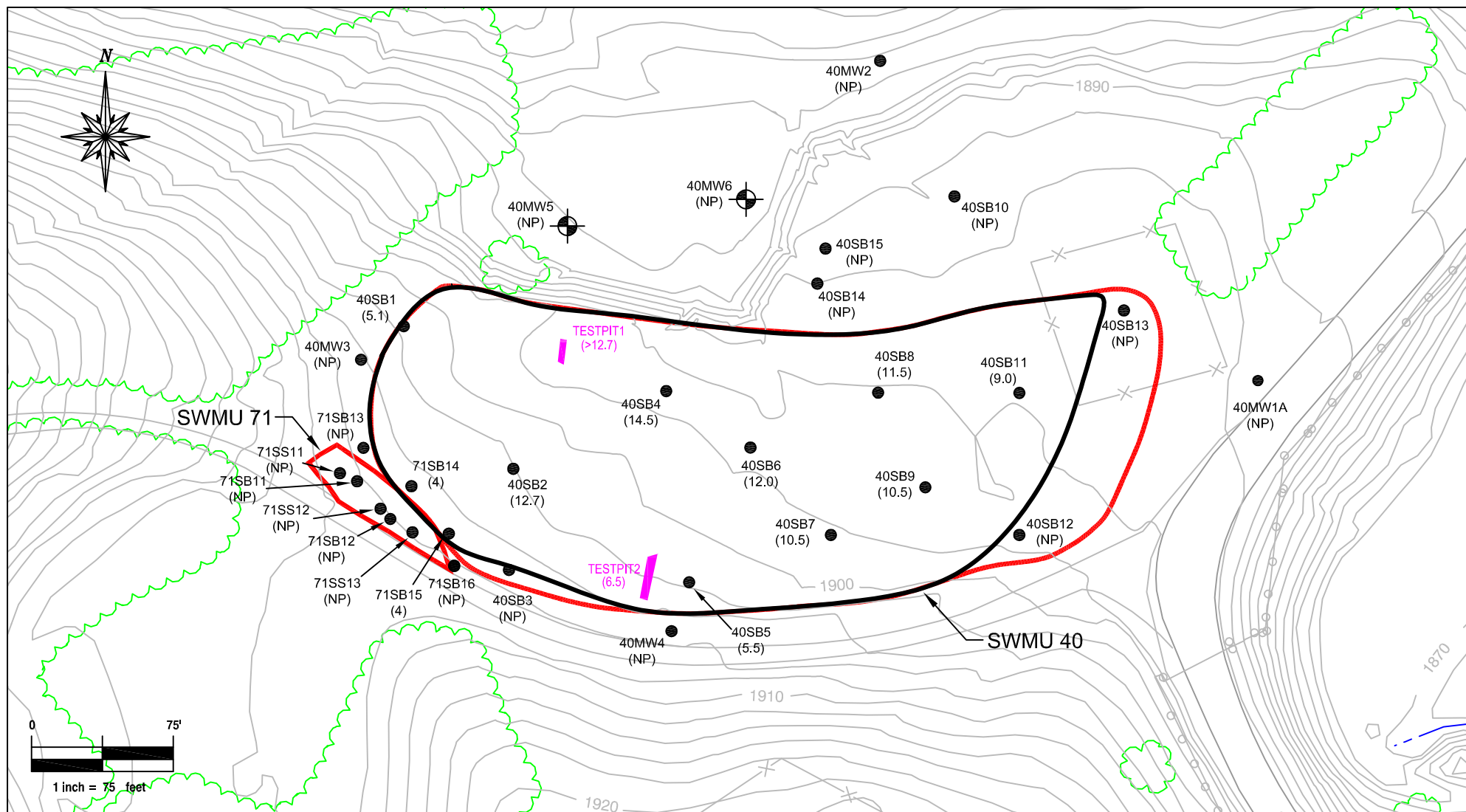
CMOs have not been developed for SWMU 71 given that the results of the site, risk, and fate and transport assessment did not indicate a requirement for implementation of corrective measures.

8.3 REMEDIAL GOALS

Establishment of numerical RGs for media at SWMU 40 (i.e., soil and groundwater) is not required based on the results of the site, risk, and fate and transport assessment, given that the expected future land use of the site will in adherence to the current and foreseeable use of the property in support of the Army mission remain a closed landfill area.

8.4 AREA AND VOLUME OF LANDFILL MATERIAL

The area at SWMU 40 containing landfill material covers an approximate 1.2 acre area as shown on Figure 8-1. Based on the data presented in Section 2.6.2, it is estimated that the in place volume of landfill material is approximately 18,700 BCY with approximately 7,357 BCY of soil cap material present above the landfill material. The thickness of landfill material observed at the site ranged from approximately 3 to 15 ft. Detailed calculations on the volume and quantities of landfill material are presented in Figure 2-11 in Section 2.0.



Legend

- Topographic Contour (feet mean sea level)
- SWMU Area
- Test Pit Location
- Soil Boring Location
- ⊕ Monitoring Well Location
- (14.5) Thickness of Landfill Material (feet)
- (NP) Landfill Material Not Present
- Lateral Extent of Landfill Material (approx. 1.2 acres)

FIGURE 8-1

Landfill Material Area

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.8-1 LF Mat. Area

SWMUs 40 and 71

RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia



URS Group, Inc.
5540 Falmouth Street
Suite 201
Richmond, Virginia 23320

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9.0 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES

In this section, corrective measures technologies are identified based on their potential applicability to site conditions, COCs and CMOs. Each of these technologies is screened based on their expected effectiveness, implementability, and cost as described below:

- **Effectiveness** – with primary consideration of the ability of the technology to meet CMOs and be protective of human health and the environment;
- **Implementability** – with primary consideration for the technical and administrative feasibility, and availability of necessary equipment and personnel for implementation; and
- **Cost** – including both capital and present value of operation and maintenance (O&M) costs, as applicable.

Screening of the technologies is presented in Table 9-1. This table briefly describes the technologies and evaluations based on their expected effectiveness, implementability, and relative cost. Key advantages, disadvantages, and/or limitations of each alternative are also identified in this table. Technologies identified and screened for this CMS include:

- Institutional controls;
- Engineering controls;
- Containment: landfill soil cap.
- Excavation and offsite disposal of soil and landfill material.

The results of the screening indicate that no single technology would be effective in addressing all media and CMOs, and therefore, a combination of the above technologies has been retained to develop corrective measure alternatives. Corrective measure alternatives are developed and evaluated in Section 10.0.

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Table 9-1
Identification and Screening of Corrective Measures Technologies
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Technology	Description	Effectiveness	Implementability	Relative Cost	Retained for CMA Development
Institutional Controls	Institutional controls are non-engineered instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use.	- Effective when used along with engineering controls and other technologies to prevent human health exposure to impacted media. - This technology does not reduce the volume or toxicity of impacted media at the site. Ranking: Moderate to High	- Readily implementable. - Administratively feasible. - Would require monitoring of institutional controls to ensure that unacceptable human exposure does not occur in the future. - Would require long term monitoring and maintenance. Ranking: High	Low	Yes
Engineering Controls	Physical barrier or method employed to actively or passively contain, stabilize, or monitor contamination, restrict the movement of contamination to ensure the long-term effectiveness of a remedial program, or eliminate potential exposure pathways to contamination. Engineering controls include, but are not limited to, pavement, caps, covers, subsurface barriers, vapor barriers, slurry walls, building ventilation systems, fences, access controls, provision of alternative water supplies via connection to an existing public water supply, adding treatment technologies to such water supplies, and installing filtration devices on private water supplies.	- Landfill area at SWMU 40 has cap in place to prevent exposure to landfill material/solid waste. - Minor cap repairs required at northern edge of landfill to prevent erosion and exposure of waste material. - Would need to be combined with institutional controls to maximize effectiveness. - This technology does not reduce the volume or toxicity of impacted media at the site. Ranking: Moderate to High	- Personnel and equipment are available for implementation. - Existing cap in place for landfill area. - Administratively feasible. - Would require long term monitoring and maintenance. Ranking: Moderate to High	Low	Yes
Soil: Containment - Cap	Caps can be constructed with a single layer (asphalt, concrete, or soil) or with multiple layers that may include an upper vegetative layer, drainage layer, and low permeability layer with geotextile and clay base. Caps may be used to minimize or prevent exposure to contaminated soil or waste, prevent vertical infiltration of water into waste that would create leachate, contain waste until it is treated, or create a surface that can be used for vegetation or other purposes.	- Repairs to existing cap are required at SWMU 40 to maintain containment of landfill material and prevent human health or ecological exposure to waste. - Would effectively prevent human health or ecological exposure to soil at the site when implemented with institutional and other controls. - This technology does not reduce the volume or toxicity of impacted media at the site. Ranking: High	- Well proven and readily implementable technology. - Existing cap at site can easily be repaired and modified to provide for effective containment. - Readily implementable. - Administratively feasible. - Would require institutional and engineering controls due to waste being left in place. - Would require long term monitoring and maintenance. Ranking: High	Low to Moderate	Yes

Table 9-1
Identification and Screening of Corrective Measures Technologies
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Technology	Description	Effectiveness	Implementability	Relative Cost	Retained for CMA Development
Soil and Landfill Material: Soil Excavation and Off-Site Disposal	Landfill material and associated soil is excavated and transported to a permitted treatment and disposal facility or facilities. Treatment options will depend on the nature of the material and whether it is a non-hazardous or hazardous waste, and may include landfilling, stabilization, and incineration.	• Effective at achieving CMOs and remedial goals for soil. • Removes release sources. • Results in a reduction in volume and toxicity of waste when soil is treated offsite before disposal. • Using this technology to address landfill material is not expected to be practicable or cost effective to achieve clean close-out and unrestricted use of the site. Ranking: High	• Well proven and implementable technology. • Excavation and management of heterogeneous landfill material would be more difficult than homogeneous materials such as soil, thereby increasing implementation time and cost. • Where used, beneficial results would be achieved immediately after completion of excavation as source areas would be removed. • Requires waste characterization to identify appropriate offsite treatment and disposal facilities and requirements. Some hazardous waste would likely be generated based on previous investigative derived material results for landfill material. • Material may require stabilization before offsite transportation and disposal. • Administratively feasible and routine in terms of requirements. • Can be implemented without special waste management permits. Appropriate health and safety measures and onsite controls will be required for implementation. • Would require county approval of an erosion and sediment control plan for land disturbance. Ranking: High	High	Yes

10.0 DEVELOPMENT OF CORRECTIVE MEASURE ALTERNATIVES – SWMU 40

Based on the identification and screening process conducted in Section 9.0, corrective measure technologies are combined into alternatives to be evaluated in the CMS. The following corrective measures alternatives have been developed to meet the CMOs identified for SWMU 40.

- Alternative No. 1: No Further Action;
- Alternative No. 2: Institutional Controls, Engineering Controls, and Long-Term Monitoring and Maintenance;
- Alternative No. 3: Excavation of Soil/Landfill Material and Offsite Disposal for Clean Closure and Unrestricted Land Use.

Corrective measures alternatives are described in the following sections.

10.1 ALTERNATIVE ONE – NO FURTHER ACTION

The No Further Action Alternative will be used as a baseline to measure the performance of the other alternatives.

10.2 ALTERNATIVE TWO – INSTITUTIONAL CONTROLS, ENGINEERING CONTROLS, AND LONG-TERM MONITORING AND MAINTENANCE

Elements of this alternative are described below.

10.2.1 Institutional Controls

Institutional controls (ICs) would consist of incorporating land use controls (LUCs) for SWMU 40 into the RFAAP Installation Master Plan, Geographic Information System, and other instructions and orders, as applicable, to ensure long-term protection of human health and the environment. A land use control (LUC) implementation plan would be designed and prepared to assure the effectiveness and reliability of the required ICs. ICs will be designed along with the engineering controls to maintain appropriate containment of landfill material and prevent unacceptable human health and environmental exposure.

10.2.2 Engineering Controls

Engineering controls will include repairs to the existing landfill soil cap along the northern edge of the landfill where small swales and gullies have cut into the northern edge/slope of the landfill. Any repaired areas will be stabilized and seeded to provide for vegetative cover consistent with the other portions of the landfill. Figure 10-1 shows the location of the soil cap repairs.

10.2.3 Long Term Monitoring and Maintenance

LTM will include periodic inspections and maintenance of the landfill area to verify the integrity of the landfill cover. Typical inspection items are identified in the following table.

Inspection and Maintenance of Landfill Area

Item	Procedure
Run-on/Runoff	Inspect and maintain proper slope/cover, as necessary.
Water/Wind Erosion	Inspect and maintain grass cover, repair any eroded areas.
Rodent/Vector Activity	Inspect grass cover and repair any comprised areas, control rodent/vector activity.
Deep Root Vegetation	Verify lack of deep rooted vegetation on grass cover. Remove any deep rooted vegetation.

Item	Procedure
Vegetation Stress	Verify integrity of grass cover and repair grass cover as necessary.
Cover Condition	Inspect cover condition, mow and maintain grass cover, fertilize, lime, etc. as necessary.
Subsidence/Cracks	Inspect grass cover and repair and regrade subsidence or cracked areas as appropriate.

Periodic groundwater monitoring also will be conducted as part of LTM activities to monitor groundwater conditions in the landfill area to verify both the effectiveness of landfill containment and that significant releases have not occurred to groundwater that would pose a potential human health and environmental concern. A long-term groundwater monitoring plan will be developed that specifies the locations, frequency, analytical requirements, management of IDM, reporting requirements, and actions to be taken if potentially significant releases are identified by monitoring. The anticipated LTM program is summarized in the following table and would include existing upgradient monitoring well LFMW01 and existing downgradient monitoring wells 40MW5 and 40MW6. A third downgradient monitoring well 40MW7 would be installed at the site to comply with the RCRA minimum monitoring requirements of three downgradient monitoring for long-term monitoring.

The proposed location of 40MW7 would correspond with the favorable drilling target for a monitoring well located approximately 135 ft west/northwest of the landfill area (Figure 10-2), as indicated by the ATS geophysical study. The proposed location of 40MW7 is identified on Figure 2-17 along geophysical Line 1 at electrode location 1-19 as a blue circle and as labeled on the pseudo-section for Line 1 on Figure 2-15 as a “possible karst feature or fracture zone” at an approximate elevation of 1850 ft mean sea level and lower. When projected out from near the center of the landfill area, this location is also along the predominant average strike of bedrock bedding planes (110°) in the site area as discussed in Section 2.7.1.1 and in the approximate direction of preferential groundwater flow indicated by the dye trace from SWMU 17 to spring SP3. As shown on Figure 2-18, potentiometric data from the landfill area identified an apparent west and northwest component of groundwater flow from the landfill area.

Long-Term Groundwater Monitoring

Monitoring Location	Position	Monitoring Frequency	Analytical Parameters
LFMW01	Upgradient	Year 1: Quarterly Years 2-5: Every 9 months Years 6-30: Annual	Field water quality: pH, turbidity, specific conductance, temperature, dissolved oxygen, oxidation/reduction potential TCL VOCs – SW-846 Method 8260B TCL SVOCs– SW-846 Method 8270C LL TCL Pesticides – SW-846 Method 8081A TAL Metals – SW-846 Methods 6000/7000 Perchlorate – SW-846 Method 6850 Dioxin/furans – SW-846 8290 (initial confirmation sampling event)
40MW5	Detection Well at Edge of Landfill Boundary		
40MW6	Detection Well at Edge of Landfill Boundary		
40MW7	Well downgradient of Landfill		

Thirty years of groundwater monitoring is assumed at the site with quarterly monitoring for the first year followed by monitoring once every nine months for years 2-5, which will allow for evaluation of seasonal variations. After the initial five years of monitoring, a remedy effectiveness evaluation (including statistical evaluations) will be conducted to verify the findings of the RFI/CMS and demonstrate long-

term effectiveness of the containment remedy. It is assumed that this initial evaluation will indicate statistical evidence of stable or decreasing concentrations of detected constituents in groundwater and demonstrated long-term effectiveness of the containment remedy, and, thereby allowing for a decrease in monitoring frequency to annual for years 6-30. Statistical evaluations and remedy effectiveness evaluations would be performed at five year intervals during the 30 year monitoring period.

Note that one round of confirmatory samples for dioxin/furans is proposed during the initial LTM sampling event to verify that dioxins have not migrated to groundwater at the site. The groundwater monitoring plan will be included in the remedy-implementation work plan submitted to the USEPA and VDEQ for approval prior to remedy implementation.

10.2.4 Work Plan

A site-specific work plan will be prepared for implementation of the remedy including implementation of ICs, cap repair, and LTM activities related to the landfill cover and groundwater monitoring. Remedy effectiveness evaluations will occur at a minimum, five year intervals. Specific details on the evaluations will be included in the remedy implementation work plan. A component of the evaluations is expected to include analysis of groundwater monitoring data for evidence of statistically significant trends and comparisons to applicable risk criteria. The work plan will be submitted to the USEPA and VDEQ for approval prior to remedy implementation.

10.2.5 Remedy Completion Report

A remedy completion report will be prepared that documents the remedial actions implemented and completed at the site. This report will be submitted to the USEPA and VDEQ.

10.2.6 Annual LTM Reports

Annual LTM reports will be prepared to describe each year's activities, such as LUC and LTM inspections and LTM and maintenance of the landfill area, and groundwater monitoring along with analytical results. Any required action or activities related to the remedy implementation will be presented to assess whether additional remedial actions or site controls are required. Remedy effectiveness evaluations as described previously will be presented in the annual LTM reports at five year minimum intervals.

10.3 ALTERNATIVE THREE – EXCAVATION OF SOIL AND LANDFILL MATERIAL, OFFSITE DISPOSAL FOR CLEAN CLOSURE AND UNRESTRICTED LAND USE

Elements of this alternative are described below.

10.3.1 Excavation of Landfill Material and Soil

Under this alternative, material within the approximately 1.2 acre area shown on Figure 8-1 will be excavated and disposed of offsite. Depending on the waste characterization results, the materials will be transported offsite to either a RCRA Subtitle C Landfill (hazardous waste) or a Subtitle D landfill (non hazardous waste). Materials that will be excavated include landfill cap soil (assumed to be average of 3.8 ft thick for an area of 1.2 acres), landfill material, and excess soil necessary to allow excavation access and stabilization. It also is assumed that up to one foot of soil underlying the landfill material will be excavated as part of the remedy. Depending on the waste characterization results, the material will be transported offsite to either a RCRA Subtitle C Landfill (hazardous waste) or a Subtitle D landfill (non hazardous waste). Based on RFI soil analytical data, it is assumed that soil material overlying, underlying, and around the landfill material will be disposed as non-hazardous waste at a local Subtitle D landfill. Based on the results of two waste characterization samples collected for the RFI, which indicated that one of two rolloff boxes material removed during test pit excavation was D008 characteristic waste (lead), it is assumed that the 50% of the 18,700 BCY of landfill material will be disposed as hazardous waste at a Subtitle C landfill with the remaining 50% disposed as non-hazardous waste at a local Subtitle D landfill. Waste characterization testing will be conducted to appropriately characterize material and

develop waste profiles for disposal as non-hazardous or hazardous waste. For purposes of cost estimating, the following excavation quantities and waste types have been assumed at SWMU 40. A material density of 1.4 tons per BCY has been assumed based on material properties.

- Non hazardous waste – 7,357 BCY or 10,300 tons of landfill cap soil;
- Non hazardous waste – 1,936 BCY or 2,710 tons of soil excavated below the landfill material;
- Non-hazardous waste – 9,350 BCY or 13,090 tons of landfill material; and
- D008 characteristic waste (lead) – 9,350 BCY or 13,090 tons of landfill material with lead levels above the TCLP threshold of 5 mg/L.

Soil and landfill material will be excavated using conventional earth moving equipment (loaders, trackhoes, etc.). Materials will be characterized before excavation to develop waste profiles for disposal as non hazardous or hazardous waste. This also will allow for direct loading of trucks.

10.3.2 Work Plan

A site-specific work plan will be prepared for excavation and site restoration activities, which will include plans and specifications for excavation, waste characterization, transportation, and disposal, decontamination, confirmatory sampling, erosion and sediment control, backfilling, and site restoration, QA requirements and procedures, and a health and safety. The work plan will be submitted to the USEPA and VDEQ for approval prior to remedy implementation.

10.3.3 Site Setup

Site set-up for excavation activities will include:

- Mobilizing equipment and personnel;
- Construction of a decontamination pad capable of decontaminated heavy equipment and trucks, which includes a high density polyethylene liner, a sump to collect liquid, and a tank to contain decontamination water;
- Setup of sediment and erosion control measures including the installation of silt fence around the limits of the areas to be excavated; and
- Preparation of staging areas.

10.3.4 Excavation

Conventional earthmoving equipment, such as loaders and excavators, will excavate the soil and landfill material and directly load it into trucks for offsite transport and disposal. Trucks will be weighed and manifested before leaving the site. A water truck also will be required for dust suppression during excavation activities. Water required for decontamination will be trucked to the site and stored in an aboveground tank at the decontamination station.

10.3.5 Confirmatory Soil Sampling

Confirmation sampling will be conducted concurrently with excavation to document that landfill material has been removed and CMOs have been achieved. Soil samples will be collected from the base and sidewalls of the excavation. The anticipated confirmatory soil sampling program is summarized in Table 10-1.

10.3.6 Description of Remediation Waste

Corrective measures activities are expected to generate the following remediation waste and IDM:

- Approximately 26,100 tons of non hazardous soil and solid waste;

- Approximately 13,090 tons of D008 hazardous landfill material (lead); and
- Approximately 5,000 gallons of decontamination water.

10.3.7 Waste Characterization

Soil samples for waste characterization will be collected prior to material excavation. It is assumed that one composite sample will be collected for each 200 BCY of material for analysis of RCRA waste characteristics. Planned waste characterization analysis is outlined in Table 10-2.

10.3.8 Waste Transportation and Disposal

The remediation contractor and Installation will select the final disposal facility for the waste based on the following:

- Treatment, storage, and disposal facility capacity to accommodate incoming waste;
- Solicitation of bids using Federal Acquisition Regulations;
- Verification of permits and insurance; and
- The disposal facility must meet the permit compliance requirements.

10.3.9 Site Restoration

Once the excavation is completed, the area will be backfilled with clean fill to a grade consistent with the surrounding terrain. The fill will be compacted in 6 to 8-inch lifts to within 6-inches of finished grade. Approximately 6-inches of topsoil will then be placed and the site will be final graded. Erosion and sediment controls will be implemented and excavation areas will be hydroseeded. This alternative also would include abandonment of existing wells 40MW3, 40MW5, and 40MW6 and screened monitoring points 40MW2 and 40MW3.

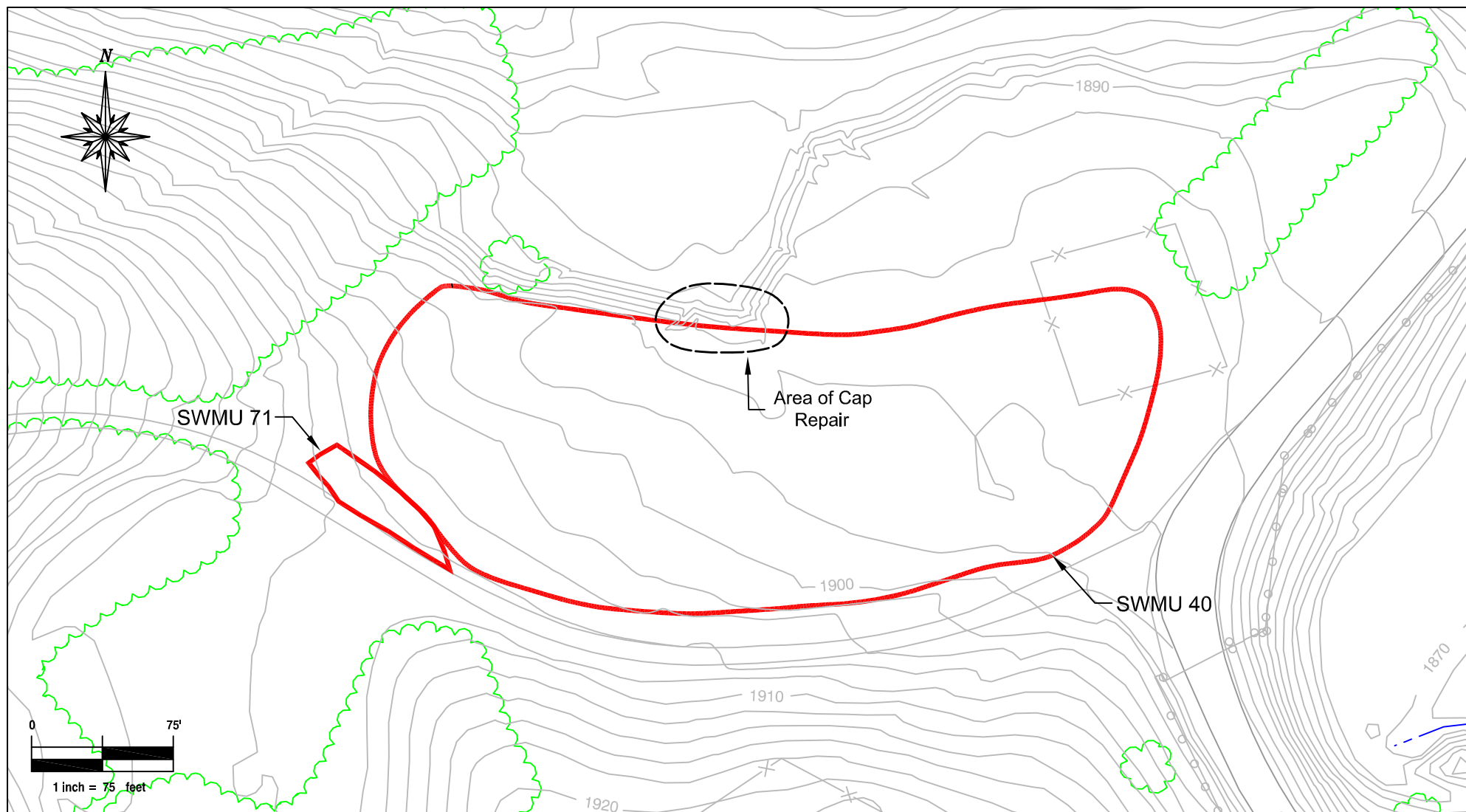
10.3.10 Health and Safety

Health and safety measures will be implemented to protect on-site workers during excavation activities. For cost-estimating purposes, modified Level D PPE and decontamination equipment has been assumed.

10.3.11 Remedy Completion Report

A remedy completion report will be prepared that documents the remedial actions implemented and completed at the site. This report will be submitted to the EPA and VDEQ.

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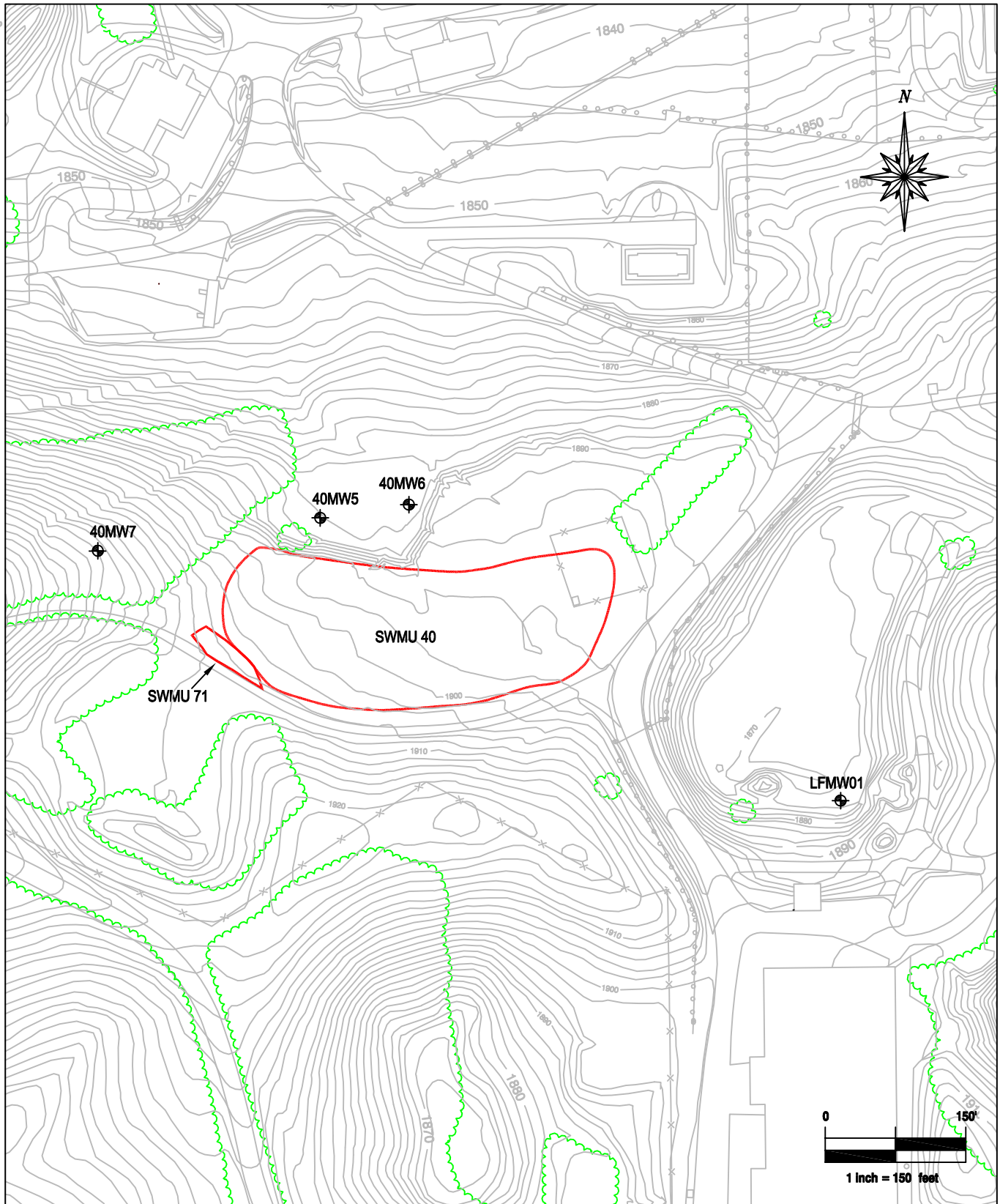
- Topographic Contour (feet mean sea level)
- SWMU Area

FIGURE 10-1 Corrective Measures Alternative 2 - Engineering Controls

Date: January 2008	Job Number: 21354880
Prepared By: DBC	Reviewed By: JOS
Scale: 1" = 75'	File Name: Fig.10-1 Corr.Meas.2

SWMUs 40 and 71 RFI/CMS Report Radford Army Ammunition Plant Radford, Virginia





Legend

- Approximate SWMU Boundary
- Topographic Contour
- Vegetation
- x x Fence
- ⊕ Monitoring Well Location

FIGURE 10-2
Long Term Monitoring Locations

Date: January 2009	URS Project #: 21354880
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 150 feet	File Name: Fig.10-2 LTM Wells

SWMUs 40 and 71
RFI/CMS Report
Radford Army Ammunition Plant
Radford, Virginia

URS URS Group, Inc.
5540 Falmouth Street
Suite 201
Richmond, Virginia 23230

Table 10-1
Excavation Confirmatory Soil Sample Analytical Program
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Excavation Area	Excavation Area (ft ²)	No. of Samples	Sample Density	Analytical Parameters	Analytical Method	Sample Unit Cost
SWMU 40 Landfill	52272	41	1 composite sample per 2500 square feet of excavation area. The composite sample will consist of four subsamples from each area.	TCL VOCs TCL SVOCs TCL PCBs Nitroglycerin	SW-846 Method 8260C SW-846 Method 8270C SW-846 Method 8082 SW-846 Method 8332	
			Sidewall: 1 composite sample per 50 linear ft	TAL Metals: Al, As, Ca, Cr, Cu, Fe, Pb, Hg, Z	SW-846 Method 6000/7000	

Table 10-2
Waste Characterization Analysis for Soil and Water
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Analytical Parameter	Media	Methods	Sample Unit Cost
pH	Soil	SW-846 9060	\$40
pH	Water	SW-846 9060	\$10
Full TCLP	Soil/Water	SW-846 Method 1311 (Extraction) VOCs - SW-846 Method 8260B SVOCs - SW-846 Method 8270C Pesticides - SW 846 Method 8081A Herbicides - SW 846 Method 8151A	\$997
Paint Filter	Soil	SW-846 Method 9095A	\$40
Chemical Oxidation Demand	Water	EPA Method 410.4	\$30
Explosives 8330/8332	Soil	EPA Method 8330/8332	\$289

11.0 EVALUATION OF CORRECTIVE MEASURES ALTERNATIVES

Criteria used to evaluate the three potential corrective measures alternatives include effectiveness, implementability, and cost as described below.

11.1 EVALUATION CRITERIA

11.1.1 Effectiveness

Effectiveness criteria evaluated for each alternative include:

- Protection of human health and the environment;
- Attain media cleanup standards and criteria;
- Control the source of releases;
- Compliance with any applicable standards for the management of wastes;
- Long-term reliability and effectiveness;
- Reduction in toxicity, mobility, and/or volume through treatment; and
- Short-term effectiveness.

11.1.2 Implementability

Implementability criteria evaluated for each alternative include:

- Technical factors including: constructability, time for implementation, and time for beneficial results;
- Administrative feasibility; and
- Availability of services and materials.

11.1.3 Cost

Cost factors that are used to evaluate alternatives include costs associated with implementation of each corrective measure alternative. The estimated cost for each alternative is based on a conceptual design for each alternative and includes both capital cost and operations and maintenance cost (O&M). The total estimated cost and present value of each alternative are presented. The actual cost of each alternative is dependent on a variety of factors including the scope of work, schedule, market conditions, and other variables.

11.2 EFFECTIVENESS

11.2.1 Protection of Human Health and the Environment

Alternative One

Alternative One may not provide for future protection of human health and the environment because corrective measures are not implemented to control future land use, site access, or ensure continued containment of landfill material.

Alternative Two

The combination of ICs, engineering controls, and LTM and maintenance will maintain appropriate containment of landfill material, control future land use and site access, and it will effectively prevent unacceptable human health and environmental exposure.

Alternative Three

Excavation of material from the entire landfill area will eliminate future exposure potential and provide for unrestricted use of the site, which will protect human health and the environment.

11.2.2 Compliance with Media Standards and Criteria

Alternative One

Media cleanup standards and criteria are not achieved by Alternative One because corrective measures are not implemented.

Alternative Two

Alternative Two is designed to achieve media standards and criteria by continued containment of landfill material and implementation of LTM and maintenance to verify continued containment. Constituent levels in groundwater samples collected immediately adjacent to the landfill were below applicable drinking water standards and criteria.

