RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

WORK PLAN ADDENDUM 028
Site Screening Process at
Site Screening Areas 18, 72, 30, 79, 60, and 77

FINAL
JUNE 2009

PREPARED BY:

URS

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CONTRACT NO. W91238-07-D-0006
DELIVERY ORDER NO. DA01

Geiger.William@epamail.epa.gov
09/22/09 03:53 PM

To "McKenna, Jim J Mr CIV USA AMC" <jim.mckenna@us.army.mil>
cc jlcutler@deq.virginia.gov, Tina_Devine@URSCorp.com
bcc
Subject Re: WPA 028 SSP at SSAs, 18, 72, 30, 79, 60 and 77 Approval

History: This message has been forwarded.

Jim, USEPA and VDEQ approve of the Final WPA 028 dated June 2009.

William A. Geiger
Remedial Project Manager
Office of Remediation (3LC20)
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July 17, 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, Work Plan Addendum 028 Site Screening Process at Site Screening Areas 18, 72, 30, 79, 60 and 77 Final June 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 June 29, 2009. Also enclosed is the 29 June 2009 transmittal email.

This document was revised per our response to comments sent via 21 April 2009 email (enclosed). Our understanding from the February 18, 2009 partnering meeting is that we anticipate approval of this document.

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

09-815-112
JMcKenna

Rich Mendoza
U.S. Army Environmental Command
1 Rock Island Arsenal
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Tom Meyer
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09-815-112
JMcKenna

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

09-815-112
JMcKenna

Concerning the following:

Radford Army Ammunition Plant
Work Plan Addendum 028
Site Screening Process at Site Screening Areas
18, 72 30, 79, 60, and 77
Final June 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: ANTONIA MUNERA
TITLE: LTC, CM
Commanding

SIGNATURE: _____
PRINTED NAME: Kent Holiday
TITLE: Vice President and General Manager
ATK Energetics Systems

09-815-112
JMcKenna

Greene, Anne

From: McKenna, Jim
Sent: Monday, June 29, 2009 1:41 PM
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 WPA 028 FedEx Tracking Numbers

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.

Immediately below are the POCs with tracking numbers:

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

Jim McKenna
540 731 5782

POCs and Tracking numbers:

Final WPA 028 SSP at SSAs 18, 72, 30, 79, 60, and 77 FedEx Tracking Numbers

James McKenna 7967 3340 0935 2 Paper copies Will Geiger 7977 2043 1460 1 Paper copy/1 CD Jim Cutler 7967 3339 5623 1 Paper copy/1 CD Tom Meyer 7977 2041 1722 1 CD Richard Mendoza 7977 2041 6893 1 CD Dennis Druck 7967 3338 1373 1 CD Elizabeth Lohman 7967 3336 3411 1 CD Susan Ryan 7967 3338 5427 1 CD

Greene, Anne

From: McKenna, Jim
Sent: Tuesday, April 21, 2009 1:29 PM
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: WPA 028 SSP at SSAs, 18, 72, 30, 79, 60 and 77 draft, Response to Comments (UNCLASSIFIED)

Attachments: RTC WPA 028 SSP Complete.pdf

RTC WPA 028 SSP Complete.pdf (...

Classification: UNCLASSIFIED
Caveats: FOUO

Will Geiger and Jim Cutler:

Attached are the subject responses. Please let us know as soon as you can if these responses are ok so we can revise and resubmit this report as final.

Thanks,
Jim

Classification: UNCLASSIFIED
Caveats: FOUO

Response to Comments (April 21, 2009)
Comments on the *Draft Work Plan Addendum 028, Site Screening Process (SSP) at Site Screening Areas (SSAs) 18, 72, 30, 79, 60, and 77*, Radford Army Ammunition Plant (RAAP), Radford, Virginia, dated December 2008 (Work Plan Addendum). Received 3/10/2009

GENERAL COMMENTS

1. The Work Plan Addendum Section 6.0 (Quality Assurance Plan Addendum) references use of the most recent version of the EPA guidance document for systematic planning using the Data Quality Objective (DQO), QA/G-4, dated February 2006. However, the terminology used throughout the Work Plan Addendum appears to be taken from the older version of this guidance. For instance, the DQO steps listed in Section 6.3 (Quality Assurance Objectives) are listed as *State The Problem, Identify the Decision, Identify Inputs to the Decision, Define the Boundaries, Develop a Decision Rule, Specify Acceptable Limits on Decision Errors, and Optimize Data Design.* The newer version of this EPA DQO guidance QA/G-4 lists the steps as *State the Problem, Identify the Goals of the Study, Identify Information Inputs, Define the Boundaries of the Study, Develop the Analytical Approach, Specify performance or Acceptance Criteria, and Develop the Plan for Obtaining Data.* The Work Plan Addendum does not need to be revised, but in the future, please correctly reference the DQO steps as listed in the most recent version of the EPA DQO guidance document, *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA/240/B-06/001), dated February 2006.

   Response: Noted for future workplans.

SPECIFIC COMMENTS

2. **Section 1.3.1.4, Soil Screening Level (SSL) Comparison – Soil, Page 1-4:** This section states that maximum detected concentrations (MDCs) of chemicals will be compared to screening levels for leaching of chemicals to groundwater, many of which "can be found in the Regional Screening Table." The target dilution attenuation factor (DAF) to be applied to the Regional SSLs, which are based on a DAF of 1, has not been specified. Additionally, the Regional Screening Table includes both risk-based SSLs and federal maximum contaminant level (MCL)-based SSLs. Please note that the risk-based SSLs should be used for this evaluation. Please revise the Work Plan Addendum to specify the DAF that will be applied to the Regional SSLs, and make a note that the risk-based SSLs will be used for this evaluation.

   Response: Section 1.3.1.4 will be revised to note that the risk-based SSLs will be used for the SSL comparison using a DAF 20, which accounts for attenuation processes in the surface and subsurface soil zones above groundwater in addition to the mixing zone with groundwater. The work plan will also indicate that this DAF value may be adjusted for a SSA to account for site-specific conditions identified during the SSP, such as site, physical soil data, chemical data, etc.

3. **Section 2.1.1, Site Description, Pages 2-1 and 2-2:** This section describes several site features which are not depicted on site figures. Outfall 004, the railroad spur, and all of

the Unit 18 subunits (Unit 18a, Unit 18b, etc.) do not appear to be identified on the site figures. Since the proposed sampling approach references these locations in Section 2.5, Planned Field Investigation, it is important to document these features on a site plan in relation to the proposed samples. Please revise Figure 2-1, Site Layout – SSA 18 and SSA 72, and any other figures, as appropriate, to identify Outfall 004, the railroad spur, all of the Unit 18 subunits, and any other important site features.

Response: Figures 2-1 and 2-11 (previously 2-10) will be revised to include key features of the site. See attached revised Figures 2-1 and 2-11. In addition, a figure will be added to Section 2 depict Outfall 004, HWMU 7, etc. See attached Figure 2-2.

4. **Section 2.2.2, Acid Sewer Survey, Page 2-4**: This section describes the results of an acid sewer survey and investigation conducted on the entire Radford Army Ammunition Plant (RFAAP) sewer infrastructure. It notes that deteriorated or broken sections of sewer lines were repaired or replaced within active areas, and further states that "No actions were undertaken in the area of SSA 18 or SSA 72 due to the inactive status of the SAR Plant wastewater system and treatment facility." However, the current status of the sewer lines in the vicinity of SSA 18 or SSA 72 is still unclear (i.e., whether the lines were found to be deteriorated or broken during the assessment, or whether they were never assessed at all). For clarity, please describe the results of the acid sewer survey for those sewer lines in the vicinity of SSA 18 and SSA 72, even if no repairs were preformed due to the inactive nature of the site. If broken or deteriorated lines were identified, the locations of these breaks should be documented in the Work Plan Addendum so that targeted sampling can be proposed in these areas. In the event an assessment of the sewer lines in the vicinity of SSA 18 and SSA 72 was never performed, allowance for an assessment of these lines would seem warranted. Please revise the data gap assessment to indicate that a lack of information regarding the sewer lines in the vicinity of SSA 18 and SSA 72 exists, and requires completion of this assessment.

Response: Additional detailed review of acid sewer survey and investigation reports indicates that an assessment of the 260 ft long 6-inch diameter plastic, gravity acid sewer line that extends from the acidic wastewater sump (SSA 72) to the SAR wastewater treatment plant was not conducted. Based on this information, a survey of this sewer line will be performed using closed-circuit television (CCTV) inspection techniques to evaluate the integrity of this line and identify the locations of any observed structural defects. Observed structural defects of the inner surface of the sewer pipe will be coded according to the National Association of Sewer Service Companies (NASSCO), Pipeline Assessment Certification Program (PACP) coding system.

Given that a CCTV inspection will be conducted along the 6-inch acid sewer line to evaluate for potential releases due to pipeline defects, it is proposed that soil samples 72SB2B and 72SB3B *only* be collected if sewer survey identifies defects that may have potentially resulted in a release. These samples would be collected below the bottom of the sewer pipe at the location of any identified defects.

The work plan will be updated to include this additional information. It is proposed that the sewer survey work and any follow-up soil sampling be completed as part of work plan implementation.

As a clarification, acid sewer systems at the facility including those in the vicinity of SSA 18 and SSA 72 are listed under the RCRA permit as Miscellaneous Unit 1 (MU-1) and therefore, will be considered separately under the RCRA permit, with the exception of the acid sewer line extending from the acidic wastewater sump to the SAR Wastewater Treatment Plant, which will evaluated under the SSP for SSA 18 and SSA 72.

5. **Section 2.4.5, Summary of Data Gaps, Page 2-7:** The table provided at the top of Page 2-7, SSA 18 and SSA 72 – Summary of Data Gap Analysis and Completion Plan, notes that soil samples will be analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, explosives and metals. Dioxins and cyanide have been excluded. This appears to be a deviation from the specifications outlined in the SSP Guidance Document, provided in Appendix A. Page 3-1 of the SSP Guidance Document states, "All environmental media samples collected during the SSP will be analyzed for the full suite of Contract Laboratory Procedure (CLP) constituents and other constituents based on the findings of the Desktop Audit including additional analytes requested by EPA." The analytical target list is supposed to include Target Compound List (TCL) VOCs, SVOCs, pesticides, PCBs and dioxins, and TAL inorganic chemicals including cyanide. Please revise the Work Plan Addendum to include sampling for dioxins and cyanide, or provide justification for excluding these constituents from the analysis. This comment applies to each of the sites described in the Work Plan Addendum, as the proposed analyte list for any of the sites addressed by this Work Plan Addendum does not include cyanide or dioxins (except at a few sites).

   Response: Cyanide will be added to the list of TAL inorganics proposed for each of the SSP samples. Regarding dioxins, consistent with the previous regulatory approved SSP work plan and reports for SWMUs 13, 37, 38, 46, 57, 68, 69, 75, 76, and AOCs A, F, Q, dioxin analysis has been proposed at sites where historical site operations, activities, or waste disposal practices suggest the potential formation/presence of dioxins (i.e., incineration, combustion, or burning related activities, by products, wastes, etc.). Based on a review of available information for each SSA, dioxin analysis of selected surface soil samples is proposed for SSA 77 where incineration activities occurred to evaluate potential releases due to particulate deposition or surface waste management activities. Dioxin testing is also proposed at SSA 60 at one representative location if burned material is encountered during sampling and test pit activities. Dioxin testing is not proposed at the asbestos trenches (SSA 30 and SSA 79) or at the acidic wastewater treatment facility (SSA 18) or wastewater sump (SSA 72) due to the nature of historical site activities in these areas. The work plan will be revised to incorporate this additional information.

6. **Section 2.5.2, Subsurface Soil Sampling, Page 2-8**: The second through fourth bullets in this section note that subsurface soil samples collected at sample locations 18SB2B, 18SB3B, and 18SB4B will be collected at a depth of 5 to 7 feet (ft) below ground surface

(bgs). The rationale for sampling at this depth is unclear but it appears that it may be related to the depth of the sewer line (since assessment of this area was initially identified as a data gap). For clarity, please revise the Work Plan Addendum to provide a discussion of which data gap is intended to be addressed for each of the proposed sampling locations and sampling intervals, including the proposed sampling at sample locations 18SB2B, 18SB3B, and 18SB4B.

Response: The work plan addendum will be revised to discuss the rationale for sample depths for 18SB2B, 18SB3B, and 18SB4B to fill data gaps as follows:

- Sample 18SB2B will be collected from a direct push boring completed at the location of surface soil sample 18SB2A at a depth of 5 to 7 ft bgs. This sample will fill an identified data gap related to evaluating potential releases to subsurface soil at the wastewater treatment facility, specifically in the area of aboveground piping running from the concrete containment area at 18f to Building 4434.
- Sample 18SB3B will be collected from a direct push boring completed at the location of surface soil sample 18SB3A at a depth of 5 to 7 ft bgs. This sample will fill an identified data gap related to evaluating potential releases to subsurface soil at the wastewater treatment facility, specifically in the area where materials were unloaded from railcars to Building 4434.
- Sample 18SB4B will be collected from a direct push boring completed at the location of surface soil sample 18SB4A at a depth of 5 to 7 ft bgs, which is 2 to 4 ft below the bottom of the acid sewer line entering the containment area for the surge tank (18f). This sample will fill an identified data gap related to evaluating potential releases to subsurface soil in the wastewater treatment facility area, specifically in the acid sewer area associated with SSA 18.

7. **Section 3.0, SSA 30 Asbestos Disposal Trench No. 1 and SSA 79 Asbestos Disposal Trench No. 2, Pages 3-1 through 3-4.** Data collected from nearby sites, such as Solid Waste Management Unit (SWMU) 51, SWMU 26, SWMU 52, and hazardous waste management unit (HWMU) 16 were used to develop the conceptual site model for SSA 30 and SSA 79. However, the boundaries of these SWMUs in relation to SSA 30 and SSA 79, an indication of whether there is any overlap, and a clear presentation of their spatial relationship to one another has not been presented. For clarity, please revise Figure 3-1, Site Layout – SSA 30 and SSA 79, and any other applicable figures to identify SWMU 51, SWMU 26 and SWMU 52, as well as, SSA 30 and SSA 79, together.

   Response: Figures 3-1 and 3-5 will be revised to include boundaries for SWMU 51, SWMU 26, SWMU 52, and HWMU 16.

8. **Section 4.2.4, Hydrogeology, Page 4-2:** The last sentence of this section states that the depth to groundwater is expected to be greater than 75 ft below the fill material placed at SSA 60. References or other justification for this statement have not been provided. Please provide the technical basis or reference the information source used for indicating that the depth to groundwater is expected to be greater than 75 ft.

Response: The expected groundwater depth at SSA 60 of greater than 75 ft below the fill material is based on the assumption that potentiometric elevations in the upland area of the facility are similar for sites whose ground surface elevations are similar. SWMU 17 and SWMU 40 are located to the west of SSA 60 and have similar ground surface elevations to SSA 60 prior to filling (1,880 to 1,910 ft msl).

Select Groundwater Elevation Data – SWMU 17 and SWMU 40

Well ID	Location	Top of Casing at Measurement Point	Ground Surface Elevation (ft msl)	Depth to Groundwater (bgs)	Groundwater Elevation (12/10/07)
17MW2	SWMU 17	1905.88	1903.99	102.90	1801.09
17PZ1	SWMU 17	1906.90	1904.70	104.16	1800.54
40MW6	SWMU 40	1884.25	1882.61	98.68	1783.93

As shown in the above table, the depth to groundwater below the ground surface at SWMU 17 and SWMU 40 within relatively undisturbed areas is greater than 98 ft and therefore it has been conservatively assumed that the depth to groundwater below the fill material at SSA 60 is greater than 75 ft. The additional information in this comment response will incorporated in Section 4.2.4 of the work plan addendum.

9. **Section 4.6.2, Drainage Ditch Sampling, Page 4-5:** The last sentence of this section states that sediment samples will be collected following the procedures outlined in Standard Operating Procedure (SOP) 30.4 and 30.9 in Appendix B. However, the method to collect the sediment samples has not been specified. SOP 30.4 includes several different methods for collecting samples (scoop or trowel, tube sampler, hand auger, etc.), and Section 3.1 of this SOP further notes that "the most appropriate method(s) of sample collection...will be specified in the work plan addendum..." Please revise Section 4.6.2 of the Work Plan Addendum to specify the proposed method of sediment sample collection, and note this comment for future submittals.

   Response: Section 4.6.2 will be revised to reference the hand auger method for collection of sediment samples.

10. **Section 5.3, Conceptual Site Model, Page 5-4:** Potential dispersion and deposition of particulate matter from the incinerator stack is a possible source of soil contamination at the site, but Figure 5-7, Conceptual Site Model – SSA 77, does not appear to include this release mechanism. Figure 5-7 does not include the incinerator stack. For a complete portrayal of the CSM, please revise Figure 5-7 to depict the potential dispersion and deposition of particulate matter from the incinerator stack as a release mechanism at the site.

    Response: Figures 5-7 will be revised to include dispersion and deposition of particulate matter from the stack as a release mechanism at the site. See attached revised Figure 5-7.

11. **Section 5.5.1, Soil Sampling in Building 7219 Area, Page 5-6:** This section notes that only two of three surface soil samples will be analyzed for dioxins, and no subsurface soil samples will be analyzed for these constituents. The Work Plan Addendum has not identified which two samples will be analyzed for dioxins. Furthermore, justification for limiting this analysis to two surface soil samples has not been provided. Given the historic use of the site as an incinerator, it appears that additional sampling for dioxins may be warranted. Please revise the Work Plan Addendum to address these concerns.

    Further, the appropriate locations for sampling of surface soils which would address particulates associated with incineration related dispersion and deposition from the incinerator stack would be dependent on information gained from a local wind rose, translation of that into a prevailing wind direction, documentation of the total stack height, and an assessment of the impacted areas for dispersion and deposition of particulates from incineration activities. It is currently unclear if the proposed sampling locations would be indicative of worst case conditions for incineration stack particulates. Please revise the Work Plan Addendum to indicate how the proposed sampling will address this data gap, or please revise the Work Plan Addendum to incorporate additional sampling locations to specifically address this data gap.

    Response: Proposed dioxin sampling will focus on surface soil at the site due to the likely release mechanisms related to any surface spills of materials removed from the chimney cleanout and deposition of particulates from the chimney. Dioxin analysis is proposed at surface sample location 77SB2A adjacent to the chimney to evaluate potential releases from removal of residual material from the chimney cleanout and deposition of particulate matter from the chimney. Dioxin analysis is also proposed at surface sample location at 77SB3A located east/southeast of the chimney at the edge of the site area to evaluate releases due to deposition of particulate matter in the prevailing wind direction (westerly/northwesterly). These soil sample locations are considered the most appropriate locations to measure for potential releases of dioxins to surface soil at the site. Subsurface soil sampling for dioxins is not proposed due to the prevalent surface release mechanisms at the site.

    The above information will be incorporated into the work plan addendum along with additional information documenting local prevailing wind direction (wind rose).

    Additional efforts and surface soil sampling to evaluate dispersion of particulate matter beyond the site area are not proposed given the co-location of SSA 77 and the currently active and larger SWMU 17 stage and burn area, which has operated since the 1940s, and the associated uncertainties with interpretation of sampling results at remote locations in the direction of prevailing winds.

12. **Section 5.5.1, Soil Sampling in Building 7219 Area, Page 5-6:** Subsurface soil samples will be collected at the borings at a depth interval of 4-6 ft bgs, but the rationale for selecting this depth interval has not been provided. For clarity and defensibility, please revise the Work Plan Addendum to include the rationale for the subsurface soil sampling depth interval.

Response: Subsurface soil samples 77SB1B, 77SB2B, and 77SB3B are proposed to fill the identified data gap for evaluating releases to subsurface soil. A depth of 4 to 6 ft bgs was selected to provide a uniform release assessment to subsurface soil in the area of the incinerator building and chimney. Sample 77SB1B will assess potential releases from previous waste handling activities adjacent to the western building entrance. Sample 77SB2B will be collected below the depth of the sewer pipe and will assess potential subsurface releases from the sewer pipe and in the area where chimney cleanout occurred. Sample 77SB3B will assess potential releases near the northeast corner of the building near the entrance to the basement firing floor. Section 5.5.1 will be revised to incorporate this additional information.

13. **Section 6.3, Quality Assurance Objectives, Page 6-6:** Item number 5, *Develop a Decision Rule* (b. iii) states "MDLs and RLs, as specified herein, will ensure that data quality is sufficient for its intended use." Although additional quality control criteria are included in Section 6.0 *Quality Assurance Plan Addendum* of the Work Plan Addendum, this specific statement describing the required action levels implies that designating and achieving analytical minimum detection limits (MDLs) and reporting limits (RLs) alone provide the action levels that will ensure the data quality is sufficient. In accordance with EPA guidance document QA/G-4 *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA/240/B-06/001) dated February, 2006, DQOs define the type, quantity, and quality of data required to reach defensible decisions and which meet the project needs. The report does not need to be revised, but please note for future reference.

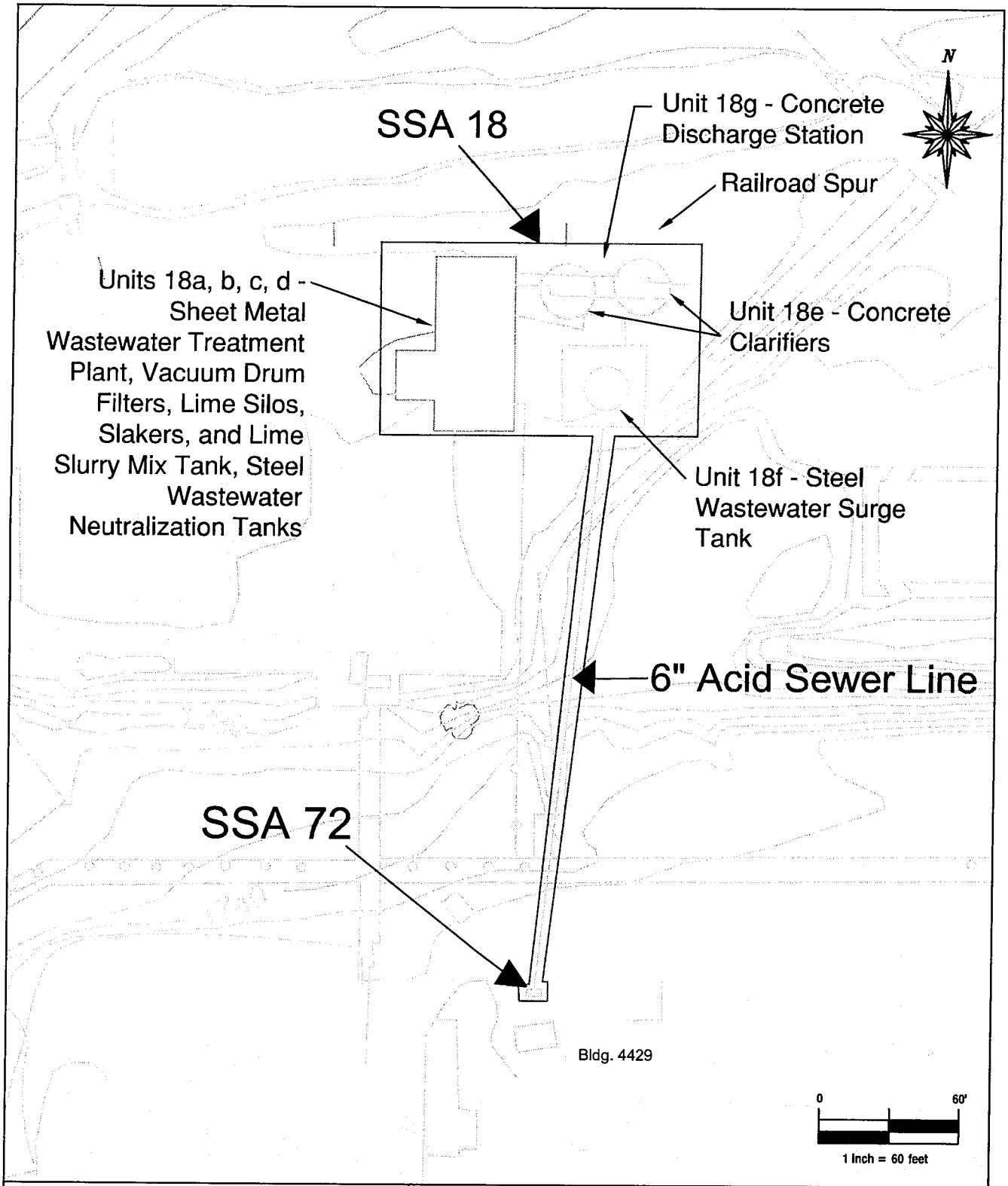
Response: Noted for future work plans.

14. **Section 6.3, Quality Assurance Objectives, Page 6-7:** Item number 6, *Specify Acceptable Limits on Decision Errors* (a.) states "MDLs and RLs below the action levels will ensure the data meet the DQOs." While this statement is applicable, MDLs and RLs are not the only action levels that can be evaluated to determine whether DQOs have been met for the project. The report does not need to be revised, but please note for future reference.

Response: Noted for future work plans.

15. **Section 6.3, Quality Assurance Objectives, Page 6-7:** Item number 6, *Specify Acceptable Limits on Decision Errors* (b.) provides a definition of Type I and Type II errors, but does not provide the actual limits. According to EPA DQO guidance document QA/G-4 (pages 49 – 56 of February 2006 version), the primary objective of this step in the DQO process is to specify the upper limits on the probabilities of each of these two types of decision errors by stating the alpha and beta limits for Type I and Type II decision errors. The report does not need to be revised, but please note for future reference.

Response: Noted for future work plans.



Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping

FIGURE 2-1

Site Layout - SSA 18 and SSA 72

Date: April 2008	URS Project #: 11656421
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.2-2 SiteLayout

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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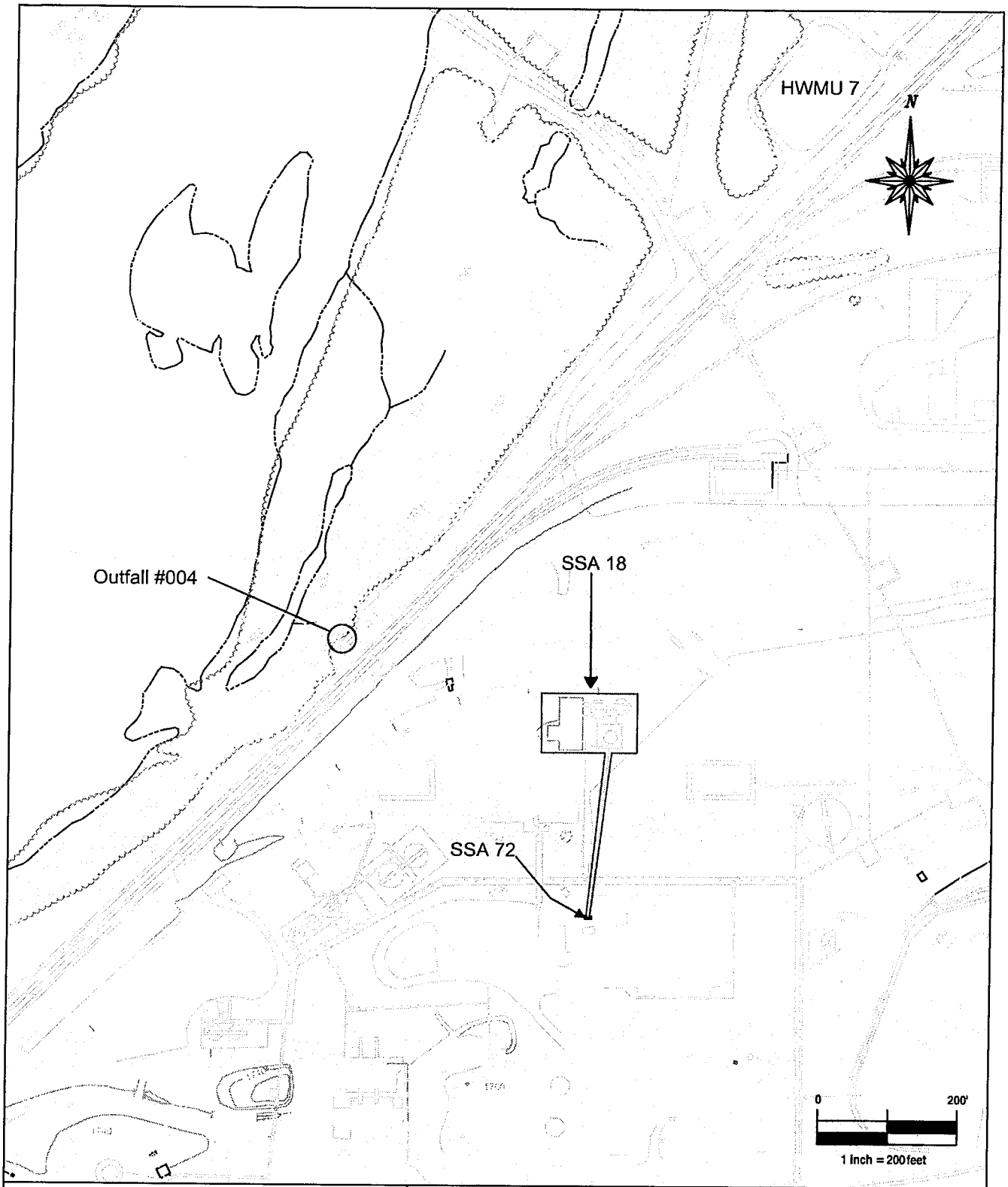

Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping

FIGURE 2-2

Additional Layout Map
SSA 18 and SSA 72

Date: March 2009	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 200 feet	File Name: Fig.2-2

MWP Addendum 028 - SSP for
SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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5540 Falmouth Street
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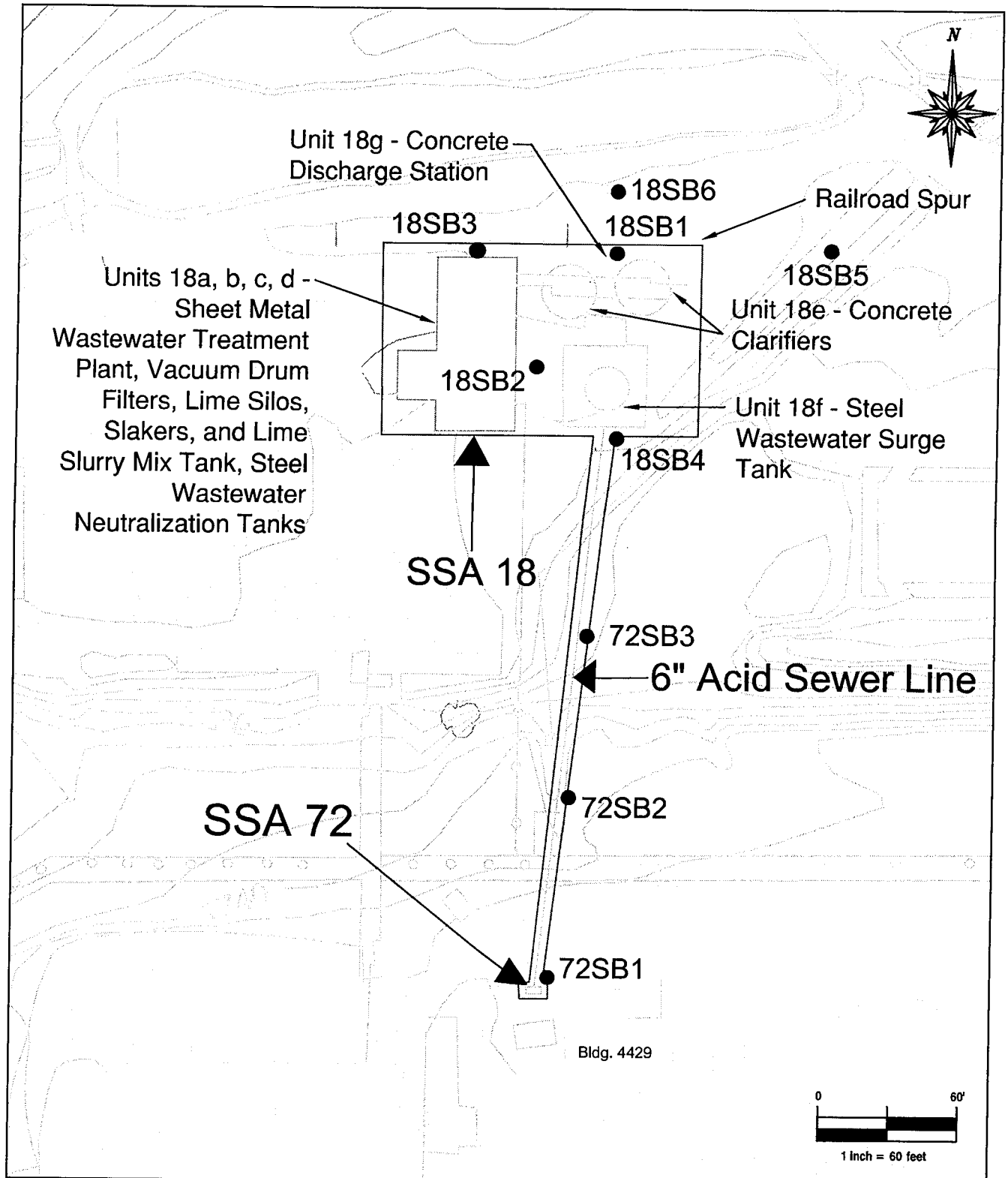

Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping
- Soil Boring Location

FIGURE 2-11

Proposed SSP Sample Locations - SSA 18 and SSA 72

Date: April 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.2-10 SSP Locs

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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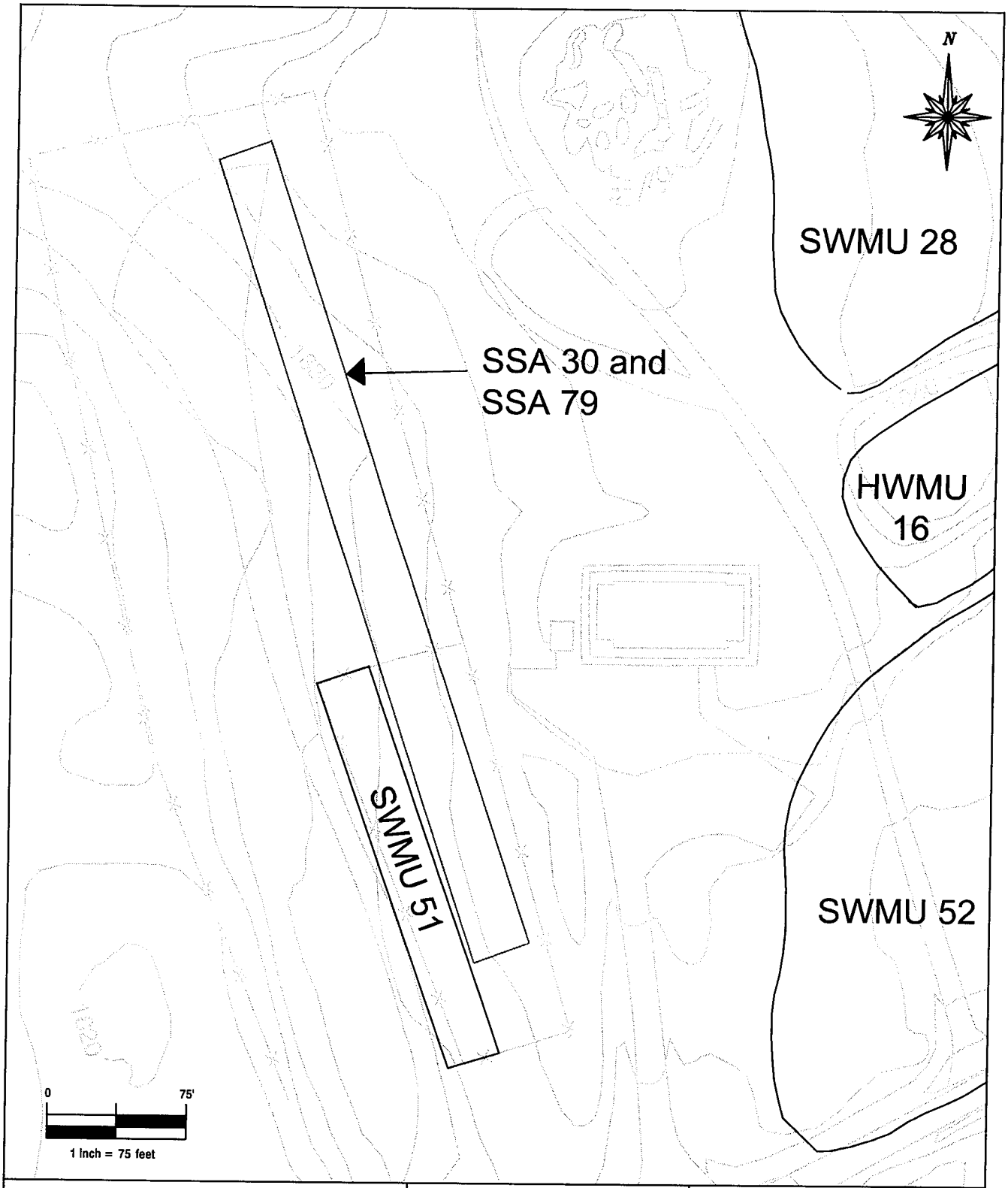

Legend

- Approximate SSA Boundary
- Topographic Contour
- Fence
- Approximate SWMU Boundary

FIGURE 3-1

Site Layout - SSA 30 and SSA 79

Date: March 2009	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 75 feet	File Name: Fig.3-1 SiteLayout

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

URS
URS Group, Inc.
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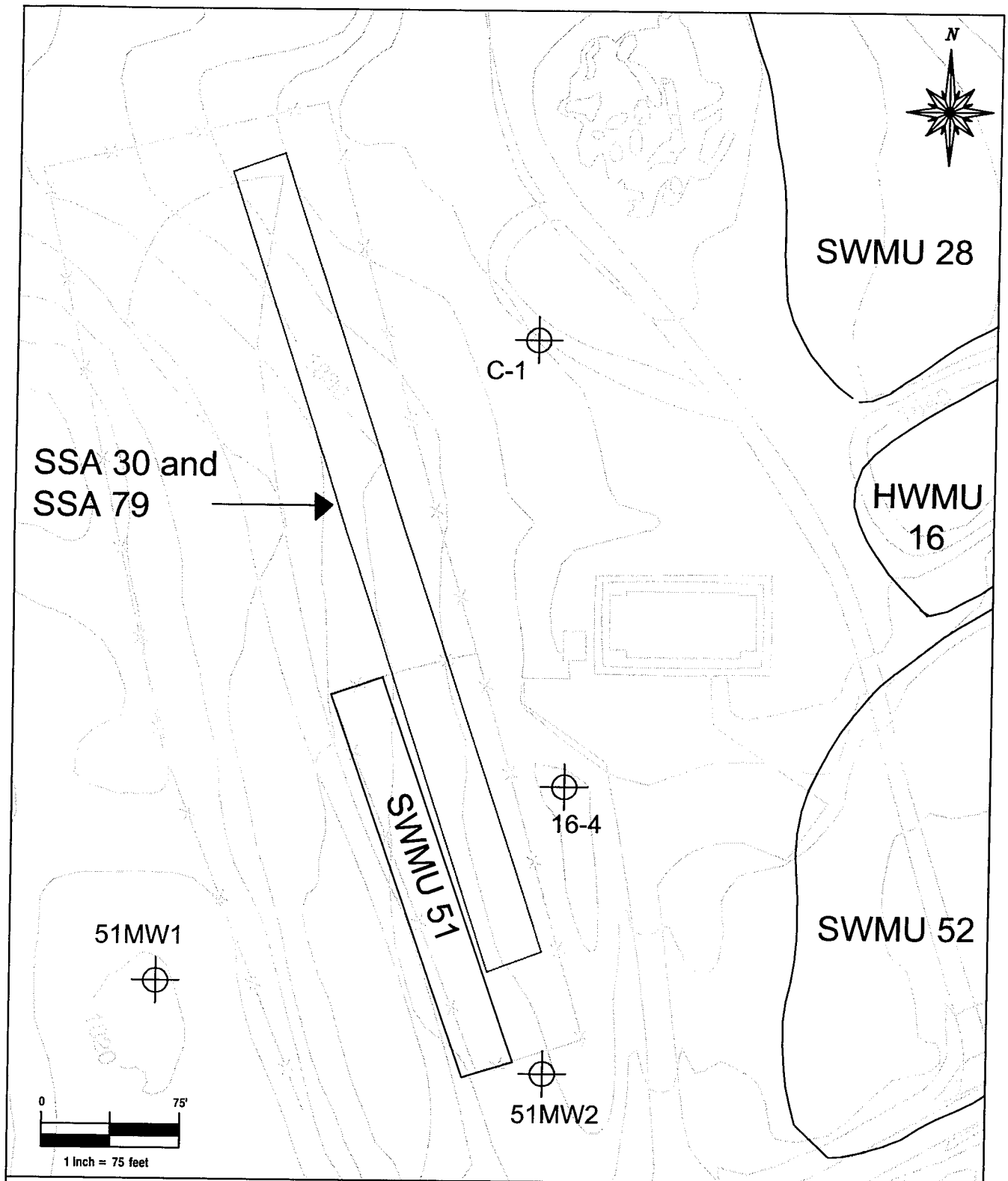
Richmond, Virginia 23230



Legend

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

FIGURE 3-5

Previous Investigation -
SSA 30 and SSA 79

Date: March 2009	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 75 feet	File Name: Fig.3-5 Prev Invest

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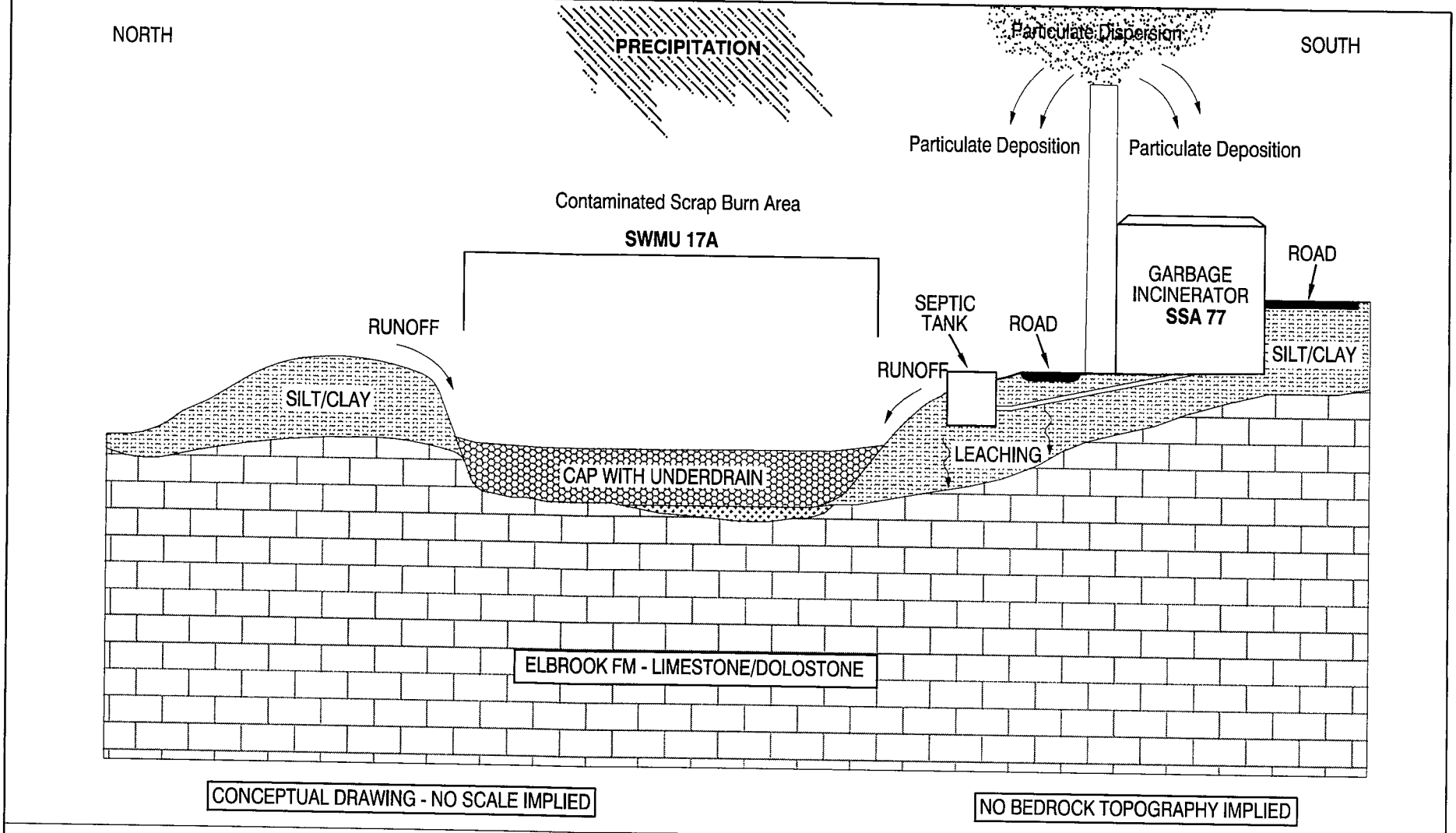

FIGURE 5-7
Conceptual Site Model - SSA 77

Date: October 2008	URS Project #: 11657490
Prepared by: SS	Approved by: JOS
Scale: Not to Scale	File Name: Fig. 5-7

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09/22/09 03:12 PM

To "McKenna, Jim J Mr CIV USA AMC" <jim.mckenna@us.army.mil>, jlcutler@deq.virginia.gov

cc Tina_Devine@URSCorp.com

Subject WPA 028 SSP at SSAs, 18, 72, 30, 79, 60 and 77 Approval

Jim, per the June 2009 Partnering Meeting, USEPA and VDEQ approve of Radford's response to our comments on Work Plan Addendum 028. Thanks.

William A. Geiger
Remedial Project Manager
Office of Remediation (3LC20)
U.S. Environmental Protection Agency
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04/21/09 01:29 PM

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cc
bcc
Subject WPA 028 SSP at SSAs, 18, 72, 30, 79, 60 and 77 draft, Response to Comments (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Will Geiger and Jim Cutler:

Attached are the subject responses. Please let us know as soon as you can if these responses are ok so we can revise and resubmit this report as final.

Thanks,
Jim

Classification: UNCLASSIFIED
Caveats: FOUO

RTC WPA 028 SSP Complete.pdf

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03/10/09 01:35 PM

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bcc
Subject WPA 028 EPA Comments

Attached are EPA comments on WPA 028. Jim Culter indicated that VDEQ may still have some concerns regarding IR eligibility for some of the sites, and he hopes to send his comment(s) later this week.

(See attached file: Comments WPA 028.doc)

William A. Geiger
USEPA Region III
1650 Arch Street, 3LC20
Philadelphia, PA 19103

(215)814-3413

Comments WPA 028.doc

Presented below are EPA comments on the *Draft Work Plan Addendum 028, Site Screening Process (SSP) at Site Screening Areas (SSAs) 18, 72, 30, 79, 60, and 77*, Radford Army Ammunition Plant (RAAP), Radford, Virginia, dated December 2008 (Work Plan Addendum).

GENERAL COMMENTS

1. The Work Plan Addendum Section 6.0 (Quality Assurance Plan Addendum) references use of the most recent version of the EPA guidance document for systematic planning using the Data Quality Objective (DQO), QA/G-4, dated February 2006. However, the terminology used throughout the Work Plan Addendum appears to be taken from the older version of this guidance. For instance, the DQO steps listed in Section 6.3 (Quality Assurance Objectives) are listed as *State The Problem, Identify the Decision, Identify Inputs to the Decision, Define the Boundaries, Develop a Decision Rule, Specify Acceptable Limits on Decision Errors, and Optimize Data Design.* The newer version of this EPA DQO guidance QA/G-4 lists the steps as *State the Problem, Identify the Goals of the Study, Identify Information Inputs, Define the Boundaries of the Study, Develop the Analytical Approach, Specify performance or Acceptance Criteria, and Develop the Plan for Obtaining Data*. The Work Plan Addendum does not need to be revised, but in the future, please correctly reference the DQO steps as listed in the most recent version of the EPA DQO guidance document, *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA/240/B-06/001), dated February 2006.

SPECIFIC COMMENTS

2. **Section 1.3.1.4, Soil Screening Level (SSL) Comparison – Soil, Page 1-4:** This section states that maximum detected concentrations (MDCs) of chemicals will be compared to screening levels for leaching of chemicals to groundwater, many of which "can be found in the Regional Screening Table." The target dilution attenuation factor (DAF) to be applied to the Regional SSLs, which are based on a DAF of 1, has not been specified. Additionally, the Regional Screening Table includes both risk-based SSLs and federal maximum contaminant level (MCL)-based SSLs. Please note that the risk-based SSLs should be used for this evaluation. Please revise the Work Plan Addendum to specify the DAF that will be applied to the Regional SSLs, and make a note that the risk-based SSLs will be used for this evaluation.

3. **Section 2.1.1, Site Description, Pages 2-1 and 2-2:** This section describes several site features which are not depicted on site figures. Outfall 004, the railroad spur, and all of the Unit 18 subunits (Unit 18a, Unit 18b, etc.) do not appear to be identified on the site figures. Since the proposed sampling approach references these locations in Section 2.5, Planned Field Investigation, it is important to document these features on a site plan in relation to the proposed samples. Please revise Figure 2-1, Site Layout – SSA 18 and SSA 72, and any other figures, as appropriate, to identify Outfall 004, the railroad spur, all of the Unit 18 subunits, and any other important site features.

4. **Section 2.2.2, Acid Sewer Survey, Page 2-4**: This section describes the results of an acid sewer survey and investigation conducted on the entire Radford Army Ammunition Plant (RFAAP) sewer infrastructure. It notes that deteriorated or broken sections of

sewer lines were repaired or replaced within active areas, and further states that "No actions were undertaken in the area of SSA 18 or SSA 72 due to the inactive status of the SAR Plant wastewater system and treatment facility." However, the current status of the sewer lines in the vicinity of SSA 18 or SSA 72 is still unclear (i.e., whether the lines were found to be deteriorated or broken during the assessment, or whether they were never assessed at all). For clarity, please describe the results of the acid sewer survey for those sewer lines in the vicinity of SSA 18 and SSA 72, even if no repairs were preformed due to the inactive nature of the site. If broken or deteriorated lines were identified, the locations of these breaks should be documented in the Work Plan Addendum so that targeted sampling can be proposed in these areas. In the event an assessment of the sewer lines in the vicinity of SSA 18 and SSA 72 was never performed, allowance for an assessment of these lines would seem warranted. Please revise the data gap assessment to indicate that a lack of information regarding the sewer lines in the vicinity of SSA 18 and SSA 72 exists, and requires completion of this assessment.

5. **Section 2.4.5, Summary of Data Gaps, Page 2-7:** The table provided at the top of Page 2-7, SSA 18 and SSA 72 – Summary of Data Gap Analysis and Completion Plan, notes that soil samples will be analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, explosives and metals. Dioxins and cyanide have been excluded. This appears to be a deviation from the specifications outlined in the SSP Guidance Document, provided in Appendix A. Page 3-1 of the SSP Guidance Document states, "All environmental media samples collected during the SSP will be analyzed for the full suite of Contract Laboratory Procedure (CLP) constituents and other constituents based on the findings of the Desktop Audit including additional analytes requested by EPA." The analytical target list is supposed to include Target Compound List (TCL) VOCs, SVOCs, pesticides, PCBs and dioxins, and TAL inorganic chemicals including cyanide. Please revise the Work Plan Addendum to include sampling for dioxins and cyanide, or provide justification for excluding these constituents from the analysis. This comment applies to each of the sites described in the Work Plan Addendum, as the proposed analyte list for any of the sites addressed by this Work Plan Addendum does not include cyanide or dioxins (except at a few sites).