Alternative Three

Alternative Three will achieve media standards and criteria by complete removal of material from the entire landfill area and disposing of this material at an appropriate offsite disposal facility. Constituent levels in groundwater samples collected immediately adjacent to the landfill were below applicable drinking water standards and criteria.

11.2.3 Control of Sources of Releases

Alternative One

Alternative One does not necessary for provide for future control of the landfill area because corrective measures are not implemented to control future land use, site access, or ensure continued containment of landfill material.

Alternative Two

Alternative Two provides for effective source control using a combination of ICs and engineering controls, which will provide for continued control and containment of the landfill material. LTM and maintenance will be conducted to verify the effectiveness of the controls and containment.

Alternative Three

Alternative Three provides for source control and elimination by removal of material from the entire landfill area and disposing of this material at an appropriate offsite disposal facility. Removed material will be replaced by clean offsite backfill material.

11.2.4 Comply with any Applicable Standards for Management of Wastes

Alternative One

Alternative One does not include any waste management activities because corrective measures are not implemented.

Alternative Two

Alternative Two involves limited waste management activities because corrective measures consist of ICs maintenance of engineering controls, and LTM. LTM of groundwater would result in the generation of limited purge water, decontamination water, and IDM. Characterization of aqueous IDM from groundwater sampling for the RFI indicated that the water was non-hazardous and could be disposed of at the RFAAP wastewater treatment. It is anticipated that similar water generated during LTM activities would be disposed of in the same manner.

Alternative Three

Alternative Three will involve excavation and offsite transportation of non-hazardous soil and landfill material, which may be a hazardous waste. Waste characterization testing will be conducted prior to excavation to appropriately characterize material and develop waste profiles for disposal as non-hazardous or hazardous waste. This will also allow for direct loading of excavated material into trucks so potential RCRA permitting requirements are avoided for temporarily staging or managing soil onsite before loading. A final disposal facility or facilities will be selected for the wastes based on the waste characterization data, treatment, storage, disposal, and facility permit requirements, compliance with the facility's RCRA permit, and compliance with Federal regulations and Commonwealth of Virginia hazardous waste management regulations and policy.

11.2.5 Long-Term Reliability and Effectiveness

Alternative One

Alternative One does not achieve long-term effectiveness and permanence because corrective measures are not implemented to control land use, site access, or maintain containment of landfill material.

Alternative Two

Alternative Two is expected to provide for long-term reliability and effectiveness using a combination of ICs, engineering controls, and containment provided by the landfill cap and low-permeability clay soil underlying the landfill material. LTM of groundwater will be required to demonstrate the long-term reliability and effectiveness of this remedy.

Alternative Three

Alternative Three will provide for long-term reliability and effectiveness by completely removing soil and landfill material from the entire footprint of the landfill area, disposing of this material at an appropriate offsite treatment and disposal facility, and allowing for unrestricted future land use.

11.2.6 Reduction in Toxicity, Mobility, and/or Volume through Treatment

Alternative One

Alternative One does not reduce the toxicity, mobility, and volume of landfill material or associated COCs because corrective measures are not implemented.

Alternative Two

Alternative Two does not reduce the toxicity, mobility, and/or volume of landfill material or associated COCs because waste is left contained in place and controlled through a combination of ICs, engineering controls, and LTM and maintenance activities.

Alternative Three

Landfill material and soil excavated would not provide for a reduction of toxicity or volume of landfill material or associated COCs as the material is not treated or destroyed but is instead moved to a new location. However, a reduction of mobility may be provided by placement of the material in a RCRA landfill.

11.2.7 Short-Term Effectiveness

Alternative One

Alternative One does not require protection of workers and the community during remedial implementation because corrective measures are not implemented. However, the lack of ICs would potentially pose a future human health and environmental risk.

Alternative Two

Alternative Two will involve limited onsite activities for remedy implementation including repair of a small area of the landfill cap. Potential short-term risks to site workers, the environment, and community will be controlled and minimized by implementation of good construction and work practices, appropriate health and safety measures, erosion and sediment control measures, and personnel protection equipment. The methodologies to safely perform these activities and mitigate short-term risks will be described in site-specific work plans and health and safety plans.

Alternative Three

Potential short-term risk to site workers, the environment, and community will be controlled and minimized by implementation of good construction and work practices, appropriate health and safety measures, standard dust suppression techniques, erosion and sediment control measures, personnel protection equipment, real-time air monitoring, and management of non-hazardous and hazardous waste in accordance with Department of Transportation, federal, and Commonwealth of Virginia requirements. The methodologies to safely perform these activities and mitigate short-term risks will be described in site-specific work plans and health and safety plans.

11.3 IMPLEMENTABILITY

11.3.1 Technical

Alternative One

Constructability would not be an issue for Alternative One because corrective measures are not implemented. Alternative One would not require time for implementation because corrective measures are not implemented; however, future beneficial results may not be achieved.

Alternative Two

When appropriately layered and combined, ICs and engineering controls are well-proven, readily implementable technologies that are commonly used to remediate waste sites. LUCs can be implemented in less than one year and cap repairs could be completed within 30 days of site mobilization. Beneficial results would be achieved immediately after implementation of the LUCs and enhancement of existing engineering controls. LTM and maintenance would be conducted to verify the continued effectiveness of the remedy.

Alternative Three

Excavation and offsite disposal is a well-proven and implementable technology that is commonly used to remediate waste sites. The degree of implementation at the site may be more difficult when compared to conventional soil excavation due to the required excavation of 18,700 BCY of heterogeneous landfill material to depths up to 15 ft. Depending on the nature of the material encountered (moisture content, etc.), it may require some stabilization before offsite transport, and material characterization may be difficult. In addition, there is limited additional area to work outside of the landfill area, which will require careful project planning, implementation, and controls. Due to the large quantity of material to be excavated (approximately 28,000 BCY) and limited work area, onsite activities for remediation implementation could require up to 10 months.

Beneficial results would be achieved immediately after completion given that the source and waste areas would be completely removed from the site, which would provide for unrestricted use of the site.

11.3.2 Administrative Feasibility

Alternative One

Alternative One would not require any permits or administrative actions because corrective measures are not implemented.

Alternative Two

This alternative is administratively feasible and is expected to be routine in terms of administrative requirements. It is anticipated that this alternative will be implemented as a final interim measure and therefore, it will not require a modification of the facility's RCRA Corrective Action Permit at the time of implementation. Implementation of this alternative will not require special permits for management, treatment, transportation, or disposal of waste. Facility-specific permits will be required to complete the work including an area entry permit and hot work permit.

Alternative Three

Alternative Three is administratively feasible and is expected to be routine in terms of administrative requirements as described above for Alternative Two. It is anticipated that this alternative will be implemented as a final interim measure and therefore, it will not require a modification of the facility's RCRA Corrective Action Permit at the time of implementation. Implementation of this alternative will not require special permits for management, treatment, transportation, or disposal of waste. Facility-specific permits will be required to complete the work including an area entry permit and hot work permit.

11.3.3 Availability of Services and Materials

Alternative One

Alternative One would not require services and materials because corrective measures are not implemented.

Alternative Two

Services and materials, such grading contractors are readily available to complete necessary cap repairs and related remedy activities.

Alternative Three

Services and materials, such excavation contractors, treatment, storage, and disposal facility capacity, and disposal services are readily available to implement excavation and site restoration activities.

11.4 COST

Alternative One does not involve any actions, so there is no cost for this alternative. Detailed cost estimates for Alternative Two and Alternative Three are presented in Tables 11-1 and 11-2, respectively, and are summarized below.

Summary of Cost for Corrective Measures Alternatives

	Total Capital Cost (\$)	Annual Cost Year 1 (\$)	Annual Cost Years 2-5 (\$)	Annual Cost Years 6-30 (\$)	Total Cost Years 1-30 (\$)	Estimated Total Cost with O&M	PV @7% (\$)
Alternative 1 – No Action	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Alternative 2 – Institution Controls, Engineering Controls, and LTM and Maintenance	\$98,430	\$65,658	\$30,081	\$23,343	\$769,554	\$867,984	\$533,711
Alternative 3 - Excavation, Offsite Disposal	\$8,502,836	\$0	\$0	\$0	\$0	\$8,502,836	\$8,502,836

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Table 11-1
Cost Estimate: Corrective Measures Alternative Two
Institutional Controls, Engineering Controls, and Long-Term Monitoring and Maintenance
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Capital Costs				
Item	Units	Unit Cost (\$)	Quantity	Total (\$)
Institutional Controls, Engineering Controls, and Monitoring Well Installation				
Preparation, Implementation of Institutional Control Plan, LTM Plan, GIS System Update	EA	20,000	1	\$20,000
Repair Landfill Cap Area and Reseed	EA	15,000	1	\$15,000
Installation of Monitoring Well 40MW7 (160 ft) with oversight, development, IDM	LS	23,000	1	\$23,000
Expenses for Construction Oversight	LS	1000	1	\$1,000
Subtotal				\$59,000
	Project Management (10%)			\$5,900
	Planning Documents (8%)			\$4,720
	Construction Oversight (6.5%)			\$3,835
	Reporting (1.5%)			\$885
	Public Notice (0.5%)			\$295
	As Built Drawings (1.5%)			\$885
	Permitting (1%)			\$590
	Other Direct Costs (5% of Labor)			\$2,950
Total - Task 1				\$79,060
	Engineering Design (4.5%)			\$3,558
	Contingency (20%)			\$15,812
Total Capital Costs				\$98,430
Annual O&M Costs Year 1				
Item	Units	Unit Cost (\$)	Quantity	Total (\$\$)
LTM: Cap Maintenance/Inspections and Quarterly Groundwater Monitoring				
Mowing, Seeding, Fertilizing, and Repairs of 1.2 acre Cap Area as Needed	YR	1,500	1	\$1,500
Groundwater Sampling - Field Labor	EVENT	2,600	4	\$10,400
Groundwater Sampling Equipment and Supplies	EVENT	555	4	\$2,220
Per Diem	EVENT	291	4	\$1,163
Vehicle and Fuel	EVENT	272	4	\$1,088
Sample Cooler Shipping	EVENT	566	4	\$2,264
First Quarter Groundwater Sample Analysis (VOCs, SVOCs, Pests, Metals, Perchlorate, Dioxins)	EA	1,320	6	\$7,920
Second - Fourth Quarter Groundwater Sample Analysis (VOCs, SVOCs, Pests, Metals, Perchlorate)	EA	720	18	\$12,960
Subtotal				\$39,515
Reporting				
Annual LTM Data Analysis and Reporting	EA	10,000	1	\$10,000
Subtotal				\$10,000
Subtotal Annual O&M Cost				\$49,515
	Project Management (10.5%)			\$5,199
	Total Annual O&M Cost			\$54,715
	Contingency (20%)			\$10,943
Total O&M Cost for Year 1				\$65,658
Annual O&M Costs Year 2-5				
Item	Units	Unit Cost (\$)	Quantity	Total (\$\$)
LTM: Cap Maintenance/Inspections and Groundwater Monitoring Every 9 Months				
Mowing, Seeding, Fertilizing, and Repairs of 1.2 acre Cap Area as Needed	YR	1,500	1	\$1,500
Groundwater Sampling - Field Labor	EVENT	2,600	1.3	\$3,380
Groundwater Sampling Equipment and Supplies	EVENT	555	1.3	\$722
Per Diem	EVENT	291	1.3	\$378
Vehicle and Fuel	EVENT	272	1.3	\$354
Sample Cooler Shipping	EVENT	566	1.3	\$736
Groundwater Sample Analysis (VOCs, SVOCs, Pests, Metals, Perchlorate)	EA	720	8	\$5,616
Subtotal				\$12,685
Reporting				
Annual LTM Data Analysis and Reporting	EA	10,000	1	\$10,000
Subtotal				\$10,000
Subtotal Annual O&M Cost				\$22,685
	Project Management (10.5%)			\$2,382
	Total Annual O&M Cost			\$25,067
	Contingency (20%)			\$5,013
Total Annual O&M Cost for Years 2-5				\$30,081
Total O&M Cost for Years 2-5				\$120,323

Table 11-1
Cost Estimate: Corrective Measures Alternative Two
Institutional Controls, Engineering Controls, and Long-Term Monitoring and Maintenance
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Annual O&M Costs Years 6-30				
Item	Units	Unit Cost (\$)	Quantity	Total (\$\$)
LTM: Cap Maintenance/Inspections and Semi-Annual Groundwater Monitoring				
Mowing, Seeding, Fertilizing, and Repairs of 1.2 acre Cap Area as Needed	YR	1,500	1	\$1,500
Groundwater Sampling - Field Labor	EVENT	2,600	1	\$2,600
Groundwater Sampling Equipment and Supplies	EVENT	555	1	\$555
Per Diem	EVENT	291	1	\$291
Vehicle and Fuel	EVENT	272	1	\$272
Sample Cooler Shipping	EVENT	566	1	\$566
Groundwater Sample Analysis (VOCs, SVOCs, Pests, Metals, Perchlorate)	EA	720	6	\$4,320
Subtotal				\$10,104
Reporting				
Annual LTM Data Analysis and Reporting	EA	7,500	1	\$7,500
Subtotal				\$7,500
Subtotal Annual O&M Cost				\$17,604
Project Management (10.5%)				\$1,848
Total Annual O&M Cost				\$19,452
Contingency (20%)				\$3,890
Total Annual O&M Cost Years 6-30				\$23,343
Total O&M Cost for Years 6-30				\$583,574
Total O&M Cost for 30 Years				\$769,554
Estimated Total Cost of Alternative Two with 30 Years of O&M				\$867,984
Present value @7%				\$533,711

Table 11-2
Cost Estimate: Corrective Measures Alternative Three
Excavation of Soil and Landfill Material for Clean Closeout and Unrestricted Land Use
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Capital Costs				
Item	Units	Unit Cost (\$)	Quantity	Total (\$)
Task 1: Soil Excavation, Backfill, and Site Restoration				
Pre-Excavation Waste Characterization	LS	10,000	1	\$10,000
Pre-Excavation Waste Characterization Sample Analysis	EA	1,100	94	\$102,850
Mobilization	LS	1	50,000	\$50,000
Decontamination Facility for Heavy Equipment and Trucks	EA	1	50,000	\$50,000
Sediment & Erosion Control	LF	3.75	1,500	\$5,625
Excavation and Load Material	BCY	9.5	27,993	\$265,934
Sheet Piling (Installed, Pulled & Decontaminated)	SF	9	23,280	\$209,520
Backfill, Offsite Material, Place and Compacted	LCY	11	36,391	\$400,300
Topsoil, Imported, 6" Deep, Furnish and Place	LCY	36	1,210	\$43,560
Hydroseeding, Vegetative Cover	AC	3,461	1.2	\$4,153
Confirmatory Soil Sample Analysis - Composite Samples (TCL + Explosives)	EA	2,060	26	\$53,560
Non-Hazardous Soil Disposal (T&D)	TON	75	31,336	\$2,350,215
Hazardous Soil Treatment and Disposal (T&D)	TON	200	13,090	\$2,618,000
Subtotal Task 1				\$6,163,717
Task 2 Site Close-Out/Monitoring Well Abandonment				
Driller Mobilization	EA	500	1	\$500
2" Well Abandonment: Pressure Grout in Place	FT	7.5	540	\$4,050
Remove of Stickup Surface Completion	EA	175	5	\$875
Decontamination	HR	150	5	\$750
Containerization and Disposal of Solid Waste	LS	150	5	\$750
Subtotal Task 2				\$6,925
Subtotal Tasks 1 and 2				\$6,170,642
	Project Management (3%)			\$185,119
	Planning Documents (3.3%)			\$203,631
	Construction Oversight (4.5%)			\$277,679
	Reporting (0.5%)			\$30,853
	Public Notice (0.5%)			\$30,853
	As Built Drawings (0.5%)			\$30,853
	Permitting (1%)			\$61,706
	Other Direct Costs (15% of Labor)			\$123,104
Total - Task 1 and 2				\$7,114,441
	Engineering Design (2.5%)			\$154,266
	Contingency (20%)			\$1,234,128
Total Capital Costs				\$8,502,836

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12.0 RANKING OF CORRECTIVE MEASURES ALTERNATIVES

The three corrective measures alternatives presented in Section 9.0 and evaluated in Section 10.0 are assessed in this section using a numerical ranking system. The alternatives are ranking according to the criteria discussed in Section 10.0 including effectiveness, implementability, and cost. Each selection criterion for each alternative is ranked 1 through 5. A score of 1 indicates a least favorable ranking value and a score of 5 indicates most favorable ranking value.

Criteria are also weighted based on importance. Effectiveness is given a weight factor of 3, because the primary purpose of the selected alternative is to be protective of human health and the environment. Implementability is given a weight factor of 2. Costs are given a weight factor of 1 because this criterion is considered the least important for selection of an alternative. The ranking for the three alternatives is presented in Table 12-1.

Based on the ranking, Alternative Two – Institutional Controls, Engineering Controls, and Long-Term Maintenance and Monitoring, is the selected alternative for SWMU 40.

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Table 12-1
Ranking Assessment of Corrective Measures Alternatives
SWMUs 40 and 71 RFI/CMS Report
Radford Army Ammunition Plant, Radford, Virginia

Alternative	Effectiveness	Implementability	Cost	Total Score
Alternative One - No Further Action	Alternative One may not provide for future protection of human health and the environment because corrective measures are not implemented to control future land use, site access, or ensure continued containment of landfill material. 33X1	The alternative does not include any actions which require implementation. Administratively, this alternative would require the regulatory community waive risk standards and criteria and therefore, is not implementable. 22X1	Capital Cost: \$0 Annual O&M Cost: \$0 Total Cost w/8 years of O&M: \$0 PV @7%: \$0 51X5	10
Alternative Two - Institutional Controls, Engineering Controls, and Long-Term Monitoring and Maintenance	The combination of institutional controls, engineering controls, and LTM and maintenance will maintain appropriate containment of landfill material, control future land use and site access, and it will effectively prevent unacceptable human health and environmental exposure. Alternative Two is designed to achieve media standards and criteria by continued containment of landfill material and implementation of LTM and maintenance to verify continued containment. Constituent levels in groundwater samples collected immediately adjacent to the landfill were below applicable drinking water standards and criteria. Alternative Two is expected to provide for long-term reliability and effectiveness using a combination of institutional controls, engineering controls, and containment provided by the landfill cap and low-permeability clay soil underlying the landfill material. LTM of groundwater will be required to demonstrate the long-term reliability and effectiveness of this remedy. Land use controls will be required for this alternative. 123X4	This alternative is administratively feasible and is expected to be routine in terms of administrative requirements. It is anticipated that this alternative will be implemented as a final interim measure and therefore, it will not require a modification of the facility's RCRA Corrective Action Permit at the time of implementation. Special permits for management, treatment, transportation, or disposal of waste will not be required. Facility-specific permits will be required to complete the work including an area entry permit and hot work permit. When appropriately layered and combined, institutional controls and engineering controls are well-proven, readily implementable technologies that are commonly used to remediate waste sites. Land use controls can be implemented in less than one year and repairs to the landfill cap could be completed within 30 days of site mobilization. Beneficial results would be achieved immediately after implementation of the land use controls and enhancement of existing engineering controls. LTM and maintenance would be conducted to verify the continued effectiveness of the remedy. This alternative is easily implemented, all services and materials include in this alternative are readily available and represent well proven technologies. 102X5	Capital Cost: \$98,430 Annual O&M Cost Year 1: \$65,658 Annual O&M Cost Years 2-5: \$30,081 Annual O&M Cost Years 6-30: \$23,343 Total Cost w/30 years of O&M: \$867,984 PV @7%: \$533,711 41X4	26
Alternative Three - Excavation of Soil and Landfill Material for Clean Close Out and Unrestricted Land Use	Excavation of material from the entire landfill area will eliminate future exposure potential and provide for unrestricted use of the site, which will protect human health and the environment. Alternative Three will achieve media standards and criteria by complete removal of material from the entire landfill area and disposing of this material at an appropriate offsite disposal facility. It also provides for source control and elimination by removal of material from the entire landfill area and disposing of this material at an appropriate offsite disposal facility. Alternative Three will provide for long-term reliability and effectiveness by completely removing soil and landfill material from the entire footprint of the landfill area, disposing of this material at an appropriate offsite treatment and disposal facility, and allowing for unrestricted future land use. Land use controls will not be required for this alternative. 153X5	Excavation and offsite disposal is a well-proven and implementable technology that is commonly used to remediate waste sites. The degree of implementation at the site may be more difficult when compared to conventional soil excavation due to the required excavation of 28,000 BCY of heterogeneous landfill material to depths up to 15 ft. Depending on the nature of the material encountered (moisture content, etc.), it may require some stabilization before offsite transport, and material characterization may be difficult. In addition, there is limited additional area to work outside of the landfill area, which will require careful project planning, implementation, and controls. Due to the large quantity of material to be excavated (28,000 BCY) and limited work area, onsite activities for remediation implementation could require in excess of 10 months. All services and materials included in this alternative are readily available. Implementation of this alternative will not require special permits for management, treatment, transportation, or disposal of waste. Facility-specific permits will be required to complete the work including an area entry permit and h required prior to land disturbance activities given that more than a 10,000ft² area will be disturbed at the site. 62X3	Capital Cost: \$8,502,836 Annual O&M Cost: \$0 Total Cost w/8 years of O&M: \$0 PV @7%: \$8,502,836 11X1	22

Notes:

<u>Ranking Value</u>	<u>Weight Factor</u>	<u>Example</u>
1 - Least Favorable → 5 - Most Favorable	Effectiveness 3	10 = Score
	Implementability 2	2 X 5 = weight factor X ranking value
	Cost 1	

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13.0 SUBSTANTIATION/JUSTIFICATION OF FINAL REMEDY

The following CMOs have been developed for SWMU 40 based on the results of the site, risk, and fate and transport assessments:

- Maintain containment of the landfill material at the site and implement necessary controls to prevent future uncontrolled human exposure to this waste material.
- Implement any necessary measures to stabilize and repair the landfill cover at the northern edge of the landfill area to prevent any further mass transport of soil material in this area.

Three potentially applicable corrective measure technologies for the site were identified and screened in the CMS with respect to their potential effectiveness and implementability in achieving the identified CMOs. Each of these technologies was retained for development of corrective measures alternatives based on the results of the technology screening. Two corrective measures alternatives were developed from these technologies in addition to a baseline no further action alternative including:

- Alternative No. 1: No Further Action;
- Alternative No. 2: Institutional Controls, Engineering Controls, and Long-Term Monitoring and Maintenance;
- Alternative No. 3: Excavation of Soil/Landfill Material and Offsite Disposal for Clean Closure and Unrestricted Land Use.

The three alternatives were evaluated with respect to criteria specified in Attachment D of the RFAAP RCRA Permit (USEPA 2000b) and criteria for evaluating corrective measures alternatives in Section IV Part E of the RCRA Corrective Plan guidance document (USEPA 1994a). Alternatives Two and Three were found to achieve the CMOs, with Alternative Three exceeding the CMOs by also achieving unrestricted future use of the site after remedy completion.

Alternative Two was selected as the final alternative for SWMU 40 because it will: 1) effectively achieve each of the CMOs by providing for continued containment of landfill material at the site, preventing future uncontrolled human health exposure to the waste material, and repairing the small areas of the cap that have eroded, and achieve the required CMOs at one eighth the total cost of Alternative 3 expressed as total dollars and at one eighteenth the total cost of Alternative 3 when costs are expressed as net present value. Implementation of Alternative Three would exceed the established CMOs but would require transferring waste material from landfill to another at significant cost without reduction of volume or toxicity.

Implementation of Alternative Two, including implementation of ICs, is expected to be completed in less than six months, with cap repairs requiring less than 30 days to complete after site mobilization. This time frame is considered an estimate and the actual time to complete the corrective measures will be subject to site-specific conditions.

Implementation of Alternative Two will include the following:

- Repairs to the landfill cap;
- Implementation of ICs;
- Installation of a third downgradient monitoring well; and
- LTM for 30 years including: inspection and maintenance of the landfill cap, periodic sampling of four groundwater monitoring wells, and preparation of annual LTM reports.

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14.0 REFERENCES

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APPENDIX A
PHOTOGRAPHIC LOG

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PHOTOGRAPHIC LOG

Client Name: RFAAP		Site Location: Radford, Virginia	Project No. 21354880
Photo No. 1	Date: 9/12/2002		
Direction Photo Taken: NE			
Description: View looking northeast across SWMUs 40 and 71.			

Photo No. 2	Date:	
Direction Photo Taken: NW		
Description: View looking west across SWMUs 40 and 71 and the Northern Scarp.		



PHOTOGRAPHIC LOG

Client Name:

RFAAP

Site Location:

Radford, Virginia

Project No.

21354880

Photo No.

3

Date:

1/1/1990

Direction Photo Taken:

NE

Description:

View looking northeast across SWMUs 40 and 71. The asbestos storage area is visible in the middle ground.

**Photo No.**

4

Date:

11/20/2002

Direction Photo Taken:**Description:**

View of test pit excavated at SWMU 40 showing the debris encountered approximately 1 to 2 feet below ground surface.



APPENDIX B

STANDARD OPERATING PROCEDURES

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SOP SERIES
SWMUs 40 and 71 RFI/CMS REPORT

SOP SERIES	TITLE
10.0	DOCUMENTATION
10.1	Field Logbook
10.2	Surface Water, Groundwater, and Soil/Sediment Field Logbooks
10.3	Boring Logs
10.4	Chain-of-Custody Forms
20.0	SUBSURFACE INVESTIGATION
20.1	Monitoring Well Installation
20.2	Monitoring Well Development
20.3	Well and Boring Abandonment
20.4	Test Pits
20.11	Drilling Methods and Procedures
30.0	SAMPLING
30.1	Soil Sampling
30.2	Groundwater Sampling
30.6	Containerized Material
30.7	Sampling Strategies
30.9	Collection of Soil Samples By USEPA SW-846 Method 5035 Using Disposable Samplers
40.0	FIELD EVALUATION
40.1	Multi-parameter Water Quality Monitoring Instrument
40.2	Well Level and Well Depth Measurements
50.0	SAMPLE MANAGEMENT
50.1	Sample Labels
50.2	Sample Packaging
70.0	INVESTIGATION-DERIVED MATERIAL
70.1	Investigation-Derived Material
80.0	DECONTAMINATION
80.1	Decontamination
90.0	AIR MONITORING EQUIPMENT
90.1	Photoionization Detector (HNU Model PI-101 and HW-101)

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STANDARD OPERATING PROCEDURE 10.1 FIELD LOGBOOK

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording daily site investigation activities.

Records should contain sufficient information so that anyone can reconstruct the sampling activity without relying on the collector's memory.

2.0 MATERIALS

- Field Logbook;
- Indelible ink pen; and
- Clear tape.

3.0 PROCEDURE

Information pertinent to site investigations will be recorded in a bound logbook. Each page/form will be consecutively numbered, dated, and signed. All entries will be made in indelible ink, and all corrections will consist of line out deletions that are initialed and dated. If only part of a page is used, the remainder of the page should have an "X" drawn across it. At a minimum, entries in the logbook will include but not be limited to the following:

- Project name (cover);
- Name and affiliation of personnel on site;
- Weather conditions;
- General description of the field activity;
- Sample location;
- Sample identification number;
- Time and date of sample collection;
- Specific sample attributes (e.g., sample collection depth flow conditions or matrix);
- Sampling methodology (grab or composite sample);
- Sample preservation, as applicable;
- Analytical request/methods;
- Associated quality assurance/quality control (QA/QC) samples;
- Field measurements/observations, as applicable; and
- Signature and date of personnel responsible for documentation.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program*. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, DC.

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STANDARD OPERATING PROCEDURE 10.2 SURFACE WATER, GROUNDWATER, AND SOIL/SEDIMENT FIELD LOGBOOKS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording surface water, groundwater, and soil/sediment sampling information, as well as instrument calibration data in field logbooks.

2.0 MATERIAL

- Applicable field logbook (see attached forms); and
- Indelible ink pen.

3.0 PROCEDURE

All information pertinent to surface water, groundwater, or soil/sediment sampling will be recorded in the appropriate logbook. Each page/form of the logbook will be consecutively numbered. All entries will be made with an indelible ink pen. All corrections will consist of line out deletions that are initialed and dated.

3.1 SOIL/SEDIMENT

3.1.1 Field Parameters/Logbook (Form 10.2-a)

1. HIGH CONCENTRATION EXPECTED?: Answer “Yes” or “No.”;
2. HIGH HAZARD?: Answer “Yes” or “No.”;
3. INSTALLATION/SITE: Record the complete name of the installation or site;
4. AREA: Record the area designation of the sample site;
5. INST. NAME: Record the two-letter installation name for Radford Army Ammunition Plant – “RD”;
6. SAMPLE MATRIX CODE: Record the appropriate sample matrix code. Common codes are “SD” for solid - sediment, “SI” for soil - gas, “SL” for solid sludge, “SO” for surface other, “SS” for solid – soil, “SW” for surface wipe, “WD” for water – potable, “WG” for water – ground, “WS” water – surface, “WT” – water treated and “WW” water -waste;
7. SITE ID: Record a code up to 20 characters or numbers that is unique to the site;
8. ENV. FIELD SAMPLE IDENTIFIER: Record a code up to 20 characters specific for the sample;
9. DATE: Enter the date the sample was taken;
10. TIME: Enter the time (12-hour or 24-hour clock acceptable as long as internally consistent) the sample was taken;
11. AM PM: Circle “AM” or “PM” to designate morning or afternoon (12-hour clock);
12. SAMPLE PROG: Record “RFI” (RCRA Facility Investigation) or other appropriate sample program;
13. DEPTH (TOP): Record the total depth sampled;
14. DEPTH INTERVAL: Record the intervals at which the plug will be sampled;

15. UNITS: Record the units of depth (feet, meters);
16. SAMPLE MEASUREMENTS: Check the appropriate sampling method;
17. CHK: Check off each container released to a laboratory;
18. ANALYSIS: Record the type of analysis to be performed on each sample container;
19. SAMPLE CONTAINER: Record the sample container type and size;
20. NO.: Record the number of containers;
21. REMARKS: Record any remarks about the sample;
22. TOTAL NUMBER OF CONTAINERS FOR SAMPLE: Record the total number of containers;
23. SITE DESCRIPTION: Describe the location where the sample was collected;
24. SAMPLE FORM: Record the form of the sample (i.e., clay, loam, etc.) using The Unified Soil Classification System (USCS);
25. COLOR: Record the color of the sample as determined from standard Munsell Color Charts;
26. ODOR: Record the odor of the sample or “none”;
27. PID: Record the measured PID values or other similar measurement instrument value;
28. UNUSUAL FEATURES: Record anything unusual about the site or sample;
29. WEATHER/TEMPERATURE: Record the weather and temperature; and
30. SAMPLER: Record your name.

3.1.2 Map File Form (refer to form 10.2-c)

1. SITE ID: Record the Site ID from the field parameter form;
2. POINTER: Record the field sample number for the sample being pointed to;
3. DESCRIPTION/MEASUREMENTS: Describe the location where the sample was taken, along with distances to landmarks;
4. SKETCH/DIMENSIONS: Diagram the surroundings and record the distances to landmarks;
5. MAP REFERENCE: Record which U.S.G.S. Quad Map references the site;
6. COORDINATE DEFINITION: Write the compass directions and the X- and Y-coordinates of the map run;
7. COORDINATE SYSTEM: Write “UTM” (Universal Transverse Mercator);
8. SOURCE: Record the 1-digit code representing the Map Reference;
9. ACCURACY: Give units (e.g., write “1-M” for 1 meter);
10. X-COORDINATE: Record the X-coordinate of the sample site location;
11. Y-COORDINATE: Record the Y-coordinate of the sample site location;
12. UNITS: Record the units used to measure the map sections;
13. ELEVATION REFERENCE: Record whether topography was determined from a map or a topographical survey;
14. ELEVATION SOURCE: Record the 1-digit code representing the elevation reference;

15. ACCURACY: Record the accuracy of the map or survey providing the topographical information;
16. ELEVATION: Record the elevation of the sampling site;
17. UNITS: Write the units in which the elevation is recorded; and
18. SAMPLER: Write your name.

3.2 SURFACE WATER

3.2.1 Field Parameter Logbook (Forms 10.2-b and 10.2-c)

1. CAL REF: Record the calibration reference for the pH meter;
2. pH: Record the pH of the sample;
3. TEMP: Record the temperature of the sample in degrees Celsius;
4. COND: Record the conductivity of the water;
5. Description of site and sample conditions (refer to 10.2-b);
6. Map File Form (refer to Section 3.1.2).

3.3 GROUNDWATER (FORMS 10.2- D)

3.3.1 Field Parameter Logbook (Form 10.2.b)

Refer to Section 3.2.1.

3.3.2 Map File and Purging Forms

1. WELL NO. OR ID: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on pages 18-21 of the IRDMIS User's Guide for chemical data entry;
2. SAMPLE NO.: Record the reference number of the sample;
3. WELL/SITE DESCRIPTION: Describe the location where the sample was taken, along with distances to landmarks;
4. X-COORD AND Y-COORD: Record the survey coordinates for the sampling site;
5. ELEV: Record the elevation where the sample was taken;
6. UNITS: Record the units the elevation was recorded in;
7. DATE: Record the date in the form MM/DD/YY;
8. TIME: Record the time, including a designation of AM or PM;
9. AIR TEMP.: Record the air temperature, including a designation of C or F (Celsius or Fahrenheit);
10. WELL DEPTH: Record the depth of the well in feet and inches;
11. CASING HEIGHT: Record the height of the casing in feet and inches;
12. WATER DEPTH: Record the depth (underground) of the water in feet and inches;
13. WELL DIAMETER: Record the diameter of the well in inches;
14. WATER COLUMN HEIGHT: Record the height of the water column in feet and inches;
15. SANDPACK DIAM.: Record the diameter of the sandpack. Generally, this will be the same as the bore diameter;

16. EQUIVALENT VOLUME OF STANDING WATER: Use one of the following equations to determine one equivalent volume (EV);

1 EV = volume in casing + volume in saturated sandpack. Or:

$$1 \text{ EV} = [\pi R_w^2 h_w + 0.30p(R_s^2 - R_w^2)h_s] * (0.0043)$$

Where:

R_s = radius of sandpack in inches

R_w = radius of well casing in inches

h_s = height of sandpack in inches

h_w = water depth in inches

$$0.0043 = \text{gal/in}^3$$

and filter pack porosity is assumed as 30%, or

$$\text{Volume in casing} = (0.0043 \text{ gal/in}^3)(p)(12 \text{ in/ft})(R_c^2)(W_h)$$

Where:

R_c = radius of casing in inches, and

W_h = water column height in feet

$$\text{Vol. in sandpack} = (0.0043 \text{ gal/in}^3)(p)(12 \text{ in/ft})(R_b^2 - R_c^2)(W_h)(0.30)$$

(if W_h is less than the length of the sandpack), or

$$\text{Vol. in sandpack} = (0.0043 \text{ gal/in}^3)(p)(12 \text{ in/ft})(R_b^2 - R_c^2)(Sh)(0.30)$$

(if W_h is greater than the length of the sandpack).

where:

R_b = radius of the borehole, and

Sh = length of the sandpack.