6. **Section 2.5.2, Subsurface Soil Sampling, Page 2-8**: The second through fourth bullets in this section note that subsurface soil samples collected at sample locations 18SB2B, 18SB3B, and 18SB4B will be collected at a depth of 5 to 7 feet (ft) below ground surface (bgs). The rationale for sampling at this depth is unclear but it appears that it may be related to the depth of the sewer line (since assessment of this area was initially identified as a data gap). For clarity, please revise the Work Plan Addendum to provide a discussion of which data gap is intended to be addressed for each of the proposed sampling locations and sampling intervals, including the proposed sampling at sample locations 18SB2B, 18SB3B, and 18SB4B.

7. **Section 3.0, SSA 30 Asbestos Disposal Trench No. 1 and SSA 79 Asbestos Disposal Trench No. 2, Pages 3-1 through 3-4.** Data collected from nearby sites, such as Solid Waste Management Unit (SWMU) 51, SWMU 26, SWMU 52, and hazardous waste management unit (HWMU) 16 were used to develop the conceptual site model for SSA

30 and SSA 79. However, the boundaries of these SWMUs in relation to SSA 30 and SSA 79, an indication of whether there is any overlap, and a clear presentation of their spatial relationship to one another has not been presented. For clarity, please revise Figure 3-1, Site Layout – SSA 30 and SSA 79, and any other applicable figures to identify SWMU 51, SWMU 26 and SWMU 52, as well as, SSA 30 and SSA 79, together.

8. **Section 4.2.4, Hydrogeology, Page 4-2:** The last sentence of this section states that the depth to groundwater is expected to be greater than 75 ft below the fill material placed at SSA 60. References or other justification for this statement have not been provided. Please provide the technical basis or reference the information source used for indicating that the depth to groundwater is expected to be greater than 75 ft.

9. **Section 4.6.2, Drainage Ditch Sampling, Page 4-5:** The last sentence of this section states that sediment samples will be collected following the procedures outlined in Standard Operating Procedure (SOP) 30.4 and 30.9 in Appendix B. However, the method to collect the sediment samples has not been specified. SOP 30.4 includes several different methods for collecting samples (scoop or trowel, tube sampler, hand auger, etc.), and Section 3.1 of this SOP further notes that "the most appropriate method(s) of sample collection…will be specified in the work plan addendum…" Please revise Section 4.6.2 of the Work Plan Addendum to specify the proposed method of sediment sample collection, and note this comment for future submittals.

10. **Section 5.3, Conceptual Site Model, Page 5-4:** Potential dispersion and deposition of particulate matter from the incinerator stack is a possible source of soil contamination at the site, but Figure 5-7, Conceptual Site Model – SSA 77, does not appear to include this release mechanism. Figure 5-7 does not include the incinerator stack. For a complete portrayal of the CSM, please revise Figure 5-7 to depict the potential dispersion and deposition of particulate matter from the incinerator stack as a release mechanism at the site.

11. **Section 5.5.1, Soil Sampling in Building 7219 Area, Page 5-6:** This section notes that only two of three surface soil samples will be analyzed for dioxins, and no subsurface soil samples will be analyzed for these constituents. The Work Plan Addendum has not identified which two samples will be analyzed for dioxins. Furthermore, justification for limiting this analysis to two surface soil samples has not been provided. Given the historic use of the site as an incinerator, it appears that additional sampling for dioxins may be warranted. Please revise the Work Plan Addendum to address these concerns.

    Further, the appropriate locations for sampling of surface soils which would address particulates associated with incineration related dispersion and deposition from the incinerator stack would be dependent on information gained from a local wind rose, translation of that into a prevailing wind direction, documentation of the total stack height, and an assessment of the impacted areas for dispersion and deposition of particulates from incineration activities. It is currently unclear if the proposed sampling locations would be indicative of worst case conditions for incineration stack particulates. Please revise the Work Plan Addendum to indicate how the proposed sampling will

address this data gap, or please revise the Work Plan Addendum to incorporate additional sampling locations to specifically address this data gap.

12. **Section 5.5.1, Soil Sampling in Building 7219 Area, Page 5-6:** Subsurface soil samples will be collected at the borings at a depth interval of 4-6 ft bgs, but the rationale for selecting this depth interval has not been provided. For clarity and defensibility, please revise the Work Plan Addendum to include the rationale for the subsurface soil sampling depth interval.

13. **Section 6.3, Quality Assurance Objectives, Page 6-6:** Item number 5, *Develop a Decision Rule* (b. iii) states "MDLs and RLs, as specified herein, will ensure that data quality is sufficient for its intended use." Although additional quality control criteria are included in Section 6.0 *Quality Assurance Plan Addendum* of the Work Plan Addendum, this specific statement describing the required action levels implies that designating and achieving analytical minimum detection limits (MDLs) and reporting limits (RLs) alone provide the action levels that will ensure the data quality is sufficient. In accordance with EPA guidance document QA/G-4 *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA/240/B-06/001) dated February, 2006, DQOs define the type, quantity, and quality of data required to reach defensible decisions and which meet the project needs. The report does not need to be revised, but please note for future reference.

14. **Section 6.3, Quality Assurance Objectives, Page 6-7:** Item number 6, *Specify Acceptable Limits on Decision Errors* (a.) states "MDLs and RLs below the action levels will ensure the data meet the DQOs." While this statement is applicable, MDLs and RLs are not the only action levels that can be evaluated to determine whether DQOs have been met for the project. The report does not need to be revised, but please note for future reference.

15. **Section 6.3, Quality Assurance Objectives, Page 6-7:** Item number 6, *Specify Acceptable Limits on Decision Errors* (b.) provides a definition of Type I and Type II errors, but does not provide the actual limits. According to EPA DQO guidance document QA/G-4 (pages 49 – 56 of February 2006 version), the primary objective of this step in the DQO process is to specify the upper limits on the probabilities of each of these two types of decision errors by stating the alpha and beta limits for Type I and Type II decision errors. The report does not need to be revised, but please note for future reference.

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December 16, 2008

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,
Work Plan Addendum 028 Site Screening Process as Site Screening Areas 18, 72, 30, 79, 60, and 77, Draft December 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 December 12, 2008. Also enclosed is the 12 December 2008 transmittal email.

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
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08-815-190
JMcKenna

Concerning the following:

Radford Army Ammunition Plant
Work Plan Addendum 028 Site Screening Process at
Site Screening Areas 18, 72, 30, 79, 60, and 77
Draft December 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:
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TITLE: Lieutenant Colonel (P), US Army
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08-815-190
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Subject: WPA 028 SSP at SSAs 18, 72, 30, 79, 60, and 77FedEx Tracking Numbers (UNCLASSIFIED)

Importance: High

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.

Immediately below are the POCs with tracking numbers.

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

Jim McKenna
540 731 5782

POCs and Fed Ex numbers:

James McKenna 7961 8092 2667 2 Paper copies/2 CDs Will Geiger 7961 8091 5025 3 Paper copies/1 CD Jim Cutler 7961 8089 0304 1 Paper copy/1 CD Durwood Willis 7971 7743 5273 1 Paper copy/1 CD Tom Meyer 7971 7742 4519 1 CD Dennis Druck 7971 7741 7241 1 CD Elizabeth Lohman 7961 8086 4167 1 CD

Classification: UNCLASSIFIED
Caveats: NONE

PREFACE

A two-stage approach has been developed to facilitate and streamline Resource Conservation and Recovery Act (RCRA) site investigations at Radford Army Ammunition Plant (RFAAP) pursuant to the Permit for Corrective Action and Waste Minimization (October, 2000). The approach consists of a single facility-wide Master Work Plan and multiple site-specific Work Plan Addenda.

The Master Work Plan provides comprehensive discussions of standard procedures, protocol, and methodologies that are to be followed during execution of field investigations at RCRA sites within the RFAAP. The Master Work Plan is a generic plan designed to streamline site-specific Work Plan Addenda development, review, and approval.

Each Work Plan Addendum describes the site-specific information for each RCRA site, providing detailed data on past site operations, potential chemicals of concern, sampling strategy, etc. Each addendum, through reference to the Master Work Plan, is developed as a concise document, focused on site-specific investigations.

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MASTER WORK PLAN ADDENDUM 028
RCRA SITE SCREENING PROCESS INVESTIGATION AT SSAs 18, 72, 30, 79, 60, and 77

TABLE OF CONTENTS

Section *Page*

PREFACE I

1.0 INTRODUCTION 1-1

1.1 OBJECTIVE 1-1
1.2 DOCUMENT ORGANIZATION 1-1
1.3 SUMMARY OF SITE SCREENING PROCESS 1-3

2.0 SSA 18 SULFURIC ACID RECOVERY PLANT, ACIDIC WASTEWATER TREATMENT FACILITY AND SSA 72 OLEUM PLANT ACIDIC WASTEWATER SUMP 2-1

2.1 SITE BACKGROUND 2-1
2.2 PREVIOUS INVESTIGATIONS 2-4
2.3 CONCEPTUAL SITE MODEL (CSM) 2-5
2.4 DATA GAP ANALYSIS 2-6
2.5 PLANNED FIELD INVESTIGATION 2-7

3.0 SSA 30 ASBESTOS DISPOSAL TRENCH NO. 1 AND SSA 79 ASBESTOS DISPOSAL TRENCH NO. 2 3-1

3.1 SITE BACKGROUND 3-1
3.2 PREVIOUS INVESTIGATIONS 3-3
3.3 CONCEPTUAL SITE MODEL (CSM) 3-4
3.4 DATA GAP ANALYSIS 3-5
3.5 PLANNED FIELD ACTIVITIES 3-6

4.0 SSA 60 RUBBLE PILE EAST OF ADMINSTRATION BUILDING (BUILDING 220) 4-1

4.1 SITE BACKGROUND AND ENVIRONMENTAL SETTING 4-1
4.2 SITE HISTORY 4-1
4.3 PREVIOUS INVESTIGATIONS 4-3
4.4 CONCEPTUAL SITE MODEL (CSM) 4-3
4.5 DATA GAP ANALYSIS 4-3
4.6 PLANNED FIELD ACTIVITIES 4-5

5.0 SSA 77 GARBAGE INCINERATOR (BUILDING 7219) 5-1

5.1 SITE BACKGROUND 5-1
5.2 PREVIOUS INVESTIGATIONS 5-2
5.3 CONCEPTUAL SITE MODEL (CSM) 5-4
5.4 DATA GAP ANALYSIS 5-4
5.5 PLANNED FIELD ACTIVITIES 5-6

6.0 QUALITY ASSURANCE PLAN ADDENDUM 6-1

6.1 INTRODUCTION 6-1
6.2 PROJECT ORGANIZATION AND RESPONSIBILITIES 6-2
6.3 QUALITY ASSURANCE OBJECTIVES 6-3
6.4 SAMPLE MANAGEMENT 6-7

MASTER WORK PLAN ADDENDUM 028
RCRA SITE SCREENING PROCESS INVESTIGATION AT SSAs 18, 72, 30, 79, 60, and 77
TABLE OF CONTENTS
(CONTINUED)

6.5 ANALYTICAL PROCEDURES 6-8
6.6 INTERNAL QUALITY CONTROL CHECKS 6-14
6.7 DATA COLLECTION AND VALIDATION 6-14

7.0 HEALTH AND SAFETY PLAN ADDENDUM 7-1

7.1 INTRODUCTION 7-1
7.2 TRAINING PLAN 7-1
7.3 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING 7-3
7.4 MONITORING PLAN 7-3
7.5 EMERGENCY RESPONSE PLAN 7-3

8.0 REFERENCES 8-1

MASTER WORK PLAN ADDENDUM 028
RCRA SITE SCREENING PROCESS INVESTIGATION AT SSAs 18, 72, 30, 79, 60, and 77
TABLE OF CONTENTS
(CONTINUED)

LIST OF FIGURES

Figure 1-1	Site Screening Areas Location Map
Figure 2-1	Site Layout – SSA 18 and SSA 72
Figure 2-2	Additional Site Layout Map – SSA 18 and SSA 72
Figure 2-3	Sewer Profile from SSA 72 to SSA 18
Figure 2-4	SSA 18 and SSA 72 Aerial Photograph - 1949
Figure 2-5	SSA 18 and SSA 72 Aerial Photograph - 1962
Figure 2-6	SSA 18 and SSA 72 Aerial Photograph – 1971
Figure 2-7	SSA 18 and SSA 72 Aerial Photograph – 1986
Figure 2-8	SSA 18 and SSA 72 Aerial Photograph – 1990
Figure 2-9	Previous Investigations – SSA 18 and SSA 72
Figure 2-10	Conceptual Site Model – SSA 18 and SSA 72
Figure 2-11	Proposed SSP Sample Locations – SSA 18 and SSA 72
Figure 3-1	Site Layout – SSA 30 and SSA 79
Figure 3-2	SSA 30 and SSA 79 Aerial Photograph – 1971
Figure 3-3	SSA 30 and SSA 79 Aerial Photograph – 1986
Figure 3-4	SSA 30 and SSA 79 Aerial Photograph – 1990
Figure 3-5	Previous Investigations – SSA 30 and SSA 79
Figure 3-6	Conceptual Site Model – SSA 30 and SSA 79
Figure 3-7	Proposed SSP Sample Locations – SSA 30 and SSA 79
Figure 4-1	Site Layout – SSA 60
Figure 4-2	SSA 60 Aerial Photograph – 1990
Figure 4-3	SSA 60 Aerial Photograph – 2002
Figure 4-4	Conceptual Site Model – SSA 60
Figure 4-5	Proposed SSP Sample Locations – SSA 60
Figure 5-1	Site Layout – SSA 77
Figure 5-2	SSA 77 Aerial Photograph - 1949
Figure 5-3	SSA 77 Aerial Photograph - 1962
Figure 5-4	SSA 77 Aerial Photograph – 1971
Figure 5-5	SSA 77 Aerial Photograph – 1986
Figure 5-6	Previous Investigations – SSA 77
Figure 5-7	Conceptual Site Model – SSA 77
Figure 5-8	Proposed SSP Sample Locations – SSA 77
Figure 6-1	Project Organizational Chart

LIST OF TABLES

Table 1-1	Applicable MWP Activities and Related SOPs
Table 2-1	Monitoring Well Construction and Groundwater Data, 2007 Oleum Plant Environmental Baseline Study including Area of SSA 18 and SSA 72
Table 2-2	Summary of Historical Analytical Data for Soil Samples Collected at SSA 18 and SSA 72
Table 2-3	Summary of Historical Analytical Data for Sump Water Samples Collected at SSA 72

MASTER WORK PLAN ADDENDUM 028
RCRA SITE SCREENING PROCESS INVESTIGATION AT SSAs 18, 72, 30, 79, 60, and 77
TABLE OF CONTENTS
(CONTINUED)

Table 2-4 Historical Analytical Data for Groundwater Samples Collected at SSA 18 and SSA 72 Area
Table 2-5 Wildlife Profiles
Table 2-6 Handling and Disposal of Investigative Derived Materials
Table 3-1 Historical Groundwater Samples for SSA 30 and SSA 79 Area, Dames & Moore 1992 RFI
Table 3-3 Historical Groundwater Samples for SSA 30 and SSA 79 Area, Eastern Horseshoe Area 2006 Groundwater Data Summary Report, Shaw Environmental
Table 5-1 Historical Groundwater Samples for SSA 77 Area, Former Lead Furnace Area RFI/CMS, Shaw Environmental
Table 6-1 Quality Assurance Measures Discussed in the MQAP
Table 6-2 Contractor and Subcontractor Key Points of Contact
Table 6-3 Summary of Project Data Quality Objectives
Table 6-4 Summary of Proposed Sample Identifiers, Depths, and Analytical Methods
Table 6-5 Summary of Sample Container, Preservation Method, and Holding Time Requirements
Table 6-6 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL VOCs (by EPA Method 8260B)
Table 6-7 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL SVOCs (by EPA Method 8270C)
Table 6-8 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL Pesticides and Herbicides (by EPA Method 8081A and 8151A)
Table 6-9 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL PCBs (by EPA Method 8082), and Perchlorate (by EPA Method 6850)
Table 6-10 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for Explosives (by EPA Methods 8330 and 8332)
Table 6-11 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TAL Metals (by EPA Methods 6010B/6020/7000/9012A)
Table 6-12 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL Dioxin/Furans (by EPA Method 8290)
Table 6-13 Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for Asbestos (by CARB Method 435 and EPA Method 100.2)
Table 6-14 Field Quality Control Samples
Table 6-15 Field Quality Control Elements Acceptance Criteria
Table 6-16 Analytical Quality Control Elements of a Quality Assurance Program
Table 6-17 Quality Control Method Criteria for Volatile Organic Compounds by EPA SW-846 Method 8260B
Table 6-18 Quality Control Method Criteria for Semi-volatile Organic Compounds by EPA SW-846 Method 8270C
Table 6-19 Quality Control Method Criteria for Explosives by EPA SW-846 Methods 8330 and 8332
Table 6-20 Quality Control Method Criteria for Target Analyte List Metals by EPA SW-846 Methods 6010B/6020/7471A/7470A/9012A
Table 6-21 Quality Control Method Criteria for Pesticides, Herbicides, and PCBs by EPA SW-846 Methods 8081A, 8151A, and 8082

Table 6-22 Quality Control Method Criteria for Asbestos by CARB Method 435 and EPA Method 100.2
Table 6-23 Quality Control Method Criteria for Total Organic Carbon by Walkley-Black Method
Table 6-24 Quality Control Method Criteria for Chemical Oxygen Demand by EPA Method of Chemical Analysis for Water and Wastes 410.4
Table 6-25 Quality Control Method Criteria for Dioxin/Furans by EPA SW-846 Method 8290
Table 7-1 Health and Safety Issues Discussed in the MHSP
Table 7-2 Emergency Telephone Numbers

LIST OF APPENDICES

Appendix A Site Screening Process Guidance
Appendix B Standard Operating Procedures
Appendix C Site Photographs
Appendix D Previous Investigation Information
D.1 SSA 18 and SSA 72
D.2 SSA 30 and 79
D.3 SSA 77
Appendix E Forms

LIST OF ABBREVIATIONS AND ACRONYMS

ºC.....Degrees Celsius
% .....Percent
AES.....Atomic Emission Spectroscopy
AOC.....Area of Concern
ARAR .....Applicable or Relevant and Appropriate Requirements
ASTM .....ASTM International
BAG.....Bioaccumulation Factor
bgs.....Below Ground Surface
CARB.....State of California Air Resources Board
CFR.....Code of Federal Regulations
CL .....Sandy Clay
CLP .....Contract Laboratory Program
cm/sec .....Centimeter per second
CMS.....Corrective Measures Study
CN.....Cyanide
COC .....Chemical of Concern
COD.....Chemical Oxygen Demand
COPC.....Chemical of Potential Concern
COPEC.....Chemical of Potential Ecological Concern
COR .....Contracting Officer's Representative
CSM.....Conceptual Site Model
dBA.....Decibels on the A-Weighted Scale
DOD.....Department of Defense
DQO.....Data Quality Objective
ECD .....Electron Capture Detector
EEI .....Ecology and the Environment, Inc.
ELCD.....Electrolytic Conductivity Detector
EM .....Electromagnetic
EPC.....Exposure Point Concentration
EPIC.....Environmental Photographic Interpretation Center
ERI.....Electrical Resistivity Imaging
ERIS.....Environmental Restoration Information System
ESI .....Electrospray Ionization
FLFA.....Former Lead Furnace Area
ft.....Feet
g .....Gram
GC.....Gas Chromatography
GPR.....Ground Penetrating Radar
GPS .....Global Positioning System
HAZCOM .....Hazard Communication
HI .....Hazard Index
HPLC .....High Performance Liquid Chromatography
HQ.....Hazard Quotient
HRGC .....High Resolution Gas Chromatography
HRMS .....High Resolution Mass Spectrometry
HSP .....Health and Safety Plan

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

HSPA .....Health and Safety Plan Addendum
HTRW.....Hazardous, Toxic, and Radioactive Waste
I-RBC.....Industrial Risk-Based Concentration
ICP .....Inductively Coupled Plasma
ICP-MS .....Inductively Coupled Plasma-Mass Spectrometry
IDM.....Investigation-Derived Material
LOAEL .....Low Observed Adverse Effect Level
m/z .....Mass-to-charge
MCL.....Maximum Contaminant Level
MDC .....Maximum Detected Concentration
MDL.....Method Detection Limit
µg/dL.....Micrograms Per Deciliter
µL.....Microliter
µm .....Micrometer
mL .....Milliliter
MHSP.....Master Health and Safety Plan
mm .....Millimeter
MMA .....Main Manufacturing Area
MQAP.....Master Quality Assurance Plan
MS.....Mass Spectrometer
MS/MS.....Tandem Mass Spectrometry
MS/MSD.....Matrix Spike/Matrix Spike Duplicate
msl.....Mean Sea Level
MWP.....Master Work Plan
NELAP.....National Environmental Laboratory Accreditation Program
NOAEL.....No Observed Adverse Effect Level
NFA .....No Further Action
nm .....Nanometer
NSV .....No Screening Value
OSHA.....Occupational Safety and Health Administration
PAH .....Polynuclear Aromatic Hydrocarbon
PCB.....Polychlorinated Biphenyl
PCDD.....Polychlorinated Dibenzo-p-Dioxins
PCDF .....Polychlorinated Dibenzofurans
PETN .....Pentaerythritol Tetranitrate
PID.....Photoionization Detector
PM.....Project Manager
ppb .....Parts Per Billion
PPE.....Personal Protective Equipment
ppm .....Parts Per Million
ppq .....Parts Per Quadrillion
ppt .....Parts Per Trillion
PTFE .....Polytetrafluoroethylene
QA.....Quality Assurance
QC.....Quality Control

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

QA/QC .....Quality Assurance/Quality Control
QAP .....Quality Assurance Plan
QAPA.....Quality Assurance Plan Addendum
QSM.....Quality Systems Manual
R.....Rinse Blank
R-RBC .....Residential Risk-Based Concentration
RBC .....Risk-Based Concentration
RCRA.....Resource Conservation and Recovery Act
RDA .....Recommended Daily Allowance
RFA.....RCRA Facility Assessment
RFI .....RCRA Facility Investigation
RFAAP.....Radford Army Ammunition Plant
RL .....Reporting Limit
SAR.....Sulfuric Acid Recovery
SB.....Soil Boring
SE.....Sediment
SHSO .....Site Health and Safety Officer
SLERA.....Screening Level Ecological Risk Assessment
SM.....Silty Sand
SMDP.....Scientific Management Decision Point
SOP .....Standard Operating Procedure
SOW.....Statement of Work
SSA .....Site Screening Area
SSL.....Soil Screening Level
SSP.....Site Screening Process
SVOC.....Semi-volatile Organic Compound
SWMU .....Solid Waste Management Unit
T .....Trip Blank
T-RBC.....Tap Water Risk-Based Concentration
TAL.....Target Analyte List
TCL.....Target Compound List
TCLP.....Toxicity Characteristic Leaching Procedure
TEM .....Transmission Electron Microscopy
TEF .....Toxicity Equivalent Factor
TEQ.....Toxicity Equivalent Quotient
TNT.....Trinitrotoluene
TOC .....Total Organic Carbon
TRV .....Toxicity Reference Value
TWA .....Time Weighted Average
UCL .....Upper Confidence Limit
URS.....URS Group, Inc.
USACE .....United States Army Corps of Engineers
USEPA.....United States Environmental Protection Agency
UV.....Ultraviolet
VDEQ .....Virginia Department of Environmental Quality

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

VOC.....Volatile Organic Compound
VPDES.....Virginia Pollution Discharge Elimination System
WPA.....Work Plan Addendum

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1.0 INTRODUCTION

In accordance with Contract Number W91238-07-D-0006, Delivery Order DA01, URS Group, Inc. (URS) has been tasked by the United States Army Corps of Engineers (USACE), Baltimore District to perform a Resource Conservation and Recovery Act (RCRA) Site Screening Process (SSP) Investigation for six Site Screening Areas (SSAs) at the Radford Army Ammunition Plant (RFAAP), Radford, Virginia (Figure 1-1). This SSP Work Plan for these SSAs is presented as Work Plan Addendum (WPA) 028 to, and incorporates by reference, the elements of the RFAAP Master Work Plan (MWP) (URS 2003).

This SSP includes the following sites:

- SSA 18 Sulfuric Acid Recovery Plant – Waste Acid Treatment Facility
- SSA 72 Oleum Plant Acidic Wastewater Sump
- SSA 30 Asbestos Disposal Trench No. 1
- SSA 79 Asbestos Disposal Trench No. 2
- SSA 60 Rubble Pile East of the Administration Building
- SSA 77 Garbage Incinerator

Figure 1-1 shows the location of the SSAs at RFAAP.

1.1 OBJECTIVE

The objectives of the SSP are to assess: 1) whether releases of hazardous substances, pollutants, hazardous wastes, or hazardous constituents have occurred to the environment at the site, and 2) whether further investigation or action (i.e., risk assessment, RCRA Facility Investigation (RFI), interim action), or no further action (NFA) is appropriate at the site (USEPA 2001). Appendix A contains the U.S. Environmental Protection Agency (USEPA) SSP Guidance for RFAAP.

1.2 DOCUMENT ORGANIZATION

This WPA provides the rationale and methods for planned field activities at the SSAs in support of the SSP investigation. Consistent with the MWP, this addendum is composed of the following sections:

- Section 2.0, WPA SSA 18 and SSA 72 (these sites are co-located)
- Section 3.0, WPA SSA 30 and SSA 79 (these sites are co-located)
- Section 4.0, WPA for SSA 60;
- Section 5.0, WPA for SSA 77;
- Section 6.0, Quality Assurance Plan (QAP) Addendum (QAPA);
- Section 7.0, Health and Safety Plan (HSP) Addendum (HSPA); and
- Section 8.0, References.

The MWP is referenced where routine activities will be performed in accordance with the MWP specifications, standard operating procedures (SOPs), and the Master Health and Safety Plan (MHSP; URS 2003). Variances to the specifications are documented in this WPA. Table 1-1 identifies the MWP SOPs that will be followed as part of the SSP for field documentation, subsurface investigation, sampling, field evaluations, sample management, data management, and management of investigative

derived material (IDM), decontamination, and field monitoring. Copies of the SOPs identified in Table 1-1 are included in Appendix B. The MWP will be kept on the site and referenced during field activities.

Changes to the approved WPA will be documented using the Work Plan Revision Form (Form E-1; Appendix E). Revisions must be reviewed and approved by the USACE Contracting Officer's Representative (COR) and the RFAAP designee prior to implementation. Project personnel will be required to read this WPA and to sign and date a Worker Acknowledgement Form (Form E-2; Appendix E). The Site Health and Safety Officer (SHSO) will retain this form on the site during investigative activities. Appropriate health and safety precautions will be taken due to the potential for exposure to or handling of hazardous materials, energetics, and/or their degradation compounds.

Table 1-1

Applicable MWP Activities and Related SOPs

Subject	MWP Section	SOPs MWP Appendix A and Appendix B to WPA 028
Documentation	4.3	10.1 Field Logbook 10.2 Surface Water, Groundwater, and Soil/Sediment Field Logbooks 10.3 Boring Logs 10.4 Chain-of-Custody Form
Sample Management	5.1	50.1 Sample Labels 50.2 Sample Packaging
Decontamination Requirements	5.12	80.1 Decontamination
Investigation-Derived Material	5.13	30.6 Containerized Material 70.1 Investigation-Derived Material
Subsurface Investigation	5.2	20.3 Well and Boring Abandonment 20.4 Test Pits 20.6 Ground-Penetrating Radar Surveys 20.7 Resistivity and Electromagnetic Surveys 20.11 Drilling Methods and Procedures 30.1 Soil Sampling 30.2 Groundwater Sampling 30.4 Sediment Sampling with Scoop or Tube Sampler 30.7 Sampling Strategies 30.9 Collection of Soil Samples by USEPA SW-846 Test Method 5035 for Volatile Organic Compounds Using Disposable Samplers 40.1 Multi-parameter Water Quality Monitoring Instrument 40.2 Water Level and Well Depth Measurements 90.1 Photoionization Detector (HNu Model PI-101 and HW-101)
Drum Sampling	5.7	30.6 Containerized Material

1.3 SUMMARY OF SITE SCREENING PROCESS

1.3.1 Human Health Risk Screening

The purpose of the SSP human health risk screening is to evaluate site data using conservative criteria so a site can be eliminated from further consideration or identify if the site requires further evaluation. The screening procedures include the following five steps:

- Identification of chemicals of potential concern (COPCs) and cumulative risk screening;
- Chemical specific screening for lead and iron;
- Comparison to soil-to-groundwater soil screening levels (SSLs);
- Comparison to Applicable or Relevant and Appropriate Requirements (ARARs); and
- Comparison to background point estimates (available for select metals).

1.3.1.1 Identification of COPCs

COPCs will be identified for the sites by comparing the maximum detected concentration (MDC) for detected chemicals in a specific medium to USEPA Region III Residential risk-based concentrations (R-RBCs) and Industrial risk-based concentrations (I-RBCs) for soil and tap water risk-based concentrations (T-RBCs) for groundwater, if available, provided in most recent the Regional Screening Table. In accordance with USEPA Region III guidance, RBCs for noncarcinogenic chemicals will be adjusted downward to a Hazard Quotient (HQ) of 0.1 to ensure that chemicals with additive effects were not prematurely eliminated during screening. For the purpose of COPC identification and risk screening, data from duplicate sample pairs will be averaged and treated as one result. If a chemical is detected in one of the sample pair, half the detection limit of the non-detect will be averaged with the detected result, and the result is considered detected. Chemicals that have a MDC above the adjusted USEPA Region III RBC or for which no screening value (NSV) exists will be selected as COPCs and retained for quantitative assessment.

1.3.1.2 Cumulative Risk Screen

The cumulative human health risk screen consists of calculating the ratios between the exposure point concentrations (EPCs) of COPCs in each medium and the corresponding RBC. For purposes of this screening process, MDCs or a 95% upper confidence limit (UCL) (if appropriate) will be considered in the cumulative risk screening as representative EPCs. 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 2002a) 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 2006c).

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 will be used to calculate EPCs for the sites.

Both carcinogenic and noncarcinogenic effects will be evaluated in accordance with Section 6.1.1.2 of the SSP Guidance (Appendix A). If the cumulative cancer risk is greater than or equal to 1E-05 then a quantitative risk assessment may be performed. If the cumulative cancer risk for a site is less than 1E-05

and other screening criteria evaluated for the SSP are below established SSP thresholds, then NFA would be recommended for the site.

If the noncarcinogenic cumulative hazard index (HI) is greater than 1, there is a potential for adverse noncarcinogenic 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 calculated. The results of the cumulative risk screens are interpreted as follows:

- If the cumulative HI for a site is greater than or equal to 0.5 for a target organ, then a quantitative risk assessment would be recommended for the site; or
- If the cumulative HI for a site is less than 0.5 for each target organ, and other screening criteria evaluated for the SSP are below established SSP thresholds, then NFA would be recommended for the site.

1.3.1.3 Lead and Iron Screening

If lead concentrations in soil are greater than 400 mg/kg (USEPA, 1994), or lead concentrations in groundwater or surface water are greater than 15 g/L (USEPA 1991), then potential risk associated with lead will be evaluated using the IEUBK model (USEPA 2007). The model will be run using site-specific input parameters based on SSP findings and consultation with USEPA Region III. If the percentage of children expected to have blood lead levels of 10 micrograms per deciliter (μg/dL) or greater is above 5%, then further investigation or response action will be required for the SSA.

If iron concentrations in soil or water result in an HQ of 0.5 or greater, then a "margin of exposure" evaluation will be performed. Risks from exposure to iron will be characterized by comparing estimated iron intake to the recommended dietary allowance (RDA) and concentrations known to cause adverse effects in children (USEPA 2006d).

1.3.1.4 SSL Comparison - Soil

MDCs (or a 95% UCL if appropriate) of chemicals found in soil will be compared to risk-based screening levels for leaching of chemicals to groundwater (i.e., soil-to-groundwater screening levels), as presented in the Regional Screening Table. A DAF 20, which accounts for attenuation processes in the surface and subsurface soil zones above groundwater in addition to the mixing zone with groundwater, will be utilized in the screening. This DAF value may be adjusted for a specific SSA to account for site-specific conditions identified during the SSP, such as site physical soil data or chemical data. Organic chemicals found at concentrations greater than generic soil-to-groundwater screening levels will be evaluated utilizing site-specific SSLs calculated using site-specific physical soil characteristics. Site-specific SSLs will be calculated using the USEPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002b).

1.3.1.5 Background Comparison - Soil

As a final step in the human health screening process, MDCs of chemicals identified as COPCs will be compared to the EPA-approved site-specific background concentrations (IT 2001). Based on the background comparison and the results of the site screening process, a recommendation will be made as to whether further investigation or response action is warranted at each SSA based on risk to human health.

1.3.2 ECOLOGICAL RISK SCREENING PROCESS

The purpose of the ecological risk screening is to provide conclusions and recommendations regarding potential ecological risk associated with the six SSAs. The Screening Level Ecological Risk Assessment

(SLERA) will be performed in accordance with the Final Process for Ecological Risk Assessment – Radford AAP (URS 2007). The SLERA process is summarized below. The findings of this ecological risk screen are used as input to risk management decision-making for the site. The scientific management decision point (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 SSA 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.

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 COPEC concentrations are above 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 SMDP for each site area based on the ecological risk screening results.

1.3.2.1 Site Characterization

The objectives of this step are to initially identify and characterize the site(s) ecological resources, and to preliminarily describe the nature and extent of chemicals of concern at the site(s) in question. Information pertaining to site land-use (past, current and future), size, proximity to operable areas and/or sensitive habitats, and habitats and ecological resources will be developed during the site characterization. The SSP is a screening level process that will be used to determine if a site should proceed further through the RFI stage. As such, detailed field sampling and quantitative analysis of biota will not be performed during the SSP. If chemicals of concern are identified which may affect ecological receptors, a recommendation in the SSP report may include biota sampling.

This step will begin with the site visit. Information about local ecological resources (including threatened and endangered species) will also be obtained from maps of the study area, available scientific literature, and federal and state agencies (e.g., U.S. Fish and Wildlife Service, Virginia Department of Game and Inland Fisheries, Department of Natural Heritage database, etc.). The site characterization will also describe likely sources, release mechanisms, complete migration pathways, the fate of chemicals resulting from site-related activities, as well as important ecological resources that could be adversely affected by these chemicals.

1.3.2.2 Identification of Chemicals of Potential Ecological Concern

The sites consist of exclusively terrestrial grassland habitat or developed industrial areas, and soil represents the potential exposure medium to ecological receptors. Soil samples will be collected from 0 to 1 foot below ground surface (and 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 foot (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. Surficial soil (0 to 1 ft bgs) represents the potential exposure media to ecological receptors. COPECs will be identified by comparison of maximum site surface soil concentrations to screening values and/or by simple food-web modeling as outlined in the Final Process for Ecological Risk Assessment – Radford AAP (URS 2007d) and in Sections 1.3.2.3 and 1.3.2.4.

1.3.2.3 Preliminary Exposure Estimate and Risk Characterization

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. Risk is assessed by comparing the preliminary exposure estimate (i.e., MDC) of each detected chemical to establish the toxicity reference value (TRV). The resulting risk is characterized in terms of an HQ, which is expressed as:

$$\mathbf{HQ = MDC/TRV}$$

Where: **HQ** = Ecological Effects Quotient for the chemical (unitless)
MDC = Maximum concentration for chemical (mg/L or mg/kg)
TRV = Toxicity Reference Value for chemical (mg/L or 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.

Dose Rate Models

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. The equation is provided below.

$$C_{TRV} = \frac{ADD \cdot BW}{(IR_{food} \ (BAF_{food} \cdot DF) + IR_s \ )AF}$$

Where:

C_{TRV} = No Observable Adverse Effect Level (NOAEL) or Lowest Observed Adverse Effect Level (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} = Bioaccumulation Factor (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 MDC 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. Risk is assessed by comparing the preliminary exposure estimate (i.e., MDC) of each detected chemical to the established C_{TRV} resulting in an HQ.

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.

1.3.2.4 Refined Exposure Estimate and Risk Characterization

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 COPECs identified in the preliminary risk characterization. The addition of step 3a focuses the outcome of the ecological screening, streamlines the review process, and functions as the initial basis for ecological risk management decision-making at each site.

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).

Direct Contact Approach

As noted below for the refined exposure estimate and risk characterization, the 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 2002a) 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 2006c).

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 will be used to calculate EPCs for the sites.

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:

$$\mathbf{HQ = EPC/TRV}$$

Where:

HQ = Hazard Quotient for the chemical (unitless)
EPC = Calculated Exposure Point Concentration for the chemical (mg/kg)
TRV = Screening Level for the 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.

Dose Modeling

The conservative assumptions used in the preliminary exposure estimate and ecological effects evaluation are replaced with more environmentally realistic assumptions resulting in a more realistic estimate of potential risk, utilizing the equation below.

$$C_{TRV} = \frac{ADD \cdot BW}{(IR_{food} \sum (BAF_{food} \cdot DF) + IR_s) AF_{refined}}$$

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. In addition, a realistic area use factor ($AF_{refined}$) is calculated as the ratio of the site area to the average home range of the receptor. Risk is assessed by comparing the preliminary exposure estimate (i.e., EPC) of each detected chemical to the established C_{TRV} resulting in an HQ.

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.

1.3.2.5 Natural Site Constituents (Background and Essential Nutrients)

Background point estimates for metals will be incorporated in the ecological risk management decision to assess site soil concentrations in the context of facility background levels (IT 2001). The 95% UTL of background will be used as the representative background concentration (IT 2001). Essential nutrients, including calcium, magnesium, potassium, and sodium were not considered to be COPECs in the risk screening as recommended by the SSP (USEPA 2001) and the MWP (URS 2003).

1.3.2.6 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.

1.3.3 Site Screening Process Conclusion and Recommendation

Results of the desktop audit, nature and extent determination (if available), and the human health and ecological screening procedures will be presented in an SSP Report for each SSA with a recommendation for future action. The EPA will review the SSP Report for each SSA and based on results of the screening procedures, a decision will be made as to whether each SSA should be recommended for no further action, or for further action. A need for further action will be based on but not limited to the following: historical use of the SSA, history of documented release (if any), analytical data from the SSA, and the overall weight of the evidence. In general, further action at an SSA may be required under the following circumstances:

- Cumulative Excess Cancer Risk (CECR) greater than 1x10-5;
- HI greater than 0.5 per target organ;
- Maximum Detected Concentration > SSL for chemical migration from soil to ground water; or
- Ecological risk considerations per Section 1.3.2.

If none of the above circumstances occur, USEPA may recommend no further action and memorialize this recommendation in a Decision Document. If any of the above circumstances occur, further action may be required. Further action may consist of one or more of the following:

- Interim Removal Action, followed by sampling to confirm that risks have been reduced to acceptable levels;
- Focused RFI (including additional sampling); or
- RFI/Corrective Measures Study (CMS).

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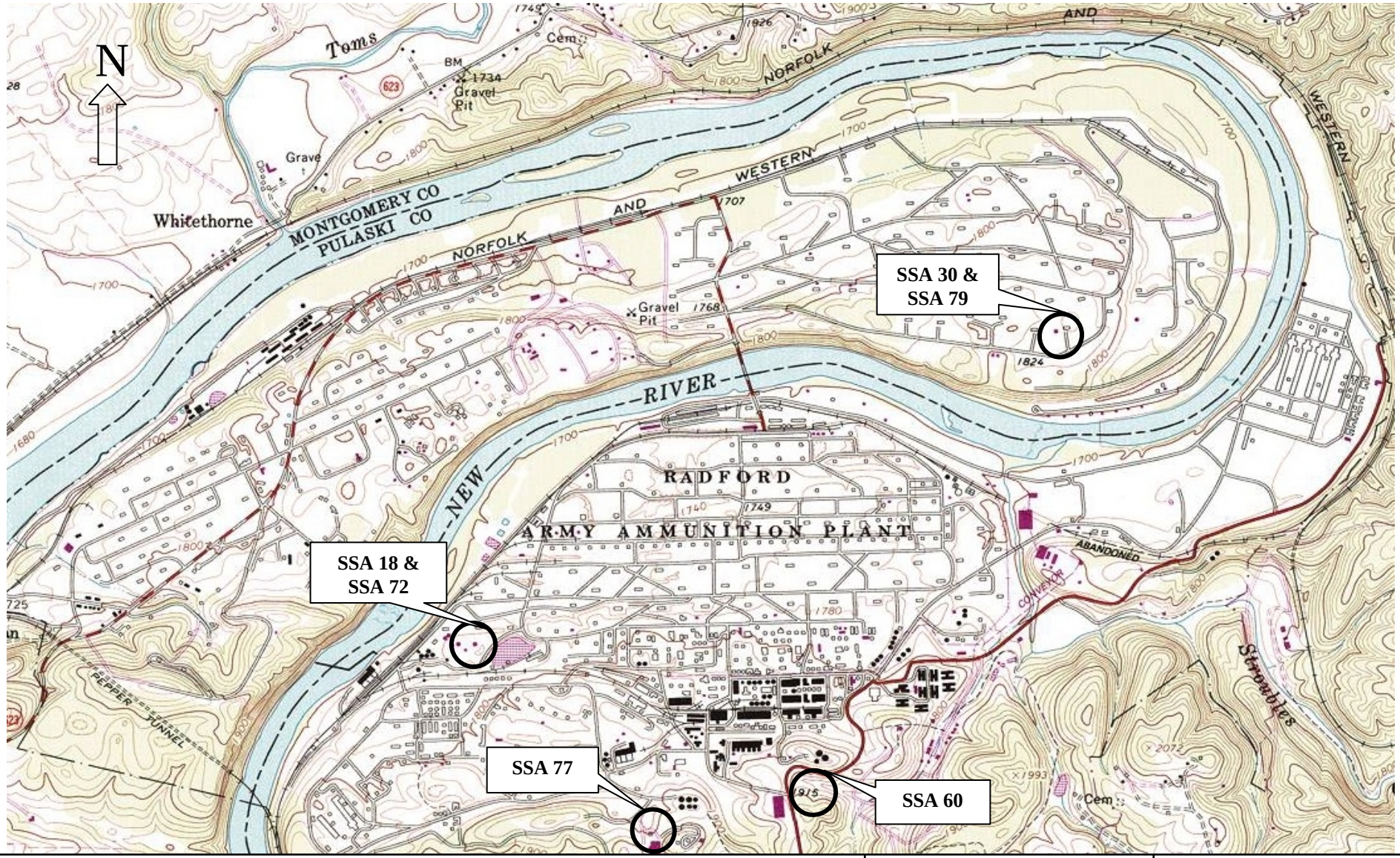

FIGURE 1-1

Site Location Map

Date: October 2008	URS Project #: 11656351
Prepared by: DBC	Approved by: JOS
Scale: *1" = 2000'*	File Name: Fig1-1 SiteLoc

MWP Addendum 028 –
SSP Investigation for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

URS Group, Inc.
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Richmond, Virginia 23230

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2.0 SSA 18 SULFURIC ACID RECOVERY PLANT, ACIDIC WASTEWATER TREATMENT FACILITY AND SSA 72 OLEUM PLANT ACIDIC WASTEWATER SUMP

2.1 SITE BACKGROUND

2.1.1 Site Description

SSA 18, the Sulfuric Acid Recovery (SAR) Plant (Oleum Plant), Acidic Wastewater Treatment Facility (Building 4434) and SSA 72, the Oleum Plant Acidic Wastewater Sump, are located in the northwest section of the main manufacturing area (MMA) approximately 400 to 600 ft east of the New River (Figure 1-1). Sulfuric acid was recovered at the SAR Plant from spent acid generated in the trinitrotoluene (TNT) manufacturing area. Acidic wastewater generated by this process was conveyed by underground sewers to the acidic wastewater sump. Wastewater collected in the sump was then discharged by gravity sewer to the SAR Wastewater Treatment Facility for treatment.

Figure 2-1 shows the layout of the SSA 18 and SSA 72 area. The acidic wastewater sump is located near the northwest corner of Building 4429 within the SAR Plant area. Sump dimensions are approximately 9.5 ft long, 5 ft wide, and 6 ft deep. The inside of the reinforced concrete sump is lined with 2-inch thick acid resistant brick. Design plans indicate that the top elevation of the concrete sump is 1,747.17 ft mean sea level (msl). The top of the sump has a manhole for access with the remaining portions covered with grates. Twelve inch diameter acid sewer lines enter the sump. Acidic wastewater discharges from the sump via a 6-inch diameter, gravity acid sewer line (at 6.63% grade), which runs 260 ft north to the SAR Acidic Wastewater Treatment Plant (SSA 18). The sewer daylights through a headwall and discharges into the steel, aboveground wastewater surge tank at SSA 18. Sewer profiles indicate an invert elevation of 1,742.17 ft msl for the 6-inch line exiting the sump and an invert elevation of 1,726.3 ft msl where the line enters the surge tank (Figure 2-2). A site photographic log for SSA 72 is included in Appendix C.

The SAR wastewater treatment facility encompasses an approximate 0.25 acre area (Figure 2-1). Ground surface elevations range from approximately 1,722 ft mean sea level (msl) to 1,726 ft msl, with a slight slope toward the north and the New River. Acidic wastewater discharged into the surge tank at the wastewater treatment facility was then pumped into the neutralization tank inside Building 4434 where it was neutralized with lime slurry, and processed through clarifiers and vacuum dry filters to remove calcium sulfate solids. Lime was delivered to the facility using a railroad spur located along the north side of Building 4434. Lime was unloaded from railroad cars into a hopper and conveyed by a screw conveyor and elevator into Building 4434 for slaking and transfer into the lime silos. A site photographic log for SSA 18 is included in Appendix C.

Effluent from the treatment plant originally discharged via a concrete outfall sump to the New River via Virginia Pollution Discharge Elimination System (VPDES) Outfall 004. This discharge was later modified in 1982 to discharge to Hazardous Waste Management Unit 7 (HWMU 7) for further treatment prior to discharge at Outfall 004. In 1985, the discharge from wastewater treatment plant was rerouted to the C-Line Acidic Wastewater Treatment Facility (Building 420-2) for further treatment before discharge at Outfall 005. The new discharge line consisted of 8 inch diameter polytetrafluoroethylene (PTFE) lined, terra cotta above grade pipe, was installed from the concrete discharge sump to the C-Line facility.

Calcium sulfate sludge from the wastewater treatment process was disposed offsite or onsite at various solid waste management units (SWMUs) including calcium sulfate drying beds at SWMU 37, SWMU 38, and Area of Concern (AOC) Q where the sludge was dried. Dried sludge was then removed from the drying beds and delivered to RFAAP's onsite SWMU 27, 50, and Hazardous Waste Management Unit (HWMU) 16 for disposal.

Seven subunits were identified in the RCRA Facility Assessment (RFA) completed at the wastewater treatment facility (USEPA 1987) including:

- *Unit 18a Sheet Metal Wastewater Treatment Plant* – this structure contains the wastewater pH adjustment and neutralization tank (Unit 18c), vacuum drum filters (Unit 18b), and associated piping and pump system.
- *Unit 18b: Vacuum Drum Filters* – neutralized wastewater was processed through two rotary vacuum dry filters to remove calcium sulfate solids from the wastewater. Extracted solid material (calcium sulfate) was then collected and placed in calcium sulfate drying beds to be dried and then removed and delivered to onsite disposal areas.
- *Unit 18c: Lime Silos, Slakers, and Lime Slurry Mix Tank* – Lime (calcium oxide) was slaked and dumped into two conical silos located inside Building 4434, then fed into the lime-slurry mix tank. The lime slurry was then pumped to the wastewater pH adjustment and neutralization tanks (Unit 18d), to be mixed with the acidic wastewater.
- *Unit 18d: Steel Wastewater Neutralization Tanks* – Acidic wastewater was pumped from the steel wastewater surge tank (Unit 18f) into two (2) 500 gallon pH adjustment neutralization tanks, then two 250 gallon wastewater neutralization tanks inside Building 4434. Lime slurry was added in these tanks to neutralize the wastewater.
- *Unit 18e; Concrete Clarifiers:*– Neutralized wastewater was pumped into the westernmost concrete clarifier, which contains a sweep/bottom solids rake designed to allow for calcium sulfate solids collection. Wastewater exiting this clarifier then overflowed into a second concrete clarifier. Each clarifier is 24 ft diameter and 6 ft deep. Residual solids from the clarifier bottoms were then pumped to the vacuum drum filters to remove residual solids. Effluent from the clarifiers was discharged into the concrete wastewater discharge station (Unit 18g).
- *Unit 18f; Steel Wastewater Surge Tank* – Acidic wastewater from the Sulfuric Acid Recovery Plant was pumped to an outdoor aboveground 20,000 gallon, closed top, steel wastewater surge tank. The surge tank is located within a concrete secondary containment area. Wastewater from the surge tank was then pumped into the pH adjustment and neutralization tanks inside Building 4434.
- *Unit 18g; Concrete Wastewater Discharge Station:* – Wastewater exiting the clarifiers flowed into a below grade, two compartment concrete sump, which served as the discharge point from the Treatment Facility. The sump dimensions are 16 ft long, 7 ft wide, and 7 ft deep to the foundation base. Effluent from this discharge station, most recently flowed to C-Line Acidic Wastewater Treatment Plant by an aboveground line.

2.1.2 Site History

The SAR Plant and the associated acid wastewater collection system (including SSA 18 and SSA 79) operated from 1976 until 1987, when these facilities were rendered inactive due to TNT manufacturing operations ceasing at RFAAP in 1986.

In 1994, the State Water Control Board (SWCB) issued RFAAP a Best Management Practice (BMP) Consent Order to correct total suspended solid issues in the Outfall 004 storm water ditch, which was also used to direct the wastewater discharge from SSA 18 from 1976 to 1982. During this period, storm water runoff from the nearby coal pile storage yard was also discharged directly into the Outfall 004 ditch, causing suspended solids and pH compliance issues. RFAAP implemented a BMP by dredging the length of the Outfall 004 ditch line to remove the residual coal fines, and placed stone rip-rap in the ditch to aid in stormwater flow distribution and solids deposition reduction. The BMP implemented satisfied the SWCB.

Plant wastewater utilities, acid area, and environmental personnel were consulted to determine if any spills or cleanup actions have occurred at SSA 18 or SSA 72. No employees recalled any chemical or wastewater spills or cleanup actions from these facilities during their years of operation.

Aerial photographs of the SSA 18 and SSA 72 area for 1949, 1962, 1971, 1986, and 1990 are presented on Figures 2-3, 2-4, 2-5, 2-6, and 2-7, respectively. Photographs from 1949 and 1962 show the site areas are undeveloped and surrounding by storage buildings related to manufacturing operations. The 1971 photograph shows the SAR Plant under construction and the SSA 18 area remaining undeveloped. More recent aerial photographs from 1986 and 1990 show the SSA 18 and SSA 72 areas in their general current configuration.

2.1.3 Surface Water

The closest natural surface water body to SSA 18 and SSA 72 is the New River, which is located approximately 400 to 600 ft west/northwest of the site. SSA 18 and SSA 72 are located at elevations above the 100 year floodplain of the New River (USHUD 1978).

Stormwater drains or catch basins are not associated with the acidic wastewater sump. The top of the sump is raised above the ground surface so that stormwater runoff will not flow into the sump. Water is present in the sump and water samples have been collected from the sump during previous investigations conducted at the Oleum Plant in 2004 and 2007 as discussed in Section 2.2

At SSA 18, the concrete floor of Building 4434 has a 4-inch cast iron floor drains that connect to a 6-inch cast iron drain leading to the sump at Unit 18g. Four inch floor drains are located in the vacuum pump and lime slurry tank areas. Condensate and hub drains also connect to the floor drains.

Stormwater drains or catch basins are not located in the immediate area of SSA 18. A drainage ditch is located approximately 30 to 60 ft east of units 18e and 18f and may receive some stormwater runoff from the easternmost portion of the site. This drainage ditch extends northeast for approximately 200 ft ending at the manmade ditch associated with VPDES Outfall 004. The outfall ditch, which originates approximately 1,400 ft east of the site, typically contains flowing surface water and ends at Outfall 004 located approximately 400 ft west of the site. A significant portion of the MMA including SSA 72 is located within the drainage watershed of Outfall 004.

2.1.4 Soil

According to the *Soil Survey of Montgomery County, Virginia* (USDA 1985), the area of SSA 18 is underlain by Unison-Urban Land complex soil. This soil has moderate permeability and medium-to-strong acidity. Soil classification is not practical in urban land areas because the original soil has been physically altered or obscured. A typical profile of undisturbed Unison soil consists of a 15-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. In general, permeability is moderate in Unison soil, natural fertility is low, and organic matter content is low to moderate.