Show this calculation in the comments section.

1. PUMP RATE: Record pump rate;
2. TOTAL PUMP TIME: Record total purge time and volume;
3. WELL WENT DRY? Write "YES" or "NO";
4. PUMP TIME: Record pump time that made the well go dry;
5. VOLUME REMOVED: Record the volume of water (gal) removed before the well went dry;
6. RECOVERY TIME: Record the time required for the well to refill;

7. PURGE AGAIN?: Answer “YES” or “NO”;
8. TOTAL VOL. REMOVED: Record the total volume of water (in gallons) removed from the well;
9. CAL REF.: Record the calibration reference for the pH meter;
10. TIME: Record time started (INITIAL T(0)), 2 times DURING the sampling and the time sampling ended (FINAL);
11. pH: Record the pH at start of sampling (INITIAL), twice DURING the sampling, and at the end of sampling (FINAL);
12. TEMP: Record the water temperature (Celsius) at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
13. COND: Record the conductivity of the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
14. D.O.: Record the dissolved oxygen level in the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
15. TURBIDITY: Record the readings from the turbidity meter (nephelometer) and units at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
16. ORD: Record the oxidation/reduction (RedOx) potential of the water sample at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
17. HEAD SPACE: Record any positive readings from organic vapor meter reading taken in well headspace before sampling;
18. NAPL: Record the presence and thickness of any non-aqueous phase liquids (LNAPL and DNAPL)
19. COMMENTS: Record any pertinent information not already covered in the form; and
20. SIGNATURE: Sign the form.

3.4 FIELD CALIBRATION FORMS (REFER TO FORM 10.2-E)

1. Record time and date of calibration;
2. Record calibration standard reference number;
3. Record meter ID number;
4. Record initial instrument reading, recalibration reading (if necessary), and final calibration reading on appropriate line;
5. Record value of reference standard (as required);
6. COMMENTS: Record any pertinent information not already covered on form; and
7. SIGNATURE: Sign form.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCE

USEPA. 1991. *User's Guide to the Contract Laboratory Program*. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response, January.

FIELD PARAMETER/LOGBOOK FORM 10.2-a
SOIL AND SEDIMENT SAMPLES

HIGH CONCENTRATION EXPECTED? _____ HIGH HAZARD? _____

INSTALLATION/SITE _____ AREA _____

INST NAME _____ FILE NAME _____

SAMPLE MATRIX CODE _____ SITE ID _____

ENV. FIELD SAMPLE IDENTIFIER _____

DATE (MM/DD/YY) __/__/__ TIME _____ AM PM SAMPLE PROGRAM _____

DEPTH (TOP) _____ DEPTH INTERVAL _____ UNIT _____

SAMPLING METHOD:

SPLIT SPOON ___ AUGER ___ SHELBY TUBE ___ SCOOP ___ OTHER _____

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE _____

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION: _____

SAMPLE FORM _____ COLOR _____ ODOR _____

PID (HNu) _____ UNUSUAL FEATURES _____

WEATHER/TEMPERATURE _____

SAMPLER _____

FIELD PARAMETER/LOGBOOK FORM 10.2-b
GROUNDWATER AND SURFACE WATER SAMPLES

HIGH CONCENTRATION EXPECTED? _____ HIGH HAZARD? _____

INSTALLATION/SITE _____ AREA _____

INST CODE _____ FILE NAME _____ SITE TYPE _____

SITE ID _____ FIELD SAMPLE NUMBER _____

DATE (MM/DD/YY) __/__/__ TIME _____ AM PM SAMPLE PROG. _____

DEPTH (TOP) _____ DEPTH INTERVAL _____ UNITS _____

SAMPLING MEASUREMENTS

CAL REF. _____ pH _____ TEMPERATURE °C _____ CONDUCTIVITY _____ REDOX _____

DISSOLVED OXYGEN _____ TURBIDITY _____ OTHER _____

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE _____

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION _____

SAMPLING METHOD _____

SAMPLE FORM _____ COLOR _____ ODOR _____

PID (HNu) _____

UNUSUAL FEATURES _____

WEATHER/TEMPERATURE _____ SAMPLER _____

EXAMPLE MAP FILE LOGBOOK FORM 10.2-c
SURFACE WATER, SOIL, AND SEDIMENT SAMPLES

SITE ID _____ POINTER _____

DESCRIPTION/MEASUREMENTS _____

SKETCH/DIMENSIONS :

MAP REFERENCE _____

COORDINATE DEFINITION (X is _____ Y is _____)

COORDINATE SYSTEM _____ SOURCE _____ ACCURACY _____

X-COORDINATE _____ Y-COORDINATE _____ UNITS _____

ELEVATION REFERENCE _____

ELEVATION SOURCE _____ ACCURACY _____ ELEVATION _____

UNITS _____

SAMPLER _____

**EXAMPLE MAP FILE AND PURGING LOGBOOK FORM 10.2-d
GROUNDWATER SAMPLES**

WELL COORD. OR ID _____ SAMPLE NO. _____

WELL/SITE DESCRIPTION _____

X-COORD. _____ Y-COORD. _____ ELEV. _____ UNITS

DATE ____/____/____ TIME _____ AIR TEMP. _____

WELL DEPTH _____ FT. _____ IN. CASING HT. _____ FT. _____ IN.

WATER DEPTH _____ FT. _____ IN. WELL DIAMETER _____ IN.

WATER COLUMN HEIGHT _____ FT. _____ IN. SANDPACK DIAM. _____ IN.

EQUIVALENT VOLUME OF STANDING WATER _____ (GAL) (L)

VOLUME OF BAILER _____ (GAL) (L) or PUMP RATE _____ (GPM) (LPM)

TOTAL NO. OF BAILERS (5 EV) _____ or PUMP TIME _____ MIN.

WELL WENT DRY? [Yes] [No] NUM. OF BAILERS _____ or PUMP TIME

VOL. REMOVED _____ (GAL) (L) RECOVERY TIME

PURGE AGAIN? [Yes] [No] TOTAL VOL. REMOVED _____ (GAL) (L)

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color / clarity / odor / partic.)
(before)									
(during)									
(during)									
(during)									
(after)									

COMMENTS _____

SIGNATURE _____

EXAMPLE FIELD CALIBRATION FORM 10.2-e
FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY,
ORD, AND DISSOLVED OXYGEN METERS

INITIAL CALIBRATION	FINAL CALIBRATION
DATE:	DATE:
TIME:	TIME:

pH METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

pH STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
7.0			
10.0			
4.0			

CONDUCTIVITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

COND. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

TEMPERATURE METER CALIBRATION

METER ID _____

TEMP. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
ICE WATER			
BOILING WATER			
OTHER _____			

EXAMPLE FIELD CALIBRATION FORM 10.2-e
FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY,
ORD, AND DISSOLVED OXYGEN METERS

TURBIDITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

ORD METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

DISSOLVED OXYGEN METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO: _____

METER ID _____

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

COMMENTS _____

SIGNATURE _____

STANDARD OPERATING PROCEDURE 10.3 BORING LOGS

1.0 INTRODUCTION

The purpose of this standard operating procedure (SOP) is to describe the methods to be followed for classifying soil and rock, as well as preparing borehole logs and other types of soil reports.

2.0 MATERIALS

The following equipment is required for borehole logging:

- HTRW ENG Form 5056-R and 5056A-R boring log forms;
- Daily inspection report forms;
- Chain-of-custody forms;
- Request for analysis forms;
- ASTM D 2488 classification flow chart;
- Soil and/or Rock color chart (i.e., Munsell®);
- Grain size and roundness chart;
- Graph paper;
- Engineer's scale;
- Previous reports and boring logs;
- Pocketknife or putty knife;
- Hand lens;
- Dilute hydrochloric acid (10% volume);
- Gloves;
- Personal protective clothing and equipment, as described in work plan addenda health and safety plan;
- Photoionization detector or other appropriate monitoring equipment per site-specific health and safety plan; and
- Decontamination supplies (SOP 80.1).

3.0 PROCEDURE

Each boring log should fully describe the subsurface environment and the procedures used to obtain this description.

Boring logs should be prepared in the field on USACE Engineer Form 5056-R and 5056-R. Logs should be recorded in the field directly on the boring log form and not transcribed from a field book.

A “site geologist” should conduct borehole logging and soil/rock identification and description or other professional trained in the identification and description of soil/rock.

3.1 BORING LOG INFORMATION

As appropriate, the following information should be recorded on the boring log during the course of drilling and sampling activities:

- Project information including name, location, and project number;
- Each boring and well should be uniquely numbered and located on a sketch map as part of the log;
- Type of exploration;
- Weather conditions including events that could affect subsurface conditions;
- Dates and times for the start and completion of borings, with notations by depth for crew shifts and individual days;
- Depths/heights in feet and in decimal fractions of feet;
- Descriptions of the drilling equipment including rod size, bit type, pump type, rig manufacturer and model, and drilling personnel;
- Drilling sequence and descriptions of casing and method of installation;
- Description and identification of soils in accordance with ASTM Standard D 2488;
- Descriptions of each intact soil sample for the parameters identified in Section 3.2;
- Descriptions and classification of each non-intact sample (e.g., wash samples, cuttings, auger flight samples) to the extent practicable;
- Description and identification of rock;
- Description of rock (core(s)) for the parameters identified in Section 3.7;
- Scaled graphic sketch of the rock core (included or attached to log) according to the requirements identified in Section 3.7;
- Lithologic boundaries, with notations for estimated boundaries;
- Depth of water first encountered in drilling, with the method of first determination (any distinct water level(s) below the first zone will also be noted);
- Interval by depth for each sample taken, classified, and/or retained, with length of sample recovery and sample type and size (diameter and length);
- Blow counts, hammer weight, and length of fall for driven samplers;
- Rate of rock coring and associated rock quality designation (RQD) for intervals cored;
- Drilling fluid pressures, with driller’s comments;
- Total depth of drilling and sampling;
- Drilling fluid losses and gains should be recorded;
- Significant color changes in the drilling fluid returned;
- Soil gas or vapor readings with the interval sampled, with information on instrument used and calibration;

- Depth and description of any in-situ test performed; and
- Description of other field tests conducted on soil and rock samples.

3.2 SOIL PARAMETERS FOR LOGGING

In general, the following soil parameters should be included on the boring log when appropriate:

- Identification per ASTM D 2488 with group symbol;
- Secondary components with estimated percentages per ASTM D 2488;
- Color;
- Plasticity per ASTM D 2488;
- Density of non-cohesive soil or consistency of cohesive soil;
- Moisture condition per ASTM D 2488 (dry, moist, or wet);
- Presence of organic material;
- Cementation and HCL reaction testing per ASTM D 2488;
- Coarse-grained particle description per ASTM D 2488 including angularity, shapes, and color;
- Structure per ASTM D 2488 and orientation;
- Odor; and
- Depositional environment and formation, if known.

ASTM D 2488 categorizes soils into 13 basic groups with distinct geologic and engineering properties based on visual-manual identification procedures. The following steps are required to classify a soil sample:

1. Observe basic properties and characteristics of the soil. These include grain size grading and distribution, and influence of moisture on fine-grained soil.
2. Assign the soil an ASTM D 2488 classification and denote it by the standard group name and symbol.
3. Provide a written description to differentiate between soils in the same group if necessary.

Many soils have characteristics that are not clearly associated with a specific soil group. These soils might be near the borderline between groups, based on particle distribution or plasticity characteristics. In such a case, assigning dual group names and symbols (e.g., GW/GC or ML/CL) might be an appropriate method of describing the soil. The two general types of soils, for which classification is performed, coarse- and fine-grained soils, are discussed in the following sections.

3.3 COURSE-GRAINED SOIL IDENTIFICATION

For soils in the coarse-grained soils group, more than half of the material in the soil matrix will be retained by a No. 200 sieve (75- μ m).

1. Coarse-grained soils are identified on the basis of the following:
 - a) Grain size and distribution;
 - b) Quantity of fine-grained material (i.e., silt and clay as a percentage); and

c) Character of fine-grained material.

2. The following symbols are used for classification:

Basic Symbols

Modifying Symbols

G = gravel	W = well graded
S = sand	P = poorly graded
	M = with silty fines
	C = with clayey fines

3. The following basic facts apply to coarse-grained soil classification.

- The basic symbol G is used if the estimated percentage of gravel is greater than that for sand. In contrast, the symbol S is used when the estimated percentage of sand is greater than the percentage of gravel.
- Gravel ranges in size from 3-inch to 1/4-inch (No. 4 sieve) diameter. Sand ranges in size from the No. 4 sieve to No. 200 sieve. The Grain Size Scale used by Engineers (ASTM Standard D 422-63) is the appropriate method to further classify grain size as specified by ASTM D 2488.
- Modifying symbol W indicates good representation of all particle sizes.
- Modifying symbol P indicates that there is an excess or absence of particular sizes.
- The symbol W or P is used only when there are less than 15% fines in a sample.
- Modifying symbol M is used if fines have little or no plasticity (silty).
- Modifying symbol C is used if fines have low to high plasticity (clayey).

Figure 10.03a is a flowchart for identifying coarse-grained soils by ASTM D 2488.

3.4 FINED-GRAINED SOIL IDENTIFICATION

If one-half or more of the material will pass a No. 200 sieve (75 μ m), the soil is identified as fine-grained.

1. Fine-grained soils are classified based on dry strength, dilatancy, toughness, and plasticity.
2. Classification of fine-grained soils uses the following symbols:

Basic Symbols

Modifying Symbols

M = silt (non plastic)	L = low liquid limit (lean)
C = clay (plastic)	H = high liquid limit (fat)
O = organic	
Pt = peat	

3. The following basic facts apply to fine-grained soil classification:

- The basic symbol M is used if the soil is mostly silt, while the symbol C applies if it consists mostly of clay.
4. Use of symbol O (group name OL/OH) indicates that organic matter is present in an amount sufficient to influence soil properties. The symbol Pt indicates soil that consists mostly of organic material.
- Modifying symbols (L and H) are based on the following hand tests conducted on a soil sample:
 - Dry strength (crushing resistance).

- Dilatancy (reaction to shaking).
- Toughness (consistency near plastic limit).
- Soil designated ML has little or no plasticity and can be recognized by slight dry strength, quick dilatancy, and slight toughness.
- CL indicates soil with slight to medium plasticity, which can be recognized by medium to high dry strength, very slow dilatancy, and medium toughness.

Criteria for describing dry strength per ASTM D 2488 are as follows:

<u>Description</u>	<u>Criteria</u>
None	Dry sample crumbles into powder with pressure of handling
Low	Dry specimen crumbles into powder with some finger pressure
Medium	Dry specimen breaks into pieces or crumbles with considerable finger pressure
High	Dry specimen cannot be broken with finger pressure but will break into pieces between thumb and a hard surface
Very high	Dry specimen cannot be broken between the thumb and a hard surface stiffness

Criteria for describing dilatancy per ASTM D 2488 are as follows:

None	No visible change in the sample
Slow	Water appears slow on the surface of the sample during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the sample during shaking and disappears quickly upon squeezing

Criteria for describing toughness per ASTM D 2488 are as follows:

<u>Description</u>	<u>Criteria</u>
Low	Only slight pressure is required to roll the thread near the plastic limit and the thread and lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit and the thread and lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit and the thread and lump have very high stiffness

Figure 10.03b is a flowchart for identifying fine-grained soils by ASTM D 2488.

3.5 DENSITY AND CONSISTENCY

Relative density for coarse-grained soils and consistency for fine-grained soils can be estimated using standard penetration test blow count data (ASTM D 1586). The number of blows required for each 6 inches of penetration or fraction thereof is recorded. If the sampler is driven less than 18 inches, the number of blows per each complete 6-inch interval and per partial interval is recorded.

For partial increments, the depth of penetration should be recorded to the nearest 1 inch. If the sampler advances below the bottom of the boring under the weight of rods (static) and/or hammer, then this information should be recorded on the log.

The following are some “rule-of-thumb” guidelines for describing the relative density of coarse-grained soils:

<u>Blow Count</u>	<u>Relative Density for Sand</u>
0–4	Very loose
4–10	Loose
10–30	Medium dense
30–50	Dense
>50	Very Dense

The following are some “rule-of-thumb” guidelines for describing the consistency of fine-grained soils:

<u>Blow Count</u>	<u>Consistency for Clays</u>	<u>Description</u>
0–2	Very Soft	Sample sags or slumps under its own weight
2–4	Soft	Sample can be pinched in two between the thumb and forefinger
4–8	Medium Stiff	Sample can be easily imprinted with fingers
8–16	Stiff	Sample can be imprinted only with considerable pressure of fingers
16–32	Very Stiff	Sample can be imprinted very slightly with fingers
>32	Hard	Sample cannot be imprinted with fingers; can be pierced with pencil

3.6 OTHER DESCRIPTIVE INFORMATION

The approximate percentage of gravel, sand, and fines (use a percentage estimation chart) should be recorded per ASTM D 2488 as follows:

<u>Modifiers</u>	<u>Descriptions</u>
Trace	Less than 5%
Few	5%–10%
Little	15%–25%
Some	30%–45%
Mostly	50%–100%

Color/discoloration should be recorded and described using a soil color chart, such as the Munsell® Soil Color Charts. A narrative and numerical description should be given from the color chart, such as Brown 10 YR, 5/3 (Munsell®). Odor should be described if organic or unusual.

Plasticity should be described as follows:

<u>Description</u>	<u>Criteria</u>
Non-plastic	A 1/8-inch thread cannot be rolled at any water content
Low	Thread can barely be rolled and lump cannot be formed when drier than plastic limit.
Medium	Thread is easy to roll; plastic limit can be reached with little effort and lump crumbles when drier than plastic limit.

High Considerable time is required to reach the plastic limit and lump can be formed without crumbling when drier than plastic limit

Moisture condition should be recorded as dry (absence of moisture), moist (damp but no visible water) or wet (visible free water).

Cementation should be recorded (carbonates or silicates) along with the results of HCL reaction testing. The reaction with HCL should be described as none (no visible reaction), weak (some reaction with slowly forming bubbles) or strong (violent reaction with bubbles forming immediately).

Particle description information for coarse-grained soil should be recorded where appropriate per ASTM D 2488 including maximum particle size, angularity (angular, subangular, subrounded, or rounded), shape (flat, elongated or flat and elongated), and color.

Structure (along with orientation) should be reported using the following ASTM D 2488 descriptions:

<u>Description</u>	<u>Criteria</u>
Stratified	Alternating layers of varying material or color with layers greater than 6 millimeters thick
Laminated	Alternating layers of varying material or color with layers less than 6 millimeters thick
Fissured	Breaks along definite planes of fracture with little resistance
Slickensided	Fracture planes that appear polished or glossy, can be striated
Blocky	Inclusion of small pockets of different soils
Homogeneous	Same color and appearance throughout

3.7 ROCK CORE PARAMETERS FOR LOGGING

In general, the following parameters should be included on the boring log when rock coring is conducted:

- Rock type;
- Formation;
- Modifier denoting variety;
- Bedding/banding characteristics;
- Color;
- Hardness;
- Degree of cementation;
- Texture;
- Structure and orientation;
- Degree of weathering;
- Solution or void conditions;
- Primary and secondary permeability including estimates and rationale; and
- Lost core interval and reason for loss.

A scaled graphic sketch of the core should be provided on or attached to the log, denoting by depth, location, orientation, and nature (natural, coring-induced, or for fitting into core box) of all core breaks. Where fractures are too numerous to be shown individually, their location may be drawn as a zone.

The RQD values for each core interval (run) should be calculated and included on the boring log. The method of calculating the RQD is as follows per ASTM D 6032:

$$\text{RQD} = [\Sigma \text{ length of intact core pieces} > 100 \text{ mm (4-inches)}] \times 100\% / \text{total core length.}$$

3.8 PROCEDURES FOR ROCK CLASSIFICATION

For rock classification record mineralogy, texture, and structural features (e.g., biotite and quartz fine grains, foliated parallel to relict bedding oriented 15 to 20 degrees to core axis, joints coated with iron oxide). Describe the physical characteristics of the rock that are important for engineering considerations such as fracturing (including minimum, maximum, and most common and degree of spacing), hardness, and weathering.

1. The following is to be used as a guide for assessing fracturing:

<u>AEG Fracturing</u>	<u>Spacing</u>
Crushed	up to 0.1 foot
Intense	0.1–0.5 foot
Moderate	0.5 foot–10 feet
Slight	1.0 foot–3.0 feet
Massive	>3.0 feet

2. Record hardness using the following guidelines:

<u>Hardness</u>	<u>Criteria</u>
Soft	Reserved for plastic material
Friable	Easily crumbled by finger pressure
Low	Deeply gouged or carved with pocketknife
Moderate	Readily scratched with knife; scratch leaves heavy trace of dust
Hard	Difficult to scratch with knife; scratch produces little powder and is often faintly visible
Very Hard	Cannot be scratched with knife

3. Describe weathering using the following guidelines:

Weathering	Decomposition	Discoloration	Fracture Condition
Deep	Moderate to complete alteration of minerals feldspars altered to clay, etc.	Deep and thorough	All fractures extensively coated with oxides, carbonates, or clay
Moderate	Slight alteration of minerals, cleavage surface lusterless and stained	Moderate or localized and intense	Thin coatings or stains
Weak	No megascopic alteration of minerals	Slight and intermittent and localized	Few strains on fracture surfaces
Fresh	Unaltered, cleavage, surface glistening		

3.9 PROCEDURE FOR LOGGING REFUSE

The following procedure applies to the logging of subsurface samples composed of various materials in addition to soil as may be collected from a landfill or other waste disposal site.

1. Observe refuse as it is brought up by the hollow stem auger, bucket auger, or backhoe.
2. If necessary, place the refuse in a plastic bag to examine the sample.
3. Record observations according to the following criteria:
 - Composition (by relative volume), e.g., paper, wood, plastic, cloth, cement, or construction debris. Use such terms as “mostly” or “at least half.” Do not use percentages;
 - Moisture condition: dry, moist, or wet;
 - State of decomposition: highly decomposed, moderately decomposed, slightly decomposed, etc.;
 - Color: obvious mottling and/or degree of mottling;
 - Texture: spongy, plastic (cohesive), friable;
 - Odor;
 - Combustible gas readings (measure down hole and at surface); and
 - Miscellaneous: dates of periodicals and newspapers, ability to read printed materials, degree of drilling effort (easy, difficult, and very difficult).

3.10 SUBMITTAL REQUIREMENTS

Each original boring log should be submitted to the Contracting Officer Representative (CRO) after completion of the boring. When a monitoring well will be installed in a boring, the boring log and well installation diagram should be submitted together.

4.0 MAINTENANCE

Not applicable.

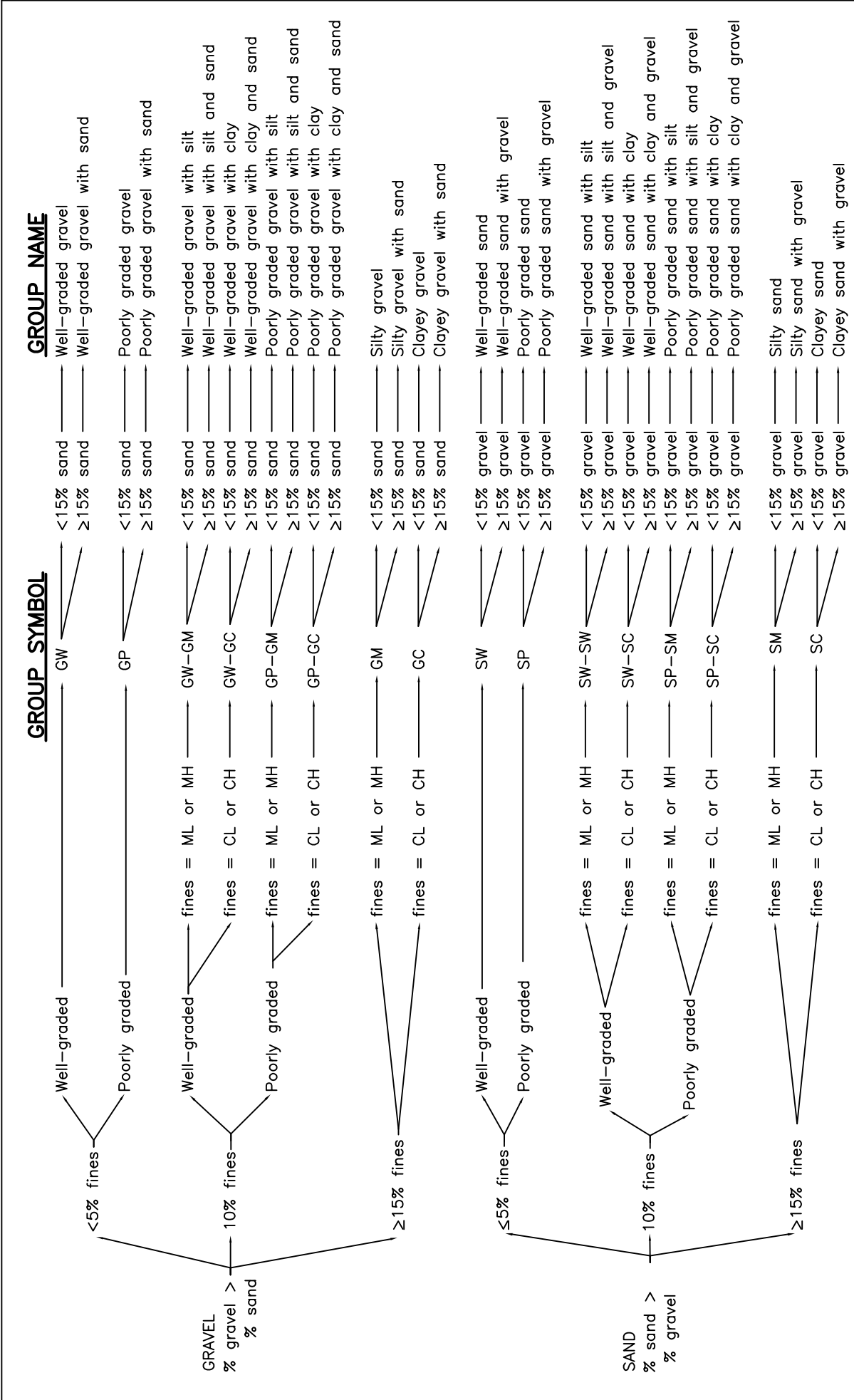
5.0 PRECAUTIONS

Not applicable.

6.0 REFERENCES

- ASTM Standard D 422-63 (2002)e1. 2002. *Standard Test Method for Particle-Size Analysis of Soils*.
- ASTM Standard D 1586-99 (1999). 1999. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.
- ASTM Standard D 2488-06. 2006. *Standard Practice for Description and Identification of Soils Visual-Manual Procedure*.
- ASTM Standard D 5434-03. 2003. *Guide for Field Logging of Subsurface Explorations of Soil and Rock*.

- ASTM Standard D 6032-02 (2006). 2006. *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core*.
- Compton, R. R. 1962. *Manual of Field Geology*. John Wiley & Sons, Inc., New York.
- USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites*. EM 1110-1-4000, 1, November.
- U.S. Department of the Interior. 1989. *Earth Manual*. Water and Power Resources Service, Washington, DC.

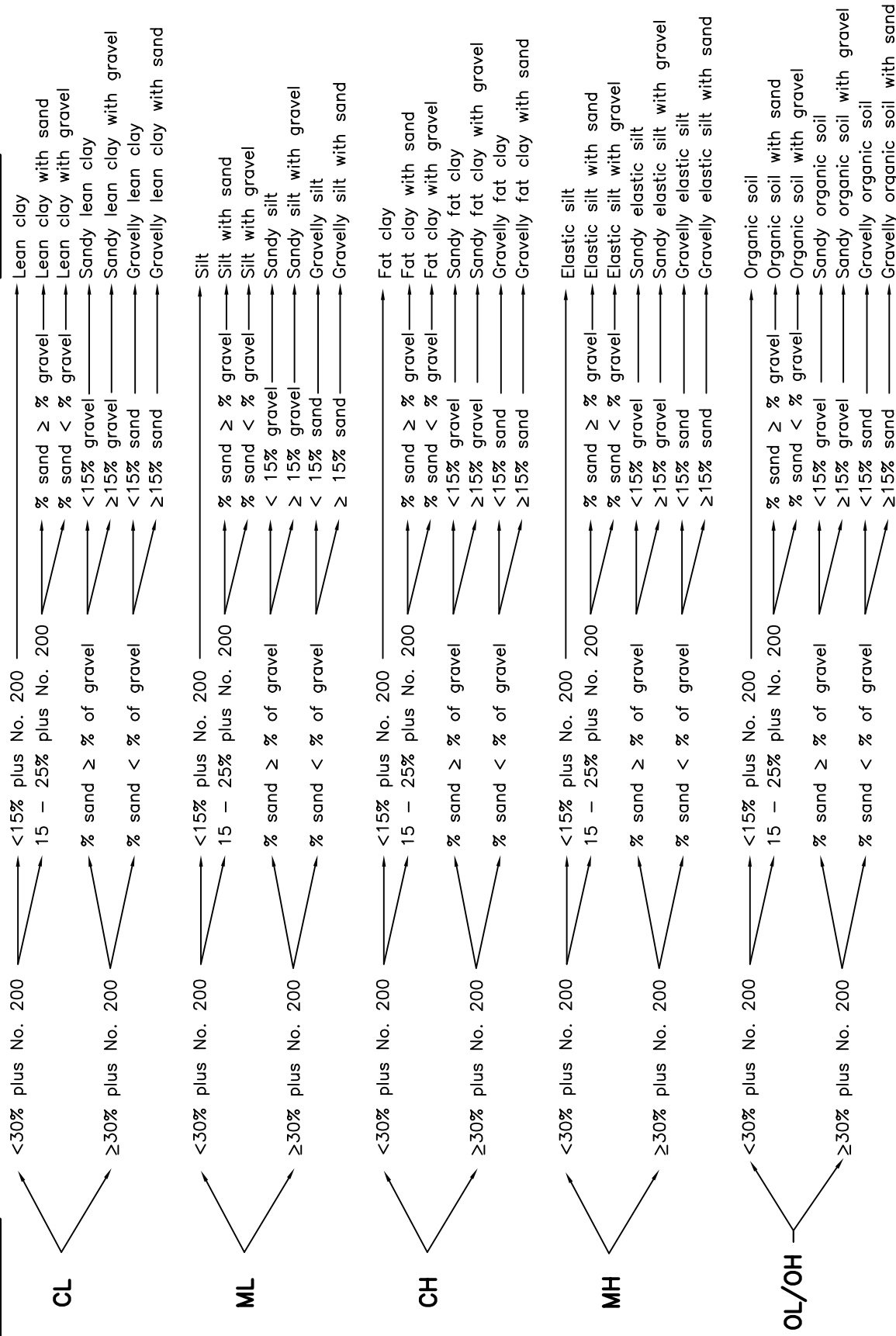


NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

Radford Army Ammunition Plant			FIGURE 10.03a
			FLOW CHART FOR IDENTIFYING COARSE-GRAINED SOILS
Date: October 2007	Prepared By: DBC/TLD		
Scale: N.T.S.	File Name: SOP Figure 10.03a_Coarse		

GROUP SYMBOL

GROUP NAME



NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

Radford Army Ammunition Plant		FIGURE 10.03b
Date: <i>October 2007</i>	Prepared By: <i>DBC/TLD</i>	FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS
Scale: <i>N.T.S.</i>	File Name: <i>SOP Figure 10.03b_Fine</i>	

STANDARD OPERATING PROCEDURE 10.4

CHAIN-OF-CUSTODY FORM

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for use of the chain-of-custody form. An example is provided as part of this SOP. Other formats with similar levels of detail are acceptable.

2.0 MATERIALS

- Chain-of-custody form; and
- Indelible ink pen.

3.0 PROCEDURE

1. Record the project name and number.
2. Record the project contact's name and phone number.
3. Print sampler's names in "Samplers" block.
4. Enter the Field Sample No.
5. Record the sampling dates for all samples.
6. List the sampling times (military format) for all samples.
7. Indicate, "grab" or "composite" sample with an "X."
8. Record matrix (e.g., aqueous, soil).
9. List the analyses/container volume across top.
10. Enter the total number of containers per Field Sample No. in the "Subtotal" column.
11. Enter total number of containers submitted per analysis requested.
12. State the carrier service and airbill number, analytical laboratory, and custody seal numbers.
13. List any comments or special requests in the "Remarks" section.
14. Sign, date, and time the "Relinquished By" section when the cooler is relinquished to the next party.
15. Upon completion of the form, retain the shipper copy and place the forms and the other copies in a zip seal bag to protect from moisture. Affix the zip seal bag to the inside lid of the sample cooler to be sent to the designated laboratory.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

- USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program*. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, DC, December 1990.
- USEPA. 1991. *User's Guide to the Contract Laboratory Program..* EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response, January 1991.
- USEPA. 1998. *EPA Requirements for Quality Assurance Project Plans*. EPA/600/R-98/018, QA/R5, Final, Office of Research and Development, Washington, D.C.

FIGURE 10.4-a
EXAMPLE CHAIN-OF-CUSTODY FORM

Project Number	Project Name			Matrix						A N A L Y S E S					LAB:				
Project Contact (Name and Phone Number)										AIRBILL No:									
Samplers:										Courier:									
Field Sample No.	Date (MM-DD-YY)	Time	C o m p	G r a b	S u b t o t a l					REMARKS									
TOTAL																			
Relinquished by:	Date/time	Received by:	Relinquished by:		Date/Time		Received by:												
Relinquished by:	Date/time	Received by: (for lab)	Date/Time		Remarks														

STANDARD OPERATING PROCEDURE 20.1 MONITORING WELL INSTALLATION

1.0 SCOPE AND APPLICATION

The installation of monitoring wells is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to delineate the quality control measures required to ensure the accurate installation of monitoring wells. For a particular site investigation, the associated work plan addenda should be consulted for specific installation instructions. The term “monitoring wells”, as used herein is defined to denote any environmental sampling well.

2.0 MATERIALS

2.1 DRILLING EQUIPMENT

- Appropriately sized drill rig adequately equipped with augers, bits, drill stem, etc;
- Steam cleaner and approved source water for decontamination of drilling equipment, etc.;
- Source of approved water;
- Photoionization detector or other appropriate monitoring instrument per the site-specific Health and Safety plan;
- Water level indicator (electrical);
- Weighted steel tape measure;
- Steel drums and other appropriate containers for investigation-derived materials (drill cuttings, contaminated PPE, decontamination solutions, etc.);
- Absorbent pads and/or logs;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination supplies, pad with heavy plastic sheeting (SOP 80.1).

2.2 WELL INSTALLATION MATERIALS

Technical information on all installed materials (screens, riser pipe, filter pack, bentonite, cement, etc.) and representative samples of the proposed filter pack will be supplied to the Contracting Officer's Representative (COR) before initiating well installation.

Well screen slot size and filter pack gradation will be determined based on existing site geology before initiating site-specific investigations.

- Well screen:
Polyvinyl Chloride (PVC): JOHNSON (or equivalent); PVC commercially slotted continuous slot, wire wrapped screen; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage or ASTM Standard Specification F 480 and bear the appropriate rating logo. PVC should be free of ink markings, cleaned, and prepackaged by manufacturer;

Stainless Steel: JOHNSON (or equivalent); stainless steel Vee-Wire continuous slot, wire wrapped screen; 304 stainless steel (unless the sum concentration of Cl⁻, F⁻, and Br⁻ is <1000 ppm, case type 316 should be used); ASTM F 480 flush threads; cleaned, wrapped, and heat-sealed by manufacturer;

- Riser pipe:
 - PVC: JOHNSON (or equivalent); STD. PVC; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to NSF Standard 14 or F 480; free of ink markings; cleaned and prepackaged by manufacturer;
 - Stainless Steel: JOHNSON (or equivalent); SCH 5; 304 stainless steel; ASTM type A312 material; 4-in. diameter.; cleaned, wrapped and heat-sealed by manufacturer;
- Plugs/Caps: JOHNSON (or equivalent); standard PVC or stainless steel;
- Filter pack: MORIE, clean sorted gravel (or equivalent);
- Bentonite seal: BAROID, bentonite pellets (3/8-in. diameter.);
- Cement: Type II Portland Cement; if sulfate concentrations are higher than 1500 ppm, Type IV Portland Cement will be used;
- Bentonite powder: BAROID, Aquagel Gold Seal;
- Steel Protective Casing: BRAINARD-KILMAN (or equivalent) zinc-plated steel, lockable, painted;
- Containers for purged water, as required;
- Submersible pump or bailer of appropriate capacity, and surge block sized to fit well;
- Hach DREL 2000 portable laboratory (or equivalent);
- Multiprobe Electronic Water Quality Recorder (Hydrolab);
- Electric well sounder and measuring tape;
- Portland Type II cement (see footnote); and
- Steel Posts (pickets), painted (see footnote).

2.3 DOCUMENTATION

- Copy of work plans and health and safety plan;
- Copy of USACE EM 110-1-4000 Monitoring Well Requirements;
- Copies of permits (area entry, hot work, well, and utility clearance);
- Boring log forms;
- Well completion diagram form; and
- Field logbook.

2.4 GEOLOGIST'S PERSONAL EQUIPMENT

- Boring log materials per SOP 10.3; and
- Personal protective equipment and clothing (PPE) as required by the site-specific health and safety plan.

3.0 PROCEDURE

3.1 MATERIALS APPROVAL

3.1.1 Source Water

Water sources for drilling, grouting, sealing, filter pack placement, well installation, and equipment decontamination must be approved by the COR before arrival of the drilling equipment. Information required for the water source includes:

- Water source;
- Manufacturer/owner and their address and telephone number;
- Type of treatment and filtration prior to tap;
- Time of access;
- Cost per gallon (if applicable); and
- Dates and results associated with all available chemical analyses over the past 2 years, and the name and address of the analytical laboratory (if applicable).

3.1.2 Bentonite

Pure sodium bentonite with no additives (bentonite) will be the only drilling fluid additive allowed, and its use must be approved by the COR before the arrival of the drilling equipment. The information required for evaluation includes brand name, manufacturer, manufacturer's address and telephone number, product description, and intended use for the product, and potential effects on chemical analysis of water samples.

3.1.3 Granular Filter Pack

Granular filter pack material must be approved by the COR before drilling. A one-pint representative sample must be supplied to the COR. Information required includes lithology, grain size distribution, brand name, source, processing method, and size of intended screen.

3.1.4 Cement

Portland Type II cement will be used for grout (or Type IV, as noted in Section 2.2).

3.2 DRILLING

The objective of the selected drilling technique used at given site is to ensure that the drilling method provides representative data while minimizing subsurface contamination, cross contamination, and drilling costs.

Drilling methods that are appropriate for boring or monitoring well installation will depend on the subsurface geology most likely to be encountered in the boring. The geology for each site should be determined by reviewing previous investigation data (boring data, geophysics, etc.) from the site or nearby areas. Specific drilling methods that will be used to support site activities will be incorporated into work plan addenda.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of monitoring wells at the Radford Army Ammunition Plant (RFAAP) based on the different types of conditions encountered. The different drilling methods discussed in this section of the Master Work Plan including:

- Hollow Stem Auger (for soil);

- Air Rotary (soil and rock);
- Water Rotary and wire-line casing advancement (soil and rock);
- Drill-Through-Casing Driver (soil and rock); and
- Sonic (soil and rock).

3.2.1 Responsibilities of the Site Geologist

A Site Geologist will be present during all well drilling and installation activities and will fully characterize all tasks performed in support of these activities in the monitoring well logbook. The Site Geologist will be responsible for the logging samples, monitoring drilling operations, recording water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures for one operating rig. The Site Geologist will have sufficient equipment in operable condition on-site to perform efficiently his/her duties.

3.2.2 Additives

No lubricants will be used on down hole drilling equipment. Additives containing either lead or copper will not be allowed. In addition, polychlorinated biphenyls will not be permitted in hydraulic fluids or other fluids used in the drilling rig, pumps, or other field equipment and vehicles.

Surface runoff or other fluids will not be allowed to enter any boring or well during or after drilling/construction.

Antifreeze used to keep equipment from freezing will not contain rust inhibitors and sealants. Antifreeze is prohibited in any areas in contact with drilling fluid. Absorbent pillows will be placed to catch any obvious leaks from the drill rig.

3.2.3 Boring Logs and Field Notes

Borings for monitoring wells will be logged by a geologist as described in SOP 10.3. Logs will be recorded on USACE HTRW ENG Form 5056-R and 5056A-R boring log forms.

Daily investigation activities at the site related to drilling should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

3.3 WELL CONSTRUCTION AND INSTALLATION

Specifications for monitoring well construction and installation for a given site being investigated are to be included in work plan addenda. In case the previously defined criteria have not been met before the depth range for a given hole is reached, the geologist will stop the drilling and confer with the supervisor. The current boring conditions (depth, nature of the stratigraphic unit, and water-table depth) will be compared to those of other wells nearby to decide whether to continue drilling or to terminate and complete the well.

3.3.1 Overburden Wells

Overburden wells at the RFAAP are typically designed as a 4-inch diameter, single cased well (see Figure 20-1a) installed into a surficial aquifer, which is present above bedrock. For this type of well, the well boring would be terminated before penetrating any underlying confining unit and/or bedrock.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of overburden wells.

If dense, non-aqueous liquid (DNAPL) is encountered during drilling, the well boring will be terminated and completed at the base of the overburden aquifer being monitored.

3.3.2 Bedrock Wells

Multi-cased wells or wells with an outer casing installed into competent bedrock should be specified for wells that are designed to monitor groundwater within bedrock (see Figure 20-1c). The installation of a multi-cased well or outer casing will isolate the zone(s) monitored from overburden and will minimize the potential for cross-contamination during and after drilling.

The general procedure to be followed for installation of a multi-cased well is as follows. This procedure assumes the installation of a 4-inch diameter monitoring well. Specific procedures, drilling techniques and design of monitoring wells will be presented in work plan addenda for site-specific investigations.

1. If soil sampling is required within overburden, use appropriate drilling techniques to advance the boring and collect the soil samples.
2. A minimum 10-inch drill bit should be advanced from the surface into competent bedrock a distance not less than 2 feet. A drilling technique appropriate for penetrating overburden and bedrock should be used such as air rotary.
3. After the borehole has been advanced to the target depth within competent bedrock, a 6-inch diameter steel or Schedule 80 PVC outer casing should be lowered to the bottom of the boring.
4. Once the outer casing has been lowered to the bottom of the boring, the casing should be grouted in-place using a decontaminated tremie pipe equipped with a side discharge. The annulus between the outer casing and borehole wall will be injected with grout until undiluted grout reaches the surface.
5. The grouting mixture, specification, and placement should be consistent with the requirements identified in Section 3.3.8.
6. The grout should be allowed to cure a minimum of 24 hours before further drilling.
7. After adequate curing time for outer casing, drilling with a 5-5/8-inch bit until the desired total depth is reached should complete the well boring.
8. Once the well boring is completed, an appropriate bedrock well will be constructed based on site-specific conditions. The types of wells that may be installed may include a constructed well with screen, casing, filter pack, seal, and grout; an open-bedrock well; or a lined open bedrock well (see Section 3.3.3).

3.3.3 Well Screen Usage

Well screen usage for a given site should be specified in work plan addenda based on expected site conditions.

In general, wells installed within overburden will be installed with a screen as per Figure 20.01-a or 20.01-b. Bedrock wells may be installed with or without a screen depending on site specific conditions such as the depth of water bearing zones, stability of bedrock, occurrence of karst zones, and construction of existing wells at the site being investigated.

In general, bedrock wells installed within karst zones will be completed as open-hole construction (see Figure 20.01c). If evidence of potential or severe borehole collapse (unstable bedrock) is indicated during drilling, casing and screen will be installed in the borehole as a removable lining. If desired, multiple flow zones may be monitored in an open bedrock well by installing a multiport well, which has monitoring/sampling intervals sealed off from the rest of the boring and from each other by packers.

3.3.4 Beginning Well Installation

Schedule

Monitoring well installation should begin within 12 hours of boring completion for holes that are uncased or partially cased with temporary drill casing. In the case where a partially cased hole into bedrock is to be partially developed prior to well insertion, the well installation should begin within 12 hours of this initial development. For holes that are fully cased, installation should begin within 48 hours. Once begun, well installation should not be interrupted.

Placement of Materials

Temporary casing and hollow stem augers may be removed from the boring prior to well installation if the potential for cross contamination is low and if the borehole will remain stable during the time required for installation.

Where borehole conditions are unstable, some or all of the well materials may need to be installed prior to removal of the temporary casing or hollow stem augers. The casing or hollow stem augers should have an inside diameter sufficient to allow the installation of the screen and casing plus annular space for a pipe through which to place filter pack and grout.

Any materials blocking the bottom of the drill casing or hollow stem auger should be dislodged and removed from the casing prior to well insertion.

3.3.5 Screens, Casing, and Fittings

Borehole Specifications

The borehole for each well should be of sufficient diameter to provide for at least 2 inches of annular space between the borehole wall and all sides of the casing.

Well Screens

Material specifications for well screens, casings, and fittings are discussed in Section 2.2.

Screen bottoms should be securely fitted with a threaded cap or plug of the same composition as the screen. The cap/plug should be within 0.5 feet of the open portion of the screen. A sediment trap/sump will not be used.

Screen slot size will be appropriately sized to retain 90%–100% of the filter pack material, the size of which will be determined by sieve analysis of formation material.

Well screen lengths should be specified in work plan addenda and will be based on various site-specific factors such as environmental setting, subsurface conditions, analytes of concern, regulatory considerations, etc.

Assembly and Placement of Well Screen and Casing

Personnel should take precautions to assure that grease, oil, or other contaminants do not contact any portion of the well screen and casing assembly. Clean latex or nitrile gloves should be worn when handling the screen and casing assembly. Flush, threaded joints usually can be tightened by hand. If necessary, steam cleaned wrenches may be used to tighten joints.

In general, each section of the well assembly is lowered into the borehole, one section at a time, screwing each section securely into the section below it. No grease, lubricant, polytetrafluoroethylene (PTFE) tape, or glue may be used in joining the sections of screen and casing.

The assembly should be lowered to its predetermined level and held in position for placement of the filter pack. It is essential that the assembly be installed straight (with centralizers as appropriate) to allow for appropriate sampling. Buoyant forces associated with fluids in the borehole may require that the assembly be installed with the aid of hydraulic rams of the drill rig. When the well assembly is placed to predetermined level, a temporary cap should be placed on the well to prevent foreign material from entering the well.

The bottoms of well screens should be placed no more than 3 feet above the bottom of the drilled borehole. If significant overdrilling is required, a pilot boring should be used. Sufficient filter pack should be placed at the bottom of the borehole.

The well casing should be pre-cut (square) to extend 2 to 2.5 feet above the ground surface. Before placement of the last piece of well casing, a notch or other permanent reference point will be cut, filed, or scribed into the top edge of the casing.

The tops of all well casing will be capped with covers composed of materials compatible with the products used in the well installation. Caps will be loose fitting, constructed to preclude binding to the well casing caused by tightness of fit, unclean surfaces, or weather conditions. In either case, it should be secure enough to preclude the introduction of foreign material into the well, yet allow pressure equalization between the well and the atmosphere.

The top of each well casing should be level so that the maximum difference in elevation between the highest and lowest points of the casing is less than or equal to 0.02 ft.

3.3.6 Filter Pack

The volume of filter pack that is required to fill the annular between the well screen/casing and borehole should be computed, measured, and recorded.

Granular filter packs will be chemically and texturally clean, inert, and siliceous. The gradation of filter packs will be selected based on the screen size used and will be specified in the work plan addenda for the site being investigated.

Primary Filter Pack

Filter pack material should be placed in the borehole using a decontaminated tremie pipe. An appropriate amount of primary filter pack should be placed in the borehole prior to final positioning of the well screen to provide an appropriate barrier between the bottom of the borehole and the bottom of the screen. Once the initial filter pack has been placed and the well assembly is appropriately positioned and centered in the borehole, the remaining primary filter pack should be placed in increments (and tamped) as the tremie pipe is gradually raised.

As the primary filter pack is placed, approved source water may need to be added to help move the filter pack. A weighted tape should be used to measure the top of the filter pack as it is being placed. If bridging of the filter pack occurs, then this bridging should be broken mechanically prior to adding additional filter pack.

When temporary casing or hollow stem augers are used, the casing or augers should be removed in increments such that lifting of the well assembly is minimal. After removal of each increment, it should be confirmed by direct measurement that the primary filter pack has not been displaced during the removal.

The primary filter pack should extend from the bottom of the borehole to 3 to 5 ft above the top of the screen.

Secondary Filter Pack

The primary filter pack may be capped with 1 to 2 feet of secondary filter pack to prevent the intrusion of the bentonite seal into the primary filter pack. The need for this filter pack (and specifications) should be addressed in work plan addenda for the site being investigated. Such factors as the gradation of the primary filter pack, the potential for grout extrusion, and site hydrogeology should be considered when evaluating the need for this filter pack.

3.3.7 Bentonite Seal

A bentonite seal, consisting of hydrated 3/8-inch diameter bentonite pellets, will be installed immediately above the filter pack. The seal may be installed with a tremie pipe, which is lowered to the top of the filter pack and slowly raised as the pellets fill the annular space. In deep wells, the pellets may bridge and block the tremie pipe; in this case, pellets may be placed by free fall into the borehole. A weighted tape should be used to measure the top of seal as it is installed.

When cement grout is to be used above the bentonite seal, a minimum of 3 to 4 hours should be allowed for hydration of the pellets.

When installing a seal above the water table, water should be added to the bentonite for proper hydration. In this case, the seal should be placed in lifts of 0.5 to 1 foot with each lift hydrated for a period of 30 minutes. If the bentonite seal is to be installed far below the water table, a bentonite slurry seal will be installed. Cement-bentonite grout will not be used below the water table. The slurry will be mechanically blended aboveground to ensure a lump-free mixture. The slurry will consist of bentonite powder and approved water mixed to a minimum of 20 percent solids by weight of pumpable slurry with a density of 9.4 pounds per gallon or greater. The slurry will be pumped into place through a tremie pipe and measured as installed. Bentonite seals should be 3 to 5 ft thick as measured immediately after placement. The final depth to the top of the bentonite seal will be measured and recorded before grouting.

3.3.8 Grout

Cement grout used in construction will be composed of the following:

- Type II Portland Cement (or Type IV as noted in Section 2.2);
- Bentonite (2 to 5% dry bentonite per 94-lb sack of dry cement); and
- A maximum of 6 to 7-gallons of approved water per 94-lb sack of cement

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump before placement. Grout placement should be performed as follows:

1. Grout should be placed from a rigid tremie pipe located just over the top of the bentonite seal. The tremie pipe should be decontaminated prior to use.
2. The tremie pipe should be kept full of grout from start to finish with the discharge end of the pipe completely submerged as it is slowly and continuously lifted.
3. The annulus between the drill casing and well casing should be filled with sufficient grout to allow for the planned drill casing removal. Grout should not penetrate the well screen or filter pack.
 - For incremental removal of drill casing, grout should be pumped to maintain at least 10 ft of grout in the drill casing remaining in the borehole after removing the selected length of casing. After each

section of casing is removed, the tremie pipe may be reinserted to the base of the casing not yet removed.

- In the case where drill casing will be removed all at once, grout should be pumped from the tremie pipe until undiluted grout flows from the annulus at the ground surface.
4. If the un-grouted portion of a borehole is less than 15 feet and without fluids after drill casing removal, then the un-grouted portion may be filled by pouring grout from the surface.
 5. If drill casing was not used for well installation, grouting should proceed to the surface in one continuous operation.
 6. For grout placement in a dry and open hole less than 15 ft deep, grout may be manually mixed and poured in from the surface providing that integrity of the bentonite seal is maintained.
 7. Protective casing should be installed immediately after completion of grouting.
 8. Grout settlement should be checked within 24 hours of the initial grout placement. Additional grout should be added to fill any observed depressions.

The following will be noted in the boring logs: (1) exact amounts of cement, bentonite, and water used in mixing grout and (2) actual volume of grout placed in the hole.

3.3.9 Well Protection

The major elements of well protection will include:

- A protective casing;
- Protective concrete pad around the well; and
- Protective steel posts set around the well outside of the concrete pad.

Well Protective Casing

Well protective casings will be installed around all monitoring wells immediately after grouting. The protective casing should consist of a minimum 5-ft long, steel pipe (protective casing) installed over the well casing and into the grout. The protective casing should be installed to a depth of approximately 2.5-feet below ground surface (extending approximately 2.5 feet above ground surface). The internal well casing (riser) and protective casing will not be separated by more than 0.2 feet of height.

An internal mortar collar will be placed within the protective steel casing and outside the well casing to a height of 0.5 above ground surface.

After placement and curing of the mortar collar, an internal drainage hole will be drilled through the protective casing, which is centered no more than 1/8 inch above the grout filled annulus between the well riser and the protective casing.

Any annulus formed between the outside of the protective casing and the borehole will be filled to ground surface with cement.

Concrete Pad

After the grout has thoroughly set and the well protective casing has been installed, a protective concrete pad will be installed around the well. This pad will be at least 4 inches thick and 4 feet square and sloped away from the well to provide for adequate drainage.

Protective Posts

Additional protection will be provided at each well location by the installation of four steel posts outside of each corner of the concrete pad. The installation of protective posts should occur before the well is sampled. The posts should have a minimum diameter of 3 inches, be placed 2 to 3 feet below ground surface, and extend at least 3 feet above ground surface. Posts should be painted orange using a brush.

Posts should be set in post holes, which are backfilled with concrete. For additional protection, the posts can be filled with concrete.

3.3.10 Well Construction Diagram and Field Notes

The construction of each well will be depicted as built in a well construction diagram (see Figure 20.1a). The diagram will be attached to the boring log and the following will be graphically denoted:

- Bottom of boring;
- Screen location, length, and size;
- Coupling locations;
- Granular filter pack;
- Seal;
- Grout;
- Cave-in;
- Centralizers;
- Height of riser;
- Protective casing detail;
- Water level 24 hours after completion with date and time of measurement;
- Quantity and composition of materials used; and
- Material between bottom of boring and bottom of screen.

Daily activities at the site related to monitoring well installation should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.4 GENERAL SEQUENCE OF MONITORING WELL COMPLETION

The following is a general sequence of monitoring well completion with reference to the specific details included in Section 3.3.

1. Completion of borehole;
2. Assembly and placement of well assembly as described in Section 3.3.5;
3. Placement of the appropriate filter pack(s) as discussed in Section 3.3.6;
4. Installation of an appropriate bentonite seal as discussed in Section 3.3.7;
5. Grouting the remaining annular space of the borehole as discussed in Section 3.3.8;
6. Set the protective casing for the well as discussed in Section 3.3.9;
7. Complete the protective concrete pad as discussed in Section 3.3.9; and
8. Install the protective posts as discussed in Section 3.3.9.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

ASTM Standard D 5092-04e1. 2004. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers*.

ASTM Standard F 480-06b. 2006. *Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80*.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites*. EM 1110-1-4000, 1, November.

EXAMPLE WELL DEVELOPMENT FORM

WELL DESIGNATION: _____ DATE(S) OF INSTALLATION: ____/____/____

SITE GEOLOGIST: _____ DEVELOPMENT DATE(S): ____/____/____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT * :

BEFORE _____ DATE _____ 24 HR. AFTER _____ DATE _____

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT * :

BEFORE _____ DATE _____ 24 HR. AFTER _____ DATE _____

DEPTH TO WELL BOTTOM * : _____ SCREEN LENGTH _____

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: _____

QUANTITY OF MUD/WATER:

LOST DURING DRILLING (+) _____ gallons

REMOVED PRIOR TO WELL INSERTION (-) _____ gallons

LOST DURING THICK FLUID DISPLACEMENT (+) _____ gallons

ADDED DURING FILTER PACK PLACEMENT (+) _____ gallons

TOTAL LOSSES _____ gallons

(a) Water column ht. (ft.) _____

(b) Well radius (in.) _____

(c) Screen length (ft.) _____

(d) Borehole radius (in.) _____

(e) QUANTITY OF FLUID STANDING IN WELL

Install Equation Editor and double-click here to view equation.

1 _____ gallons
(Show Calculation)

Install Equation Editor and double-

(f) QUANTITY OF FLUID IN ANNULUS click here to view equation.
(Show Calculation)

1 _____ gallons

DEVELOPMENT VOLUME = (5 * TOTAL LOSSES) + [5 * (e + f)] = _____ gallons
(Show Calculation)

* ALL DEPTHS MEASURED FROM TOP OF WELL CASING

EXAMPLE WELL DEVELOPMENT RECORD

WELL DESIGNATION _____ DATE(S) OF DEVELOPMENT: ____/____/____

TYPE AND SIZE OF PUMP: _____

TYPE AND SIZE OF BAILER: _____

DESCRIPTION OF SURGE TECHNIQUE: _____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/odor/partic.)
(before)									
(during)									
(during)									
(during)									
(after)									

TYPICAL PUMPING RATE _____ GAL./HR. EST. RECHARGE RATE _____

TOTAL QUANTITY OF WATER REMOVED _____ TIME REQUIRED _____

REMARKS _____

SIGNATURE OF SITE GEOLOGIST _____

Facility/Project Name	Local Grid Location of Well ☐ N. ☐ E. ☐ S. ☐ W.	Well Number
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. _____ Long. _____ or St. Plane _____ m. N. _____ m. E.	Date Well Installed (Start)
Type of Protective Cover: Above-Ground ☐ Flush-To-Ground ☐	Section Location of Waste/Source _____ 1/4 of _____ 1/4 of Sec. _____ T. _____ N.R. ☐ E. ☐ W.	Date Well Installed (Completed)
Well Distance From Waste/Source Boundary	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	Well Installed By: (Person's Name & Firm)
Maximum Depth of Frost Penetration (estimated)		

Note: Use top of casing (TOC) for all depth measurements.

- A. Protective casing, top elevation _____ m. MSL
- B. Well casing, Top elevation _____ m. MSL
- C. Land surface elevation _____ m. MSL
- D. Surface seal, bottom _____ m. TOC or _____ m. MSL
16. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

17. Sieve analysis attached? ☐ Yes ☐ No

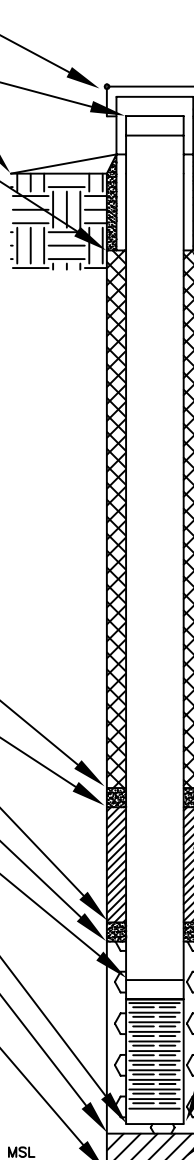
18. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Other ☐

19. Drilling fluid used Water ☐ Air ☐
Drilling mud ☐ None ☐

20. Drilling additives used? ☐ Yes ☐ No
Describe _____

21. Source of water (attach analysis):

- E. Secondary filter, top _____ m. TOC or _____ m. MSL
- F. Bentonite seal, top _____ m. TOC or _____ m. MSL
- G. Secondary filter, top _____ m. TOC or _____ m. MSL
- H. Primary filter, top _____ m. TOC or _____ m. MSL
- I. Screen joint _____ m. TOC or _____ m. MSL
- J. Well bottom _____ m. TOC or _____ m. MSL
- K. Filter pack, bottom _____ m. TOC or _____ m. MSL
- L. Borehole, bottom _____ m. TOC or _____ m. MSL
- M. Borehole, diameter _____ mm.
- N. O.D. well casing _____ mm.
- O. I.D. well casing _____ mm.
- P. 24-hr water level after completion _____ m. TOC or _____ m. MSL

- 
1. Cap and Lock? ☐ Yes ☐ No
2. Protective posts? ☐ Yes ☐ No
3. Protective casing:
a. Inside diameter: _____ mm.
b. Length: _____ m.
4. Drainage port(s) ☐ Yes ☐ No
5. Surface seal:
a. Cap _____ Gravel blanket ☐
Bentonite ☐
Concrete ☐
Other ☐
- b. Annular space seal: Bentonite ☐
Cement ☐
Other ☐
6. Material between well casing and protective casing: Bentonite ☐
Cement ☐
Other ☐
7. Annular space seal:
a. Granular Bentonite ☐
b. _____ Lbs/gal mud weight.....Bentonite-sand slurry ☐
c. _____ Lbs/gal mud weight.....Bentonite slurry ☐
d. _____ x Bentonite.....Bentonite-cement grout ☐
e. _____ m³ volume added for any of the above ☐
f. How installed: Tremie ☐
Tremie pumped ☐
Gravity ☐
8. Centralizers ☐ Yes ☐ No
9. Secondary Filter ☐ Yes ☐ No
a. Volume added _____ m³ _____ Bags/Size
10. Bentonite seal:
a. Bentonite granules ☐
b. 1/4in. 3/6in. 1/2in. Bentonite pellets ☐
c. _____ Other ☐
11. Secondary Filter ☐ Yes ☐ No
a. Volume added _____ m³ _____ Bags/Size
12. Filter pack material: Manufacturer, product name & mesh size
a. _____
b. Volume added _____ m³ _____ Bags/Size
13. Well casing: Flush threaded PVC schedule 40 ☐
Flush threaded PVC schedule 80 ☐
Other ☐
14. Screen material:
a. Screen type: Factory cut ☐
Continuous slot ☐
Other ☐
b. Manufacturer _____
c. Slot size: 0. _____ in.
d. Slotted length: _____ in.
15. Backfill material (below filter pack): None ☐
Other ☐

Radford Army Ammunition Plant

Date:
October 2007

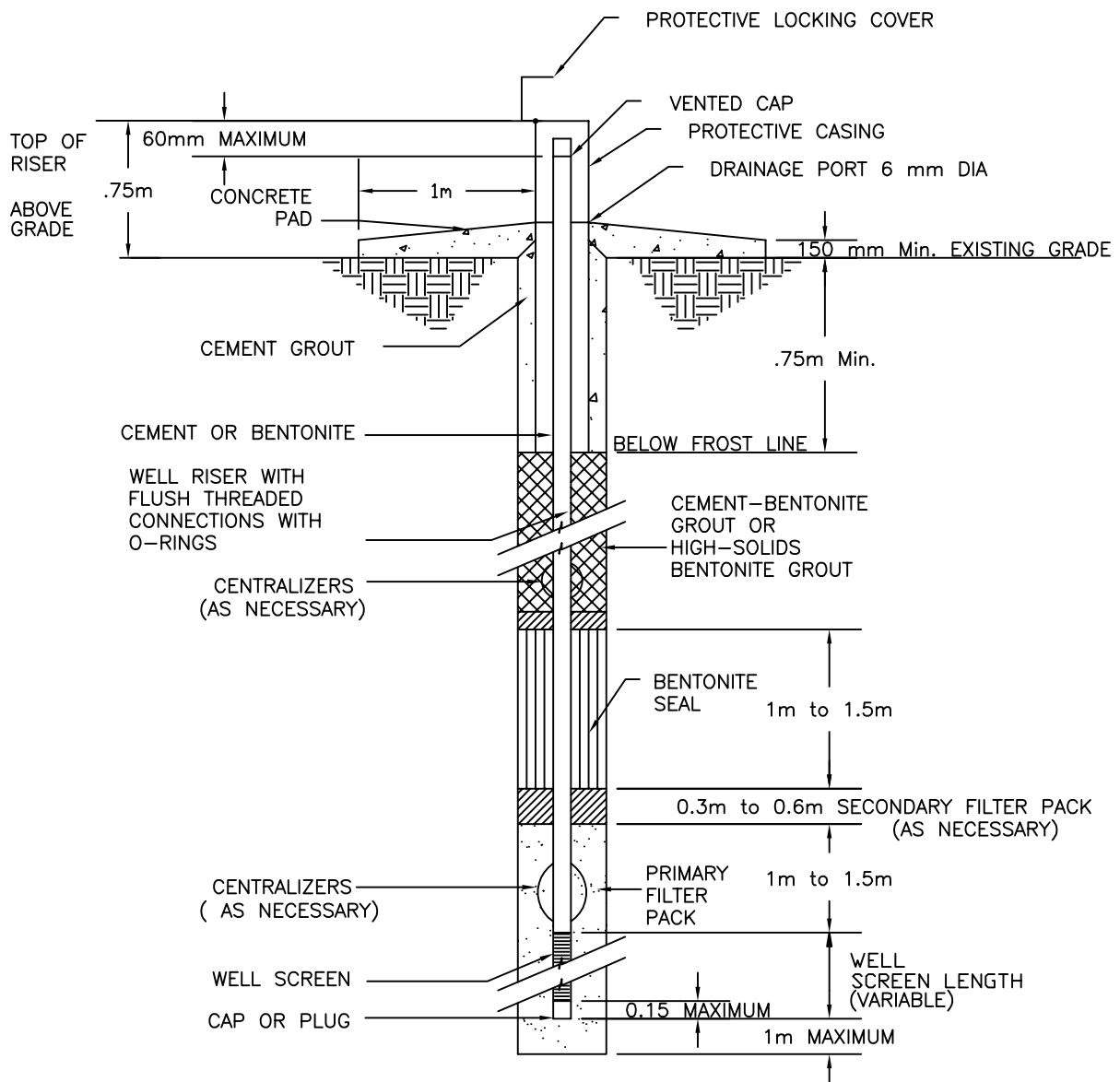
Scale:
NO SCALE

Prepared By:
URS Corp./DBC

File Name:
SOP Figure 20-1a

FIGURE 20-1a

**SCHEMATIC
CONSTRUCTION
DIAGRAM OF
MONITORING WELL**



Radford Army Ammunition Plant

Date:
October 2007

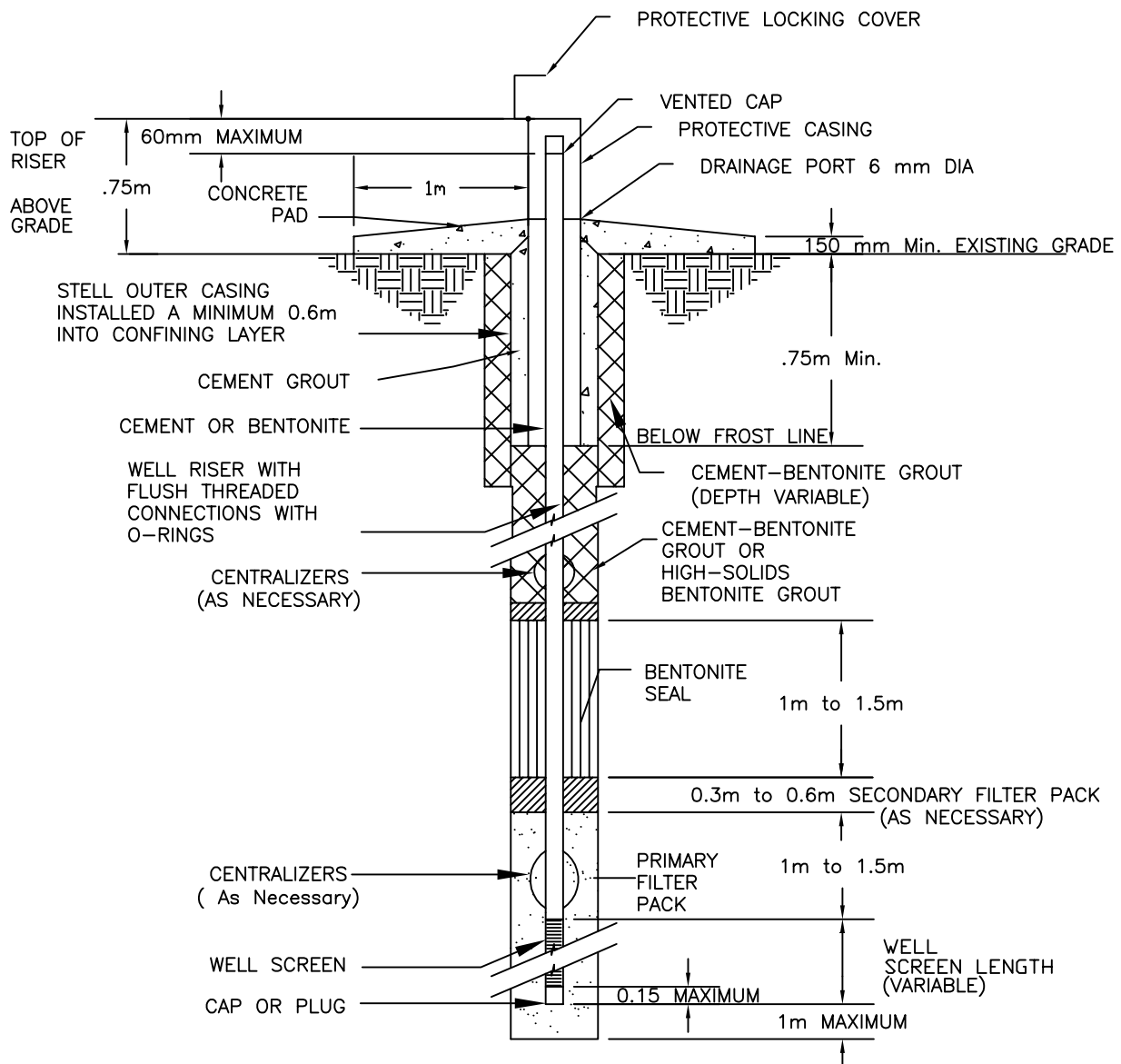
Prepared By:
URS Corp./DBC

Scale:
NO SCALE

File Name:
SOP Figure 20-1b

FIGURE 20-1b

**SCHEMATIC
CONSTRUCTION OF
SINGLE-CASED WELL WITH
STICKUP COMPLETION**



Radford Army Ammunition Plant

Date:
October 2007

Prepared By:
URS Corp./DBC

Scale:
NO SCALE

File Name:
SOP Figure 20-1c

FIGURE 20-1c

**SCHEMATIC
CONSTRUCTION OF
MULTI-CASED WELL WITH
CONCRETE PAD**

STANDARD OPERATING PROCEDURE 20.2 MONITORING WELL DEVELOPMENT

1.0 SCOPE AND APPLICATION

Well development is the process by which drilling fluids, solids, and other mobile particulates within the vicinity of the newly installed monitoring well are removed, while ensuring proper hydraulic connection to the aquifer. Development stabilizes the formation and filter pack sands around the well screen to ensure aquifer water moves freely to the well.