2.1.5 Geology

Geologic conditions have been previously investigated in the Oleum Plant and surrounding areas for an Environmental Baseline Study (EBS) conducted by Ecology and the Environment, Inc. (EEI) in 2007 (EEI 2007). This investigation indicated that the site area is underlain by approximately 25 to 30 ft of alluvial terrace deposits consisting of silt and clay (ML/CL) to depths up to 19 ft bgs underlain by silty sand (SM). Limestone/dolomite bedrock of the Elbrook Formation is present at approximate depths of 25 to 30 ft. Appendix D.1 includes boring logs for the EBS investigation conducted by EEI.

2.1.6 Hydrogeology

Six monitoring wells were installed for the EBS conducted in the Oleum Plant and surrounding areas by EEI (EEI 2007). Figure 2-8 shows the locations of the monitoring wells. Groundwater monitoring well construction and water level measurement data from the EBS are summarized in Table 2-1. Groundwater was encountered under water table conditions within the lower portion of the alluvium in the area of SSA 18, where measured static water levels were approximately 24 to 26 ft bgs. South of SSA 18 at higher elevations in the SAR Plant area groundwater was encountered within bedrock but not alluvium with potentiometric levels greater than 30 ft bgs. In the EBS Report, EEI indicated an implied groundwater flow direction of approximately 15 degrees north of west based on triangulation of potentiometric data from the three monitoring wells screened within bedrock. A similar groundwater flow direction was implied for groundwater within the alluvium. Appendix D.1 includes boring logs and construction data for monitoring wells installed for the EBS.

2.2 PREVIOUS INVESTIGATIONS

2.2.1 RCRA Facility Assessment – USEPA 1987

An assessment was conducted at SSA 18 (listed as Unit 18 in RFA) and SSA 72 (listed as Unit 72 in RFA) to evaluate potential hazardous waste or hazardous chemical releases and implement corrective actions, as necessary. The assessment consisted of a preliminary review and evaluation of available site information, personnel interviews, and a visual inspection of the site. Environmental samples were not collected at SSA 18 or SSA 72 as part of the inspection. The assessment identified seven units at SSA 18 including: sheet metal fabricated building (unit a), vacuum filters (unit b), lime silos (unit c), neutralization tank (unit d), concrete clarifiers (unit e), steel feed tank (unit f), and concrete discharge station (unit g). The RFA indicated that no visible signs of releases were observed during the site inspection.

2.2.2 Acid Sewer Survey

From 1998 to 2000, an Acid Sewer Survey and Investigation was conducted on the entire RFAAP acid sewer infrastructure to determine the condition of the sewers. Videotaping of the interior lines was conducted and submitted to the USEPA. Deteriorated or broken sections of sewer lines were repaired or replaced within active areas. Review of acid sewer survey and investigation reports indicates that an assessment of the 260 ft long 6-inch diameter plastic, gravity acid sewer line that extends from the acidic wastewater sump (SSA 72) to the SAR wastewater treatment plant was not conducted. .

2.2.3 Oleum Plant Site Screening Investigation - Draper Aden Associates, 2004

In June 2004, Draper Aden Associates advanced four soil borings (B-1, B-2, B-3, and B-4) within the vicinity of the process sewers in the Oleum Plant. Soil samples were collected from the surface and the approximate depth of the sewer invert (6 ft bgs). The soil samples were analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), TCL semi-volatile organic compounds (SVOCs), polynuclear aromatic hydrocarbons (PAHs), explosives, and Target Analyte List (TAL) inorganics by SW-846 Methods. One surface soil sample (B-4) also was analyzed for TCL pesticides and TCL polychlorinated biphenyls (PCBs) by SW-846 Methods. Boring B-3 was completed adjacent to the Oleum Plant Acidic Wastewater Sump (SSA 72) as shown on Figure 2-8. In addition, one water sample (B-3 Drain) was collected from the acidic wastewater sump and analyzed for perchlorate by USEPA Method 314.0.

Detected results for B-3 surface and subsurface soil samples collected at SSA 72 are summarized in Table 2-2. VOCs, SVOCs, and metals were detected these soil samples. Organic constituents detected in B-3 samples above their current adjusted R-RBCs were limited to three PAHs, with benzo(a)pyrene also detected at a concentration above its current adjusted I-RBC. Detected metals concentrations were

below their adjusted R-RBCs or their facility background point estimates. Perchlorate was not detected in the water sample collected from the acidic wastewater sump (Table 2-3).

2.2.4 Oleum Plant Environmental Baseline Study – Ecology and Environment, Inc. 2007

The study area for this EBS was focused on the Oleum Plant area and included the collection of soil and groundwater samples from a study area encompassing SSA 18 and a water sample from the acidic wastewater sump at SSA 72. Specific locations sampled that may be used to evaluate potential releases from SSA 18 included: soil boring SB08/monitoring well MW04 (collocated) located north of Unit 18g and monitoring well MW03 located west/northwest and downgradient of SSA 18 (Figure 2-8). The study also included the installation of wells at locations (MW05 and MW06) that are upgradient of SSA 18. Soil and groundwater samples were analyzed for TCL VOCs, TCL SVOCs, TCL PCBs, TLC pesticides, explosives, TAL metals, nitrate/nitrite, and perchlorate (sump water and groundwater).

Detected results for the two subsurface soil samples collected from soil boring SB08 are summarized in Table 2-2. Subsurface soil samples were collected from depth intervals of 2 to 4 ft bgs and 16 to 18 ft bgs. VOCs, Aroclor 1254, pesticides, metals, and nitrate/nitrite were detected in one or more of the soil samples. Detected constituent concentrations were below their current adjusted R-RBCs or background point estimates, with the exception of arsenic, which was detected at concentrations above its I-RBC but below the facility's background point estimate of 15.8 milligrams per kilogram (mg/kg).

Detected results for the groundwater samples collected from monitoring wells MW03, MW04, MW05, and MW06 are summarized in Table 2-4. VOCs, SVOCs, pesticides, explosives, and metals were detected in one or more of these samples. Perchlorate was detected in each of the samples collected from these wells. With the exception of MW06, chloroform was detected in each of the groundwater samples above its adjusted T-RBC but below the MCL for trihalomethanes. Perchlorate was detected in sample MW04 at a concentration of 3.59 micrograms per liter [µg/L], which was above the adjusted T-RBC.

Detected results from the water sample collected from the acidic wastewater sump at SSA 72 are summarized in Table 2-3. VOCs, SVOCs, pesticides, explosives, and metals were detected in this sample. Alpha-BHC and heptachlor were detected above their adjusted T-RBCs in addition to nine metals. Arsenic and antimony were detected at concentrations above their MCLs and lead was detected at a concentration above its action level.

2.3 CONCEPTUAL SITE MODEL (CSM)

A Conceptual Site Model (CSM) for SSA 18 and SSA 72 is presented on Figure 2-9. The sites are located on an alluvial terrace approximately 400 to 600 ft east of the New River. Approximately 30 ft of alluvial terrace deposits overlies limestone/dolomite bedrock at the site. Groundwater is present within the lower portion of the alluvium and within underlying bedrock at depths of approximately 25 to 26 ft bgs.

Potential constituent sources at the site are related to handling and treatment of acidic wastewater, discharge of neutralized wastewater and handling materials used for wastewater treatment. Potentially affected media at the site include:

- Surface soil from leaks or spills from related to outside storage and treatment of wastewater in aboveground tanks and structures or from materials handling;
- Subsurface soil from any constituents released to surface soil;
- Subsurface soil from possible leaks from below ground sumps, wastewater drains or wastewater lines; and
- Groundwater via leaching of constituents from subsurface soil.

Although current and likely future land-use scenarios are limited to industrial operations, both residential and industrial scenarios will be evaluated in the SSP human health screening (USEPA 2001).

SSA 18 and 72 are exclusively an upland habitat that lacks wetland and significant onsite drainage features. Therefore, soil represents the potential exposure medium for ecological receptors. 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*). Refer to Table 2-5 for wildlife receptor profiles.

2.4 DATA GAP ANALYSIS

Data gaps identified for the SSP investigation are discussed in the following sections.

2.4.1 Release Assessment to Surface Soil

An assessment of potential releases to surface soil has not been performed at SSA 18. This data gap will be filled by collecting surface soil samples for chemical analysis from the wastewater treatment facility area. Proposed field investigation activities are discussed in Section 2.5.1

2.4.2 Release Assessment to Subsurface Soil/Sewer Line Integrity

Limited soil sampling (soil boring SB08) has been conducted in the area of SSA 18 to assess releases to subsurface soil. This data gap will be filled by completing additional soil borings in the wastewater treatment facility and collecting subsurface soil samples for chemical analysis. Proposed field investigations are discussed in Section 2.5.1.

At SSA 72, the surface soil sample collected adjacent to SSA 72 was not analyzed for TCL PCBs or pesticides. This data gap will be filled by collecting another surface sample from this location for analysis of PCBs and pesticides. The subsurface sample B-3 collected by Draper Aden adjacent to the acidic water sump was collected below the invert depth of the sewer leaving the sump but not significantly below the depth of the sump bottom.

In addition, subsurface sampling has not been conducted along the sewer running from SSA 72 to SSA 18. Review of acid sewer survey and investigation reports indicated that an assessment of the 260 ft long 6-inch diameter plastic, gravity acid sewer line that extends from the acidic wastewater sump (SSA 72) to the SAR wastewater treatment plant was not conducted. A survey of this sewer line will be performed using closed-circuit television (CCTV) inspection techniques to evaluate the integrity of this line and identify the locations of any observed structural defects. Observed structural defects of the inner surface of the sewer pipe will be coded according to the National Association of Sewer Service Companies (NASSCO), Pipeline Assessment Certification Program (PACP) coding system. Given that a CCTV inspection will be conducted along the 6-inch acid sewer line to evaluate for potential releases due to pipeline defects, it is proposed that subsurface soil samples in this area will be collected only if sewer survey identifies defects that may have potentially resulted in a release. These samples would be collected below the bottom of the sewer pipe at the location of any identified defects.

These data gaps will be filled by completing additional soil borings to evaluate potential releases to subsurface soil in these areas and collecting subsurface soil samples for chemical analysis. Proposed field investigations are discussed in Section 2.5.1.

2.4.3 Release Assessment to Groundwater

Potential releases to groundwater will be evaluated using existing groundwater data collected in the site area in 2007. Additional release assessments to groundwater will be conducted by evaluating subsurface soil data and comparing these data to USEPA Region III soil-to-groundwater SSLs.

2.4.4 Physical Soil Testing

Two representative samples of soil at the site (one surface sample and one subsurface sample) will be submitted for analysis of physical and geotechnical properties, as described in Section 2.5.3

2.4.5 Summary of Data Gaps

The data gap analysis completed for SSA 18 identified data gaps for characterizing releases to surface soil and subsurface soil, and characterizing physical and geotechnical properties of site soil. The following table summarizes these identified data gaps and the completion plan to fill the data gaps.

SSA 18 and SSA 72- Summary of Data Gap Analysis and Completion Plan

DATA GAPS			COMPLETION PLAN
Item	**Physical**	**Chemical**	
Releases to Soil	Surface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect surface soil samples in area of SSA 18 and SSA 72 for chemical analysis
	Subsurface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect subsurface soil samples from area of SSA 18 and SSA 72 for chemical analysis.
Sewer Pipe Integrity	No CCTV of Sewer Line	Not applicable	Complete CCTV inspection of sewer line to evaluate line integrity.
Releases to Groundwater	Subsurface Soil Samples	Use subsurface soil sample data and existing groundwater data	Compare subsurface soil data to soil-to-groundwater SSLs and compare existing groundwater data to T-RBCs.
Site-Wide Soil Characteristics	Physical / Geotechnical Properties	pH, total organic carbon, grain size, Atterberg Limits, and moisture content	Collect samples for geotechnical and physical property analysis.

2.5 PLANNED FIELD INVESTIGATION

The SSA 18 and SSA 72 SSP field program is designed to address the data gaps identified in Section 2.4 and meet the SSP objectives identified in Section 1.1. The selection of the investigation areas and sample locations followed SOP 30.7 (Sampling Strategies, included in Appendix B) using biased sampling techniques to identify potential releases.

Sample analysis will be conducted consistent with the requirements of the Master Quality Assurance Plan (MQAP) and Section 6.0 of this WPA. Sample management and analytical methods are discussed in detail in Sections 6.4 and 6.5 of this WPA, respectively.

2.5.1 Surface Soil Sampling

Six surface soil samples will be collected from the following locations to evaluate potential releases at SSA 18 and SSA 72:

- Sample 18SB1A will be collected adjacent to the concrete discharge station (Unit 18g) near the concrete clarifiers (Unit 18e);
- Sample 18SB2A will be collected between the aboveground surge tank (Unit 18f) and Building 4343 in the area where aboveground influent piping runs from the containment area at Unit 18f to the building;
- Sample 18SB3A will be collected between Building 4343 and the railroad spur where material unloading occurred from railcars.
- Sample 18SB4A will be collected immediately south of the secondary containment area for the aboveground surge tank (Unit 18f) adjacent to where the aboveground influent acid sewer line enters the secondary containment area;
- Sample 18SB5A will be collected from the drainage ditch/swale located east of the wastewater treatment facility; and
- Sample 72SB1A will be collected adjacent to the acidic wastewater sump at the previous Draper Aden sample location for PCB and pesticide analysis.

Proposed surface soil samples locations are shown on Figure 2-10. Surface soil samples will be collected from 0 to 0.5 ft bgs, with the exception of VOC samples, which will be collected from 0.5 to 1 ft bgs. Soil samples will be submitted for chemical analysis of the following parameters (with the exception of the surface sample from the area of SSA 72):

- TCL VOCs by SW-846 Method 8260B;
- TCL SVOCs by SW-846 Method 8270C (low level);
- TCL PCBs and TCL pesticides by SW-846 Methods 8082 and 8081A;
- Explosives by SW-846 Methods 8330 and 8332; and
- TAL inorganics by SW-846 Methods 6010/6020/7471A/9012A.

Surface soil samples will be collected following the procedures outlined in SOP 30.1 and 30.9 in Appendix B.

2.5.2 Subsurface Soil Sampling

Eight subsurface soil samples will be collected from the following locations to evaluate potential releases at SSA 18 and SSA 72:

- Sample 18SB1B will be collected from a direct push boring completed at the location of surface soil sample 18SB1A at a depth below the bottom elevation of the sump (1,720 ft msl). The planned sampling depth will be 8 to 10 ft bgs;
- Sample 18SB2B will be collected from a direct push boring completed at the location of surface soil sample 18SB2A at a depth of 5 to 7 ft bgs. This sample will fill an identified data gap related to evaluating potential releases to subsurface soil at the wastewater treatment facility, specifically in the area of aboveground piping running from the concrete containment area at 18f to Building 4434;
- Sample 18SB3B will be collected from a direct push boring completed at the location of surface soil sample 18SB3A at a depth of 5 to 7 ft bgs. This sample will fill an identified data gap

related to evaluating potential releases to subsurface soil at the wastewater treatment facility, specifically in the area where materials were unloaded from railcars to Building 4434;

- Sample 18SB4B will be collected from a direct push boring completed at the location of surface soil sample 18SB4A at a depth of 5 to 7 ft bgs, which is 2 to 4 ft below the bottom of the acid sewer line entering the containment area for the surge tank (18f). This sample will fill an identified data gap related to evaluating potential releases to subsurface soil in the wastewater treatment facility area, specifically in the acid sewer area associated with SSA 18;
- Sample 18SB6B will be collected from a direct push boring completed along the original alignment of the effluent discharge line between the concrete discharge station (18g) and the Outfall 004 drainage ditch. The sample will be collected at a depth below the bottom of the effluent line from an interval of 8 to 10 ft bgs
- Sample 72SB1B will be collected from a direct push boring completed at the location of surface soil sample 72SB1A at a depth of 8 to 10 ft bgs; and
- Samples 72SB2B and 72SB3B will be collected from direct push borings completed along the sewer alignment between SSA 72 and SSA 18 at depths of 2 to 4 ft below the bottom of the sewer pipe. Given that a CCTV inspection will be conducted along the 6-inch acid sewer line to evaluate for potential releases due to pipeline defects, soil samples 72SB2B and 72SB3B will be collected if sewer survey identifies defects that may have potentially resulted in a release.

Proposed subsurface soil samples locations are shown on Figure 2-10. Subsurface soil samples will be analyzed for the same parameters as surface soil samples. A four-foot, Geoprobe Macro-Core® sampling device will be used to collect soil samples continuously from each of the borings, as described in SOP 30.1, SOP 20.11, and SOP 30.9 in Appendix B. Soil core samples will be screened with a photoionization detector (PID) for the presence of VOCs. Borings logs will be prepared as outlined in SOP 10.3 in Appendix B.

2.5.3 Physical Soil Testing

Two representative soil samples (one surface soil sample and one subsurface soil sample) will be analyzed to characterize physical and geotechnical properties of site soil as outlined in Section 6.5.4:

- Grain-size analysis (ASTM International [ASTM] D 422);
- Atterberg limits (ASTM D 4318);
- Soil moisture content (ASTM D 2216);
- Total organic carbon (Walkley-Black Method); and
- pH (ASTM D 4972).

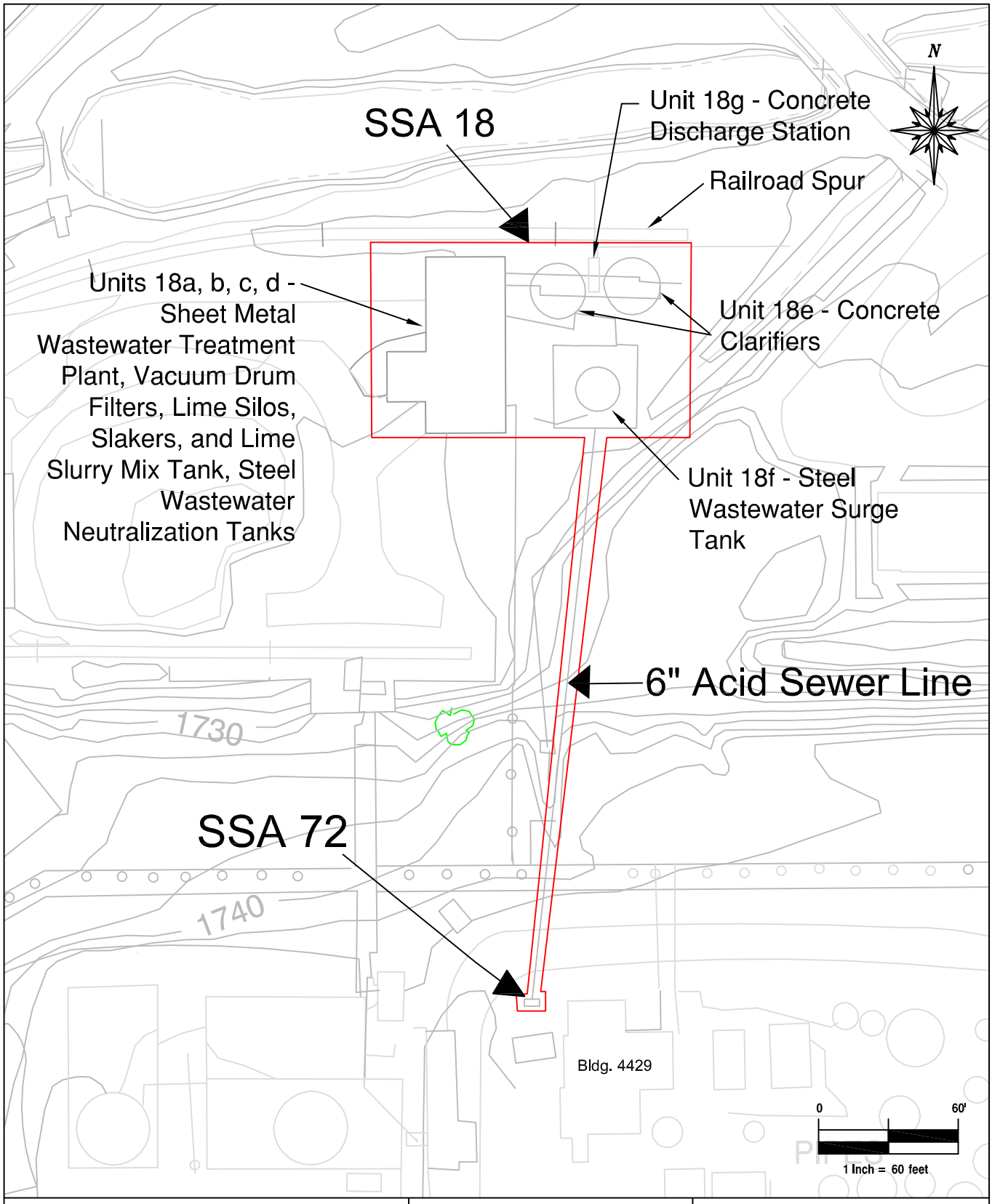
Physical soil data will be used for qualitative soil screening evaluations as outlined in the USEPA SSP document (USEPA 2001) including calculation of site-specific soil screening levels for migration to groundwater, as required.

2.5.3.1 Surveying

Horizontal coordinates and ground surface elevations for test pits and soil borings will be obtained using a global positioning system (GPS) unit with submeter accuracy for horizontal measurements (+1 part per and million) and vertical measurements (+ 2 parts per million for vertical measurements).

2.5.3.2 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration (OSHA) and USEPA regulations regarding the identification, handling, and disposal of non-hazardous and hazardous IDM. Activities will be performed in accordance with the Installation safety rules, protocols, and SOP 70.1. Information on the expected nature (hazardous versus non-hazardous) of the materials that will be generated during the field investigations is summarized in Table 2-6.



Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping

FIGURE 2-1

Site Layout - SSA 18 and SSA 72

Date: April 2008	URS Project #: 11656421
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.2-2 SiteLayout

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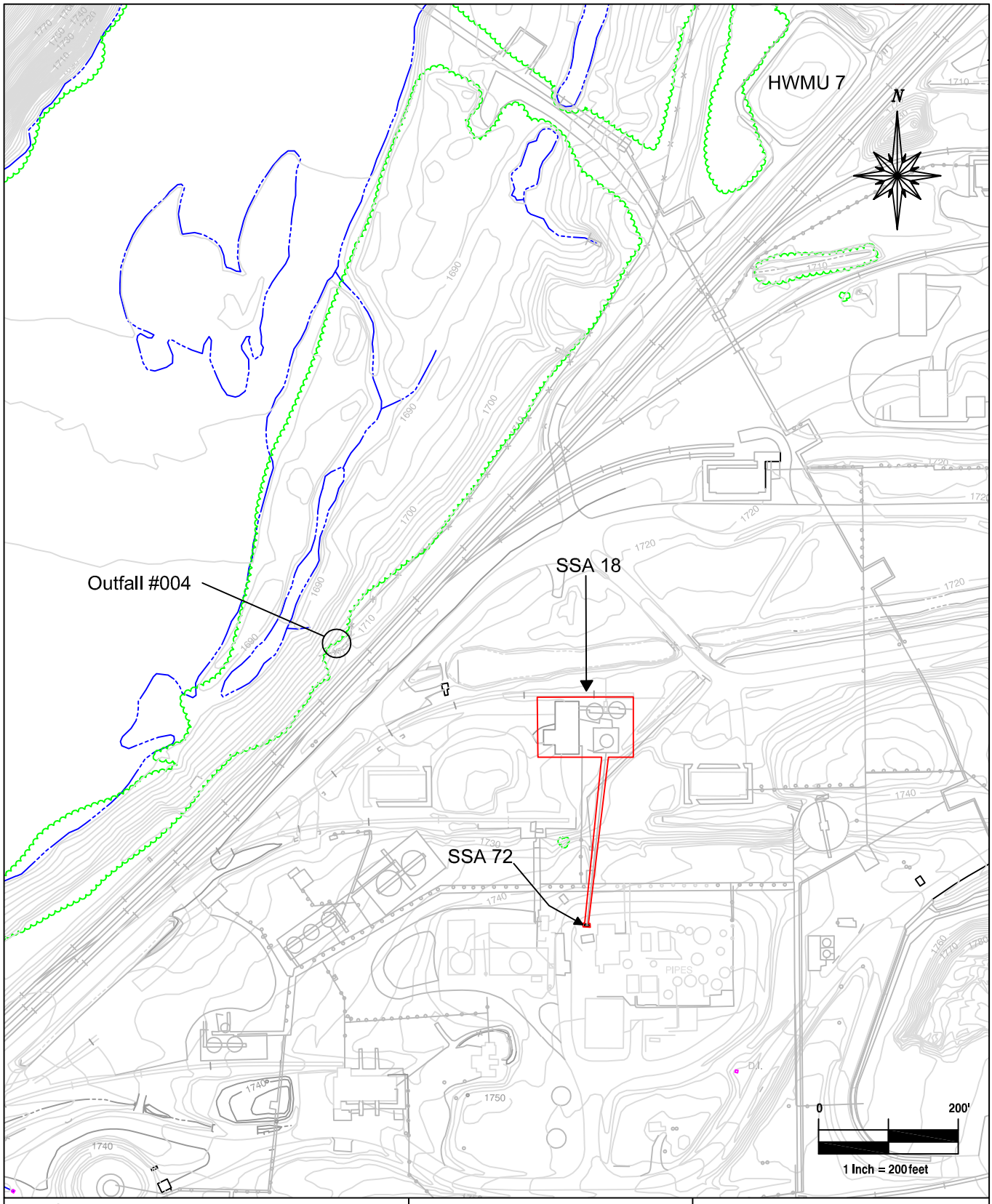

Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping

FIGURE 2-2

Additional Layout Map
SSA 18 and SSA 72

Date: March 2009	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 200 feet	File Name: Fig.2-2

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Suite 201
Richmond, Virginia 23230

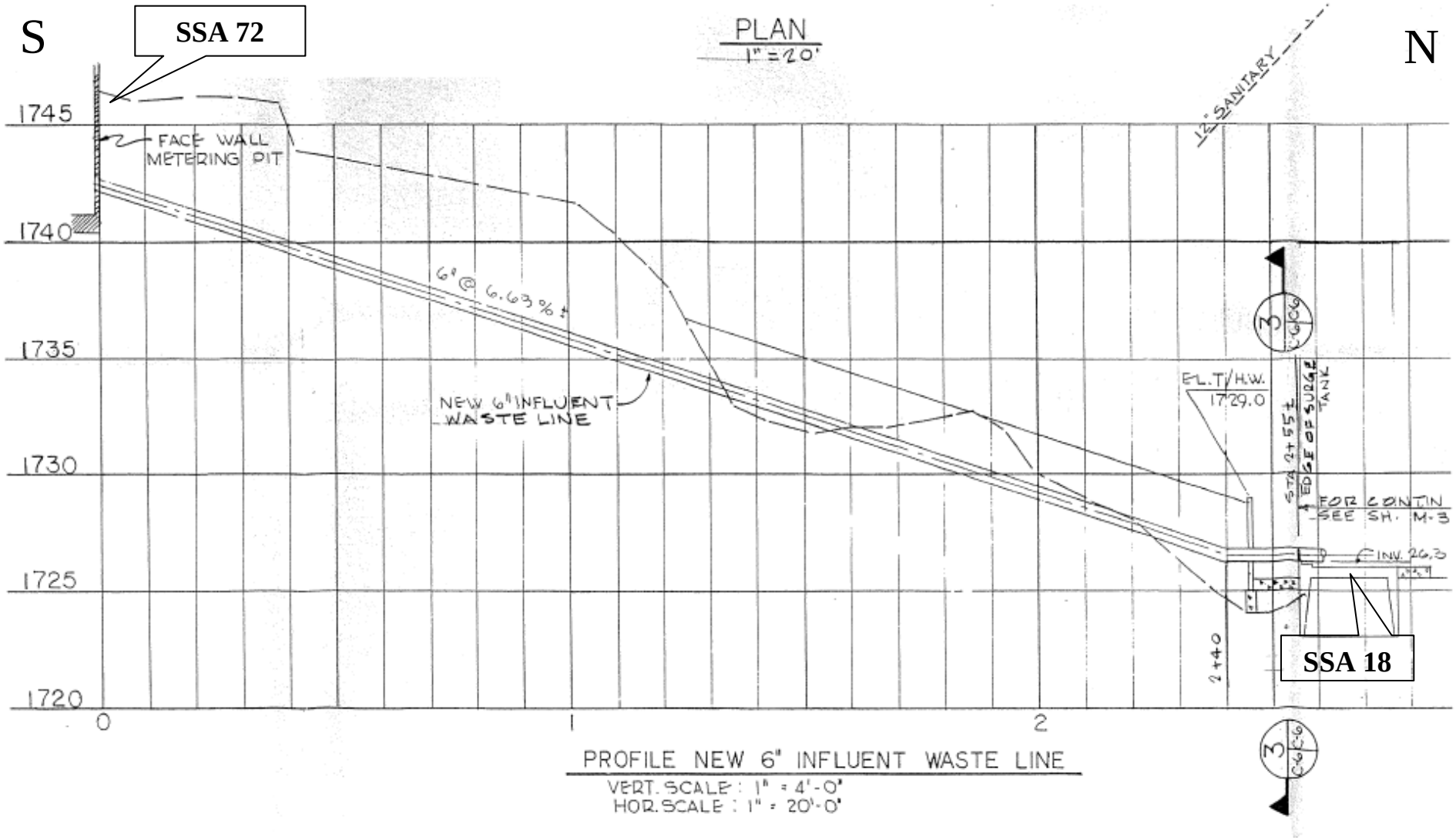

FIGURE 2-3

Sewer Profile from SSA 72 to SSA 18

Date: October 2008	URS Project #: 11656351
Prepared by: DBC	Approved by: JOS
Scale: *1" = 2000'*	File Name: Fig1-1 SiteLoc

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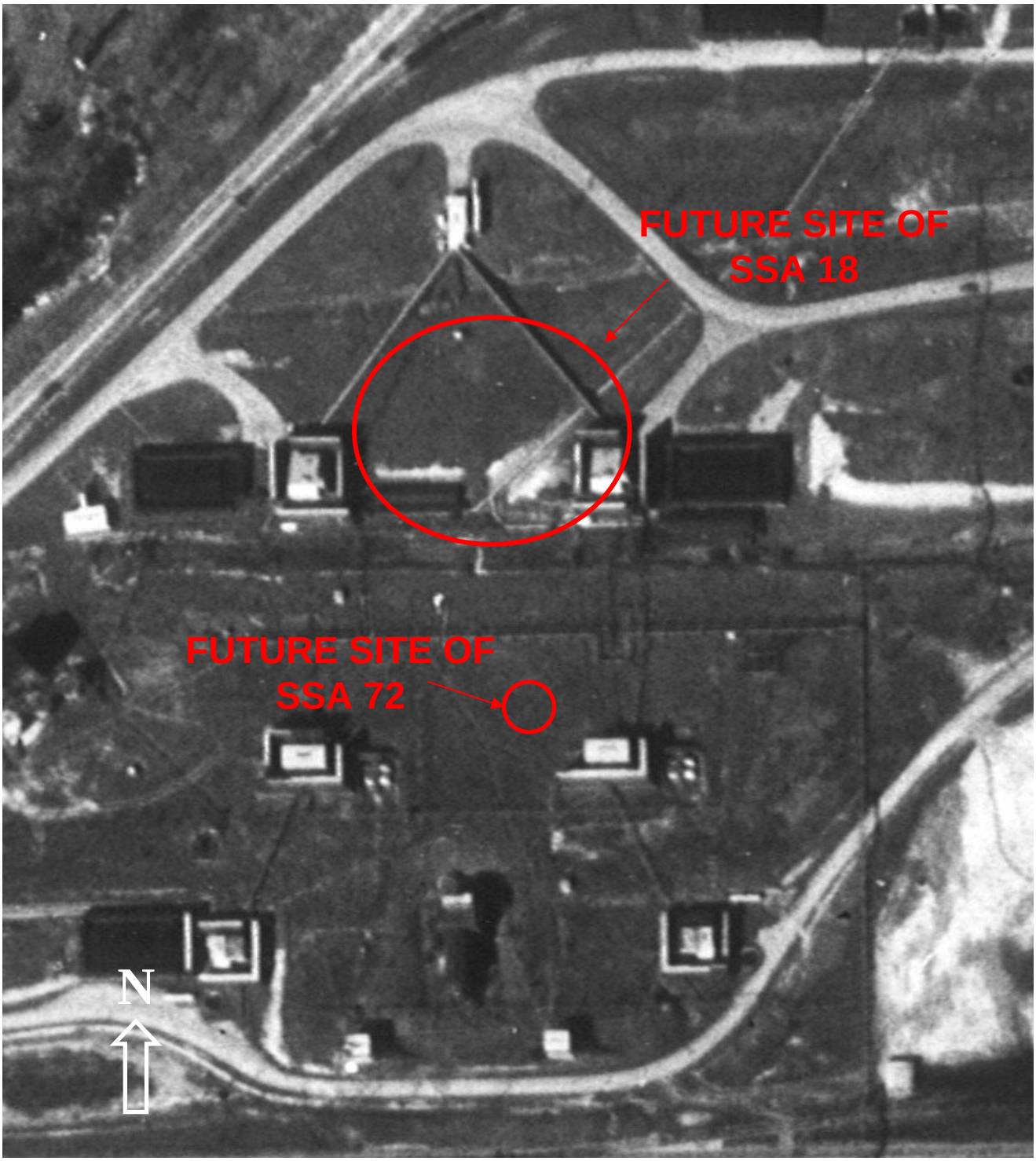
SSP Investigation for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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



SSA 18 and SSA 72
AERIAL PHOTOGRAPH – 1949

FIGURE 2-4

Date: *October 2008*

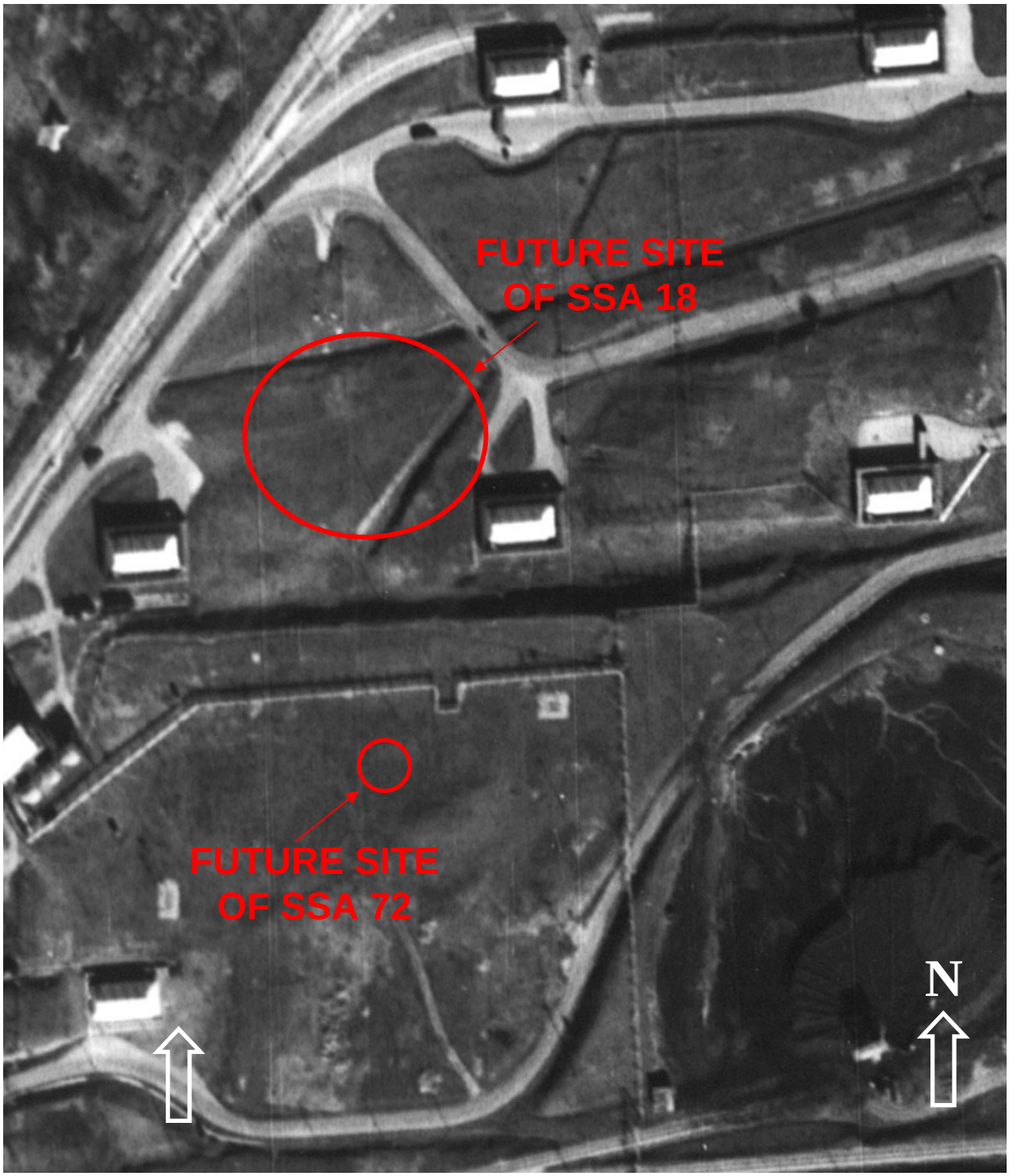
Prepared by: *HA/CLD*

Scale: *No Scale Implied*

File Name: *11657490*

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77



SSA 18 and SSA 72
AERIAL PHOTOGRAPH – 1962

FIGURE 2-5

Date: *October 2008*

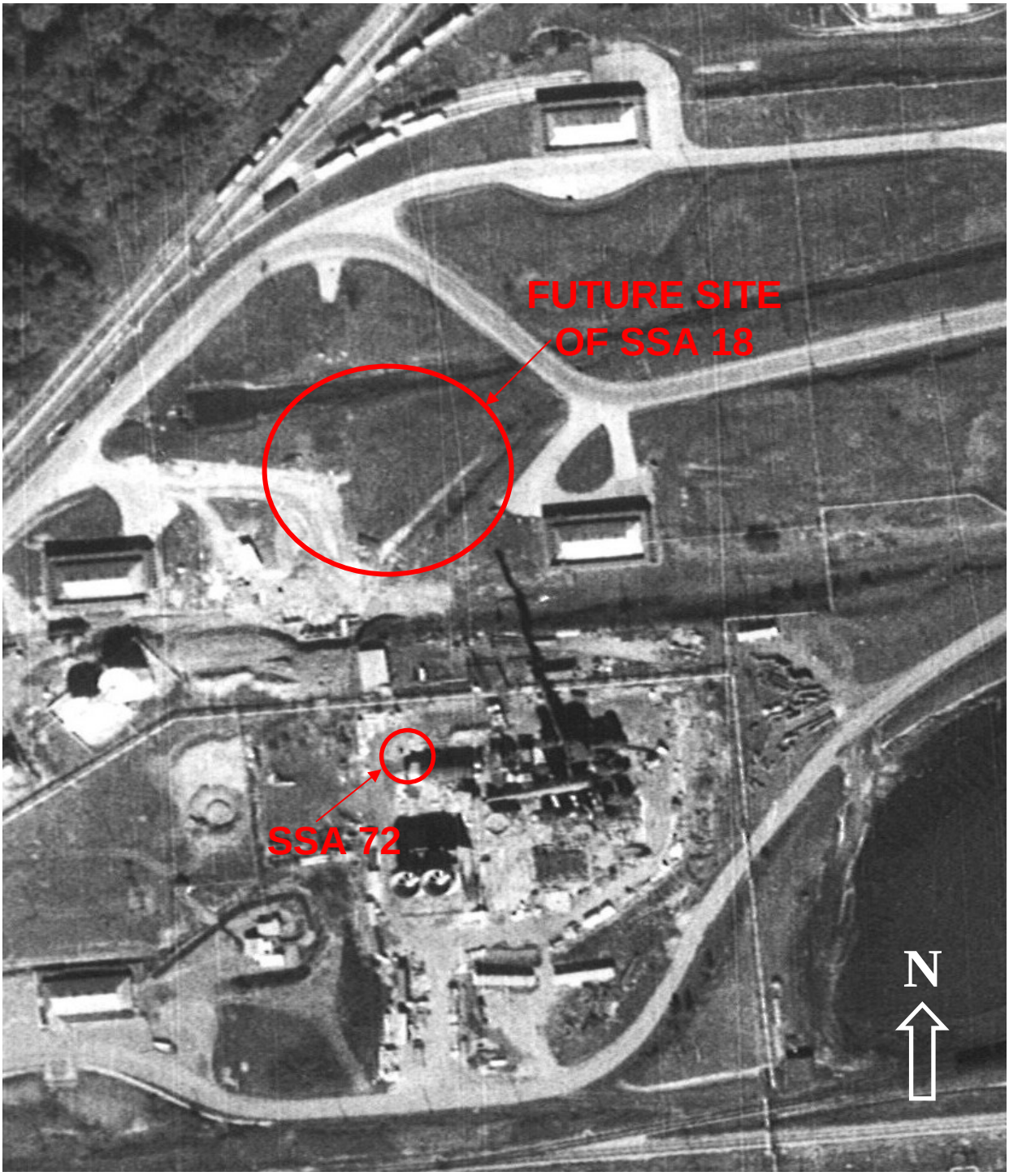
Prepared by: *HA/CLD*

Scale: *No Scale Implied*

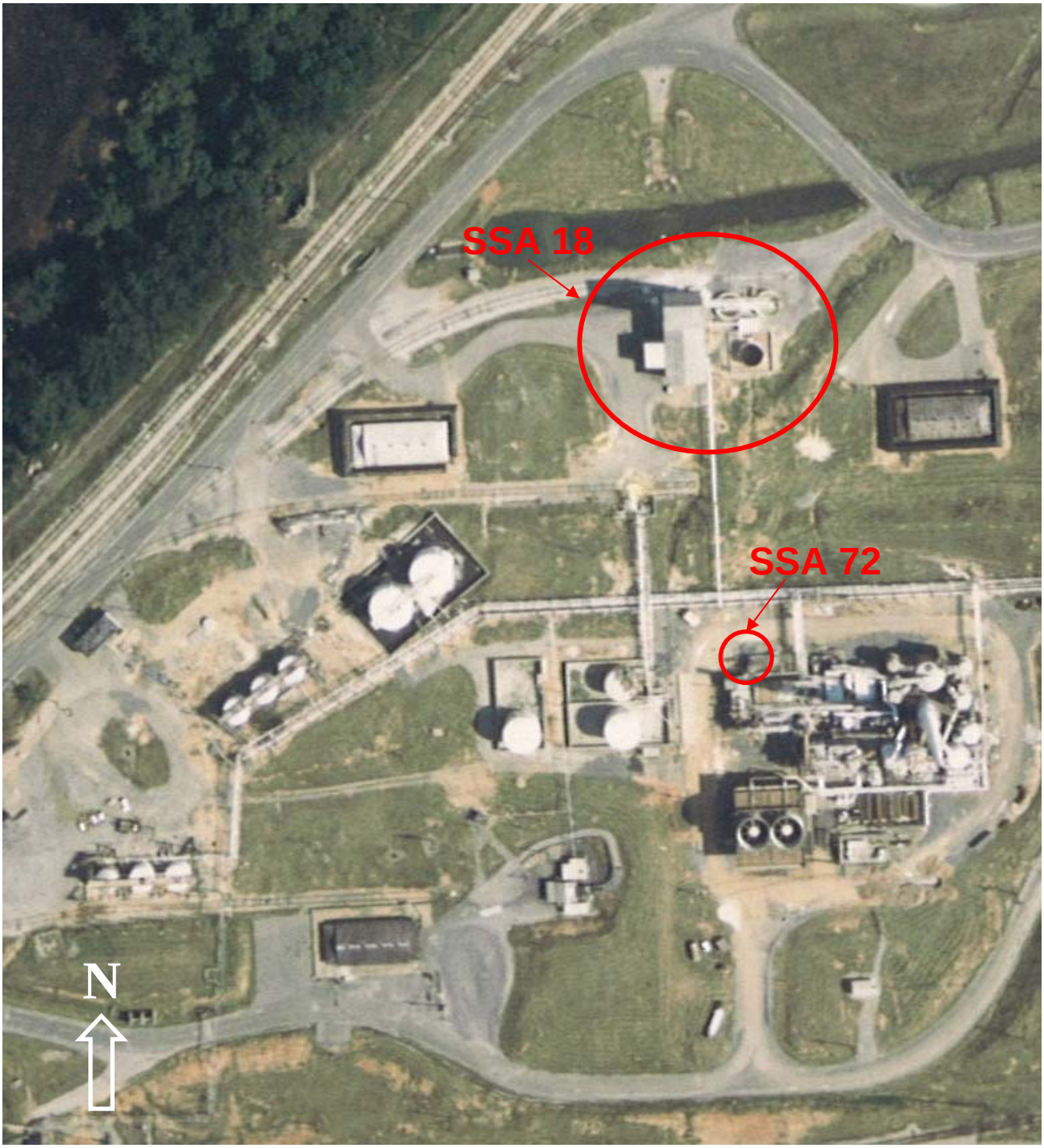
File Name: *11657490*

MWP Addendum 028 –

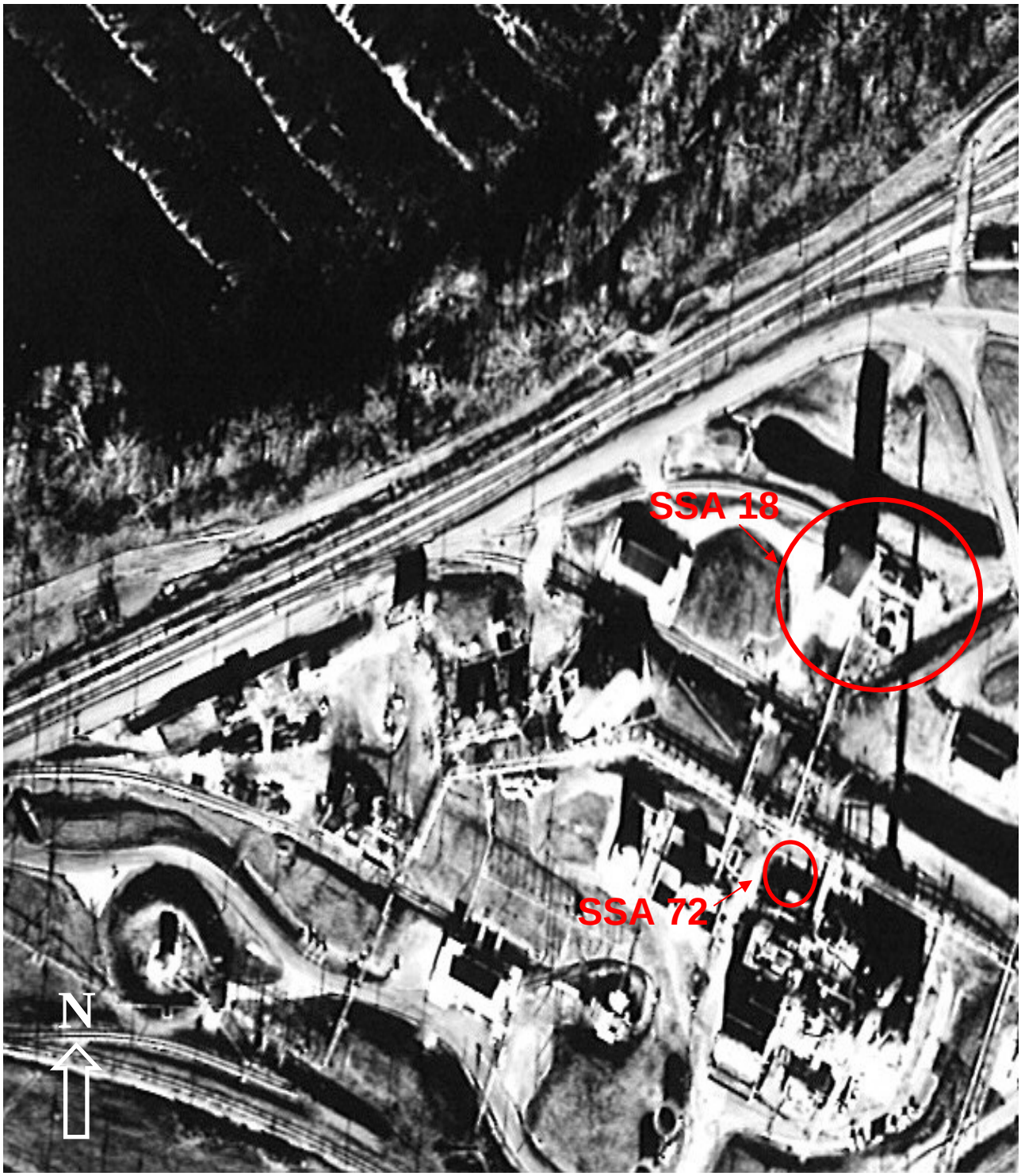
SSP for SSAs 18, 72, 30, 79, 60, and 77



SSA 18 and SSA 72 AERIAL PHOTOGRAPH – 1971		FIGURE 2-6
Date: *October 2008*	**Prepared by:** *HA/CLD*	**MWP Addendum 028 –** **SSP for SSAs 18, 72, 30, 79, 60, and 77**
Scale: *No Scale Implied*	**File Name:** *11657490*	



SSA 18 and SSA 72 AERIAL PHOTOGRAPH – 1986		FIGURE 2-7
Date: *October 2008*	**Prepared by:** *HA/CLD*	**MWP Addendum 028 –** **SSP for SSAs 18, 72, 30, 79, 60, and 77**
Scale: *No Scale Implied*	**File Name:** *11657490*	



SSA 18 and SSA 72
AERIAL PHOTOGRAPH – 1990

FIGURE 2-8

Date: *October 2008*

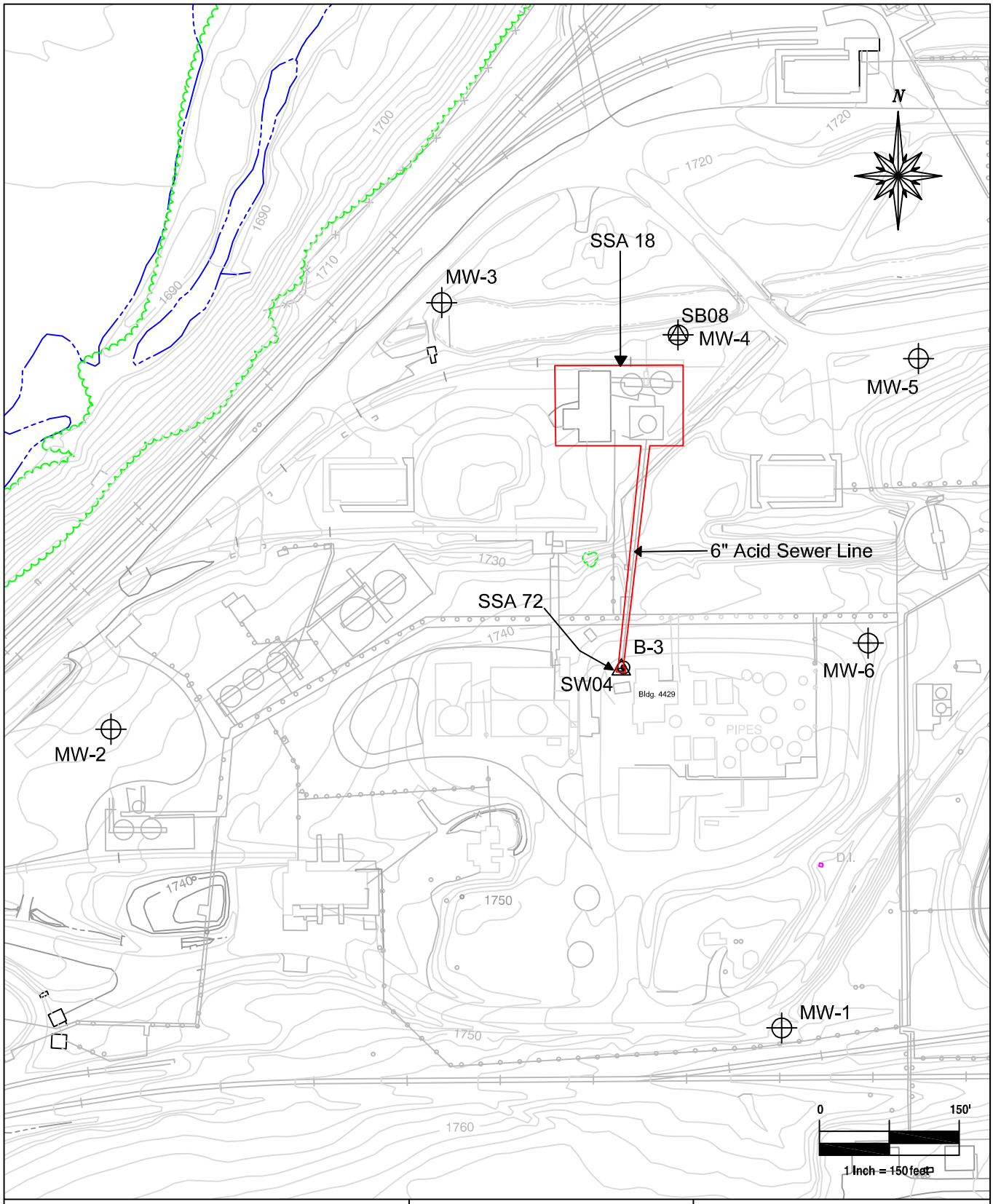
Prepared by: *HA/CLD*

Scale: *No Scale Implied*

File Name: *11657490*

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77



Legend

- Monitoring Well Location
- Ecology and Environmental Sample Location
- Draper Aden Sample Location
- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping

FIGURE 2-9

Previous Investigation - SSA 18 and SSA 72

Date: April 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 150 feet	File Name: Fig.2-8 Prev Invest

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
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Radford, Virginia

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Richmond, Virginia 23230

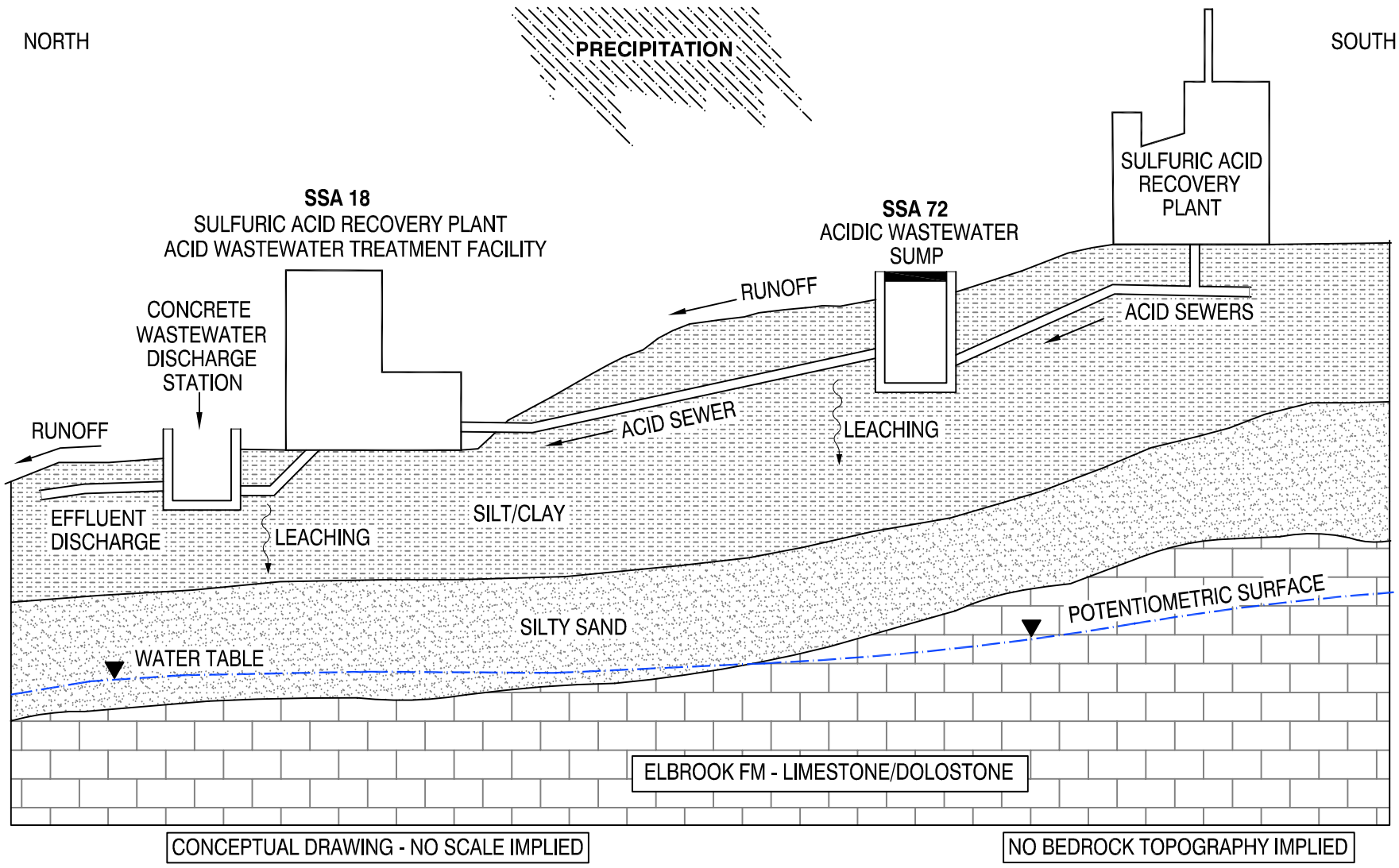

FIGURE 2-10

Conceptual Site Model - SSA 18 and SSA 72

Date: October 2008	URS Project #: 11657490
Prepared by: SS	Approved by: JOS
Scale: Not to Scale	File Name: Fig. 2-9

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60 and 77

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Radford, Virginia

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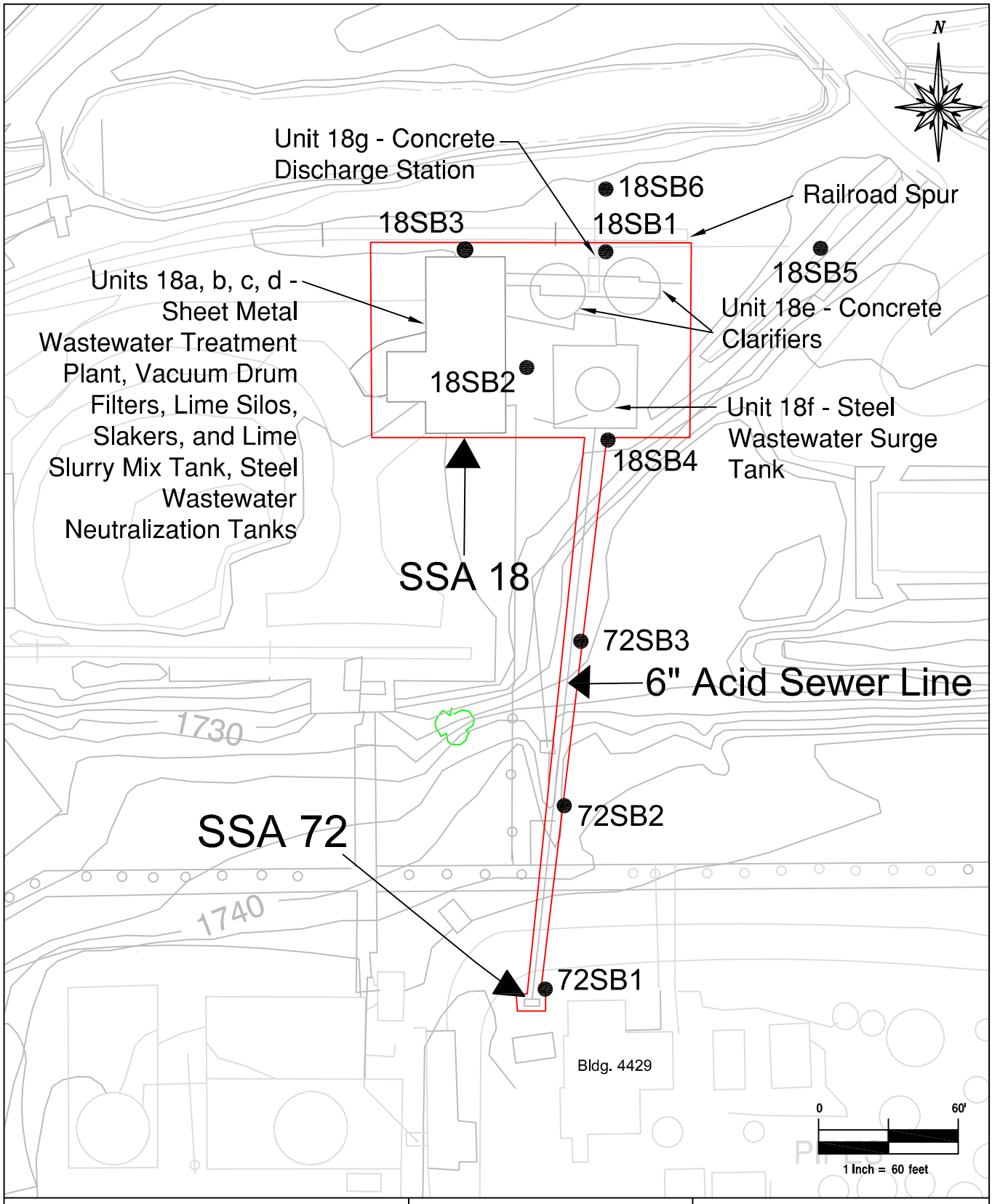
5540 Falmouth Street
Suite 201
Richmond, Virginia 23230



Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping
- Soil Boring Location

FIGURE 2-11

Proposed SSP Sample Locations - SSA 18 and SSA 72

Date: April 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 60 feet	File Name: Fig.2-10 SSP Locs

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

URS Group, Inc.
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Suite 201
Richmond, Virginia 23230

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Table 2-1
Monitoring Well Construction and Groundwater Data
2007 Oleum Plant Environmental Baseline Study Including Area of SSA 18 and SSA 72
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77

	Monitoring Well Construction Information						5/7/2007- 5/8/2007	
Well Identification	**Date Installed**	**Well Diameter (In)**	**Total Well Depth (ft bgs)**	**Elevation Ground Surface (ft msl)***	**Elevation TOC (ft msl)***	**Screened Interval (ft bgs)**	**Depth to Water (ft bgs)**	**Groundwater Elevation (ft msl)**
MW-1	5/3/2007	4	50	1756.71	1759.35	40.0-50.0	44.35	1712.36
MW-2	5/1/2007	4	50	1727.90	1730.55	39.5-49.5	34.50	1693.40
MW-3	5/2/2007	4	34	1718.51	1720.71	24.0-34.0	24.36	1694.15
MW-4	5/2/2007	4	33	1723.70	1726.07	20.5-30.5	26.55	1697.15
MW-5	5/2/2007	4	25	1724.90	1727.42	13.6-23.6	17.99	1706.91
MW-6	5/3/2007	4	82	1748.26	1751.22	72.0-82.0	37.14	1711.12

Notes:
TOC = Top of Casing
BTOC = Below Top of Casing
ft = feet
msl = mean sea level
bgs = below ground surface

Table 2-2
Summary of Historical Analytical Data For Soil Samples Collected at SSAs 18 and 72
Modified from Previous Investigations
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

					Draper Aden Investigation 2004 Acidic Wastewater Sump SSA 72		Ecology and Environment 2007 SSA 18	
Sample ID Sample Date Sample Depth (ft bgs)	CAS	Facility-Wide Background	Adjusted Soil RBC (Residential)	Adjusted Soil RBC (Industrial)	B-3 Surface 25-Jun-04 0-1	B-3 (D=6') 25-Jun-04 6	ATK-SS-SB08 19-Apr-07 2-4	ATK-SUB-SB08 19-Apr-07 16-19
TAL Inorganics (mg/kg)								
Aluminum	7429-90-5	40,041	7,700	99,000	24,000	19,400	17,700	19,800
Antimony	7440-36-0	--	3.1	41	0.81	0.6	ND	1.3
Arsenic	7440-38-2	15.8	0.39	1.6	**2.9**	**2.6**	**3**	**2.5**
Barium	7440-39-3	209	1,500	19,000	91	94.1	143	115
Beryllium	7440-41-7	1.02	16	200	1.2	1.2	1.2	1.2
Cadmium	7440-43-9	0.69	7	81	ND	ND	0.47	0.52
Chromium	7440-47-3	65.3	280	1,400	26.5	21.9	26.9	32.7
Cobalt	7440-48-4	72.3	2.3	30	13.9	21.1	17.7	9.7
Copper	7440-50-8	53.5	310	4,100	15.3	15.9	11.3	17.6
Iron	7439-89-6	50,962	5,500	72,000	37,200	33,000	25,300	29,000
Lead [1]	7439-92-1	26.8	400	800	13.2	13.1	17.9	9.1
Manganese	7439-96-5	2,543	180	2,300	518	697	1240	484
Mercury	7439-97-6	0.13	0.67	2.8	ND	0.027	0.023	0.013
Nickel	7440-02-0	62.8	160	2,000	14.4	13.5	12.5	17.1
Selenium	7782-49-2	--	39	510	0.58	0.72	ND	ND
Thallium	7440-28-0	2.11	0.51	6.6	1.1	1.3	ND	ND
Vanadium	7440-62-2	108	55	720	75.2	65.6	50.4	56.9
Zinc	7440-66-6	202	2,300	31,000	53.3	64.9	58.3	60.4
VOCs (ug/kg)								
2-Butanone (MEK)	78-93-3	--	2,800,000	19,000,000	ND	ND	19	ND
Acetone	67-64-1	--	6,100,000	61,000,000	16	31	150	12
Carbon Disulfide	75-15-0	--	67,000	300,000	6	20	ND	ND
Ethylbenzene	100-41-4	--	5,700	29,000	2	ND	ND	ND
Isopropylbenzene	98-82-8	--	220,000	1,100,000	1	ND	ND	ND
SVOCs (ug/kg)								
Anthracene	120-12-7	--	1,700,000	17,000,000	100	1.2	ND	ND
Benzo(a)anthracene	56-55-3	--	150	2,100	290	9.2	ND	ND
Benzo(a)pyrene	50-32-8	--	15	210	**430**	9.6	ND	ND
Benzo(b)fluoranthene	205-99-2	--	150	2,100	210	6.5	ND	ND
Benzo(g,h,i)perylene [2]	191-24-2	--	170,000	1,700,000	380	11	ND	ND
Benzo(k)fluoranthene	207-08-9	--	1,500	21,000	120	3.7	ND	ND
bis(2-ethylhexyl)phthalate	117-81-7	--	35,000	120,000	390	610	ND	ND
Chrysene	218-01-9	--	15,000	210,000	280	9.4	ND	ND
Fluorene	86-73-7	--	230,000	2,200,000	80	ND	ND	ND
Fluoranthene	206-44-0	--	230,000	2,200,000	410	11	ND	ND
Indeno(1,2,3-cd)pyrene	193-39-5	--	150	2,100	130	ND	ND	ND
Phenanthrene [2]	85-01-8	--	170,000	1,700,000	190	3.9	ND	ND
Pyrene	129-00-0	--	170,000	1,700,000	790	17	ND	ND
PCBs (ug/kg)								
Aroclor 1254	11097-69-1	--	110	740	ND	ND	ND	34

Notes:

USEPA = U.S. Environmental Protection Agency
ft bgs = Feet Below Ground Surface
RBC = Risk-Based Concentration
USEPA Region III Risk-Based Concentration (RBC) values from the October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
mg/kg = Milligram per Kilogram
ug/kg = Microgram per Kilogram
TAL = Target Analyte List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PCB = Polychlorinated Biphenyls
-- = No Risk Criteria Available
ND = Not Detected
[A] = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)

= Concentration Exceeds Soil Residential RBC

bold = Concentration Exceeds Soil Industrial RBC

underline = Concentration Exceeds Site Background Values

[1] = Lead criteria are Action Levels; see USEPA Region III guidance
[2] = RBC value for pyrene was used for these compounds

Table 2-3
Historical Analytical Data for Sump Water Samples Collected at SSA 72
Modified from Previous Investigations
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

				Draper Aden Investigation 2004	Ecology and Environment 2007
Sample ID Sample Date	CAS	Adjusted Tap Water RBC	MCL		ATK-SW-04 9-May-07
TAL Inorganics (ug/L)					
Aluminum	7429-90-5	3,700	--	NT	12,300
Antimony	7440-36-0	1.5	6	NT	**18.8**
Arsenic	7440-38-2	0.045	10	NT	**32.7**
Barium	7440-39-3	730	2,000	NT	124
Chromium [1]	7440-47-3	5,500	100	NT	77.7
Cobalt	7440-48-4	1.1	--	NT	5.2
Copper	7440-50-8	150	1,300	NT	134
Iron	7439-89-6	2,600	--	NT	26,600
Lead [2]	7439-92-1	15	--	NT	4050
Manganese	7439-96-5	180	--	NT	211
Mercury	7439-97-6	0.063	2	NT	0.45
Nickel	7440-02-0	73	--	NT	53.7
Vanadium	7440-62-2	26	--	NT	28.3
Zinc	7440-66-6	1,100	--	NT	154
Pesticides (ug/L)					
4,4'-DDT	50-29-3	0.2	--	NT	0.0096
alpha-BHC	319-84-6	0.011	--	NT	0.032
alpha-chlordane [3]	5103-71-9	0.19	--	NT	0.0064
Endrin aldehyde [4]	7421-93-4	1.1	--	NT	0.0064
Heptachlor	76-44-8	0.015	0.4	NT	0.022
Methoxyclor	72-43-5	18	40	NT	0.013
VOCs (ug/L)					
Acetone	67-64-1	2,200	--	NT	14
Carbon Disulfide	75-15-0	100	--	NT	0.11
SVOCs (ug/L)					
Di-n-butylphthalate	84-74-2	370	--	NT	3.2
Fluoranthene	206-44-0	150	--	NT	1.5
Phenanthrene [5]	85-01-8	110	--	NT	2.1
Pyrene	129-00-0	110	--	NT	1.4
Perchlorate (ug/L)					
Perchlorate	14797-73-0	2.6	--	ND	0.386

Notes:

USEPA = U.S. Environmental Protection Agency
MCL = Maximum Contaminant Level
RBC = Risk-Based Concentration
USEPA Region III Risk-Based Concentration (RBC) values from the October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
ug/L = Microgram Per Liter
TAL = Target Analyte List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
-- = No Risk Criteria Available
ND = Not Detected
NT = Not Tested

= Concentration Exceeds Adj. Tap Water RBC

bold = Concentration Exceeds MCL

[1] = Chromium III RBC used
[2] = Lead criteria are Action Levels
[3] = Chlordane RBC used
[4] = Endrin RBC used
[3] = RBC value for pyrene was used for these compounds

Table 2-4
Historical Analytical Data For Groundwater Samples Collected at SSAs 18 and 72
Modified from Ecology and Environment Investigation 2007
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Sample ID / Sample Date	CAS	Adjusted Tap Water RBC	MCL	ATK-GW-MW01 8-May-07	ATK-GW-MW02 7-May-07	ATK-GW-MW03 7-May-07	ATK-GW-MW04 8-May-07	ATK-GW-MW05 8-May-07	ATK-GW-MW06 7-May-07
TAL Inorganics (ug/L)									
Aluminum	7429-90-5	3,700	--	227	1,250	970	660	220	731
Barium	7440-39-3	730	2,000	39.5	45.2	33.6	34.3	62.5	46.2
Chromium [1]	7440-47-3	5,500	100	<15	<15	<15	<15	<15	<15
Cobalt	7440-48-4	1.1	--	<50	<50	<50	<50	<50	2.5
Iron	7439-89-6	2,600	--	162	845	852	512	185	558
Manganese	7439-96-5	180	--	20.5	25.2	29.2	20.3	4.2	68.3
Nickel	7440-02-0	73	--	<40	<40	2.4	<40	<40	3.2
Zinc	7440-66-6	1,100	--	3.3	11.4	5.1	3.9	2.6	5.2
Pesticides (ug/L)									
alpha-chlordane [2]	5103-71-9	0.19	--	0.005	<0.05	<0.05	<0.05	<0.05	<0.05
beta-BHC	319-85-7	0.037	--	<0.05	<0.05	0.0096	<0.05	<0.05	0.011
Endosulfan sulfate [3]	1031-07-8	22	--	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Heptachlor epoxide	1024-57-3	0.0074	0.2	<0.05	<0.05	<0.05	<0.05	<0.05	0.0054
VOCs (ug/L)									
1,1-dichloroethene	75-35-4	34	7	0.15	<1	<1	<1	<1	<1
4-Methyl-2-pentanone (MIBK)	108-10-1	200	--	<5	<5	<5	0.89	<5	<5
Carbon tetrachloride	56-23-5	0.2	5	<1	<1	<1	0.11	0.22	<1
Chloroform	67-66-3	0.19	80	8.1	8.9	18	0.53	1.8	<1
Methylene chloride	75-09-2	4.8	--	<2	<2	<2	<2	<2	<2
Tetrachloroethene	127-18-4	0.11	5	<1	0.12	0.39	0.7	<1	<1
Toluene	108-88-3	230	1000	<1	0.92	<1	<1	<1	<1
Trichloroethene	79-01-6	1.7	5	<1	0.42	<1	<1	<1	0.63
SVOCs (ug/L)									
bis(2-Ethylhexyl)phthalate	117-81-7	4.8	--	<10	<10	<10	<10	<10	19
Di-n-octylphthalate	117-84-0	--	--	<10	<10	<10	<10	<10	4
Naphthalene	91-20-3	0.14	--	<10	<10	<10	<10	<10	0.7
Explosives (ug/L)									
2,4-Dinitrotoluene	121-14-2	7.3	--	<0.2	0.11	<0.2	<0.2	<0.2	<0.2
2,6-Dinitrotoluene	606-20-2	3.7	--	<0.2	0.098	<0.2	<0.2	<0.2	<0.2
RDX	121-82-4	0.61	--	<0.5	<0.5	<0.5	0.47	0.47	<0.5
Nitrobenzene	98-95-3	0.34	--	0.42	1.7	<0.2	<0.2	<0.2	<0.2
HMX	2691-41-0	180	--	0.12	0.83	0.49	2.7	3.2	<0.5
Perchlorate (ug/L)									
Perchlorate	14797-73-0	2.6	--	0.587	2.1	1.91	3.59	2.47	0.0707

Table 2-4
Historical Analytical Data For Groundwater Samples Collected at SSAs 18 and 72
Modified from Ecology and Environment Investigation 2007
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Notes:

USEPA = U.S. Environmental Protection Agency

MCL = Maximum Contaminant Level

RBC = Risk-Based Concentration

USEPA Region III Risk-Based Concentration (RBC) values from the October 2008 Regional Screening Table

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

ug/L = Microgram per Liter

TAL = Target Analyte List

VOC = Volatile Organic Compound

SVOC = Semivolatile Organic Compound

-- = No Risk Criteria Available

= Concentration Exceeds Adj. Tap Water RBC

bold = Concentration Exceeds MCL

(1) = Chromium III RBC used

(2) = Chlordane RBC used

(2) = Endosulfan RBC used

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Table 2-5
Wildlife Profiles
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Representative Species			Composition of Diet [1] (%)				Preliminary Assessment						Refined Assessment				
							Minimum Body Weight [1]	Maximum Body Weight [1]	Maximum Food Ingestion Rate [2]	Maximum Substrate Ingestion Rate [1]		Maximum Water Ingestion Rate [3]	Average Body Weight [1]	Average Food Ingestion Rate [2]	Average Substrate Ingestion Rate [1]	Average Water Ingestion Rate [3]	Home Range (ha)
Food-web Classification	Common Name	Scientific Name	Plants (incl. fungi)	Inverte-brates	Small mammals	Fish	kg	kg	kg dw/day	% of dry intake	kg dry wt./day	L/day	kg	kg dw/day	kg dry wt./day	L/day	
Birds																	
soil-probing invertivore	American robin	*Turdus migratorius*	62%	38%			0.0635	0.103	0.020	5%	0.001	0.013	0.077	0.016	0.0008	0.011	0.48
large carnivore	Red-tailed hawk	*Buteo jamaicensis*			100%		0.957	1.235	0.063	0%	0	0.068	1.134	0.059	0	0.064	250
Mammals																	
small herbivore	Meadow vole	*Microtus pennsylvanicus*	100%				0.017	0.0524	0.010	2.4%	0.00024	0.0070	0.037	0.008	0.00019	0.0051	0.037
medium carnivore	Red fox	*Vulpes vulpes*	17%	4%	79%		2.95	7.04	0.342	2.8%	0.0096	0.573	4.53	0.238	0.0067	0.39	96
small invertivore	Short-tailed shrew	*Blarina brevicauda*	14%	86%			0.0125	0.0225	0.003	10%	0.00031	0.0033	0.015	0.002	0.00021	0.0023	0.39

Notes:
kg = Kilogram
kg dw/day = Kilogram Dry-weight per Day
L/day = Liter per Day

[1]Wildlife Exposure Factors Handbook. U.S. Environmental Protection Agency (EPA). 1993. Office of Research and Development. 2 Volumes. EPA/600/R93/187a&b. December.
[2] Estimated food intake rate (kg [dw]/day) calculated as follows:
FI ((kg/day) = 0.0687 $Wt.^{0.882}$ for mammals (red fox and short-tailed shrew)
FI ((g/day) = 0.577 $Wt.^{0.727}$ for herbivores (meadow vole)
FI ((g/day) = 0.301 $Wt.^{0.751}$ for non-passerine birds (red-tailed hawk)
FI ((g/day) = 0.398 $Wt.^{0.850}$ for passerine birds (american robin)
[3] Estimated water intake rate (L/day) calculated as follows:
Birds: $WI=0.059Wt^{0.67}$(kg)
Mammals: $WI=0.099Wt^{0.90}$(kg)
The soil ingestion rate for the american robin set equal to 38% of the american woodcock value (0.34*10.4%=4%), based on a robin diet of 38% invertbrates.