Well development will be initiated not less than 48 consecutive hours but no longer than 7 calendar days following grouting and/or placement of surface protection.

2.0 MATERIALS

- Work Plans;
- Well Development Form;
- Field Logbook;
- Boring Log and Well Completion Diagram for the well;
- Submersible pump, control box, associated equipment, etc;
- Photoionization detector or other appropriate monitoring instrument as specified in site-specific health and safety plan;
- Personal protective equipment and clothing (PPE) as specified in site-specific health and safety plan;
- Flow-through-cell and probes measuring specific conductance, pH, temperature, oxidation/reduction potential, dissolved oxygen, and turbidity;
- Decontamination supplies (SOP 80.1);
- Electric well level indicator and measuring tape;
- Appropriate containers for purged water and other investigation-derived material, as required; and
- Drilling tools for reverse-air circulation development, as appropriate.

3.0 PROCEDURE

3.1 SELECTING METHOD OF DEVELOPMENT

The type of subsurface conditions encountered should determine the method of well development used at a particular site at the Radford Army Ammunition Plant (RFAAP).

When monitoring wells are installed within overburden material, fractured bedrock or karst aquifers producing little sediment, a combination of mechanical surging and pumping (over pumping) or bailing is generally appropriate for well development. In general, over-pumping is the method of pumping the well at a rate

higher than recharge occurs. Moving a tight-fitting surge block along the inside of the well screen to create a vacuum completes surging.

When monitoring wells are installed with solution features containing excessive amounts of sediment, reverse-circulation airlifting should be used as the initial step of development. Because reverse-circulation tools airlift methods avoid forcibly exposing the annular space to air, reverse-circulation tools can be run throughout the entire water column in the wells being developed.

After the excessive sediment has been removed by reverse-circulation airlifting, conventional pumping techniques may be used as appropriate to complete the well development.

3.2 DEVELOPMENT AND SAMPLING TIMING

Final development of monitoring wells should not be initiated any sooner than 48 hours after or more than 7 days beyond the final grouting of the well. Pre-development or preliminary development may be initiated before this 48-hour minimum period. Preliminary development may be conducted for open wells or for screened wells after installation of the well screen, casing, and filter pack but before installation of the annular seal. Pre-development is recommended when the natural formation will be used as a filter pack.

Well development should be completed at least 14 days prior to sampling.

3.3 SUMMARY OF PROCEDURES

In general, the following procedure should be followed when developing a well using the pump and surge technique:

1. Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
2. Calibrate water quality meters (refer to SOP 40.1).
3. Determine the depth to water and total depth of well (refer to SOP 40.2).
4. Calculate the equivalent volume (EV) of water in well to be developed (refer to SOP 30.2).
5. Pump or bail the well to ensure that water flows into it and to remove some of the fine materials from the well. Removal of a minimum of one EV is recommended at this point. The rate of removal should be high enough to stress the well by lowering the water level to approximately one-half its original level.
6. Remove pump or bailer, slowly lower a close-fitting surge block into the well until it rests below the static water level but above the screened interval. (NOTE: The latter is not required in the case of an LNAPL well.)
7. Begin a gentle surging motion along top on-third length of the screen, which will allow any material blocking the screen to break up, go into suspension, and move into the well. Note that development should always begin above or at the top of the screen and move progressively downward to prevent the surge block from becoming sand locked in the well casing. Continue surging for 5-10 minutes, remove surge block, and pump or bail the well, rapidly removing at least one EV.
8. Repeat previous step at successively lower levels within the well screen, until the bottom of the well is reached. As development progresses, successive surging can be more vigorous and of longer duration as long as the amount of sediment in the screen is kept to a minimum.
9. Development should continue until the well development criteria listed in Section 3.1.3 have been achieved.
10. All water removed must be managed as directed by the site investigation plan.

3.3.1 Well Development Criteria

In general, well development should proceed until the following criteria are met:

1. At a minimum, removal of three EV of water from the well.
2. Removal of three times of the amount of fluid (mud and/or water) lost during drilling.
3. Removal of three times the fluid used for well installation.
4. The following indicator parameters should be stabilized as indicated by three successive readings within:
 - ± 0.2 for pH;
 - $\pm 3\%$ for specific conductance;
 - ± 10 mV for oxidation/reduction potential;
 - ± 1 degree Celsius for temperature; and
 - $\pm 10\%$ for turbidity and dissolved oxygen (except for wells installed in karst aquifers).
5. Well water is clear to the unaided eye (except for wells installed in karst aquifers).
6. The sediment thickness remaining within the well is less than one percent of the screen length or less than 0.1 ft for screens equal to or less than 10 feet.
7. Site specific factors should be evaluated to determine appropriate well development criteria have been if:
 - Well recharge is so slow that the required volume of water cannot be removed during 48 consecutive hours of development;
 - Water discoloration persists after the required volumetric development; and
 - Excessive sediment remains after the required volumetric development.

3.4 WELL DEVELOPMENT RECORD

Record all data as required on a Well Development Record Form (see example), which becomes a part of the complete Well Record. These data include the following:

- Project name, location;
- Well designation, location;
- Date(s) and time(s) of well installation;
- Static water level from top of well casing before and 24 hours after development;
- Depths and dimensions of the well, the casing, and the screen, obtained from the Well Diagram;
- Water losses and uses during drilling, obtained from the boring log for the well;
- Water contained in the well, obtained from calculations using the depth of the water column and the well radius, plus the radius and height of the filter pack and an assumed 30% porosity;
- Measurements of the following indicator parameters: pH, conductivity, oxidation/reduction potential, temperature, and turbidity before and after development and once during each EV;
- Notes on characteristics of the development water;
- Data on the equipment and technique used for development; and
- Estimated recharge rate and rate/quantity of water removal during development.

Well development records shall be submitted to the COR after the development has been completed.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addendum for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

- Aller, Linda, et al. 1989. *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*. National Water Well Association.
- ASTM Standard D 5092-04e1. 2004. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers*.
- EPA Groundwater Handbook. 1989.
- Nielsen, David M. 1993. *Correct Well Design Improves Monitoring*, in "Environmental Protection," Vol. 4, No.7, July, 1993.
- USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites*. EM 1110-1-4000, 1 November.

EXAMPLE WELL DEVELOPMENT FORM

WELL DESIGNATION: _____ DATE(S) OF INSTALLATION: ____/____/____

SITE GEOLOGIST: _____ DEVELOPMENT DATE(S): ____/____/____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT :

BEFORE _____ DATE _____ 24 HR. AFTER _____ DATE _____

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT * :

BEFORE _____ DATE _____ 24 HR. AFTER _____ DATE _____

DEPTH TO WELL BOTTOM * : _____ SCREEN LENGTH _____

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: _____

QUANTITY OF MUD/WATER:

LOST DURING DRILLING (+) _____ gallons

REMOVED PRIOR TO WELL INSERTION (-) _____ gallons

LOST DURING THICK FLUID DISPLACEMENT (+) _____ gallons

ADDED DURING FILTER PACK PLACEMENT (+) _____ gallons

TOTAL LOSSES _____ gallons

(a) Water column ht. (ft.) _____

(b) Well radius (in.) _____

(c) Screen length (ft.) _____

(d) Borehole radius (in.) _____

(e) QUANTITY OF FLUID STANDING IN WELL

Install Equation Editor and double-
click here to view equation.

1 _____ gallons
(Show Calculation)

Install Equation Editor and double-

(f) QUANTITY OF FLUID IN ANNULUS click here to view equation.
(Show Calculation)

1 _____ gallons

DEVELOPMENT VOLUME = (3 * TOTAL LOSSES) + [5 * (e + f)] = _____ gallons
(Show Calculation)

* ALL DEPTHS MEASURED FROM TOP OF WELL CASING

EXAMPLE WELL DEVELOPMENT RECORD

WELL DESIGNATION _____ DATE(S) OF DEVELOPMENT: ____/____/____

TYPE AND SIZE OF PUMP: _____

TYPE AND SIZE OF BAILER: _____

DESCRIPTION OF SURGE TECHNIQUE: _____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/odor/partic.)
(before)									
(during)									
(during)									
(during)									
(after)									

TYPICAL PUMPING RATE _____ GAL./HR. EST. RECHARGE RATE _____

TOTAL QUANTITY OF WATER REMOVED _____ TIME REQUIRED _____

REMARKS _____

SIGNATURE OF SITE GEOLOGIST _____

STANDARD OPERATING PROCEDURE 20.3 WELL AND BORING ABANDONMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to establish the protocols by which all borings and wells will be abandoned. The primary objective of boring or well abandonment activities is to permanently abandon the boring or well so that the natural migration of groundwater or soil vapor is not significantly influenced.

2.0 MATERIALS

- Well abandonment equipment including appropriate grout mixing/placement equipment, and heavy equipment as appropriate (drill rig, crane, backhoe, etc.);
- Pure sodium bentonite powder with no additives (bentonite);
- Bentonite pellets (seal);
- Cement (Portland Type II); and
- Approved source water.

3.0 PROCEDURE

The volume of grout required for borehole or well abandonment should be calculated prior to proceeding with abandonment. These calculations should consider loss of material to the formation, changes in borehole diameter, potential zones of washout, and shrinkage of material. Calculations should be recorded on an abandonment record (see Section 3.1.4).

In general, cement grout should be used for boring and well abandonment per the specifications in Section 3.1 and procedures identified in the following sections. Specialized narrow diameter soil borings (3-inches or less) associated with direct push methods or hand augers may be abandoned using bentonite pellets or chips (see Section 3.5).

Any replacement borings or wells associated with the abandonment should be offset at least 20 feet from any abandoned site in a presumed up- or cross-gradient direction.

3.1 GROUT

Grout used in construction will be composed by weight of the following:

- Type II Portland cement (Type IV Portland Cement if sulfate concentrations are greater than 1,500 ppm);
- Bentonite (2 to 5% dry bentonite per 94-lb sack of dry cement); and
- A maximum of 6 to 7 gallons of approved water per 94-lb sack of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump before placement.

Grout placement will be performed using a commercially available grout pump and a rigid tremie pipe. Removal and grouting will be accomplished in stages, aquifer by aquifer, sealing the boring from the bottom to ground surface. This will be accomplished by placing a grout pipe to the bottom and pumping grout through the pipe until undiluted grout reaches the bottom of the next higher section of casing or, for the top-most section, until grout flows from the boring at ground surface.

After 24 hours, the abandoned drilling site will be checked for grout settlement. Any settlement will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at the ground surface.

3.2 BORINGS

The term “borings” as used in this SOP applies to any drilled hole made that is not completed as a well. This includes soil test borings, soil sampling borings, and deep stratigraphic borings. Whether completed to the planned depth or aborted for any reason before reaching that depth, borings will be grouted and will be normally closed within 12 hours.

To achieve an effective seal, the borehole to be abandoned should be free of debris and foreign matter that may restrict the adhesion of the grout to the borehole wall. Borehole flushing with a tremie pipe may be required to remove such materials prior to grouting.

Each boring to be abandoned should be sealed by grouting from the bottom of the boring to the ground surface. This will be accomplished by placing a tremie pipe to the bottom of the borehole and pumping grout through the pipe at a steady rate. The grouting should be completed slowly and continuously to prevent channeling of material. The tremie pipe should be raised when pumping pressure increases significantly or when undiluted grout reaches the surface.

After 24 hours of completing the abandonment, the abandoned boring or well should be checked for any grout settlement. The settlement depression should be filled with grout and rechecked 24 hours later. Grout should be placed with a tremie pipe if the open hole is 15 feet or deeper or if the hole is not dry. Otherwise, the grout may be poured from the surface.

3.3 NARROW BORINGS

Narrow borings, those with diameter less than 3 inches, advanced by hand auger or direct push methods, may be sealed using bentonite pellets or chips rather than a grout mixture. Often times a grout pump is not available to mix the grout when these methods have been used. Bentonite pellets or chips will be poured into the boring from the ground surface. Then bentonite will hydrate by absorbing moisture from the ground; unapproved water should not be added to the boring. After 24 hours, the abandoned boring will be checked, and any grout settlement will be topped off with more bentonite. The process will be repeated until bentonite remains at ground surface unless site condition indicates otherwise.

3.4 WELLS

The following procedure applies to wells aborted before completion and existing wells determined to be ineffective or otherwise in need of closure.

General Considerations

A number of techniques are available for abandoning monitoring wells and other monitoring devices including:

- Abandonment in place by grouting the well screen and casing in place;

- Removal of the well by pulling; and
- Overdrilling.

The particular method used for abandonment should be specified in the work plan addenda developed for a site-specific investigation. Several factors must be considered when selecting the appropriate abandonment technique including well construction, well condition, and subsurface conditions.

In general the preferred method for abandonment of wells is to remove all existing well materials to:

- Reduce the potential for the formation of a vertical conduit to occur at the contact between the casing and annular seal;
- Reduce the potential for well materials interfering with the abandonment procedures; and
- Decrease the potential for reaction between the well materials and grout used for abandonment.

In general, all well materials will be removed during abandonment (including screen and casing) by either pulling out the casing, screen, and associated materials or by overdrilling using a rotary or hollow stem auger drilling procedure.

Abandonment with Well Materials In Place

In the event that it is not possible to remove the casing and screen, the casing and screen will be perforated using a suitable tool. A minimum of four rows of perforations several inches long and a minimum of five perforations per linear foot of casing or screen is recommended.

After the screen and casing have been appropriately perforated, the well should be abandoned by grouting from the bottom of the well to the ground surface using a tremie pipe as described in Section 3.2. The tremie pipe should be raised when pumping pressure increases significantly or when undiluted grout reaches the surface.

After 24 hours of completing the abandonment, the abandoned well should be checked for any grout settlement. The settlement depression should be filled with grout and rechecked 24 hours later. Grout should be placed with a tremie pipe if the open hole is 15 feet or deeper or if the hole is not dry. Otherwise, the grout may be poured from the surface.

Abandonment by Removal

Site conditions permitting, relatively shallow monitoring wells may be successfully abandoned by removal providing that the well is generally good condition and sections of casing (including screen) can be successfully removed with materials intact.

This method of abandonment is generally accomplished by removing (pulling) sections of casing and screen out of the subsurface using a drill rig, backhoe, crane, etc. of sufficient capacity. Materials with lower tensile strength such as polyvinyl chloride (PVC) generally cannot be removed by pulling if they have been appropriately cemented in place.

Once the well materials have been removed from the borehole, the borehole should be abandoned by grouting in the same manner discussed for borings in Section 3.2. If the borehole collapses after removal of well materials, then the borehole should be over drilled to remove all material and then grouted to the surface.

Overdrilling

With this method of abandonment, the well materials are removed by overdrilling (overreaming) the well location. Overdrilling using rotary techniques may be accomplished using an overreaming tool. This tool

consists of a pilot bit that is approximately the same size as the inner diameter of well casing and a reaming bit that is slightly larger than the diameter of the borehole. As drilling proceeds, all well materials are destroyed and returned to the surface. After completion of the overdrilling, the borehole should be immediately grouted with a tremie pipe as described in Section 3.2.

In the case of overburden wells, a hollow stem auger may be used for overdrilling providing that this method of drilling is appropriate for the subsurface conditions. The hollow stem auger should be equipped with outward facing carbide-cutting teeth with a diameter 2 to 4 inches larger than the well casing. With this method, the casing guides the cutting head and remains inside the auger. When the auger reaches the bottom of the well boring and the well materials have been removed, the borehole may be grouted with a tremie pipe (Section 3.2) through the augers as the augers are gradually withdrawn.

Considerations for Fractured Bedrock and Karst Wells

Multi-cased wells completed into bedrock as screened wells, open wells, or open-lined wells may be abandoned with the outer casing left in place providing that the integrity of this casing and associated annular seal is good. A cement bond log (acoustic amplitude boring geophysical log) may be used to evaluate the integrity of the casing and annular seal, if the outer casing is to be left in place.

Borings or wells completed in karst zones may be difficult to abandon because of the potential presence of large conduits, which may make it difficult to grout. Where large conduits exist or difficulties are encountered when abandoning a boring or well, fill the portion of the borehole penetrating the solution cavity with inert gravel (quartz, claystone, etc.). Packers can be used to isolate critical intervals for filling with grout above and below these zones.

3.5 RESTORATION

All work areas around the borings or wells abandoned should be restored to a condition essentially equivalent to that before the borings and wells were installed.

3.6 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material should be managed in accordance with the requirements of SOP 70.1 and the work plan addenda associated with the site investigation

3.7 DOCUMENTATION

For each abandoned boring or well, a record should be prepared to include the following as appropriate:

- Project and boring/well designation;
- Location with respect to replacement boring well (if any);
- Open depth of well/annulus/boring prior to grouting;
- Casing or items left in hole by depth, description, composition, and size;
- Copy of the boring log;
- Copy of construction diagram for abandoned well;
- Reason for abandonment;
- Description and total quantity of grout used initially;
- Description and daily quantities of grout used to compensate for settlement;
- Disposition of investigation-derived material;

- Water or mud level prior to grouting and date measured; and
- Remaining casing above ground surface, height above ground surface, size, and disposition of each.

Daily investigation activities at the site related to boring and well abandonment should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

4.0 PRECAUTIONS

Refer to the health and safety plan associated with the Work Plan Addenda and the Master Health and Safety Plan.

5.0 REFERENCES

ASTM Standard D 5299-99 (2005). 2005. *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities*.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites*. EM 1110-1-4000, 1 November.

STANDARD OPERATING PROCEDURE 20.4 TEST PITS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the excavation of test pits and provide general guidelines for sample collection from the test pits.

Test pit excavations are conducted to investigate and identify possible areas of contamination. Thus, samples taken from the excavation will be positively biased according to visual inspection (i.e., soil discoloration, soil staining) and field screening. Areas showing evidence of possible contamination will be sampled directly. If no evidence of contamination is present during excavation, then samples will be collected in two equally spaced intervals or at intervals specified in work plan addenda for site-specific investigations. In either case, no less than two representative samples per excavation site should be collected. Excavation (and sampling) shall terminate if the water table is encountered before terminal depth.

2.0 MATERIALS

- Master Work Plan;
- Work Plan Addenda;
- Field log books;
- Appropriate health and safety equipment for monitoring conditions in the work zone and excavation area including a photoionization detector (PID) or other types of monitoring equipment;
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan;
- Backhoe and associated equipment;
- Appropriate soil sampling equipment such as stainless steel scoops, trowels, spoons, and bowls/trays (SOP 30.1);
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Tarps or plastic sheeting;
- Measuring tape;
- Camera and film; and
- Decontamination equipment and supplies.

3.0 PROCEDURE

3.1 DOCUMENTATION

Field activities and sampling information should be recorded in the field logbooks as outlined in SOPs 10.1 and 10.2.

Cross-sections and sketches of the layout will be prepared upon completion of the excavation. The sketches will indicate soil horizons and geologic observations. Soil horizons will be differentiated based upon variations in soil color (i.e., Munsell Chart), texture, coarse fragment content, structure, and consistence. Refer to SOP 10.3 for boring log completion procedures. In addition, depth and thickness of horizontal depth

to bedrock (if encountered) and indicators of seasonal high water table (presence of redoximorphic features) will be recorded. Sketches will also indicate the location of any samples collected. Photographs of the excavation will be taken and locations noted on the field map.

3.2 DECONTAMINATION

Decontamination of the backhoe, trowels or spoons, bowls, field tape measure, and other associated equipment will be carried out before use and between each test pit as outlined in work plan addenda and SOP 80.1.

3.3 SITE PREPARATION

Mark out dimensions of excavation and possible hazards (e.g., utilities, former structures). The backhoe must be equipped with a protective shield and the operator properly trained in the use of level B respiratory and dermal protection. The backhoe bucket and arm must be thoroughly decontaminated by steam cleaning before use and between each test pit location as described in work plan addenda and SOP 80.1. Discuss all hazards with equipment operator before any intrusive activities.

Set up exclusion zone with caution tape and position backhoe upwind of excavation site. All activities must be conducted in accordance with the health and safety plan developed for work plan addenda.

3.4 EXCAVATION AND SAMPLING

The backhoe operator shall be directed to excavate until the sampler indicates the desired depth has been reached. If the pit is less than 3 ft deep, the sampler can enter the pit and collect the samples using a decontaminated stainless steel trowel or spoon as described in SOP 30.1. As the pit becomes deeper, the sampler will collect the soil samples directly from the center of the bucket of the backhoe in an area not in contact with the sides of the bucket. The samples will then be transferred from the bucket into the appropriate sample container following sampling techniques outlined in SOP 30.1. Screening processes and analytical parameters for field screening soil samples will vary from site to site as specified per scope of work.

Begin excavating in increments of 6 to 12 inches per pass. Deeper passes may be necessary if the soil is rocky. Total excavation width will be of adequate dimensions to visually characterize the soil profile as observed on the excavation walls, typically not exceeding the width of the backhoe bucket. However, total width of the excavation will be dependent on the depth of the excavation, thus wider dimensions may be necessary for characterization of deeper pits. Excavation will be continuously monitored with health and safety monitoring equipment. Safety measures must be exercised when working near and around the backhoe arm and excavation pit. Health and safety procedures and any installation safety procedures must be strictly followed.

All soil removed during excavation shall be placed on a tarp or plastic sheeting. Soil exhibiting signs of contamination based on visual or olfactory observations, as well as monitoring results, will be separated from uncontaminated soil and containerized for site removal.

Samples will be collected at desired intervals as specified in work plan addenda. Sampling procedures will follow the requirement of work plan addenda and SOP 30.1.

3.5 BACK FILL

Once the terminal depth of the excavation is reached or the water table is encountered and all samples are collected, the trench will be backfilled with certified clean fill. Soils removed during excavation shall be containerized and disposed of at an approved landfill or moved to an approved storage area for subsequent disposal. All backfilled material will be tamped to a proper compacted level to ensure no major settling will occur. After all backfilling and compacting procedures are complete, the area will be raked and seeded or resurfaced with asphalt, as appropriate. When the area is properly secured, decontamination procedures shall begin.

4.0 PRECAUTIONS

- Appoint an excavation competent person;
- Conduct daily inspections of excavation and surrounding area;
- Excavation entry is prohibited without approval of the excavation competent person;
- Protect employees in excavations deeper than four feet by means of properly designed protective systems;
- Protective systems must comply with 29 CFR 1926 Subpart P Appendices B, D, and E;
- Excavations will be clearly identified and barricaded to keep unauthorized individuals out.

5.0 REFERENCE

USEPA. 1987. *A Compendium of Superfund Field Operations Methods*. December.

STANDARD OPERATING PROCEDURE 20.7 RESISTIVITY AND ELECTROMAGNETIC INDUCTION SURVEYS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide a general description and technical management guidance on the use of Resistivity and Electromagnetic Induction (Terrain Conductivity) Surveys.

2.0 MATERIALS

- Work Plans;
- Field Logbook;
- Site maps;
- Electromagnetic induction unit; and
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan.

3.0 PROCEDURE

3.1 DESCRIPTION OF METHODS

3.1.1 Theory and Principles of Operations

Resistivity. A resistivity survey measures the electrical resistivity of a geohydrologic section indirectly. A DC or low-frequency AC electrical current is injected into the ground through electrodes embedded in the ground surface. The flow of current within the subsurface produces an electric field with lines of equal potential perpendicular to the current flow. This potential field (voltage) is measured between a second pair of electrodes also embedded in the ground surface.

The actual resistivity is a complex function of the applied current, observed voltage, and the characteristics of the subsurface section that provide multiple current flow paths. The apparent subsurface resistivity can be calculated as a function of the applied current, the measured voltage, the separation of the electrodes, and the geometry of the current and potential electrode pairs. For the simplest electrode configuration in which all four electrodes are equally spaced in the order current-potential-current (i.e., the Wenner array) the apparent resistivity is given by the following equation:

$$a = \frac{2\pi AV}{I}$$

Where:

- a = apparent resistivity in ohm-meters or ohm-feet,
- V = the measured potential difference in volts, and
- I = the applied current in amperes.

The calculations are similar for other electrode configurations except geometric factors other than 2 are used. Equipment operating manuals provide nomographs for determination of apparent resistivity from field measurements for all standard electrode configurations. These calculations are simple and can be performed on a hand-held calculator.

Of the many possible geometric configurations of current and potential electrodes, some of the most commonly used arrays are as follows:

- Linear array with electrodes in the order current-potential-potential-current. A Wenner array results if the spacing between each successive pair of electrodes is equal. For a Schlumberger array, the distance between the two potential electrodes is a small fraction of the distance between the two current electrodes.
- Linear array with electrodes in the order current-current-potential-potential. In this dipole-dipole configuration, the separation of the two current and the two potential electrodes is equal, with an equal or greater separation of the two dipole pairs.

Resistivity surveys may be conducted to determine either vertical or horizontal electrical anomalies. *Vertical electrical soundings* (VES) are made by symmetrically expanding a Wenner or Schlumberger array in line about a point, i.e., the electrode spacing is increased for successive readings. Measurements of potential and input current are made for each set of electrode spacings, and the apparent resistivity is calculated as described below. The resultant plot of spacing versus apparent resistivity is interpreted to yield the resistivity distribution with depth beneath the midpoint between the potential electrodes. However, the resistivity being measured is that of the materials beneath the entire array.

For *horizontal profiling*, apparent resistivity from a series of measurements is plotted as a function of the X+Y coordinates of the site. One or more of the following procedures accomplishes horizontal profiling:

- A series of VES profiles at several locations are compared;
- Measurements are made with fixed-electrode spacing along a line or over an area; and/or
- Dipole-dipole measurements are made with the current or potential dipole at a fixed location and the other dipole located at increasing distances along a line. This process provides a resistivity “cross-section” beneath the line.

The Wenner and Schlumberger configurations are most often used for vertical investigation, whereas the dipole-dipole configuration is most often used for lateral surveys.

Electromagnetic Induction (EM). In the Electromagnetic Induction (EM) method, the electrical conductivity of a geohydrologic section is measured by transmitting a high-frequency electromagnetic field into the earth, producing eddy currents that generate secondary electromagnetic fields that can be detected by a receiver. The eddy currents are induced in the earth by an aboveground transmitter coil, and the resulting secondary electromagnetic fields are coupled to an aboveground receiver coil. Thus, EM measurements do not require direct ground contact, as is the case for resistivity measurements, and surveys across a line or area may be performed quite rapidly.

EM instruments are calibrated to read subsurface conductivity directly in units of millimhos per meter, Where:

$$1,000 \text{ milliohm per meter} = \frac{1}{\text{ohm-meter}}$$

This relation indicates that the conductivity obtained from EM measurements varies inversely with the resistivity measured using a resistivity survey. However, because the subsurface sections associated with the two methods are generally of different depth or cross-sectional area, there is not an exactly inverse relationship between conductivity and resistivity surveys.

The conductivity value obtained by an EM instrument depends on the combined effects of the number of soil and rock layers, their thicknesses and depths, and the inherent conductivities of the materials. The quantity actually measured is an apparent conductivity of the earth volume between the ground surface and an effective penetration depth, which is defined as the depth at which variations in conductivity no longer have a significant effect on the measurement. The sampling depth is related to the spacing between the transmitter and receiver coils of the instrument, approximately as follows:

$$\begin{aligned}\text{Sampling depth} &= 1.5 (\text{coil spacing}) (\text{Vertical Dipole}) \\ &= 0.75 (\text{coil spacing}) (\text{Horizontal Dipole})\end{aligned}$$

Vertical profiling can be accomplished by multiple measurements about a point, with varying coil spacings. Horizontal profiling is performed by making measurements along traverses with a fixed coil spacing.

3.1.2 Application

The measurement of a subsurface resistivity or conductivity at a hazardous waste site provides a valuable contribution to site characterization for the following reasons:

1. Conductivity (resistivity) is a function of the geohydrologic section and is overwhelmingly influenced by the presence of water. Therefore, conductivity (resistivity) can provide indirect evidence on the porosity and permeability of subsurface materials and the degree of saturation. These parameters, in turn, are directly related to subsurface lithology, and to the potential for infiltration/migration of contaminants from a source area.
2. Conductivity (resistivity) is influenced by the presence of dissolved electrolytes in soil or rock pore fluids. Contaminant plumes in the vadose (unsaturated) and saturated zones can be mapped if there is sufficient change in conductivity to be detected by EM or resistivity measurements.

In general, contaminant plumes of inorganic wastes are most easily detected because conductivity may be increased by 1 to 3 orders of magnitude above background values. The limit of detection is a change from a background of 10%–20%. Plumes of non-polar organic constituents from spills or leaking containers may be detected if sufficient soil moisture has been displaced to affect the ground conductivity to a measurable degree.

3. Conductivity (resistivity) can be used to detect the presence of buried wastes if the degree of saturation, containerization, or inherent electrical properties of the wastes produce sufficient variation from the soil matrix. The degree of detail provided by typical surveys cannot distinguish the size, shape, or mass of sources except in a qualitative manner.

For these reasons, resistivity and conductivity surveys should be investigated as potentially appropriate site characterization tools when any of the following information is desirable:

- Detection and mapping of contaminant plumes; the rate of plume movement may also be deduced from measurements made over time;
- Estimates of depth, thickness, and resistivity of subsurface layers, depth to the water table, or probable geologic composition of a layer;
- Detection, mapping, and depths of burial pits, landfills, clay caps or lenses, or deposits of buried waste;
- Determination of locations for drilling to intercept contamination or to investigate aquifer properties; and
- Corroboration of limited chemical and geohydrologic data at a site.

In general, surface geophysical measurements alone cannot provide a complete assessment of subsurface conditions. When appropriately integrated with other investigative information from subsurface borings,

borehole geophysics, etc., surface geophysical surveys can be an effective, accurate, and cost effective method of obtaining subsurface information. Geophysics at Radford Army Ammunition Plant will, where coverage permits, integrate surface and down hole methods to develop more accurate and refined interpretations of subsurface conditions that possible with either type of method alone.

3.1.3 Instrumentation

Resistivity. The basic components of a field resistivity system are two current and two potential electrodes, electrical cables, centralized power unit (current source), and resistivity meter. Automated instrumentation is commonly used to conduct two or three-dimensional surveys. One such system is the Advanced Geosciences, Inc. (AGI) Sting/Swift system, which includes a central power unit, resistivity meter (Sting), control unit (Swift), and switched electrode cables for use with up to 254 electrodes. This AGI allows for automated measurements, complete control of the measurement array, programmable measurement cycles, large capacity storage of data with linkup to a personal computer. The Sting/Swift system allows for rapid collection of resistivity data and testing of arrays. Measurement ranges for the Sting/Swift system are 0.1 milliohm to 400kohms (resistance) and 0 to 500 volts full-scale auto ranging (volts).

Electromagnetic Induction (EM). Generally EM instruments are available in two forms:

1. Single-piece models operable by one person, with a fixed coil spacing 12 feet; these provide sampling depths on the order of 10 and 20 feet. The Geonics EM31DL is one example of this type of instrument.
2. Dual-coil models, operable by two persons, with variable coil spacing up to about 40 feet (sampling depth up to about 60 feet). The Geonics EM 34-3XL is an example of this type of instrument.

The 12-foot fixed coil and the dual coil apparatus are most commonly used in hazardous waste site investigations. In either case, an additional person to record data and identify measurement locations is highly desirable and more time efficient. The instruments are calibrated to read directly in conductivity units, and values are typically read and recorded on a data sheet. Some units have been modified to provide direct digital recording on magnetic tape.

3.2 DATA ACQUISITION

3.2.1 Field Procedures

Initial Operations. As with most geophysical surveys, conductivity or resistivity surveys involve the following initial steps:

- **Planning.** Known or assumed geohydrologic features of the site, potential source locations and migration characteristics of hazardous constituents, are used to select specific techniques and equipment to establish appropriate locations and depths for geophysical measurements (see Section 5.1.2). The level of detail necessary (data quality objectives) determines the amount of effort and, in simple terms, the required number and density of data points. As a minimum, the data quality will depend on the method and specific equipment selected and the supporting hardware and software capabilities.

An “expert” system known as the Geophysics Advisor Expert System, developed by the Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas, may be used as a planning tool to assist in selecting an appropriate geophysical method. This system prompts the user through a series of site-specific questions that will eventually rank various geophysical methods as to their feasibility at a specific site.

Most of the details can be planned before site activities; however, some leeway must be accorded to the field procedures to account for variable site conditions and weather.

- **Site Layout.** One of the most labor-intensive and time-consuming aspects of the fieldwork involves layout of grids and surveying or careful measurement of locations to allow geophysical surveys to be accomplished in a systematic, documentable manner. Location coordinates of sufficient resolution to accomplish the objectives of the survey must uniquely identify every data point.
- **Array and Spacing Tests.** Select one area or line that typifies the site. Test different array types and spacing. Analyze the data to see if the results match induction or normal resistivity and drilling logs from nearby wells. Select the optimal array type and spacing configuration, and proceed with the survey. If induction or normal resistivity logs are not available for wells at or near the site, log these wells before executing the surface surveys.

Resistivity Measurements. Resistivity electrodes must be installed in the proper array and spacing at a particular site grid location (according to specific manufacturers directions). The cables connecting the electrodes to the current source and potentiometer are then attached, and the current flow is initiated. Voltage is measured directly on the potentiometer. The process is repeated at the next site grid location (for horizontal profiling) or with the next electrode spacing (for vertical electric soundings) as necessary for QC purposes.

General rules for electrode spacings are difficult to specify because of site-specific variation; depending on the site geohydrology and source characteristics. As a general rule of thumb, the maximum electrode spacing should be at least three to five times that of the maximum target depth.

Electromagnetic Induction Measurements. At a given site grid location, the specified orientation of the apparatus is established, i.e., with the axis of the coils either parallel or perpendicular to the direction of the survey line. The meter reading is recorded and the apparatus is moved to the next site grid location.

For the dual-coil method, both the intercoil spacing and coplanarity of the coils must be established before recording the data. Surveys are normally conducted with the coil axes horizontal and at right angles to the survey direction.

EM profiles can be accomplished in a continuous manner using vehicle-mounted equipment in conjunction with strip charts, magnetic tape recorders, or digital recorders. Location information must be appended by tic marks or voice-over and some means provided to reference written field logs in a consistent manner.

3.2.2 Data Format

General. Information obtained during a resistivity or EM survey should be presented according to a standard data format, using standardized data sheets with original field entries. As a minimum, the heading for each data sheet should contain the following information:

- Project, task, site, and location identification;
- Company or organization;
- Date (and time, if applicable);
- Operator's name and signature;
- Method/technique identification;
- Instrument make, model, serial number, and calibration date/frequency (if applicable);
- Test location (according to the survey plan);
- Electrode or coil type and configuration;

- Line or site grid location(s);
- Weather and site conditions and temperatures;
- Identity of relevant calibration and QC data; and
- Records of data for each sounding or profile on a single sheet, if possible;

Resistivity. Survey data should include, in a tabular format, the following information:

- Electrode location, per the survey plan;
- Electrode spacing, in feet or meters;
- Input current applied, in amperes; and
- Measured potential, in volts.

Electromagnetic Induction. Survey data should include, in a tabular format, the following information:

- Coil location, per the survey plan;
- Coil spacing;
- Coil configuration (unless specified in the heading); and
- Meter reading, in millimhos per meter.

Special precautions to systematize and preserve data will be required for data that are recorded continuously on strip charts, magnetic tape recorders, or digital recorders. Strip charts should be permanently affixed to the field logbook. The first original hard copy of output from magnetic tape should be treated similarly. Identifying header information must be recorded directly on the tape.

3.3 DATA INTERPRETATION

3.3.1 Resistivity Data

For each data point, the apparent resistivity is calculated according to the formula appropriate for the type of electrode array employed. For horizontal profiling, curves of apparent resistivity versus distance along a line defined by the site grid locations are plotted. These curves of lateral changes in resistivity at a given electrode spacing (therefore, at a given survey depth) provide a cross-section for interpretation of the anomalous subsurface features. Multiple parallel profile lines can be combined to produce an area map of apparent resistivity at a particular depth.

For vertical electrical soundings, the series of apparent resistivities are plotted versus corresponding electrode spacings on log-log graph paper. The curves can be compared qualitatively with known or suspected subsurface conditions or with idealized layer-models to determine layer thicknesses and depths. Computer processing is typically applied for analysis of complex data sets and inverse layer modeling.

3.3.2 Electromagnetic Induction Data

Corrections may be applied to EM data for accuracy and drift, variation in location from pre-established coordinates, topography, changes in scale, and non-linearities associated with high conductivity values. In all cases, such corrections must be fully supported by data originally recorded or annotated in the field. Profile data along traverses are obtained as plots of conductivity versus distance. As with resistivity profiling, parallel traverse data may be combined to provide conductivity contour maps of a site. Two or more profiles at different sampling depths, as well as sounding data at a given location, provide information

on the relative conductivities of shallow and deeper layers. Contour plots may provide valuable information on the extent and direction of groundwater flow and contaminant transport.

Detailed comparison of EM sounding measurements with layer models of the site can be made. This type of interpretation has been used at sites with relatively simple, uniform geohydrology to determine overburden and bedrock spatial and depth relationships. In some cases, very detailed interpretations, including aquifer flow properties, location of permeable zones, and interaquifer transfer, are possible.

3.4 POTENTIAL PROBLEMS

Resistivity and EM surveys are geophysical methods that, although standardized and frequently applied, are subject to a wide variety of problems. Problems can be expected to arise in the following areas:

- **Planning and Execution.** Rarely is a survey accomplished exactly according to the original plan. Site features not previously specified and myriad other variations can occur that force changes in the details of the approach. However, the data quality objectives of the survey, the general methodology, the amount of data required, and the degree of data interpretation requested should remain unchanged. Project work scopes should be written with some degree of latitude to allow a change in plans whenever justified.
- **Noise and Interferences.** Measurements can be affected severely both by natural and man-made sources of electrical and electromagnetic noise. Nearby power lines, stray ground currents, and atmospheric discharges adversely affect both types of surveys. Large masses of buried metal, fences, railroad tracks and underground pipes or cables can strongly distort measurements and reduce instrument sensitivity to features of interest. These problems generally can be accounted for or overcome but must be recognized early in the survey so that appropriate avoidance measures can be implemented. Known or suspected sources of interference should be included in the initial planning for a project.
- **Weather Conditions.** It is possible to conduct the surveys under almost any conditions that permit traverse of the site. However, snow cover, standing water, heavy rainfall, or thoroughly saturated surface soils may severely restrict the ability to meet project objectives and schedules. Scheduling contingencies should be included whenever possible, especially during periods when inclement weather is expected.
- **Technical Difficulties.** Preventable difficulties include equipment malfunction or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the geophysical response of the site is not as initially conceptualized. Early recognition and response by technical management can minimize the effect and severity of any problems. Interim, real-time scrutiny of the data by the site geophysicist is essential. The geophysicist must be responsive regarding equipment replacement, repair, or changes in personnel. The site manager and the site geologist should be cognizant of technical difficulties beyond the control of the field personnel and should recognize the need to change plans, field personnel, or cancel a survey, as appropriate.
- **Topographic Changes.** Significant changes in topography should be addressed when planning and making measurements.

3.5 QUALITY CONTROL

3.5.1 General

Geophysical surveys, including resistivity and conductivity surveys, are subject to misapplication, erroneous interpretations, and use of incomplete or inadequate data. All of these avoidable errors can severely affect both the cost of subsequent site investigations and the validity of the site characterization. This susceptibility

to misuse and potential for negative effect demands an assurance that appropriate quality control measures have been implemented. Quality control aspects common to most types of geophysical field programs are as follows:

- Integrating surface-based results (indirect measurements) with well sampling results, drilling logs, and down hole (direct measurement) geophysical logs.
- Program management personnel with technical expertise in preparing statements of work; reviewing proposals, work plans, and reports; and supervising technical subcontracts and field-related programs.
- Insistence on a defined scope of work, clear specifications, and data validation procedures.
- Appropriate justification before rejection of data points from a data set. Field data sheets should contain all observed data and the conditions that could affect data validity.
- Field data should be recorded in permanent ink in a bound logbook with each page signed and dated by the operator. Original unaltered logbooks should be retained in the site file.
- Complete and clear understanding of manufacturer's operation manual for the particular apparatus being used.
- Properly calibrated instrument provides an added measure of data validity and permits correlation and comparison of the associated data with site features and geohydrologic characteristics not evident at the time of the field effort. Some geophysical survey objectives can be met by relative measurements across an area or with depth.
- An evaluation should be made of noise, interferences, and obstructions at a site. Such measurements, inferences, and explanations should be recorded in the field. These real-time quality control procedures aid field personnel in correction of noise sources over which they have control, in validating suspected external sources, and in early detection of problems that may jeopardize the survey objectives.

3.5.2 Resistivity Surveys

The resistivity apparatus consists of a current source and potentiometer, both of which must be calibrated at least twice a day, e.g., once at the beginning of the day and once at the end of the day.

The current source (source of the energy driving the system) is calibrated by placing an ammeter in series with the electrode cables. The reading obtained on the reference ammeter is then compared with the value read from the ammeter on the current source. The current source ammeter is then adjusted to the reading on the reference ammeter.

The potentiometer is the other apparatus that must be calibrated. This is normally accomplished by placing a precision resistor in series with the current load. A precision resistor is an electronic device that has a predetermined (as specified by the manufacturer) resistance to the electric current passing through the device, i.e., reduction in amperage. The potentiometer is then placed across the resistor. The potential measured should be equal to the product of the known resistance and the indicated current. Precision resistors can be purchased at most electronics supply stores.

All data sets should be accompanied by quality control data that indicate the level of quality of each individual data point. Periodically taking replicate measurements or re-running with the spacing and array configuration accomplishes this. These measurements should be averaged or statistically compared so that measurement precision can be estimated. Each data set should also be referenced to the most recent calibration. Data obtained before a calibration requiring significant changes in instrument controls is suspect. (NOTE: A significant change in instrument readings as a result of recalibration is interpreted as successive calibration values that vary by more than 10%).

Resistivities should be calculated and plotted during data acquisition to determine the overall quality of the data and whether the survey results are consistent with the site conceptualization. Data points representing discontinuities in the curves should be validated by repetition and, if necessary, a fine grid of measurements made to determine whether the anomaly represents a site feature of interest, a spurious reading, or an obstructive interference.

3.5.3 Electromagnetic Induction Surveys

Calibration. The manufacturer calibrates EM instruments over massive rock outcrops of known characteristic that are used as a geologic standard to measure the absolute conductivity over a uniform section of earth. The user should maintain the EM apparatus in calibration by noting drift in the readings at a stable “secondary standard” site. A secondary standard site is a location established in the field that is used to check the accuracy (calibration of the instrument and the drift precision of the instrument). A secondary standard site is a location used daily on large projects to check instrument accuracy, much the same way the manufacturer uses massive rock outcrops for precision and accuracy determination.

Unacceptable drift or erratic operation shall be corrected by replacement with an instrument in proper working order. Values that are obtained from measurements over the stable secondary standard site that vary by more than 10%–15% are considered to be unacceptable drift, if environmental conditions remain somewhat constant (i.e., heavy precipitation can make measurements radically different).

All aspects of the daily quality control measures discussed for resistivity measurements apply also to EM measurements. Repeated periodic measurements (at least twice a day) should be made at one or more locations and orientations at the site to determine the precision of measurements and to detect instrument drift.

4.0 HEALTH AND SAFETY CONSIDERATIONS

All procedures for hazardous waste site entrance, traverse, and egress that apply to general field operations also apply to conduct of geophysical surveys. Resistivity and conductivity surveys depend on traverse of the site on foot or in vehicles, and there are extended periods during which personnel are subject to adverse environments at the site. In addition, resistivity measurements require implanting electrodes beneath the surface, which increases the risk of contact with toxic or hazardous agents. An appropriate level of protection against these risks must be provided during the surveys.

The geophysical methods discussed herein do not require extremely strenuous activity, and exposure to heat or cold is similar to that during other field activities. Extreme weather conditions will have adverse effects on the time required to obtain validated data, thereby increasing the duration of personal exposure to the elements and to hazardous site influences.

In resistivity surveys, substantial levels of electrical charges and voltage may be present across the current electrodes, and field procedures must be designed to ensure that no personnel are in contact with the electrodes when the current source is energized. The site-specific Health and Safety Plan must address emergency procedures in the event of electrical shock and possible loss of consciousness.

5.0 REFERENCES

Discussion of various survey techniques and applications can be found in the following references:

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- Olhoeft, Gary R. 1989. *Geophysics Advisor Expert System: Version 1.0*. Interagency Agreement DW 14932497, USEPA EMSL, Las Vegas, NV.
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STANDARD OPERATING PROCEDURE 20.11 DRILLING METHODS AND PROCEDURES

1.0 SCOPE AND APPLICATION

The use of an appropriate drilling procedure is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to outline procedures for the various methods of soil and rock drilling identified in the Master Work Plan. In addition it provides procedures for using sampling devices commonly used during soil and rock drilling such as split-barrel sampling, thin walled tube sampling, direct push samplers, and rock coring. For a particular site investigation, the associated work plan addendum will identify the appropriate drilling method and method of sampling, along with proposed sampling depths and intervals and any special procedures or methods.

2.0 MATERIALS

The following types of materials are generally appropriate for drilling:

2.1 SPLIT-BARREL SAMPLING

- Split barrel sampler;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.2 THIN WALLED TUBE SAMPLING

- Thin walled tubes;
- Sealing materials for sample such as sealing wax, metal disks, wood disks, tape, cheesecloth, caps, etc;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.3 DIRECT PUSH SAMPLING

- Direct push unit with hydraulic ram, hammer, etc;
- Sample collection devices, associated equipment and expendable supplies such as sample liners, sample retainers, appropriate lubricants, etc;
- Hollow extension rods;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;

- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.4 HOLLOW-STEM AUGER DRILLING

- Drill rig and associated equipment;
- Hollow stem auger assemblies for drilling to appropriate depth including auger heads, drive assembly, pilot assembly, and hollow-stem auger sections;
- Auxiliary devices such as wrenches, auger forks, hoisting hooks, swivels, and adaptors;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.5 DIRECT AIR ROTARY DRILLING

- Drill rig with rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Sampling devices and equipment, as appropriate;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.6 DRILL-THROUGH CASING DRIVER

- Drill rig equipped with a mast-mounted, percussion driver;
- Casing, drill rods, and drill bits or hammers;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Sampling devices and equipment, as appropriate;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Welding equipment and materials for installation of casing;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and

- Decontamination supplies and equipment per SOP 80.1.

2.7 DIRECT WATER-BASED ROTARY DRILLING

- Drill rig with derrick, rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, cyclone de-sander(s), drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1.
- Decontamination supplies and equipment per SOP 80.1.

2.8 DIRECT ROTARY WIRELINE-CASING ADVANCEMENT DRILLING

- Drill rig with either hollow spindle or top-head drive;
- Drill rods, coring or casing bits, overshot assembly, pilot bit, and core barrel;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.9 DIAMOND CORE DRILLING

- Direct rotary drill rig and associated equipment (see Sections 2.4, 2.5 or 2.6);
- Core barrels and core bits;
- Core lifters;
- Core boxes, engineers scale, permanent marking pen, and camera for photographing cores;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

3.0 PROCEDURES

3.1 PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

The following general procedure may be followed as outlined in ASTM Standard Test Method D 1586.

1. Advance the boring to the desired sampling depth using an appropriate drilling method (see sections below) and remove excessive cuttings from the borehole.
2. Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.
3. Position the hammer above and attach the anvil to the top of the drilling rods.
4. Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the borehole, remove the sampler and rods from borehole and remove the cuttings.
5. Mark the drill rods in three successive 6-inch increments so that the advance of the sampler can be observed.
6. Drive the sampler with blow from the 140 pound hammer and count the number of blows applied in each 6-inch increment until:
 - a. Fifty (50) blows have been applied during one of the three 6-inch increments.
 - b. A total of 100 blows have been applied.
 - c. There is no observed advance of the sampler during the application of 10 successive blows of the hammer.
7. The sampler is advanced the complete 18-inches without the limiting blow counts occurring as described above.
8. Record the number of blows that is required to achieve each 6-inch increment of penetration or fraction of this increment on the boring.
 - a. The first 6 inches is considered the seating driver.
 - b. The sum of the second and third 6-inch penetration intervals is termed the “standard penetration resistance” or “N-value.”
 - c. If the sampler is driven less than 18 inches as discussed in No. 6, then the number of blow for each partial increment will be recorded.
 - d. For partial increments, the depth of penetration should be recorded to the nearest 1-inch on the boring log.
 - e. If the sampler advances below the bottom of the boring under the weight of rods (static) and/or hammer, then this information will be recorded on the boring log.
9. The raising and dropping of the 140 pound hammer may be accomplished by:
 - a. Using a trip, automatic, or semi-automatic hammer drop system that lifts the hammer and allows it to drop 30 ± 1 inches.
 - b. Using a cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 inches. The cathead should be operated at a minimum speed of rotation of 100 revolutions per minute. No more than 2-1/4 rope turns on the cathead may be used when conducting the penetration test.

10. For each hammer blow, a 30-inch lift and drop shall be used.
11. After completing the penetration test, retrieve the sampler and open. Record the percent recovery or the length of sample recovered. Following the procedures outlined in SOP 30.1 when collecting environmental soil samples.
12. Borehole logging should be completed per SOP 10.3.
13. Split-barrel samples must be decontaminated before and after each use per the requirements of SOP 80.1.

3.2 THIN WALLED TUBE SAMPLING

The following general procedure may be followed for collection of relatively undisturbed, thin walled tube samples (e.g., Shelby tube) as outlined in ASTM Standard Practice D 1587.

1. Clean out the borehole to targeted sampling depth using most appropriate method, which avoids disturbing the material to be sampled. If groundwater is encountered, maintain the liquid level in the borehole at or above the groundwater level during sampling.
2. Place the sample tub so that its bottom rests on the bottom of the borehole.
3. Advance the sampler without rotation by a continuous relatively rapid motion.
4. Determine the length of the advance by the resistance and condition of the formation, the length of the advance should never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clay.
5. When the formation is too hard for push type of sampling, the tube may be driven or the practice used for ring-lined barrel sampling may be used per ASTM Standard D 3550. When a sample is driven, the weight and fall of the hammer must be recorded along with the penetration achieved.
6. The maximum length of sample advance will be no longer than the sample-tube length minus an allowance for the sample head and a minimum of 3-inches for sludge-end cuttings.
7. Upon removal of the tube, measure the length of the sample in the tube. Remove the disturbed material in the upper end of the tube and re-measure the sample length.
8. Remove at least one-inch of material from the lower end of the tube for soil description and identification per SOP 10.3. Measure the overall sample length. Seal the lower end of the tube. If directed, the material from the end of the tube will not be removed for soil identification and description; in this case the tube will be sealed promptly.
9. Prepare sample labels and affix (or markings) on the tube.

3.3 DIRECT PUSH SOIL BORING

The following general procedures outlined in this section may be followed as described in ASTM Standard Test Method D 6282.

General considerations for this method include the following:

- A variety of direct push drive systems may be used to advance soil borings based on the intended sampling depths and subsurface conditions and include the following:

Shallower Depths and Less Difficult Conditions

- Percussive driving systems – use hydraulically operated hammers and mechanically operated hammers.

- Static push drive systems – use hydraulic rams to apply pressure and exert static pull (e.g., cone penetrometer systems).
- Vibratory/sonic systems – use a vibratory device, which is attached to the top of the sampler extension rods.

Greater Depths and More Difficult Conditions

- Sonic or resonance drilling systems – use a high power vibratory system to advance larger diameter single or dual tube systems.
 - Rotary drilling equipment – use hydraulic system of drill rig for direct push.
- The equipment used for direct push must be capable of apply sufficient static force, or dynamic force, or both, to advance the sampler to the required depth of collection. Additionally, this equipment must have adequate retraction force to remove the sampler and extension/drive rods once the sample has been collected.
 - Avoid using excessive down pressure when advancing the drilling tools/sampler. Excessive pressure may cause the direct push unit to offset from the boring location and may damage drilling tools and samplers.
 - Sample liners should be compatible with the material being sampled and the type of analysis to be conducted on the sample. Sealing of liners for submittal to the laboratory for physical testing should be accomplished according to ASTM Standard D 4220 (Standard Practice for Preserving and Transporting Soil Samples).
 - The general procedure for completing direct push soil borings is the following:
 1. Stabilize direct push unit and raise mast at desired location.
 2. Attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit the position over the borehole, and ready the tools for insertion.
 3. Inspect the direct push tools before and after use. Decontaminate all down hole tools before and after use per SOP 80.1.
 4. Inspect drive shoes for damaged cutting edges, dents or thread failures and these conditions could cause loss of sample recovery and slow the rate of advancement.
 5. Assemble samplers and install where required, install sample retainers where needed, and install and secure sampler pistons to ensure proper operation where needed (see Steps 14 through 20 for the various sampler assembly procedures, etc.).
 6. After sampler has been appropriately installed (see Steps 14 through 20 for installation procedures, etc.) advance the boring to the target sampling depth using an appropriate direct push technique, as identified above under general considerations.
 7. Collect the soil sample from the target sampling depth using one of the methods identified in Steps 14 through 20.
 8. Retrieve the sampler and appropriately process the soil sample as identified in Steps 14 through 20 below and in SOP 30.1.
 9. Log the borehole per the requirements of SOP 10.3.
 10. If collecting another soil sample, decontaminate the sampler for reuse per the requirements of SOP 80.1 or use another decontaminated sampler.
 11. Appropriately manage investigation-derived material (discarded samples, decontamination fluids, etc.) per SOP 70.1.

12. Upon completion of the boring and collection of the desired soil samples, abandon the boring per the requirements of SOP 20.2.
13. The following single tube sampling systems (generally piston rod) may be used to collect soil samples (see Steps 14 through 16 below):
 - a. Open Solid Barrel Sampler;
 - b. Closed Solid Barrel Sampler (e.g. Geoprobe Macro-Core® Piston Rod Sampler); and
 - c. Standard Split Barrel Sampler (see Section 3.1).
14. The following two tube sampling systems may be used to collect soil samples (see Steps 17 through 20 below):
 - a. Split Barrel Sampler;
 - b. Thin Wall Tubes;
 - c. Thin Wall Tube Piston Sampler; and
 - d. Open Solid Barrel Samplers.
15. Sampling with the single tube, open solid barrel sampler:
 - a. Attach the required liner to the cutting shoe by insertion into the machined receptacle or by sliding over the machined tube.
 - b. Insert the liner and shoe into the solid barrel and attach the shoe.
 - c. Attach the sampler head to the sampler barrel.
 - d. Attach the sampler assembly to the drive rod and the drive head to the drive rod.
 - e. Position the sampler assembly under the hammer anvil and advance the sampler assembly into the soil at a steady rate slow enough to allow the soil to be cut by the shoe and move up into the sample barrel.
 - f. At the completion of the sampling interval, removal the sampler from the borehole. Remove the filled sampler liner from the barrel by unscrewing the shoe. Cap the liner for laboratory testing or split open for field processing (see SOP 30.1).
 - g. Log the borehole per the requirements of SOP 10.3.
16. Sampling with the closed, solid barrel sampler (e.g., Macro-Core® sampler).
 - a. Insert or attach the sample liner to the shoe and insert the assembly into the solid barrel sampler. Install the sample, retaining basket, if desired.
 - b. Attach the latch coupling or sampler head to the sampler barrel, and attach the piston assembly with point and “O” rings if free water is present, to the latching mechanism.
 - c. Insert the piston or packer into the liner to its proper position so that the point leads the sampler shoe. Set latch, charge packer, or install locking pin, and attach assembled sampler to drive rod.
 - d. Add drive head and position under the hammer anvil. Apply down pressure, and hammer if needed, to penetrate the soil strata above the targeted sampling interval.
 - e. When the sampling interval is reached, insert the piston latch release and recovery tool, removing the piston, or insert the locking pin removal/extension rods through the drive rods, turn counter clockwise, and remove the piston locking pin so the piston can float on top of the sample, or release any other piston holding device.
 - f. Direct push or activate the hammer to advance the sampler the desired interval.
 - g. Retrieve the sampler from the borehole by removing the extension/drive rods. Remove the shoe, and withdraw the sample line with sample for processing (see SOP 30.1).

- h. Clean and decontaminate the sampler, reload as described above and repeat the same procedure for collection of additional samples.
 - i. Log the borehole per the requirements of SOP 10.3.
17. Sampling with standard split barrel (split spoon) sampler generally consists of the following:
- a. Attach the split barrel sampler to an extension rod or drill rod.
 - b. Using a mechanical or hydraulic hammer drive the sampler into the soil the desired interval. The maximum interval that should be driven is equal to the sample chamber length of the split barrel sampler, which is either 18-inches or 24-inches.
 - c. Retrieve the sampler from the borehole by removing the extension/drive rods.
 - d. Split the sampler open for field processing (see SOP 30.1).
 - e. Clean and decontaminate the sampler (SOP 80.1), re-attach and repeat the same procedure for collection of additional samples.
 - f. Log the borehole per the requirements of SOP 10.3.
18. Sampling with a two tube, split barrel sampler generally consists of the following:
- a. Assemble the outer casing with the drive shoe on the bottom, attach the drive head to the top of the outer casing, and attach the sampler to the extension rods.
 - b. Connect the drive head to the top of the sampler extension rods, and insert the sampler assembly into the outer casing.
 - c. The cutting shoe of the sampler should contact the soil ahead of the outer casing to minimize sample disturbance.
 - d. The sample barrel should extend a minimum of 0.25 inches ahead of the outer casing.
 - e. Mark the outer casing to identify the required drive length, position the outer casing and sampler assembly under the drill head.
 - f. Move the drill head downward to apply pressure on the tool string. Advance the casing assembly into the soil at a steady rate, which is slow enough to allow the soil to be cut by the shoe and move up inside the sample barrel.
 - g. Occasional hammer action during the push may assist recovery.
 - h. If smooth push advancement is not possible because of subsurface conditions, use the hammer to advance the sampler.
 - i. Stop the application of pressure or hammering when target interval has been sampled. Move the drill head off the drive head. Attach a pulling device to the extension rods or position the hammer bail and retrieve the sampler from the borehole.
 - j. At the surface, remove the sampler from the extension rods and process the sample per Section 3.01 and SOP 30.1.
 - k. Log the borehole per the requirements of SOP 10.3.
19. Sampling with a two tube, thin wall tube sampler generally consists of the following:
- a. Attach the tube to the tube head using removable screws.
 - b. Attach the tube assembly to the extension rods and position at the base of the outer casing shoe protruding a minimum of 0.25 inches to contact the soil ahead of the outer casing.
 - c. Advance the tube with or without the outer casing at a steady rate.
 - d. After completing the sampling interval, let the tube remain stationary for one minute. Rotate the tube slowly two revolutions to shear off the sample.

- e. Remove the tube from the borehole and measure the recovery, and log the borehole per the requirements of SOP 10.3.
 - f. For field processing, extrude the sample from the tube sampler and process per SOP 30.1. Alternatively, the tube may be sealed and shipped to the laboratory.
20. Sampling with two tube, thin wall tube, piston sampler generally consists of the following:
- a. Check the fixed piston sampling equipment for proper operation of the cone clamping assembly and the condition of the “O” rings.
 - b. Slide the thin wall tube over the piston, and attach it to the tube head. Position the piston at the sharpened end of the thin wall tube just above the sample relief bend.
 - c. Attach the tube assembly to the extension rods and lower the sampler into position through the outer casing. Install the actuator rods through the extension rod, and attach to the actuator rod in the sampler assembly.
 - d. Attach a holding ring to the top of the actuator rod string and hook the winch cable or other hook to the holding ring to hold the actuator rods in a fixed position.
 - e. Attach the pushing fork to the drill head/probe hammer and slowly apply downward pressure to the extension rods advancing the thin wall tube over the fixed piston into the soil for the length of the sampling interval.
 - f. After completing the sampling interval, let the tube remain stationary for one minute. Rotate the tube slowly one revolution to shear off the sample.
 - g. Remove the tube sampler from the borehole and measure the recovery, and log the borehole per the requirements of SOP 10.3.
 - h. For field processing, extrude the sample from the tube sampler and process per SOP 30.1.
21. Sampling with an two tube, open solid barrel sampler generally consists of the following:
- a. This sampling technique may be used when soil conditions prevent advancement of a split barrel sampler or advancement of an outer casing.
 - b. The solid, single, or segmented barrel sampler requires the use of a liner.
 - c. Use sampler in advance of outer casing when this casing cannot be advanced.
 - d. Follow the procedures outlined for two tube, split barrel sampling.

3.4 HOLLOW-STEM AUGER DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5784.

1. Stabilize drill rig and raise mast at desired location.
2. Attach an initial assembly of hollow-stem auger components (hollow stem auger, hollow auger head, center rod and pilot assembly, as appropriate) to the rotary drive of the drill rig.
3. Push the auger assembly below the ground surface and initiate rotation at a low velocity.
4. Decontamination of auger head may be necessary after this initial penetration if this surface soil is contaminated.
5. Continue drilling from the surface, usually at a rotary velocity of 50 to 100 rotations per minute to the depth where sampling or in-situ testing is required or until the drive assembly is within approximately 6- to 18 inches of the ground surface.
6. As appropriate, collect a soil sample from the required depth interval. The sample may be conducted by
 - a. Removing the pilot assembly, if used, and inserting and driving a sampler through the hollow stem auger of the auger column; or

- b. Using a continuous sampling device within the lead auger section, where the sampler barrel fills with material as the auger is advanced.
- 7. Additional sections of hollow stems augers may be added to drill to a greater depth. After these auger sections are added, rotation of the hollow-stem auger assembly may be resumed.
- 8. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.

Monitoring wells or piezometers may be installed using hollow-stem augers by:

- a. Drilling with or without sampling to the target depth.
 - b. Removal of the pilot assembly, if used, and insertion of the monitoring well (or piezometer) assembly.
 - c. The hollow stem auger column should be removed incrementally as the monitoring well (or piezometer) completion materials are placed (see SOP 20.1 for grouting).
- 9. If materials enter the bottom of the auger hollow stem during the removal of the pilot assembly, it should be removed with a drive sampler or other appropriate device.
- 10. If sampling or *in-situ* testing is not required during completion of the boring, the boring may be advanced with an expendable knock out plate or plug of an appropriate material instead of a pilot assembly.
- 11. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1. It may be necessary to drill through a hole of sheet of plywood or similar material to prevent cuttings from contacting the ground surface.
- 12. The hollow-auger assembly and sampling devices must be decontaminated before and after each use per the methods specified in SOP 80.1.
- 13. Borehole logging should be completed per SOP 10.3.
- 14. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.5 DIRECT AIR ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5784.

- 1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).
- 2. Establish point for borehole measurements.
- 3. Attach an initial assembly of a bit, down hole hammer, or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed below the top of the dust collector.
- 4. Activate the air compressor to circulate air through system.
- 5. Initiate rotation of bit.
- 6. Continue with air circulation and rotation of the drill-rod column to the depth where sampling or *in-situ* testing is required or until the length of the drill rod section limits further penetration.
- 7. Monitor air pressure during drilling operations. Maintain low air pressure at bit to prevent fracturing of surrounding material.
- 8. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.
- 9. Open reaching a desired depth of sampling, stop the air circulation and rest bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.

10. When sampling, remove the drill rod column from the borehole or leave the drill rod assembly in place if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 12 should be conducted for each sampling or testing interval.
14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
15. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
16. Monitoring wells or piezometers may be installed by:
 - a. Drilling with or without sampling to the target depth.
 - b. Removal of the drill rod assembly and insertion of the monitoring well (or piezometer) assembly.
 - c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
17. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
18. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
19. Borehole logging should be completed per SOP 10.3.
20. Borehole abandonment, when required, should be conducted according to SOP 20.3

3.6 DRILL-THROUGH CASING DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5872.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit or down hole hammer with a single section of drill rod and casing to the top-head drive unit.
4. Activate the air compressor to circulate air through system.
5. Drilling may be accomplished by
 - a. Method 1- the casing will fall, or can be pushed downward behind the bit.
 - b. To drill using Drive the casing first followed by drilling out the plug inside the casing.
 - c. Method 2 - Advancing the casing and bit as a unit, with the drill bit or hammer, extending up to 12-inches below the casing.
6. Method 3 - Under reaming method where bit or hammer pens a hole slightly larger than the casing so that Method 1, drive the casing first and drill out the plug in the casing by moving the bit or hammer beyond the casing and then withdrawing it into the casing. Air exiting the bit will remove the cuttings up the hole. Separate cuttings from the return air with a cyclone separator or similar device.
7. To drill using Method 2, advance casing and bit as unit with the bit or hammer extending up to 12-inches beyond the casing depending on the conditions. While drilling, occasionally stop the casing

advancement, retract the bit or hammer inside the casing to clear and maintain air circulation to clear cuttings.

8. To drill using Method 3, use a special down hole bit or hammer to open a hole slightly larger than the outside diameter of the casing so that the casing will fall or can be pushed downward immediately behind the bit. After advancing the casing, retract the radial dimension of the drill bit to facilitate removal of the down hole bit or hammer and drill tools inside the casing. Cuttings are removed from the borehole with the air that operates the bit or hammer and can be separated from the air with a cyclone separator or similar device.
9. Monitor air pressure during drilling operations. Maintain low air pressure at bit or hammer to prevent fracturing of surrounding material.
10. Continue air circulation and rotation of the drill rod column until drilling is completed to the target depth (for sampling, in-situ sampling, etc.) or until the length of the drill-rod section limits further penetration.
11. Stop rotation and lift bit or hammer slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.
12. After reaching a desired depth of sampling, stop the air circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
13. When sampling, remove the drill rod column from the borehole. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
14. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
15. The procedure described in Steps 11 through 14 should be conducted for each sampling or testing interval.
16. Drilling to a greater depth may be accomplished by attaching an additional drill rod section and casing section to the top of the previously advanced drill-rod column/casing and resuming drilling operations as described above.
17. Monitoring wells or piezometers may be installed by:
 - a. Casing advancement in increments, with or without sampling to the target depth.
 - b. Removal of the drill rods and the attached drill bit while the casing is temporarily left in place to support the borehole wall.
 - c. Insertion of the monitoring well (or piezometer) assembly.
 - d. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
18. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
19. The drill rod assembly, casing, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
20. Borehole logging should be completed per SOP 10.3.
21. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.7 DIRECT WATER-BASED ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5783.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the mud tub and install surface casing and seal at the ground surface.

2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed with the top of the surface casing.
4. Activate the drilling-fluid circulation pump to circulate drill fluid through the system.
5. Initiate rotation of bit and apply axial force to bit.
6. Document drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, etc.) as described in SOP 10.3.
7. Continue with drill fluid circulation as rotation and axial force are applied to the bit until drilling to the depth
 - a) Where sampling or in-situ testing is required;
 - b) Until the length of the drill rod section limits further penetration; or
 - c) Until core specimen has completely entered the core barrel (when coring) or blockage has occurred.
8. Stop rotation and the lift bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue fluid circulation until the drill cuttings are removed from the borehole annulus.
9. After reaching a desired depth of sampling, stop the fluid circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
10. When sampling, drill rod removal is not necessary if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 11 should be conducted for each sampling or testing interval.
14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
15. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
16. Monitoring wells or piezometers may be installed using hollow-stem augers by:
 - a. Drilling with or without sampling to the target depth.
 - b. Removal of the drill rod assembly and insertion of the monitoring well (or piezometer) assembly.
 - c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
17. Drill cuttings and fluids should be appropriately controlled and contained as IDM per SOP 70.1.
18. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
19. Borehole logging should be completed per SOP 10.3.
20. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.8 DIRECT ROTARY WIRELINE CASING ADVANCEMENT DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5876.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the mud tub (for water based rotary) and install surface casing and seal at the ground surface.
2. Record the hole depth by knowing the length of the rod-bit assemblies and comparing its position relative to the established surface datum.
3. Attach an initial assembly of a lead drill rod and a bit or core barrel below the top-head drive unit, with the bit placed with the top of the surface casing.
4. Activate the drilling-fluid circulation pump to circulate drill fluid through the system.
5. Initiate rotation of bit and apply axial force to bit.
6. Document drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, down feed pressures etc.) as described in SOP 10.3.
7. In general, the pilot bit or core barrel can be inserted or removed at any time during the drilling process and the large inside diameter rods can act as a temporary casing for testing or installation of monitoring devices.
8. Continue with drill fluid circulation as rotation and axial force are applied to the bit until drilling to the depth
 - a) Where sampling or in-situ testing is required;
 - b) Until the length of the drill rod section limits further penetration; or
 - c) Until core specimen has completely entered the core barrel (when coring) or blockage has occurred.
9. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue fluid circulation until the drill cuttings are removed from the borehole annulus.
10. After reaching a desired depth of sampling, stop the fluid circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
11. When sampling, drill rod removal is not necessary if the sampling can be performed through the hollow axis of the drill rods and bit.
12. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
13. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it may be necessary to further clean the hole by rotary recirculation.
14. Continuous sampling may be conducted with a soil core barrel or rock core barrel (see Section 1.7).
15. The pilot bit or core barrel may need to be removed during drilling such as when core barrels are full or there is evidence of core blocking. Before the drill string is reinserted, the depth of the boring should be rechecked to evaluate hole quality and determine whether casing may be required.
16. Water testing may be performed in consolidated deposits by pulling back on the drill rods and passing inflatable packer(s) with pressure fitting to test the open borehole wall (see ASTM Standards D 4630 and D 4631).
17. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
18. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings might be required to isolate zones suspected contamination (see SOP 20.1 for

grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.

19. Monitoring wells or piezometers may be installed by:
 - a. Drilling with or without sampling to the target depth.
 - b. Removal of the pilot bit or core barrel and insertion of the monitoring well (or piezometer) assembly.
 - c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
20. Drill cuttings and fluids should be appropriately controlled and contained as IDM per SOP 70.1.
21. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
22. Borehole logging should be completed per SOP 10.3.
23. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.9 DIAMOND CORE DRILLING

The following general procedure may be followed as outlined in ASTM Standard Practice D 2113.

1. Use core-drilling procedures, such as the water-rotary drilling method outlined in Section 3.6.
2. Seat the casing on bedrock or firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the formation that the casing will be seated on as needed.
3. Begin core drilling using an N-size double-tube, swivel-type core barrel or other approved size or type. Continue core drilling until core blockage occurs or until the net length of the core has been drilled.
4. Remove the core barrel from the borehole, and dis-assemble the core barrel as necessary to remove the core.
5. Reassemble the core barrel and return it to hole.
6. Continue core drilling.
7. Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box. Wrap soft or friable cores, etc. as needed or required. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core that might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.
8. The core within each completed box should be photographed after core surface has been cleaned or peeled, as appropriate, and wetted. Each photo should be in sharp focus and contain a legible scale in feet and tenths of feet (or metric if appropriate). The core should be oriented so that the top of the core is at the top of the photograph. A color chart should be included in the photograph frame as a check on photographic accuracy. The inside lid of the box should also be shown.
9. The inside of the box lid should be labeled at a minimum with the facility name, project name, boring number, box number, and core interval.
10. A preliminary field log of the core must be completed before the core box has been packed for transport (see SOP 10.3). Detailed logging may be conducted at a later time providing the core is appropriately handled and transported.
11. Four levels of sample protection may be used depending on character of the rock and the intended use of the rock core including:
 - a. *Routine care* – for rock cored in 5 to 10 foot runs. Consists of placing in structurally sound boxes. Lay flat tubing may be used prior to placing the core.

- b. *Special care* – for rock samples to be tested that are potentially moisture sensitive, such as shale. This care consists of sealing with a tight fitting wrapping of plastic film and application of wax at the ends of the sample.
 - c. *Critical care* – for rock samples that may be sensitive to shock and vibration and/or temperature. Protect by encasing each sample in cushioning material, such as sawdust, rubber, polystyrene, foam, etc. A minimum one-inch thick layer of cushioning material should be used. Thermally insulate samples that are potentially sensitive to changes in temperature.
 - d. *Soil-Like care* – handle per ASTM Standard D 4220.
- 12. Drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, down feed pressures, core blockage etc.) should be documented on the boring log as described in SOP 10.3.
 - 13. Drill cuttings and fluids should be appropriately controlled and contained as investigation-derived material per SOP 70.1.
 - 14. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
 - 15. Borehole logging should be completed per SOP 10.3.
 - 16. Borehole abandonment, when required, should be conducted according to SOP 20.3.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to site-specific health and safety plan included in work plan addenda.

6.0 REFERENCES

- ASTM Standard D 2113-06 (2006). 1993. *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation*.
- ASTM Standard D 1586-99. 1999. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.
- ASTM Standard D 1587-00 (2007) e1. 2007. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*.
- ASTM Standard D 3550-01 (2007). 2007. *Standard Practice for Thin Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils*.
- ASTM Standard D 4220-95 (2007). 2007. *Standard Practices for Preserving and Transporting Soil Samples*.
- ASTM Standard D 4630-96 (2002). 2002. *Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test*.
- ASTM Standard D 4631-95 (2000). 2000. *Standard Test Method for Determining Transmissivity and Storativity of Low-Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique*.
- ASTM Standard D 5079-02 (2006). 2006. *Standard Practices for Preserving and Transporting Rock Core Samples*.

- ASTM Standard D 5782-95 (2006). 2006. *Standard Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices*.
- ASTM Standard D 5783-95 (2006). 2006. *Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices*.
- ASTM Standard D 5784-95 (2006). 2006. *Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices*.
- ASTM Standard D 5872-95 (2006). 2006. *Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices*.
- ASTM Standard D 5876-95 (2005). 2005. *Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices*.
- ASTM Standard D 6282-98 (2005). 2005. *Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations*.
- USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites*. EM 1110-1-4000. 1, November.

STANDARD OPERATING PROCEDURE 30.1 SOIL SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for sampling surface and subsurface soils.

2.0 MATERIALS

- Stainless steel scoop, spoon, trowel, knife, spatula, (as needed);
- Split-spoon, Shelby tube, or core barrel sampler;
- Hand auger or push tube sampler;
- Drill rig and associated equipment (subsurface soil);
- Stainless steel bowls;
- Photoionization detector or other appropriate instrument as specified in site-specific health and safety plan;
- Sampling equipment for collection of volatile organic samples;
- Appropriate sample containers;
- Appropriate sample labels and packaging material.;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination equipment and supplies (SOP 80.1).

3.0 PROCEDURE

3.1 DOCUMENTATION

Soil sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.2 SURFICIAL SOIL SAMPLES

The targeted depths for surficial soil samples (surface and near surface) will be specified in the work plan addenda developed for site-specific investigations.

1. All monitoring equipment should be appropriately calibrated before beginning sampling according to the requirements of the work plan addenda and SOP 90.1 or 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Use a spade, shovel, or trowel or other equipment (manufactured from material, which is compatible with the soil to be sampled) to remove any overburden material present (including vegetative mat) to the level specified for sampling.
4. Measure and record the depth at which the sample will be collected with an engineers scale or tape.

5. Remove the thin layer that was in contact with the overburden removal equipment using a clean stainless steel scoop or equivalent and discard it.
6. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
7. When a sample will not be collected with a core type of sampler (push tube, split spoon, etc.), the sample for VOC analysis will be collected from freshly exposed soil. The method of collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
8. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
9. Collect a suitable volume of sample from the targeted depth with a clean stainless steel scoop (or similar equipment), push tube sampler, or bucket auger
10. For core type of samplers, rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife. Samples collected with a bucket auger or core type of sampler should be logged per the requirements of SOP 10.3.
11. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
12. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
13. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
14. Return any remaining unused soil to the original sample location. If necessary, add clean sand to bring the subsampling areas back to original grade. Replace the vegetative mat over the disturbed areas.

3.3 SUBSURFACE SAMPLES

All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.

1. All monitoring equipment should be appropriately calibrated before sampling according to the requirement of the work plan addendum and SOP 90.1 or SOP 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Collect split-spoon; core barrel, Shelby tube, sonic core or other similar samples during drilling.
4. Upon opening sampler or extruding sample, immediately screen soil for VOCs using a PID or appropriate instrument. If sampling for VOCs, determine the area of highest concentration; use a

stainless steel knife, trowel, or lab spatula to cut the sample; and screen for VOCs with monitoring instrument(s).

5. Log the sample on the boring log before extracting from the sampler per the requirements of SOP 10.3.
6. Any required VOC samples will be collected first followed by the other parameters. VOC samples will not be composited or homogenized and will be collected from the area exhibiting the highest screening level. The method of VOC sample collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
8. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
9. If homogenization or compositing of the sampling location is not appropriate for other parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
10. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
15. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
16. Discard any remaining sample into the drums used for collection of cuttings.
17. Abandon borings according to procedures outlined in SOP 20.2.

3.4 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

NOTES: If sample recoveries are poor, it may be necessary to composite samples before placing them in jars. In this case, the procedure will be the same except that two split-spoon samples (or other types of samples) will be mixed together. The boring log should clearly state that the samples have been composited, which samples were composited, and why the compositing was done. In addition, VOC fraction should be collected from the first sampling device.

When specified, samples taken for geotechnical analysis (e.g., percent moisture, density, porosity, and grain size) will be undisturbed samples, such as those collected using a thin-walled (Shelby tube) sampler, sonic core sampler, etc.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

Soil samples will not include vegetative matter, rocks, or pebbles unless the latter are part of the overall soil matrix.

6.0 REFERENCES

ASTM Standard D 1586-99. 1999. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.

ASTM Standard D 1587-00 (2007) e1. 2007. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes*.

ASTM Standard D 5633-04. 2004. *Standard Practice for Sampling with a Scoop*.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans*. EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 30.2 GROUNDWATER SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the collection of groundwater samples from monitoring wells.

2.0 MATERIALS

- Work Plans;
- Field logbooks and field parameter forms;
- Plastic sheeting;
- Decontamination equipment and supplies (SOP 80.1);
- Variable-speed, low-flow submersible pump with safety drop cable;
- Nylon stay-ties;
- Generator;
- Dedicated Teflon tubing or Teflon lined polyethylene tubing;
- Flow-through-cell and probes for measuring pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity (SOP 40.1);
- Electronic water-level indicator;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Cooler with ice;
- Silicone tubing;
- 0.45-micron disposable filters (as appropriate).
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan;
- Photoionization detector (PID) or other appropriate monitoring instrument per the site-specific health and safety plan; and
- Appropriate containers for investigation-derived material.

3.0 PROCEDURE

3.1 DOCUMENTATION

Groundwater sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

The following are general rules for the field parameter logbook for groundwater, as described in SOP 10.2:

- Only information for one site or installation per logbook. The same book maybe used for more than one sampling event.

- The first five pages will be reserved for index, general notes, etc. Sign and date each entry.
- Fill in the forms.
- Duplicate copies, index pages, and calibration sheets remain intact.

3.2 OVERVIEW OF SAMPLING TECHNIQUES

In general, two different techniques may be used to sample groundwater from monitoring wells at Radford Army Ammunition Plant (RFAAP):

- Low flow purging and sampling (Type I); and
- Conventional purging and low-flow sampling (Type II).

These two sampling techniques are intended to address the different groundwater conditions that may be encountered at RFAAP.

The Type I sampling technique will be used in the following situations:

- In wells where only one discrete water-producing zone is encountered;
- In wells with no discrete water bearing zone and a low yield (generally < 0.5 liters per minute); and
- In wells sampled during seasonal low groundwater conditions with greatly reduced yield.

The Type II sampling technique will be used in the following situations:

- In a well with potential or documented multiple flow zones and where individual flow zones will not be evaluated;
- In moderately producing wells (> 0.5 liters per minute) where no discrete flow zones were documented during drilling; and
- In wells sampled during seasonal high groundwater conditions with enhanced yield (and potentially additional flow zones).

Groundwater samples should be collected no sooner than 14 days after well development. Information from the boring logs, well completion records, and well development records should be reviewed before sampling a well to determine the most appropriate sampling technique. Pertinent information for each well to be sampled includes:

- Well construction;
- Depth and nature of water producing zones;
- Sustainable pumping rate of the well to be sampled;
- Well recharge characteristics; and
- Baseline turbidity.

Because of the heterogeneous nature of the fracture and solution-enhanced fractured bedrock at RFAAP, monitoring well purging and sampling techniques will need to be flexible. This flexibility is necessary to obtain representative samples that meet the data quality objectives (DQOs) specified in site-specific work plan addenda.

In general, when using the pumps specified in the following sections, situate any gasoline-powered generator on level ground approximately 15 ft downwind from the well. All generator maintenance (oil and fueling) is to be performed off site. If the hose(s) and/or power cord of the pump is not on a reel, place the pump with its hose and power cord on the plastic sheeting downhill from the well.

3.3 TYPE I SAMPLING PROCEDURES

Type I low flow purging and sampling procedures include the following:

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.
- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.
- Well depth at the time of purging will be obtained from well construction and existing data.
- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the desired depth. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- For wells with very low sustainable pumping rates (≤ 0.5 liters per minute), the pump should be set in the middle of the saturated screen section of the well or middle of the water column for open wells. The pump should be set 12 hours prior to purging so that the depth to water equilibrates and sediments disturbed during pump placement have time to settle.
- For wells with sustainable pumping rates (> 0.5 liters per minute), the pumps will be set at a desired depth prior to purging, allowing for the depth to water to equilibrate before sampling. The desired depth will be specified in work plan addenda based on site-specific conditions and DQOs.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into a appropriate container(s) to collect purge water.
- Immediately prior to purging, the depth to water will be measured and record. Start pumping the water at a rate of 100 to 400 milliliters per minute. Avoid surging. The pumping rate should cause minimal drawdown (less than 0.2 ft). Water level measurements should be collected continuously to document stabilization of the water level. Pumping rates should, if needed, be reduced to the minimal capabilities of the pump to avoid dewatering the screen interval and ensure stabilization of indicator parameters.
- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.

- Continue purging until stabilization of indicator parameters is achieved. Stabilization is defined as three consecutive readings that are within the following criteria:
 - ± 0.1 for pH;
 - $\pm 3\%$ for specific conductance;
 - ± 10 mV for oxidation/reduction potential (Eh); and
 - $\pm 10\%$ for turbidity and dissolved oxygen.
- If the parameters have stabilized, but the turbidity is not in the range of 5 to 10 NTU, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-through cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- In general, samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is VOCs, extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any well location are site-specific and are specified in work plan addenda.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well by replacing and locking the lid.

3.4 TYPE II SAMPLING PROCEDURES

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.
- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.

- Well depth at the time of purging will be obtained from well construction and existing data.
- Calculate the standing water column in the well by subtracting the depth to water from the total depth of the well as recorded during completion of the well.
- From the water depth, well diameter, sand pack length, etc., calculate the equivalent volume (1 EV) of water in the well.

1 EV = volume in casing + volume in saturated sand pack. Therefore; if the water table lies below the top of the sand pack, use the following equation:

$$1 \text{ EV} = (pR_w^2 h_w) + (0.30p(R_s^2 - R_w^2)h_w) * (0.0043)$$

If the water table lies above the top of the sand pack use this equation:

$$1 \text{ EV} = [(pR_w^2 h_w) + (0.30p(R_s^2 - R_w^2)h_s)] * (0.0043)$$

Where: R_s = radius of sand pack in inches

R_w = radius of well casing in inches

h_s = height of sand pack in inches

h_w = water depth in inches

0.0043 gal/in³

Assumed filter pack porosity = 30%

Tables and graphs showing equivalent volumes for typical well constructions are available.

- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the middle of the saturated screen interval or water column in an open borehole. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into an appropriate container to collect purge water.
- Start purging the well at the minimally achievable pumping rate. Gradually increase the pumping rate to achieve the maximum flow rate of the pump or the maximum sustainable flow rate that does not draw down the static water level to a point below the top of the first water bearing zone, whichever is achieved first.
- During purging, water level measurements should be collected periodically to verify water levels in the well.
- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.
- Note when each indicator parameter stabilizes. Stabilization is defined as three consecutive readings that are within the following criteria:
 - ± 0.1 for pH;
 - $\pm 3\%$ for specific conductance;
 - ± 10 mV for oxidation/reduction potential (Eh); and
 - $\pm 10\%$ for turbidity and dissolved oxygen.

- Three calculated eVs of water in the well will be purged prior to sampling. It will be documented if stabilization of the indicator parameters has not occurred after three calculated well volumes have been removed and sampling procedures begin.
- If the turbidity is not in the range of 5 to 10 NTU when purging has been completed, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-through cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well by replacing and locking the lid.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addendum for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Refer to manufacturer's requirements for maintenance of pumps and generators.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

- ASTM Standard D 5903-96 (2006). 2006. *Planning and Preparing for a Groundwater Sampling Events*.
- USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans*. EM 200-1-3, 1 February.
- USEPA. 1995. *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures United States Environmental Protection Agency*, Office of Solid Waste and Emergency Response, EPA/540/S-95/504, December 1995.
- USEPA. 1997. *Recommended Procedure for Low-flow Purging and Sampling of Groundwater Monitoring Wells*. Bulletin No. QAD023, October.

STANDARD OPERATING PROCEDURE 30.6 CONTAINERIZED MATERIAL

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the opening and sampling of containerized liquids of potentially unknown substances.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Personal protective equipment and clothing per the site-specific health and safety plan;
- Monitoring instruments per the site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Tools;
- Historical data, if available;
- Sampling tube; and
- Remote samplers, as required.

3.0 PROCEDURE

Sealed containers with unknown contents represent potential severely hazardous situations for sampling teams. Even when the original identity of the contents is reasonably certain, contents may be under pressure or in a decomposed state and may readily react (sometimes violently) with air or water vapor in the atmosphere.

Only hazardous material specialists that have appropriate training and experience will inspect and sample unidentifiable drums or containers. Specialist team members will use extreme caution and care when opening sealed drums or cans of unknown content for purposes of inspection and sampling.

Efforts will be made to determine the identity of the contents, through markings, history of activities at the site, and similarity and proximity to containers of known contents. The range of possible hazards will dictate which specific procedure will be followed, and specific procedures will be identified in work plan addenda. All predetermined procedures will be strictly followed as designated by the site-specific conditions.

Using this SOP and appropriate health and safety protocols, field personnel will use extreme caution and care in opening sealed drums or cans of unknown contents for purposes of inspection and sampling. Specific activities include the following:

- Determine the identity of the contents through markings, history of activities at the site, and similarity and proximity to containers of known contents. The range of possible hazards will dictate which specific procedure should be followed.

- Handle containers as little as possible; however, if it is necessary to reorient a drum to allow access to a bung or cap, perform this activity using remote-handling forklift equipment with special drum-holding attachments.
- If contents are deemed to be under pressure, highly reactive, or highly toxic (or if these possibilities cannot be disproven), perform initial opening of the container remotely.
- Air monitoring stations will be established as necessary, using the following procedures:
 1. Affix a remote bung opener to the drum.
 2. Evacuate personnel to a safe distance or station them behind a barricade.
 3. Activate the non-sparking motor of the opener.
 4. After the bung is removed, monitor the drum for potential activity of the contents, such as vapor emission, smoking, or audible reaction.
 5. Approach cautiously while monitoring for toxic levels of airborne contaminants.
- If the contents of the drum pose acceptable hazards, accomplish opening (or inspection if previously opened remotely) and sampling with one of three approved devices. The preferred method is to use a clean glass tube, with or without bottom stopper, which can be placed in the drum (breaking it if necessary) after sampling is complete. Alternately (if a bung has been removed), a well sampler such as a Kemmererbailer can be used (but would require removal and cleaning or disposal according to the nature of the waste). By opening either of these devices at a desirable depth, stratified sampling can be performed. Also, the sampling tubes can be made with a plunger rod and O-ring seals at selected intervals, allowing simultaneous collection of multiple samples in a stratified medium.
- Following sampling, the drum will be resealed and/or overpacked to prevent any possibility of leakage while analysis determines the identity of the contents.
- Drums that do not have removable bungs may be opened remotely with a solenoid-activated punch (this requires that the drum be recontainerized or overpacked after sampling is complete).

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Not applicable.

6.0 REFERENCE

USEPA, 1989. A Compendium of Superfund Field Operation Methods. EPA/540/P-87/001. December.

STANDARD OPERATING PROCEDURE 30.7 SAMPLING STRATEGIES

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate sampling strategies for sampling various media.

2.0 MATERIALS

- Historical site data;
- Site topography;
- Soil types; and
- Sampled media.

3.0 PROCEDURE

The primary goal of any investigation is to collect samples representative of existing site conditions. Statistics are generally used to ensure samples are as representative as possible. Sampling plans may employ more than one approach to ensure project data quality objectives are adequately addressed. A comparison of sampling strategies is presented in Table 1.

3.1 CLASSICAL STATISTICAL SAMPLING

Classical statistical sampling strategies are appropriately applied to either sites where the source of contamination is known or small sites where the entire area is remediated as one unit. Primary limitations of this sampling approach include (1) inability to address media variability; (2) inadequate characterization of heterogeneous sites; and (3) inadequate characterization of sites with unknown contamination characteristics.

3.1.1 Simple Random Sampling

Simple random sampling is generally more costly than other approaches because of the number of samples required for site characterization. This approach is generally used when minimal site information is available and visible signs of contamination are not evident and includes the following features:

- Sampling locations are chosen using random chance probabilities.
- This strategy is most effective when the number of sampling points is large.

3.1.2 Stratified Random Sampling

This sampling approach is a modification to simple random sampling. This approach is suited for large site investigations that encompass a variety of soil types, topographic features, and/or land uses. By dividing the site into homogenous sampling strata based on background and historical data, individual random sampling techniques are applied across the site. Data acquired from each stratum can be used to determine the mean or total contaminant levels and provide these advantages:

- Increased sampling precision results due to sample point grouping and application of random sampling approach.
- Control of variances associated with contamination, location, and topography.

3.1.3 Systematic Grid

The most common statistical sampling strategy is termed either systematic grid or systematic random sampling. This approach is used when a large site must be sampled to characterize the nature and extent of contamination.

Samples are collected at predetermined intervals within a grid pattern according to the following approach:

- Select the first sampling point randomly; remaining sampling points are positioned systematically from the first point.
- Determine the grid design: one or two-dimensional. One-dimensional sample grids may be used for sampling along simple man-made features. Two-dimensional grid systems are ideal for most soil applications.
- Determine the grid type: square or triangular. Sampling is usually performed at each grid-line intersection. Other strategies include sampling within a grid center or obtaining composite samples within a grid.
- Each stratum is sampled based on using the simple random sampling approach but determined using a systematic approach.

3.1.4 Hot-Spot Sampling

Hot spots are small, localized areas of media characterized by high contaminant concentrations. Hot-spot detection is generally performed using a statistical sampling grid. The following factors should be addressed:

- Grid spacing and geometry. The efficiency of hot-spot searches is improved by using a triangular grid. An inverse relationship exists between detection and grid point spacing, e.g., the probability of hot-spot detection is increased as the spacing between grid points is decreased.
- Hot-spot shape/size. The larger the hot spot, the higher the probability of detection. Narrow or semi-circular patterns located between grid sampling locations may not be detected.
- False-negative probability. Estimate the false negative (β -error) associated with hot-spot analysis.

3.1.5 Geostatistical Approach

Geostatistics describe regional variability in sampling and analysis by identifying ranges of correlation or zones of influence. The general two-stage approach includes the following:

- Conducting a sampling survey to collect data defining representative sampling areas.
- Defining the shape, size, and orientation of the systematic grid used in the final sampling event.

3.2 NON-STATISTICAL SAMPLING

3.2.1 Biased Sampling

Specific, known sources of site contamination may be evaluated using biased sampling. Locations are chosen based on existing information.

3.2.2 Judgmental Sampling

This sampling approach entails the subjective selection of sampling locations that appear to be representative of average conditions. Because this method is highly biased, it is suggested that a measure of precision be included through the collection of multiple samples.

4.0 MAINTENANCE

Not applicable.

5.0 REFERENCES

- Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. John Wiley & Sons, Inc. 320 p.
- USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans*. EM200-1-3. 1 February.

TABLE 1
SAMPLING STRATEGIES

SAMPLING STRATEGY	DESCRIPTION	APPLICATION	LIMITATIONS
Classical Statistical Sampling Strategies			
Simple Random Sampling	Representative sampling locations are chosen using the theory of random chance probabilities.	Sites where background information is not available and no visible signs of contamination are present.	May not be cost-effective because samples may be located too close together. Does not take into account spatial variability of media.
Stratified Random Sampling	Site is divided into several sampling areas (strata) based on background or site survey information.	Large sites characterized by a number of soil types, topographic features, past/present uses, or manufacturing storage areas.	Often more cost-effective than random sampling. More difficult to implement in the field and analyze results. Does not take into account spatial variability of media.
Systematic Grid Sampling	Most common statistical strategy; involves collecting samples at predetermined, regular intervals within a grid pattern.	Best strategy for minimizing bias and providing complete site coverage. Can be used effectively at sites where no background information exists. Ensures that samples will not be taken too close together.	Does not take into account spatial variability of media.
Hot-Spot Sampling	Systematic grid sampling strategy tailored to search for hot spots.	Sites where background information or site survey data indicate that hot spots may exist.	Does not take into account spatial variability of media. Tradeoffs between number of samples, chance of missing a hot spot, and hot spot size/shape must be weighed carefully.
Geostatistical Approach	Representative sampling locations are chosen based on spatial variability of media. Resulting data are analyzed using kriging, which creates contour maps of the contaminant concentrations and the precision of concentration estimates.	More appropriate than other statistical sampling strategies because it takes into account spatial variability of media. Especially applicable to sites where presence of contamination is unknown.	Previous investigation data must be available and such data must be shown to have a spatial relationship.
Non-Statistical Sampling Strategies			
Biased Sampling	Sampling locations are chosen based on available information.	Sites with known contamination sources.	Contaminated areas can be overlooked if background information or visual signs of contamination do not indicate them. Best used if combined with a statistical approach, depending on the project objectives.
Judgmental Sampling	An individual subjectively selects sampling locations that appear to be representative of average conditions.	Homogenous, well-defined sites.	Not usually recommended due to bias imposed by individual, especially for final investigations.

STANDARD OPERATING PROCEDURE 30.9 COLLECTION OF SOIL SAMPLES BY USEPA SW 846 METHOD 5035 USING DISPOSABLE SAMPLERS

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) outlines the recommended protocol and equipment for collection of representative soil samples to monitor potential volatile organic contamination in soil samples.

This method of sampling is appropriate for surface or subsurface soils contaminated with low to high levels of volatile organic compounds (VOCs). This sampling procedure may be used in conjunction with any appropriate determinative gas chromatographic procedure, including, but not necessarily limited to, SW-846 Method 8015, 8021, and 8260.

2.0 MATERIALS

- Work Plans;
- Field Logbook;
- Photoionization Detector (PID) or other monitoring instrument(s) per site-specific health and safety plan;
- Personal protective equipment and clothing per site-specific health and safety plan;
- Soil sampling equipment, as applicable (SOP 30.1);
- Disposable sampler;
- T-handle and/or Extrusion Tool; and
- Decontamination equipment and supplies (SOP 80.1).

3.0 PROCEDURE

3.1 METHOD SUMMARY

Disposable samplers are sent to the field to be used to collect soil samples. Three samplers must be filled for each soil sampling location, two for the low-level method (sodium bisulfate preservation) and one for the high level method (methanol preservation). After sample collection, disposable samplers are immediately shipped back to the laboratory for preservation (adding soil sample into methanol and sodium bisulfate solution). The ratio of volume of methanol to weight of soil is 1:1 as specified in SW-846 Method 5035 (Section 2.2.2). The amount of preservative in the solution corresponds to approximately 0.2 g of preservative for each 1 g of sample. Enough sodium bisulfate should be present to ensure a sample pH of ≤ 2 .

If quality assurance/quality control (QA/QC) samples are needed, seven samplers will be needed for the original, matrix spike, and matrix spike duplicate analysis. Soil samples are collected in the field using the disposable samplers, sealed and returned to the laboratory. A separate aliquot of soil is collected in a 125-mL container for dry weight determination.

3.2 SAMPLE CONTAINERS, PRESERVATION, HANDLING AND STORAGE

After sample collection, the disposable samplers must be cooled to and maintained at 4°C. The contents of the samplers will be analyzed using EPA methods 8015, 8021, and/or 8260. The **disposable** sampler is a single use device. It cannot be cleaned and/or reused.

Disposable samplers have a 48 hour holding time from sample collection to sample preparation in the laboratory. Return the samplers to the laboratory immediately after sampling.

3.3 SAMPLE PROCEDURES

Before sampling, the disposable sampler should be prepared as follows:

1. Unpack the cooler/sampling kit received from the laboratory. Disposable samplers are packed in sealed aluminized bags. These should be over packed in plastic zip lock bags. A T-Handle will also be needed to collect samples with the disposable sampler.
2. Hold coring body and push plunger rod down until small O-ring rests against tabs. This will assure that plunger moves freely.
3. Depress locking lever on the sampler T-Handle (or other extraction device). Place coring body, plungers end first, into the open end of the T-Handle, aligning the two slots on the coring body with the two locking pins in the T-Handle. Twist the coring body clockwise to lock the pins in the slots. Check to ensure the sampler is locked in place. Sampler is ready for use.

The following procedure should be followed when using a disposable sampler to sample for VOCs in soil:

1. After the soil-sampling device (split spoon, corer, etc.) is opened, the sampling process should be completed in a minimum amount of time with the least amount of disruption.
2. Visual inspection and soil screening should be conducted after the sampler is opened and a fresh surface is exposed to the atmosphere. Soil screening should be conducted with an appropriate instrument (PID or FID).
3. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
4. Orient the T-Handle with the T-up and the coring body down. This positions the plunger bottom flush with bottom of coring body (ensure that plunger bottom is in position). Using T-Handle, push sampler into soil until the coring body is completely full taking care not to trap air behind the sampler. When full, the small o-ring will be centered in the T-Handle viewing hole. Remove sampler from soil. Wipe excess soil from coring body exterior with a clean disposable paper towel.
5. Cap coring body while it is still on the T-Handle. **Push** cap over flat area of ridge **and twist** to lock cap in place. ***Cap must be seated to seal sampler.***
6. Remove the capped sampler by depressing locking lever on T-Handle while twisting and pulling sampler from T-Handle.
7. Lock plunger by rotating extended plunger rod fully counterclockwise until wings rest firmly against tabs.
8. Fill the 125-mL wide mouth jar for the non-preserved portion of the sample to be used for a moisture determination. These may be in a cardboard box. Retain all packaging to return the samples.
9. The disposable sampler should collect approximately 5 grams of soil (not necessary to weigh in the field). After a sample has been collected and capped, tear off the identification tag found at the bottom of the label on the aluminized bag. This tag is added to the sampler on the cap used to seal the sampler.

10. Place the sampler back in the aluminized bag and seal the top (a zip-lock seal). Make sure all the appropriate information is on the label. Record the sampler ID number on the chain-of-custody. Make sure each sampler and 125-mL container is labeled with the same location identification. The sampler should be placed inside the plastic zip-lock bags.
11. Place the 125-mL wide mouth jars in the cooler with the sampler on top. These should be sandwiched between bags of ice to maintain the correct temperature. If sent with the jars and samplers, a temperature bottle (used to evaluate the temperature on receipt) should be placed in the middle of the jars. The sample temperature should be 4°C during shipment.
12. Ship the samples so that they will be received within 24 hours of sampling. The laboratory must receive the sampler within 40 hours of the collection so that they can be correctly preserved.

3.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

1. All data must be documented on chain-of-custody forms, field data sheets and in the field logbook.
2. An equipment blank is a QA/QC sample that will determine potential contamination from sampling equipment used to collect and transfer samples from the point of collection to the sample container. An equipment blank is performed by pouring demonstrated analyte free water from one sample container, over a sampler, and into a separate set of identical sample containers. The equipment blank is optional when sampling with the methanol preservation technique. It may be required on a site-specific basis if elevated analytical results are suspected to be due to cross contamination from sampling equipment.
3. A trip blank is a QA/QC sample, which will determine additional sources of contamination that may potentially influence the samples. The sources of the contamination may be from the laboratory, sample containers, or during shipment. The laboratory prepares a trip blank at the same time and in the same manner as the sample containers. The trip blank must accompany the sample containers to the field and back to the laboratory along with the collected samples for analysis. It must remain sealed at all times until it is analyzed at the laboratory. The frequency of collection for the trip blank must be at a rate of one per sample shipment.

3.5 LIMITATIONS IN SAMPLING

This sampling protocol will not be applicable to all solid environmental matrices, such as those that cannot be cored including non-cohesive granular material, gravel, or hard dry clay. In this case, the procedure for collecting VOC samples using Methanol Preservation should be used (see SOP 30.8).

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

En Novative Technologies, Inc. 2000. Users Manual for En Core® Sampler. February 2001.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans*. EM 200-1-3, 1 February.

USEPA. 1997. *Test Methods for Evaluating Solid Waste, Volume IB: Laboratory Manual Physical/Chemical Methods*, Third Edition, (as updated through update IIIA). Office of Solid Waste and Emergency Response, Washington, DC.

STANDARD OPERATING PROCEDURE 40.1 MULTIPARAMETER WATER QUALITY MONITORING INSTRUMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operation with the multiparameter water quality logging system (data transmitter and visual display). This system can monitor up to eleven basic parameters, including dissolved oxygen, percent saturation, temperature, pH, specific conductance, resistivity, salinity, total dissolved solids, redox, level, and depth.

2.0 MATERIALS

- Visual display;
- Data transmitter;
- Underwater cables; and
- Field logbooks.

3.0 PROCEDURE

3.1 CALIBRATION

Calibration will be performed in the field daily before use according to manufacturer's specifications. The following parameters are calibrated to the following standards:

- Temperature—none required;
- Specific conductance—KCl or seawater standards;
- pH—pH 7 buffer plus a slope buffer;
- Dissolved oxygen—saturated air or saturated water;
- Redox—quinhydrone or transfer;
- Depth—set zero in air;
- Level—set zero in air; and
- Salinity—uses calibration for specific conductance.

3.2 OPERATION

1. Attach the cable to the transmitter.
2. Connect the other end of the cable to the display.
3. Press the On/Off key on the display panel. Allow a few seconds for the transmitter to start sending data to the display screen.
4. Calibrate the transmitter.
5. Deploy the sensor into a minimum of 4 in. of water.
6. Write data values from the display screen in the appropriate field logbook.

7. Retrieve sensor and clean the transmitter to prevent cross-contamination.
8. Move to the next sampling location. If travel time is great, turn off display by pressing On/Off key. Check condition of probes after each deployment.
9. Disconnect the transmitter when finished sampling for the day.

4.0 MAINTENANCE

Maintain according to specific manufacturer's specifications.

5.0 PRECAUTIONS

- Check condition of probes frequently between sampling; and
- Do not force pins into the connectors; note the keying sequence.

6.0 REFERENCES

Manufacturer's Handbook.

STANDARD OPERATING PROCEDURE 40.2 WATER LEVEL AND WELL-DEPTH MEASUREMENTS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for measuring water level and well depth. This procedure is applicable to the sampling of monitoring wells and must be performed before any activities that may disturb the water level, such as purging or aquifer testing.

2.0 MATERIALS

- Work Plans;
- Well construction diagrams;
- Field logbook;
- Photoionization detector (PID) or other monitoring instruments per site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Electric water level indicator (dipmeter) with cable measured at 0.01 ft increments;
- Oil-water interface probe (if non-aqueous phase liquid (NAPLs) are suspected to be present); and
- Plastic sheeting.

3.0 PROCEDURE

3.1 PRELIMINARY STEPS

1. Locate the well and verify its position on the site map. Record whether positive identification was obtained, including the well number and any identifying marks or codes contained on the well casing or protective casing. Gain access to the top of the well casing.
2. Locate the permanent reference mark at the top of the casing. This reference point will be scribed, notched, or otherwise noted on the top of the casing. If no such marks are present, measure to the top of the highest point of the well casing and so note this fact in field logbook. Determine from the records and record in the notebook the elevation of this point.
3. Record any observations and remarks regarding the completion characteristics and well condition, such as evidence of cracked casing or surface seals, security of the well (locked cap), and evidence of tampering.
4. Keep all equipment and supplies protected from gross contamination; use clean plastic sheeting. Keep the water level indicator probe in its protective case when not in use.

3.2 OPERATION

1. Sample the air in the well head for gross organic vapors by lifting the well cap only high enough for an organic vapor meter (PID or FID) probe to be entered into the well casing. This will indicate the presence of gross volatile contaminants as well as indicating potential sampler exposure.

2. Remove cap. Allow well to vent for 60–90 seconds. Resample headspace. Record both readings. If the second reading is lower than the first, use the second reading to determine whether respiratory protection will be required during subsequent water level and well depth determinations and sampling.
3. Note that all headspace sampling must be performed at arm's length and from the upwind side of the well if possible.
4. If NAPL contamination is suspected, use an interface probe to determine the existence and thickness of NAPLs.
 - Open the probe housing, turn the probe on, and test the alarm. Slowly lower the probe into the well until the alarm sounds. A continuous alarm indicates a NAPL, while an intermittent alarm indicates water. If a NAPL is detected, record the initial level (first alarm). Mark the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable sufficiently to record the depth.
 - Continue to slowly lower the probe until it passes into the water phase. Slowly retract the probe until the NAPL alarm sounds and record that level in the manner as described above.
 - Record the thickness of the LNAPL (see Section 3.3.1).
 - Continue to slowly lower the interface probe through the water column to check for the presence of DNAPL.
 - Measure and record the thickness of the DNAPL layer (if any) as described above.
 - Slowly raise the interface probe, recording the depth to each interface as the probe is withdrawn. If there is a discrepancy in depths, clean the probe sensors and re-check the depths.
 - NOTE: Air-liquid interface depth is more reliable if probe is lowered into liquid. NAPL-water depths are more accurate if probe is moved from water into NAPL.
 - Always lower and raise interface probe slowly to prevent undue mixing of media.
 - Always perform NAPL check in wells installed in areas with suspected NAPL contamination. Always perform NAPL check if headspace test reveals presence of volatiles. Always perform NAPL check the first time a well is sampled. If a well has been sampled previously and no NAPLs were present and none of the proceeding conditions are met, the NAPL check may be omitted.
5. If no NAPL is present, use an electronic water level detector as follows.
 - Remove the water level indicator probe from the case, turn on the sounder, and test check the battery and sensitivity scale by pushing the red button. Adjust the sensitivity scale until you can hear the buzzer.
 - Slowly lower the probe and cable into the well, allowing the cable reel to unwind. Continue lowering until the meter buzzes. Very slowly, raise and lower the probe until the point is reached where the meter just buzzes. Marking the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable and record the depth.
6. To measure the well depth, lower electric water level indicator probe or tape until slack is noted. Very slowly raise and lower the cable until the exact bottom of the well is “felt.” Measure (cable) or read the length (tape) and record the depth.

7. Note that if the electric water level indicator is used to determine depth of well, the offset distance between the tip of the probe and the electrode must be added to the reading to determine actual depth.
8. Withdraw the probe or tape.
9. Decontaminate the probe(s) and cable(s), in accordance with SOP 80.1.

3.3 DATA RECORDING AND MANIPULATION

Record the following information in the field logbook and appropriate sampling forms:

- Date and time;
- Weather;
- Method of measurement;
- Casing elevation;
- NAPL surface elevation = casing elevation - depth to NAPL;
- Apparent measured LNAPL thickness = depth to bottom of NAPL - depth to top of NAPL;
- Water level elevation = casing elevation - depth to water; and
- Well bottom elevation = casing elevation - depth to bottom (or read directly from tape).

4.0 CALIBRATION

No calibration is required. Ensure operability of electric water level indicator by testing sounder before use.

5.0 PRECAUTIONS

- Depending upon the device used, correction factors may be required for some measurements;
- Check instrument batteries before each use; and
- Exercise care not to break the seals at the top of the electric water level indicator probe.

6.0 REFERENCES

- ASTM Standard D 4750-87 (2001). 2001. *Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)*.
- M^cAlary, T. A., and Barker, J.F. 1987. "Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials" in *Ground Water Monitoring Review*. Fall 1987.
- Thornhill, Jerry T. 1989. Accuracy of Depth to Groundwater Measurements; in "EPA Superfund Ground Water Issue" EPA/540/4-89/002.

STANDARD OPERATING PROCEDURE 50.1 SAMPLE LABELS

1.0 SCOPE AND APPLICATION

Every sample will have a sample label uniquely identifying the sampling point and analysis parameters. The purpose of this standard operating procedure (SOP) is to delineate protocols for the use of sample labels. An example label is included as Figure 50.1-A. Other formats with similar levels of detail are acceptable.

2.0 MATERIALS

- Sample label; and
- Indelible marker.

3.0 PROCEDURE

The use of preprinted sample labels is encouraged and should be requested from the analytical support laboratory during planning activities.

As each sample is collected, fill out a sample label ensuring the following information has been collected:

- Project name;
- Sample ID: enter the SWMU number and other pertinent information concerning where the sample was taken. This information should be included in site-specific work plan addenda;
- Date of sample collection;
- Time of sample collection;
- Initials of sampler(s);
- Analyses to be performed (NOTE: Due to number of analytes, details of analysis should be arranged with lab *a priori*); and
- Preservatives (water samples only).

Double-check the label information to make sure it is correct. Detach the label, remove the backing and apply the label to the sample container. Cover the label with clear tape, ensuring that the tape completely encircles the container.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

USEPA. 2001 (Reissued May 2006). *EPA Requirements for Quality Assurance Project Plans*. EPA/240/B-01/003, QA/R5, Final, Office of Research and Development, Washington, D.C. March 2001

**FIGURE 50.1-A
SAMPLE LABEL**

PROJECT NAME	_____
SAMPLE ID	_____
DATE:	____/____/____ TIME: ____:____
ANALYTES:	VOC SVOC P/P METALS CN
	PAH D/F HERBs ANIONS TPH
	ALK TSS
PRESERVATIVE:	[HCl] [HNO ₃] [NaOH] [H ₂ SO ₄]
SAMPLER:	_____

STANDARD OPERATING PROCEDURE 50.2

SAMPLE PACKAGING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the packing and shipping of samples to the laboratory for analysis.

2.0 MATERIALS

- Waterproof coolers (hard plastic or metal);
- Metal cans with friction-seal lids (e.g., paint cans);
- Chain-of-custody forms;
- Chain-of-custody seals (optional);
- Packing material;
- Sample documentation;
- Ice;
- Plastic garbage bags;
- Clear Tape;
- Zip-top plastic bags; and
- Temperature blanks provided by laboratory for each shipment.

3.0 PROCEDURE

1. Check cap tightness and verify that clear tape covers label and encircles container.
2. Wrap sample container in bubble wrap or closed cell foam sheets. Samples may be enclosed in a secondary container consisting of a clear zip-top plastic bag. Sample containers must be positioned upright and in such a manner that they will not touch during shipment.
3. Place several layers of bubble wrap, or at least 1 in. of vermiculite on the bottom of the cooler. Line cooler with open garbage bag, place all the samples upright inside the garbage bag and tie.
4. Double bag and seal loose ice to prevent melting ice from soaking the packing material. Place the ice outside the garbage bags containing the samples.
5. Pack shipping containers with packing material (closed-cell foam, vermiculite, or bubble wrap). Place this packing material around the sample bottles or metal cans to avoid breakage during shipment.
6. A temperature blank (provided by laboratory) will be included in each shipping container to monitor the internal temperature. Samples should be cooled to 4 degrees C on ice immediately after sampling.
7. Enclose all sample documentation (i.e., Field Parameter Forms, Chain-of-Custody forms) in a waterproof plastic bag and tape the bag to the underside of the cooler lid. If more than one cooler is being used, each cooler will have its own documentation. Add the total number of shipping containers included in each shipment on the chain-of-custody form.

8. Seal the coolers with signed and dated custody seals so that if the cooler were opened, the custody seal would be broken. Place clear tape over the custody seal to prevent damage to the seal.
9. Tape the cooler shut with packing tape over the hinges and place tape over the cooler drain.
10. Ship all samples via overnight delivery on the same day they are collected if possible.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

5.1 PERMISSIBLE PACKAGING MATERIALS

- Non-absorbent
 - Bubble wrap; and
 - Closed cell foam packing sheets.
- Absorbent
 - Vermiculite.

5.2 NON-PERMISSIBLE PACKAGING MATERIALS

- Paper;
- Wood shavings (excelsior); and
- Cornstarch “peanuts.”

6.0 REFERENCES

- USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program*. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, D.C., December 1990.
- USEPA. 1991. *User's Guide to the Contract Laboratory Program*. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response. January 1991.
- USEPA. 2001 (Reissued May 2006). *EPA Requirements for Quality Assurance Project Plans*. EPA/240/B-01/003, QA/R5, Final, Office of Research and Development, Washington, D.C. March 2001

STANDARD OPERATING PROCEDURE 70.1 INVESTIGATION-DERIVED MATERIAL

1.0 SCOPE AND APPLICATION

Management of investigation-derived material (IDM) minimizes the potential for the spread of waste material onsite or offsite through investigation activities. The purpose of this standard operating procedure (SOP) is to provide general guidelines for appropriate management of potentially contaminated materials derived from the field investigations. Specific procedures related to the transportation and disposal of hazardous waste are beyond the scope of this SOP.

2.0 INTRODUCTION

Investigation derived material (IDM) consists of waste materials that are known or suspected to be contaminated with waste substances through the actions of sample collection or personnel and equipment decontamination. These materials include decontamination solutions, disposable equipment, drill cuttings and fluids, and water from groundwater monitoring well development and purging. To the extent possible, the site manager will attempt to minimize the generation of these materials through careful design of decontamination schemes and groundwater sampling programs. Testing conducted on soil and water investigation-derived material will show if they are also hazardous wastes as defined by RCRA. This will determine the proper handling and ultimate disposal requirements.

The criteria for designating a substance as hazardous waste according to RCRA is provided in 40 CFR 261.3. If IDM meet these criteria, RCRA requirements will be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR 262.34. Those materials that are judged potentially to meet the criteria for a regulated solid or hazardous waste will be placed in DOT-approved 55-gallon steel drums or another type of DOT approved container; based on waste characteristics and volume.

Investigation-derived material will be appropriately placed in containers, labeled, and tested to determine disposal options in accordance with RCRA regulations and Virginia Hazardous Waste Management Regulations.

3.0 INVESTIGATION-DERIVED MATERIAL MANAGEMENT

Procedures that minimize potential for the spread of waste material include minimizing the volume of material generated, material segregation, appropriate storage, and disposal according to RCRA requirements.

3.1 WASTE MINIMIZATION

In the development of work plan addenda, each aspect of the investigation will be reviewed to identify areas where excess waste generation can be eliminated. General procedures that will eliminate waste include avoidance of unnecessary exposure of materials to hazardous material and coordination of sampling schedules to avoid repetitious purging of wells and use of sampling equipment.

3.2 WASTE SEGREGATION

Waste accumulation and management procedures to be used depend upon the type of material generated. For this reason, IDM described below are segregated into separate 55-gallon storage drums or other appropriate DOT containers. Waste materials that are known to be free of potential hazardous waste contamination (such as broken sample bottles or equipment containers and wrappings) must be collected separately for disposal to municipal systems. Large plastic garbage or "lawn and leaf" bags are useful for collecting this trash. Even "clean" sample bottles or Tyvek should be disposed of with care. Although they are not legally a problem, if

they are discovered by the public they may cause concern. Therefore, items that are known to be free from contamination but are also known to represent “hazardous or toxic waste” to the public must not be disposed of in any public trash receptacle, such as found at your hotel or park.

3.2.1 Decontamination Solutions

Solutions considered investigation-derived materials range from detergents, organic solvents, and acids used to decontaminate small hand samplers to steam-cleaning rinsate used to wash drill rigs and other large equipment. These solutions are to be placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT approved containers. Residual liquid IDM from decontamination pads will be removed and appropriately placed in container(s) at the end of each field day.

3.2.2 Soil Cuttings and Drilling Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities or drilling for the collection of subsurface soil samples or the installation of monitoring wells. Depending on the type of drilling, drilling fluids known as “muds” may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Drill cuttings, whether generated with or without drilling fluids, are to be removed with a flat-bottomed shovel and placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT containers, as conditions or volume of IDM dictate.

3.2.3 Well Development and Purge Water

Well development and purge water is removed from monitoring wells to repair damage to the aquifer following well installation, obtain characteristic aquifer groundwater samples, or measure aquifer hydraulic properties. The volume of groundwater to be generated will determine the appropriate container to be used for accumulation of IDM.

For well development and purging, 55-gallon drums are typically an efficient container for accumulation. When larger volumes of water are removed from wells, such as when pumping tests are conducted, the use of large-volume portable tanks such as “Baker Tanks” should be considered for IDM accumulation.

Analytical data for groundwater samples associated with the well development and purge water will be used to assist in characterizing IDM and evaluating disposal options.

3.2.4 Personal Protective Equipment and Disposable Sampling Equipment

Personal protective equipment and clothing (PPE) may include such items as Tyvek coveralls, gloves, booties, and APR cartridges. Disposable sampling equipment may include such items as plastic sheeting, bailers, disposable filters, disposable tubing and paper towels. PPE and disposable sampling equipment that have or may have contacted contaminated media (soil, water, etc.) will be segregated and placed in 55-gallon drums separate from soil and water IDM. Disposition of this type of IDM will be determined by the results of IDM testing of the media in which the PPE and sampling equipment contacted.

3.3 MATERIAL ACCUMULATION

The IDM in containers must be placed in an appropriate designated RCRA container accumulation area at RFAAP, where it is permissible to accumulate such waste. IDM placed into a designated 90-day accumulation area will be properly sealed, labeled and covered. All drums will be placed on pallets.

A secure and controlled waste staging area will be designated by the installation prior the commencement of field sampling activities. Per the facility’s requirements as a RCRA large quantity generator, waste accumulation cannot exceed 90 days for materials presumed or shown to be RCRA-designated hazardous wastes; waste which is known not to be RCRA-designated waste should be promptly disposed to municipal waste systems or appropriate facility.

3.3.1 IDM Accumulation Containers

Containers will be DOT-approved (DOT 17H 18/16GA OH unlined) open-head steel drums or other DOT approved container, as appropriate.

Container lids should lift completely off be secured by a bolt ring (for drum). Order enough containers to accumulate all streams of expected IDM including soil, PPE and disposable sampling equipment, decontamination water, purge water, etc.

Solid and liquid waste streams will not be mixed in a container. PPE and expendable sampling equipment will be segregated from other IDM and placed in different containers than soil. Containers inside containers are not permitted. PPE must be placed directly in a drum not in a plastic bag.

Pallets are often required to allow transport of filled drums to the staging area with a forklift. Normal pallets are 3×4 ft and will hold two to three 55-gallon drums depending on the filled weight. If pallets are required for drum transport or storage, field personnel are responsible for ensuring that the empty drums are placed on pallets before they are filled and that the lids are sealed on with the bolt-tighten ring after the drums are filled. Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move the drums by hand.

3.3.2 Container Labeling

Each container that is used to accumulate IDM will be appropriately labeled at the time of accumulation and assigned a unique identification number for tracking purposes. The following information will be written in permanent marker on a drum label affixed on the exterior side at a location at least two-thirds of the way up from the bottom of the drum.

- Facility name.
- Accumulation start date and completion date.
- Site identifier information (SWMU, boring, well, etc.).
- Description of IDM.
- Drum ID No.

4.0 MATERIAL CHARACTERIZATION AND DISPOSAL

IDM will be characterized and tested to determine whether it is a hazardous waste as defined by 40 CFR Part 261 and to determine what disposal options exist in accordance with RCRA regulations and the Virginia Hazardous Waste Management Regulations (VHWMR).

In general, IDM will be considered a hazardous waste if it contains a listed hazardous waste or if the IDM exhibits a characteristic of hazardous waste.

Work plan addenda will identify the appropriate characterization and testing program for IDM based on the following:

- Site-specific conditions related to chemicals of concern, etc.
- The nature and quantity of expected IDM to be generated during site-specific investigations.
- Applicable Federal, State, and local regulations, such as RCRA, VHWMR regulations and policies and procedures, and Army Regulation 200-1.

- RFAAP specific requirements and policies for IDM characterization and disposal at the time of the investigation.

In general, appropriate USEPA SW 846 Test Methods for Evaluating Solid Waste will be used for testing IDM and will be specified in work plan addenda. Other appropriate test methods may be specified by RFAAP in addition to SW 846 Methods that are specific to installation operations, the site of interest (percent explosive content, reactivity, etc.), or requirements for disposal at RFAAP water treatment facilities or publicly owned treatment works.

Responsibility for the final disposal of IDM will be determined before field activities are begun and will be described in work plan addenda. Off-site disposal of IDM will be coordinated with RFAAP (generator) to ensure appropriate disposition. The contractor will coordinate IDM transportation and disposal activities for RFAAP (generator).

At the direction of RFAAP, appropriate waste manifests will be prepared by the USACE contractor or Alliant Techsystems subcontractor for transportation and disposal. Alliant Techsystems or other appropriate RFAAP entity will be listed as the generator and an appointed representative from RFAAP will review and sign the manifest for offsite disposal.

RFAAP will make the final decision on the selection of the transporter, storage, and disposal facility (TSDFs) or recycling facility. RFAAP will provide the contractor a listing of previously used TSDFs for priority consideration. Proposed facilities that are not included on the listing are required to provide a copy of the TSDFs most recent state or federal inspection to the installation. Waste characterization and testing results will be submitted to RFAAP (generator) for review and approval before final disposition of the material.

Hazardous waste: Prior to final disposition, a hazardous waste manifest will be furnished by the TSDF to accompany transport to the disposal facility. Following final disposition, a certificate of disposal will be furnished by the disposal facility. Copies of the manifests and certificates of disposal are to be provided to RFAAP and retained on file by the contractor or subcontractor.

5.0 PRECAUTIONS

- Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move drums by hand.
- Refer to the site-specific health and safety plan when managing IDM.

6.0 REFERENCES

Safety Rules for Contractors and Subcontractors, (As Updated). Alliant Techsystems, Incorporated, Radford Army Ammunition Plant.

STANDARD OPERATING PROCEDURE 80.1 DECONTAMINATION

1.0 SCOPE AND APPLICATION

Before leaving the site, all personnel or equipment involved in intrusive sampling or having entered a hazardous waste site during intrusive sampling must be thoroughly decontaminated to prevent adverse health effects and minimize the spread of contamination. Equipment must be decontaminated between sites to preclude cross-contamination. Decontamination water will be free of contaminants as evidenced through either chemical analyses or certificates of analysis. This standard operating procedure (SOP) describes general decontamination requirements for site personnel and sampling equipment. Decontamination procedures for contaminants requiring a more stringent procedure, e.g., dioxins/furans, will be included in site-specific addenda.

2.0 MATERIALS

- Plastic sheeting, buckets or tubs, pressure sprayer, rinse bottles, and brushes;
- U.S. Army Corps of Engineers or installation approved decontamination water source;
- Deionized ultra-filtered, HPLC-grade organic free water (DIUF);
- Non-phosphate laboratory detergent;
- Nitric Acid, 0.1 Normal (N) solution;
- Pesticide-grade solvent, Methanol;
- Aluminum foil;
- Paper towels;
- Plastic garbage bags; and
- Appropriate containers for management of investigation-derived material (IDM).

3.0 PROCEDURE

3.1 SAMPLE BOTTLES

At the completion of each sampling activity the exterior surfaces of the sample bottles must be decontaminated as follows:

- Be sure that the bottle lids are on tight.
- Wipe the outside of the bottle with a paper towel to remove gross contamination.

3.2 PERSONNEL DECONTAMINATION

Review the site-specific health and safety plan for the appropriate decontamination procedures.

3.3 EQUIPMENT DECONTAMINATION

3.3.1 Drilling Rigs

Drilling rigs and associated equipment, such as augers, drill casing, rods, samplers, tools, recirculation tank, and water tank (inside and out), will be decontaminated before site entry, after over-the-road mobilization and immediately upon departure from a site after drilling a hole. Supplementary cleaning will be performed before site entry. There is a likelihood that contamination has accumulated on tires and as spatter or dust en route from one site to the next.

1. Place contaminated equipment in an enclosure designed to contain all decontamination residues (water, sludge, etc.).
2. Steam-clean equipment until all dirt, mud, grease, asphaltic, bituminous, or other encrusting coating materials (with the exception of manufacturer-applied paint) has been removed.
3. Water used will be taken from an approved source.
4. When cross-contamination from metals is a concern, rinse sampling components such as split spoons, geo-punch stems, and augers with nitric acid, 0.1N.
5. Rinse with DIUF water.
6. When semi-volatile and non-volatile organics may be present, rinse the sampling components with pesticide-grade solvent methanol.
7. Double rinse the sampling components with DIUF water.
8. Decontamination residues and fluids will be appropriately managed as IDM per work plan addenda and SOP 80.1.

3.3.2 Well Casing and Screen

Prior to use, well casing and screen materials will be decontaminated. This activity will be performed in the leak proof, decontamination pad, which will be constructed prior to commencement of the field investigation. The decontamination process will include:

- Steam cleaning with approved source water.
- Rinse with DUIF water.
- Air-dry on plastic sheeting.
- Wrap in plastic sheeting to prevent contamination during storage/transit.

3.3.3 Non Dedicated Submersible Pumps Used for Purging and Sampling

1. Scrub the exterior of the pump to remove gross (visible) contamination using appropriate brushes, approved water, and non-phosphate detergent (steam cleaning may be substituted for detergent scrub).
2. Pump an appropriate amount of laboratory detergent solution (minimum 10 gallons) to purge and clean the interior of the pump.
3. Rinse by pumping no less than 10 gallons of approved water to rinse.
4. Rinse the pump exterior with approved decontamination water.

5. When cross-contamination from metals is a concern, rinse the pump exterior with approved nitric acid 0.1N solution.
6. Rinse the pump exterior with DIUF water.
7. When semi-volatile and non-volatile organics may be present, rinse the pump exterior with pesticide-grade solvent methanol.
8. Double rinse the pump exterior with DIUF water.
9. Air-dry on aluminum foil or clean plastic sheeting.
10. Wrap pump in aluminum foil or clean plastic sheeting, or store in a clean, dedicated PVC or PTFE storage container.
11. Solutions and residuals generated from decontamination activities will be managed appropriately as IDM per work plan addenda and SOP 80.1.

3.3.4 Sample Equipment and Measuring Water Level Devices

1. Scrub the equipment to remove gross (visible) contamination using appropriate brush (es), approved water, and non-phosphate detergent.
2. Rinse with approved source water.
3. When cross-contamination from metals is a concern, rinse the sampling equipment with approved nitric acid 0.1N solution.
4. Rinse equipment with DIUF water.
5. When semi-volatile and non-volatile organics may be present, rinse the sampling equipment with pesticide-grade solvent methanol.
6. Double rinse the sampling equipment with DIUF water.
7. Air-dry on aluminum foil or clean plastic sheeting.
8. Wrap in aluminum foil, clean plastic sheeting, or zip top bag or store in a clean, dedicated PVC or PTFE storage container.
9. Solutions and residuals generated from decontamination activities will be managed appropriately as IDM per work plan addenda and SOP 80.1.

3.3.5 Other Sampling and Measurement Probes

Temperature, pH, conductivity, Redox, and dissolved oxygen probes will be decontaminated according to manufacturer's specifications. If no such specifications exist, remove gross contamination and triple-rinse probe with DIUF water.

4.0 PRECAUTIONS

- Manage IDM appropriately according to the requirements specified in work plan addenda.
- Follow appropriate procedures as specified in the site-specific health and safety plan.

5.0 REFERENCES

USACE. 2001. Requirements for the Preparation of Sampling and Analysis Plans. EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 90.1

PHOTOIONIZATION DETECTOR (HNu Model PI-101 and HW-101)

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with a photoionization detector (HNu Systems Model PI-101 or HW-101). The photoionization detector (PID) detects total ionizables; hence it is used to monitor both organic and inorganic vapors and gases to determine relative concentrations of air contaminants. This information is used to establish level of protection and other control measures such as action levels. The PID cannot effectively detect compounds having ionization potentials above the photon energy level of the lamp used; therefore, methane, which has an ionization potential of 12.98 eV, is undetectable by PIDs because the lamps produce 9.5, 10.2, or 11.7 eV.

Use of brand names in this SOP is in not intended as an endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc., are acceptable. If alternate equipment is to be used, the contractor shall provide applicable and comparable SOPs for its maintenance and calibration.

2.0 MATERIALS

- HNu Systems Model PI-101 or HW-101 survey probe with 9.5, 10.2, or 11.7 eV lamp;
- Lead-acid gel-cell battery;
- Calibration gas (e.g., isobutylene, 101 ppm) with regulator;
- Tygon tubing;
- Tedlar bag (optional);
- Instrument logbook; and
- Field logbook.

3.0 PROCEDURE

These procedures are to be followed when using the HNu in the field.

3.1 STARTUP

1. Before attaching the probe, check the function switch on the control panel to ensure that it is in the off position. Attach the probe by plugging it into the interface on the top of the readout module.
2. Turn the function switch to the battery check position. The needle on the meter should read within or above the green battery arc on the scale; if not, recharge the battery. If the red indicator light comes on, the battery needs recharging or service may be indicated.
3. Turn the function switch to any range setting. Listen for the hum of the fan motor. Check meter function by holding a solvent-based marker pen near the sample intake. If there is no needle deflection, look briefly into the end of the probe (no more than 1 or 2 sec) to see if the lamp is on; if it is on, it will give a purple glow. Do not stare into the probe any longer than 2 sec. Long-term exposure to UV light can damage the eyes. (See further information in Section 5.)
4. To zero the instrument, turn the function switch to the standby position and rotate the zero adjustment until the meter reads zero. A calibration gas is not needed since this is an electronic zero adjustment. If

the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted if necessary. Allow the instrument to warm up for 3–5 min to ensure that the zero reading is stable. If necessary, readjust the zero.

3.2 OPERATIONAL CHECK

Follow the startup procedure in Section 3.1.

With the instrument set on the 0–20 range, hold a solvent-based marker near the probe tip. If the meter deflects upscale, the instrument is working.

3.3 FIELD CALIBRATION PROCEDURE

1. Follow the startup procedures in Section 3.1 and the operational check in Section 3.2.
2. Set the function switch to the range setting for the concentration of the calibration gas.
3. Attach a regulator HNu P/N 101-351 or equivalent (flow = 200 to 300 ml/min) to a disposable cylinder of isobutylene (HNu 101-351 or equivalent). Connect the regulator to the probe of the HNu with a piece of clean Tygon tubing. Turn on the valve of the regulator.
4. After 5 sec, adjust the span dial until the meter reading equals the benzene concentration of the calibration gas used, corrected to its equivalence, which should be marked on the canister (Isobutylene ~0.7X benzene).
5. Record in the field log the instrument ID No., serial No., initial and final span settings, date, time, location, concentration and type of calibration gas used, and the signature of the person who calibrated the instrument.
6. If the HNu does not function or calibrate properly, the project equipment manager is to be notified as soon as possible. Under no circumstances is work requiring monitoring with a PI-101 or HW-101 to be done with a malfunctioning instrument.

3.4 CALIBRATION TO A GAS OTHER THAN ISOBUTYLENE

The HNu may be calibrated to any certified calibration gas. However, after calibration, all subsequent instrument readings will be relative to the calibration gas used. General procedures include the following:

1. Calibrate according to procedure 3.3.
2. Partially fill and flush one-to-two times a gas bag (Tedlar recommended) with the certified National Institute of Standards and Technology (NIST) (formerly NBS) traceable calibration gas. Then fill the bag with 1–3 L of the calibration gas. If the gas is toxic, this must be done in a fume hood.
3. Feed the calibration gas into the probe with the range set for the value of the gas. After 5 sec, adjust the span control until the meter reads the value of the calibration gas.
4. Record the results of the calibration on the calibration/maintenance log and attach a new calibration sticker (if available) or correct the existing sticker to reflect the new calibration data. All subsequent readings will be relative to the new calibration gas.

3.5 OPERATION

1. Follow the startup procedure, operational check, and calibration check (refer to Section 3.1).
2. Set the function switch to the appropriate range. If the concentration of gas vapors is unknown, set the function switch to 0-20 ppm range. Adjust if necessary.

3. Prevent exposing the HNu to excessive moisture, dirt, or contaminant while monitoring the work activity as specified in the Site Health and Safety Plan.
4. When the activity is completed, or at the end of the day, carefully clean the outside of the HNu with a damp disposable towel to remove all visible dirt. Return the HNu to a secure area and place on charge. Charge after each use; the lead acid batteries cannot be ruined by over charging.
5. With the exception of the probe's inlet and exhaust, the HNu can be wrapped in clear plastic to prevent it from becoming contaminated and to prevent water from getting inside in the event of precipitation. If the instrument becomes contaminated, make sure to take necessary steps to decontaminate it. Call the Equipment Administrator if necessary; under no circumstances should an instrument be returned from the field in a contaminated condition.

4.0 MAINTENANCE

Calibration/maintenance logs are to be filled in completely whenever a PI-101 or HW-101 receives servicing. This is true of both contractor-owned and rental instruments.

The equipment manager should be called to arrange for a fresh instrument when necessary. The contractor's equipment facility is responsible for arranging all repairs that cannot be performed by the project equipment manager.

4.1 ROUTINE SERVICE

The PID's performance is affected by a number of factors. These include but are not limited to the decay of the UV lamp output over time and the accumulation of dust and other particulate material and contaminants on the lamp and in the ion chamber. Because of these factors, the PID should not be left in the field for a period of more than 2 weeks before being replaced with a fresh instrument. If a site is going to be inactive for a period of more than a week, all monitoring instruments are to be returned to the project equipment manager or his trained designee for servicing and/or reassignment. The following procedures are to be performed at the designated intervals for routine service.

<u>Procedure</u>	<u>Frequency</u>
Operational check	Before use and at instrument return
Field calibration	Before use and at instrument return
Full calibration	Bi-weekly (return instrument to equipment manager for replacement with a fresh unit)
Clean UV lamp and	Bi-weekly or as needed ion chamber
Replace UV Lamp	As needed

4.1.1 UV Lamp and Ion Chamber Cleaning

During periods of analyzer operation, dust and other foreign materials are drawn into the probe forming deposits on the surface of the UV lamp and in the ion chamber. This condition is indicated by meter readings that are low, erratic, unstable, non-repeatable, or drifting and show apparent moisture sensitivity. These deposits interfere with the ionization process and cause erroneous readings. Check for this condition regularly to ensure that the HNu is functioning properly. If the instrument is malfunctioning, call your equipment manager to arrange to have a fresh replacement.

4.1.2 Lamp eV Change

If different applications for the analyzer would require different eV lamps, separate probes, each with its own eV lamp, must be used. A single readout assembly will serve for any of the probes (9.5, 10.2, and 11.7 eV). A change in probe will require resetting of the zero control and recalibrating the instrument. The 11.7 eV lamp will detect more compounds than either of the two lower eV lamps. However, the 11.7 eV probe needs more frequent calibration; it burns out much faster than the lower eV lamps.

5.0 PRECAUTIONS

- The HNu PI-101 and HW-101 are designed to sample air or vapors only. *Do not allow any liquids or low boiling vapors to get into the probe or meter assembly.*
- High concentrations of any gas can cause erroneous readings. High humidity can also cause the instrument readings to vary significantly from the actual concentration of gases or vapors present. This is true even though the HNu cannot react to water vapor.
- High humidity, dust, and exposure to concentrations of low boiling vapors will contaminate the ion chamber, causing a steady decrease in sensitivity.
- Continued exposure to ultraviolet light generated by the light source can be harmful to eyesight. If a visual check of the UV lamp is performed *do not look at the light source from a distance closer than 6 inches with unprotected eyes.* Use eye protection (UV-blocking sunglasses or safety glasses). Only look briefly—never more than about 2 sec.
- Place the instrument on charge after each use; the lead batteries cannot be ruined by over charging.
- If at any time the instrument does not check out or calibrate properly in the field, the equipment manager is to be notified immediately and a replacement obtained for the malfunctioning instrument. Under no circumstances should fieldwork requiring continuous air monitoring for organic vapors and/or gases be done with a malfunctioning Hnu or without a HNu or an approved comparable instrument.

6.0 REFERENCES

Manufacturer's Equipment Manual.

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**SOLID WASTE
MANAGEMENT UNITS
40 (RAAP-009) AND
71 (RAAP-002)
RCRA FACILITY
INVESTIGATION/
CORRECTIVE
MEASURES STUDY
REPORT**

VOLUME I

**RADFORD ARMY
AMMUNITION PLANT
RADFORD, VIRGINIA**

**FINAL
APRIL 2009**



**CONTRACT NO.
DACA31-00-D-0011
DELIVERY ORDER NO. 0023**

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MANAGEMENT UNITS
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