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Table 2-6
Handling and Disposal of Investigation-Derived Materials
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Material	Description	Quantity	Action	Expected Nature of Material
Excess Soil from Borings	From 20 Soil Borings	Approximately One 55-gallon drum	Full TCLP, Corrosivity, Paint Filter Liquids, and Explosives	Non-hazardous. Concentrations are not expected to exceed TCLP, or pH limits.
Excess Soil from Test Pits	From 2 Test Pits at SSA 60	Approximately fifteen 55-gallon drums	Full TCLP, Corrosivity, Paint Filter Liquids, and Explosives	Non-hazardous. Concentrations are not expected to exceed TCLP, or pH limits.
Well Purge Water and Decontamination Water	Aqueous IDM	Approximately three 55-gallon drums	TCLP Metals, COD, and pH	Non-hazardous. Concentrations are not expected to exceed treatment plant limits.
PPE	Miscellaneous IDM	Approximately two 55-gallon drums	Evaluate Soil and Water Results	Non-hazardous material. Will be disposed of with soil IDM.

Notes:
IDM = Investigation-Derived Material
TCLP = Toxicity Characteristics Leaching Procedure
COD = Chemical Oxygen Demand
PPE = Personal Protective Equipment and Clothing

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3.0 SSA 30 ASBESTOS DISPOSAL TRENCH NO. 1 AND SSA 79 ASBESTOS DISPOSAL TRENCH NO. 2

3.1 SITE BACKGROUND

3.1.1 Site Description

Asbestos Disposal Trench No. 1 (SSA 30) and Asbestos Disposal Trench No. 2 (SSA 79) are located in the southeastern horseshoe area of RFAAP (Figure 1-1). SSA 30 and SSA 79 are contiguous trenches orientated in continuous line approximately 450 ft long with long axis (northwest to southeast) parallel to and east of SWMU 51, a trinitrotoluene (TNT) waste neutralization pit (Figure 3-1). The trench area is reportedly 15 ft wide with a maximum depth of 15 ft (USEPA 1987). The asbestos trench area has been filled to grade and is vegetated with grass. A fence surrounds the site area and aboveground power lines cross the middle of the site. The closest structures are storage magazine buildings located north (Building 4601-13), east (Building 4601-13), and west (Building 4601-12) of SSA 30 and SSA 79.

SSA 30 and SSA 79 are located within an elevated plateau area of the horseshoe area. Ground surface in the site area slopes from east to west from a maximum elevation of approximately 1,834 ft msl to a minimum elevation of 1,824 ft msl. A local topographic high exists between the site area and landfill areas (closed sanitary landfill areas SWMU 26 and 52 and hazardous waste landfill SWMU 16) east of the site. A site photographic log for SSA 30 and SSA 79 is included in Appendix C.

3.1.2 Site History

Asbestos Disposal Trench No. 1 (SSA 30) and Asbestos Disposal Trench No. 2 (SSA 79) were used for disposal of asbestos containing material from 1982 to 1987 (USEPA 1987). The trenches received 250 to 500 pounds of double bagged asbestos material per day, 3 to 5 days per week, when asbestos removal activities were ongoing at RFAAP. Daily soil cover was placed on the double bagged asbestos material. The volume of asbestos materials placed in the trench areas is unknown.

Aerial photographs of SSA 30 and SSA 79 area for 1971, 1986, and 1990 are presented as Figures 3-2, 3-3, and 3-4, respectively. The 1971 photograph shows the site area before excavation of the trenches for asbestos disposal and the recently backfilled and re-vegetating area of SWMU 51 located adjacent to and west of the future trench area. In 1986, the aerial photograph clearly shows the location of the active and backfilled portions of the asbestos trench. The northern half of the trench (SSA 79 – Trench No 2) is active and white objects (likely double bagged asbestos material) are apparent in the bottom middle of the trench area. The southern portion of the trench area (SSA 30) is backfilled to grade with soil. Observations noted on the 1986 aerial photograph were consistent with the information presented in the 1987 RFA and site visit notes, which indicated that SSA 79 was still active, SSA 30 had been recently backfilled at the time of the RFA site visit in 1986 but not re-vegetated, and that the trench areas were indistinguishable. The closed trench area of SWMU 51 is clearly visible on the 1986 aerial photograph as a rectangular dark green vegetated area adjacent to the asbestos trench area. In 1990, the aerial photograph shows that the area of the asbestos trench has been backfilled and re-vegetated. Perimeter fences around the area of SWMU 51 and the area of SSA 30 and SSA 79 are visible in the area of the photograph. A cinder road is visible east of SWMU 51 and the asbestos trench area.

3.1.3 Surface Water

Surface water bodies, drainage ditches, manholes, catch basins, or preferential flow paths for surface water flow are not located in the area of former asbestos disposal trenches. Overland flow of stormwater across the site is expected to follow topographic slope (east to west).

3.1.4 Soil

According to the *Soil Survey of Montgomery County, Virginia* (USDA 1985), the site area is underlain by the Braddock Loam with gentle slopes of 2 to 7%. Reaction of Braddock soils ranges from very strongly acid to strongly acid. The organic matter content of this soil is moderately low and permeability is moderate. Available water capacity of the Braddock soil is moderate and surface runoff is medium. The Braddock soil does not have a seasonally high water table within 60 inches of the surface. A typical profile of the Braddock soil consists of a seven-inch thick surface layer of dark yellowish brown loam underlain by a minimum 60-inch thick subsoil of yellowish-red clay and red clay. Depth to bedrock is greater than 60 inches.

Physical data for four soil samples collected from monitoring well borings 51MW1 and 51MW2 installed for a 1992 RFI conducted at SWMU 51 (Dames & Moore, 1992b) adjacent to SSA 30 and SSA 79 are summarized in the following table. Monitoring well locations are shown on Figure 3-5,

Summary of RFI Physical Soil Data (Dames & Moore, 1992)

Sample No.	Sample Depth (ft bgs)	Moisture (%)	Grain Size Distribution			Atterberg Limits (LL/PI)	USCS Classification
			Gravel (%)	Sand (%)	Fines (%)		
51MW1	10-11.3	8.6	65.8	22.0	12.2	38/18	SC
51MW1	30-32	125	5.3	17.0	77.7	60/26	MH
51MW2	10-12	21.9	0.0	77.5	22.5	32/8	SM
51MW2	25-27	18.6	12.0	66.9	21.1	36/13	SC

Notes: Gravel = retained on #4 sieve, Sand = passed #4 sieve and retained on #200 sieve, Fines = passed #200 sieve., MH = elastic silt, SC = clayey sand, SM = silty sand.

3.1.5 Geology

Geologic conditions have been previously investigated in the area of SSA 30 and SSA 79 for RFIs conducted at adjacent SWMU 51. Soil and rock borings also were completed adjacent to the site for monitoring wells C1 and 16-4 associated with adjacent landfills SWMU 26, SWMU 52, and HWMU 16 (Figure 3-5). These investigations indicate that the site area is underlain by approximately 40 to 50 ft of unconsolidated deposits consisting of alluvial terrace material and underlying residual soil weathered from underlying bedrock. Alluvial terrace deposits are typically 30 to 35 ft thick and consist of upper layers of silt/clay (ML/CL), silty sand (SM), and clayey sand (SC), and a lower layer of silty gravel (river jack). Residual soil weathered from underlying bedrock is typically clay or silt saprolite containing relict shale or siltstone structure. Coring of bedrock at borings 51MW2, 16-4, and C1 indicated interbedded green shale, siltstone, and dolomite/limestone bedrock of the Cambrian Age Elbrook Formation. The uppermost intervals of bedrock are typically variably weathered with a moderate to high degree of fracturing.

Appendix D.2 includes several geologic cross-sections developed by Shaw for the SWMU 51 RFI/CMS Report (Shaw 2008b) illustrating subsurface conditions in the site area and boring logs for monitoring wells 51MW1, 51MW2, C1, and 16-4.

3.1.6 Hydrogeology

Hydrogeology in the area of SSA 30 and SSA 79 has been previously characterized by the installation of two groundwater monitoring wells for the SWMU 51 RFI (51MW1 and 51MW2) and the installation of two groundwater monitoring wells (C1 and 16-4) to monitor groundwater conditions upgradient of the SWMU 26 and 52 landfills and the HWMU 16 landfill. Construction and hydrogeologic data for these wells are summarized below.

Monitoring Well Construction Data – Area of SSA 30 and SSA 79

Well ID	Installation Date	Total Depth (ft)	Screen Depth Interval (ft bgs)	Unit Monitored	Slug Test Result (cm/sec)
51MW1	09/24/91	35.0	25.0-35.0	UA	--
51MW2	09/09/91	53.0	43.0-53.0	UA/Bedrock	4.17E-05*
C1	07/29/80	70.0	55.0-70.0	Bedrock	--
16-4	11/02/84	80.0	45.0-80.0	Bedrock	--

Note: UA = unconsolidated alluvium, cm/sec = centimeters per second. * Rising head slug test conducted by Dames & Moore (1992).

These investigations indicate that groundwater in the site area is present within bedrock with measured water levels in wells near the top of competent bedrock. At 51MW2, groundwater also is present within the overburden overlying bedrock. Groundwater studies conducted in the horseshoe area by Shaw (2005, 2006, and 2007) indicate that precipitation infiltrates in high areas of the horseshoe area and recharges the bedrock aquifer with groundwater flow through the bedrock aquifer to the floodplain of the New River and into the New River. The SWMU 51 RFI conducted by Shaw indicated that groundwater flow in the site area is radial outward toward the west and south. Select groundwater elevation data and a groundwater contour map from the SWMU 51 RFI/CMS Report illustrating these conditions are included Appendix D.2.

3.2 PREVIOUS INVESTIGATIONS

3.2.1 RCRA Facility Assessment – USEPA 1987

An assessment was conducted at SSA 30 (listed as Unit 30 in RFA) and SSA 79 (listed as Unit 79 in RFA) to evaluate potential hazardous waste or hazardous chemical releases and implement corrective actions, as necessary. The assessment consisted of a preliminary review and evaluation of available site information, personnel interviews, and a visual inspection of the site. Environmental samples were not collected at SSA 30 or SSA 70 as part of the inspection. The assessment indicated that the closure status of SSA 30 was "uncertain due to the active status" of SSA 79. The RFA indicated that no data indicating releases had been collected.

3.2.2 Installation Assessment – USEPA 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 (USEPA 1992). The photogeologic analysis was performed to locate waste management areas, identify the location of sinkholes that existed prior to the construction of the RFAAP, and map fracture traces. A specific assessment was not conducted for the asbestos disposal trenches; however, an assessment was conducted for adjacent SWMU 51. The aerial photographic analysis of SWMU 51 indicated that activity was first noted at the SWMU 51 in 1975, where a trench appeared to empty, was visible on the photograph. By 1981, the trench had been filled and a re-vegetating ground scar was the sole remaining feature.

3.2.3 RCRA Facility Investigation at SWMU 51 - Dames & Moore 1992

In 1992, Dames & Moore reported the results of an RFI conducted at SWMU 51 located adjacent to SSA 30 and SSA 79. The RFI focused on evaluating potential releases to groundwater in the area of SWMU 51 and at adjacent landfill areas to the east and north of the site. Monitoring wells sampled around the periphery of the SSA 30 and SSA 79 area included 51MW1, 51MW2, C1, and 16-4 (Figure 3-5). Groundwater samples collected from these wells were analyzed for VOCs, SVOCs, explosives, dissolved metals, total organic carbon (TOC), total organic halogens (TOX), and pH. Sample results are

summarized in Table 3-1 for detected constituents. Bis(2-ethylhexyl)phthalate and 2,6-dinitrotoluene were detected in wells 16-4 and 51MW2 (2,6-dinitrotoluene only) at concentrations above their current USEPA Region III adjusted T-RBCs. The concentration of bis(2-ethylhexyl)phthalate detected in 16-4 also was above its MCL.

3.2.4 Geophysical Survey at SWMU 51 – Argonne National Laboratory 2002

A geophysical survey was conducted in the SWMU 51 area in 2002 to characterize the lateral and vertical extent of the former TNT neutralization-sludge disposal trench. Surface geophysical surveys performed included electromagnetic (EM) 31/34 terrain-conductivity mapping, two-dimensional electrical resistivity imaging (2D-ERI), and seismic refraction tomography. Downhole seismic velocity profiling and electrical logging was conducted at wells 51MW1, 51MW2, and 16-4 to assist in constraining the resistivity models. A copy of the Argonne National Laboratory geophysical report is included in Appendix D.2.

The geophysical survey showed a high conductivity anomaly for EM-31 and low resistivity anomaly along profile L-4 in the general trench area shown on the 1986 photograph (Figures B-5 and B-6 in the geophysical report provided in Appendix D.2).

3.2.5 Eastern Horseshoe Area Groundwater Sampling – Shaw 2006

In 2006, Shaw reported the results of area wide groundwater sampling in the eastern horseshoe area including wells 51MW1, 51MW2, C1, and 16-4 located in the area of SSA 30 and SSA 79 (Shaw 2006). Groundwater samples were analyzed for TCL VOCs, TCL SVOCs, TCL pesticides, TCL PCBs, TCL dioxin/furans, PAHs, TAL metals (total), and perchlorate. Sample results in Table 3-2 are summarized for detected constituents. Constituents detected in one or more samples at concentrations above their current adjusted T-RBCs included VOCs methylene chloride ("B" flagged due to blank contamination), tetrachloroethene, and 1,1-dichloroethane, pesticides alpha-chlordane and heptachlor epoxide, and total antimony. Detected concentrations were below MCLs.

3.2.6 RCRA Facility Investigation/Corrective Measures Study at SWMU 51 – Shaw 2008

In 2008, Shaw reported the results of an RFI/CMS conducted at SWMU 51 located adjacent to SSA 30 and SSA 79. Soil sampling was limited to the immediate area of the SWMU 51 trench. Samples were analyzed for TCL VOCs, TCL SVOCs, pesticides, PCBs, herbicides, explosives, TAL metals, and dioxin/furans. The soil samples were not analyzed for asbestos.. Existing 2006 groundwater data from the Eastern Horseshoe Area groundwater sampling for 51MW1, 51MW2, C1, and 16-4 were used in the RFI assessment.

3.3 CONCEPTUAL SITE MODEL (CSM)

A CSM for SSA 30 and SSA 79 is presented on Figure 3-6. The site is located on the highest level alluvial terrace within the eastern horseshoe area at RFAAP. Approximately 40 to 50 ft of unconsolidated material overlies competent bedrock in the site area. Groundwater occurs near the overburden/bedrock interface and within bedrock at depths of approximately 30 to 40 ft below the bottom of the asbestos trenches. Groundwater flows radially from the site area toward the west and south. Surface water bodies, drainage ditches, manholes, catch basins, or preferred drainage paths or features are not present at SSA 30 or SSA 79. The heavy tall grass and weed vegetation present on the sites would reduce storm water runoff. Any overland runoff from the site area would follow the approximately 5% topographic slope toward the west.

Potential constituent sources at the site are related to the disposal of double bagged asbestos waste material in the trench area to depths up to 15 ft. The volume of asbestos material placed in the trenches

is unknown. Daily soil cover was placed over the disposed bagged material. Potentially affected media at the site include:

- Surface and subsurface soil from asbestos disposal activities;
- Subsurface soil via leaching of asbestos material from the trench area; and
- Groundwater via leaching of asbestos material from subsurface soil.

Although current and likely future land-use scenarios are limited to industrial operations, both residential and industrial scenarios will be evaluated in the SSP human health screening (USEPA 2001).

SSA 30 and SSA 79 are exclusively an upland habitat that lacks wetland and significant onsite drainage features. Therefore, soil represents the potential exposure medium for ecological receptors. 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*). Refer to Table 2-5 for wildlife receptor profiles.

3.4 DATA GAP ANALYSIS

Data gaps identified for the SSP investigation are discussed in the following sections.

3.4.1 Delineation of Trench Areas

The precise limits of the asbestos trench area have not been delineated at the site and subsurface investigations specific to the trenches have not been conducted. This data gap will be filled by completing surface geophysical investigations across the site area where the trench is located. Soil borings will be completed within the site area to confirm and supplement the geophysical results. Proposed field investigation activities are discussed in Section 3.5.1.

3.4.2 Soil Release Assessment

Soil sampling has not been performed at SSA 30 and SSA 79 to evaluate potential releases to soil from previous asbestos waste disposal activities or potential commingling of waste with soil cover. This data gap will be filled by collecting surface soil samples from the trench areas for analysis of asbestos, TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL metals. Subsurface soil samples will not be collected from within or directly below the trench areas due to the nature of disposal activities and waste (double bagged asbestos material) and associated risk of inadvertently releasing asbestos into the environment. Data gaps for releases to deeper subsurface soil will be filled by completing soil borings adjacent to the trench areas and collecting subsurface soil samples for asbestos analysis at depths below the bottom of the trench. The proposed field program is discussed in Section 3.5.2 and 3.5.3.

3.4.2.1 Groundwater

Groundwater monitoring wells 51MW1, 51MW2, C1, and 16-4 located around the perimeter of SSA 30 and SSA 79 have been sampled to evaluate releases from SWMU 51 and adjacent landfill areas; however, these wells but have not been sampled for asbestos to evaluate releases to groundwater from the asbestos disposal trenches. Additional groundwater samples will be collected from these wells for analysis of asbestos to evaluate potential releases to groundwater and fill this data gap, as described in Section 3.5.5.

3.4.2.2 Other

Physical soil testing of soil in the site area is limited to one boring completed within the SWMU 51 area, which penetrated sludge material not considered representative of site soil and four soil samples collected from well borings 51MW1 and 51MW2 for limited parameters (grain size analysis, Atterburg limits, moisture content, and soil classification). Additional physical testing of representative surface soil and surface soil is proposed to fill this data gap and more completely characterize physical and geotechnical properties of site soil, as described in Section 3.5.4.

3.4.3 Summary of Data Gaps

The data gap analysis completed for SSA 30 and SSA 79 identified data gaps for delineating asbestos trench areas, evaluating potential releases to soil and groundwater from asbestos disposal activities, and characterizing physical and geotechnical properties of site soil. The following table summarizes these identified data gaps and the completion plan to fill the data gaps.

SSA 30 and SSA 79 - Summary of Data Gap Analysis and Completion Plan

DATA GAPS			COMPLETION PLAN
Item	**Physical**	**Chemical**	
Delineation of Trench Areas	Geophysical Survey and Soil Borings	Not Applicable	Complete geophysical survey and soil borings
Releases to Soil	Surface Soil Samples	Chemical Data – asbestos, TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect surface soil samples within trench area for chemical analysis
	Subsurface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect subsurface soil samples from soil borings completed adjacent to trench areas at depths below trench.
Releases to Groundwater	Groundwater Samples	Chemical Data – Asbestos	Sample existing groundwater monitoring wells 51MW1, 51MW2, C1, and 16-4.
Site-Wide Soil Characteristics	Physical / Geotechnical Properties	pH, total organic carbon, grain size, Atterberg Limits, and moisture content	Collect samples for geotechnical and physical property analysis.

3.5 PLANNED FIELD ACTIVITIES

The SSA 30 and SSA 79 SSP field program is designed to address the data gaps identified in Section 3.4 and meet the SSP objectives identified in Section 1.1. The selection of the investigation areas and sample locations followed SOP 30.7 (Sampling Strategies, included in Appendix B) using biased sampling techniques to identify potential releases.

Sample analysis will be conducted consistent with the requirements of the MQAP and Section 6.0 of this WPA. Sample management and analytical methods are discussed in detail in Sections 6.4 and 6.5 of this WPA, respectively.

3.5.1 Surface Geophysical Survey

Surface geophysical surveys will be conducted at SSA 30 and SSA 79 with the objective of locating the lateral and vertical extent of the asbestos disposal trench areas at the site. A combination of EM, GPR, and 2D-ERI surveys will be conducted within the site area as described below.

Electromagnetic (EM) Survey

An EM survey will be conducted using a Geonics® EM-31 terrain conductivity meter (both quadrature and in-phase modes), with the objective of locating the lateral limits of the asbestos trench areas and to guide the follow-on 2D-ERI survey. The EM-31 instrument will be programmed to take measurements at one second intervals. A global positioning unit (GPS) will be time synchronized with the EM unit and programmed to collect measurements at intervals of one second. EM data will collected in a grid pattern along traverses trending east to west and north to south approximately 10 ft apart. The survey data and synchronized GPS and EM data will provide earth conductivity data with spatial coordinates for subsequent contouring on the site base map. Identified targets will be marked and locations will be obtained with a Trimble GPS unit. The EM survey will conducted across the site area.

EM survey procedures will be performed consistent with SOP 20.7 in Appendix B. This SOP also provides information on the principles and theory of EM surveys.

Ground Penetrating Radar

A Groundwater Penetrating Radar (GPR) survey will be completed within the study area to confirm the results of the EM survey. GPR operates by transmitting pulses of ultra high frequency radio waves (microwave electromagnetic energy) into the ground through a transducer or antenna. The transmitted energy is reflected from various buried objects or distinct contacts between earth materials. The antenna then receives the reflected waves and stores them in the digital control unit. Buried objects are expressed as hyperbolic reflections.

The GPR survey will reference the same spatial grid as used in the EM survey. GPR traverses will be conducted in the east-west direction perpendicular to the anticipated direction of the trench area. GPR survey procedures will be consistent with SOP 20.6 in Appendix B. This SOP also provides information on the principles and theory of GPR surveys.

Resistivity Survey (2D-ERI)

A 2D-ERI survey will be conducted using a Tigre® 64 resistivity system manufactured by Allied Associates, Ltd in Great Britain with the objective of assessing the vertical extent of the disposal trenches at the site and to confirm the lateral extent of trench areas. It is anticipated that two resistivity lines will be completed in the longitudinal direction of the trench area and three in the perpendicular direction. Electrodes will be placed at 3 meter (10 ft) intervals and marked with a stake flag with a unique identifier for future reference. The exact locations and length of the resistivity lines will be determined from the results of infield processing of the EM survey. The locations of resistivity lines and electrode points will be obtained using a Trimble GPS unit. 2D-ERI survey procedures will be consistent with SOP 20.7 in Appendix B. This SOP also provides information on the principles and theory of resistivity.

3.5.2 Surface Soil Sampling

Six surface soil samples, 30SS1, 30SS2, 30SS3, 79SS1, 79SS2, and 79SS3, will be collected from within the asbestos disposal trench area(s) of SSA 30 and SSA 79 as delineated by the geophysical surveys to

evaluate potential releases to surface soil and commingling of waste with surface soil. Figure 3-7 shows the approximate sample locations based on aerial photographic interpretation of trench locations. The actual locations will be dependant on the results of geophysical surveys. Surface soil samples will be collected from 0 to 0.5 ft bgs, with the exception of VOC samples, which will be collected from 0.5 to 1 ft bgs. Soil samples will be submitted for chemical analysis of the following parameters:

- Asbestos by State of California Air Resources Board (CARB) Method 435;
- TCL VOCs by SW-846 Method 8260B;
- TCL SVOCs by SW-846 Method 8270C (low level);
- TCL PCBs and TCL pesticides by SW-846 Methods 8082 and 8081A;
- Explosives by SW-846 Methods 8330 and 8332; and
- TAL inorganics by SW-846 Methods 6010/6020/7471A/9012A.

Surface soil samples will be collected following the procedures outlined in SOP 30.1 and 30.9 in Appendix B.

3.5.3 Subsurface Soil Sampling

Six direct push soil borings (30SB1, 30SB2, 30SB3, 79SB1, 79SB2, and 79SB3) will be completed adjacent to the identified trench areas to evaluate releases to subsurface soil below the trenches. One subsurface soil sample ("B" sample) will be collected each of the six soil borings from the two foot depth interval immediately below the bottom of the trenches. Subsurface soil samples will be analyzed for the same parameters as surface soil samples. Approximate boring locations are shown on Figure 3-7 based on the trench location shown on the 1986 aerial photograph. Actual boring locations will be dependent on geophysical results and conditions encountered at the site.

A four-foot, Geoprobe Macro-Core® sampling device will be used to collect soil samples continuously from each of the borings, as described in SOP 30.1, SOP 20.11, and SOP 30.9 in Appendix B. Soil core samples will be screened with a PID for the presence of VOCs. Borings logs will be prepared as outlined in SOP 10.3 in Appendix B.

3.5.4 Physical Soil Testing

Two representative soil samples (one surface soil sample and one subsurface soil sample from depth interval below trenches) will be analyzed to characterize physical and geotechnical properties of site soil as outlined in Section 6.5.4:

- Grain-size analysis (ASTM D 422);
- Atterberg limits (ASTM D 4318);
- Soil moisture content (ASTM D 2216);
- Total organic carbon (Walkley-Black Method); and
- pH (ASTM D 4972).

Physical soil data will be used for qualitative soil screening evaluations as outlined in the USEPA SSP document (USEPA 2001) including calculation of site-specific soil screening levels for migration to groundwater, as required.

3.5.5 Groundwater Sampling

Groundwater samples will be collected from existing monitoring wells 51MW1, 51MW2, C1, and 16-4 located around the periphery of the SSA-30 and SSA-79 area to evaluate for potential releases to groundwater from the asbestos disposal trench areas. Groundwater samples will be analyzed for asbestos by Transmission Electron Microscopy (TEM) using USEPA Method 100.2.

Groundwater sampling will be conducted following the procedures outlined in SOP 30.2 in Appendix B. A single continuous set of static water levels will be collected from site monitoring wells prior to purging and sampling. Low flow sampling will be performed according to SOP 30.2 and the latest USEPA guidance. Water quality parameters pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity will be measured using an in-line flow cell (SOP 40.1 in Appendix B) during purging and immediately before sample collection to document parameter stabilization and water quality parameters.

3.5.6 Surveying

Horizontal coordinates and ground surface elevations for geophysical surveying, soil samples, and soil borings will be obtained using a global positioning system (GPS) unit with submeter accuracy for horizontal measurements (+1 part per and million) and vertical measurements (+ 2 parts per million for vertical measurements).

3.5.7 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration (OSHA) and USEPA regulations regarding the identification, handling, and disposal of non-hazardous and hazardous IDM. Activities will be performed in accordance with the Installation safety rules, protocols, and SOP 70.1. Information on the expected nature (hazardous versus non-hazardous) of the materials that will be generated during the field investigations is summarized in Table 2-6.

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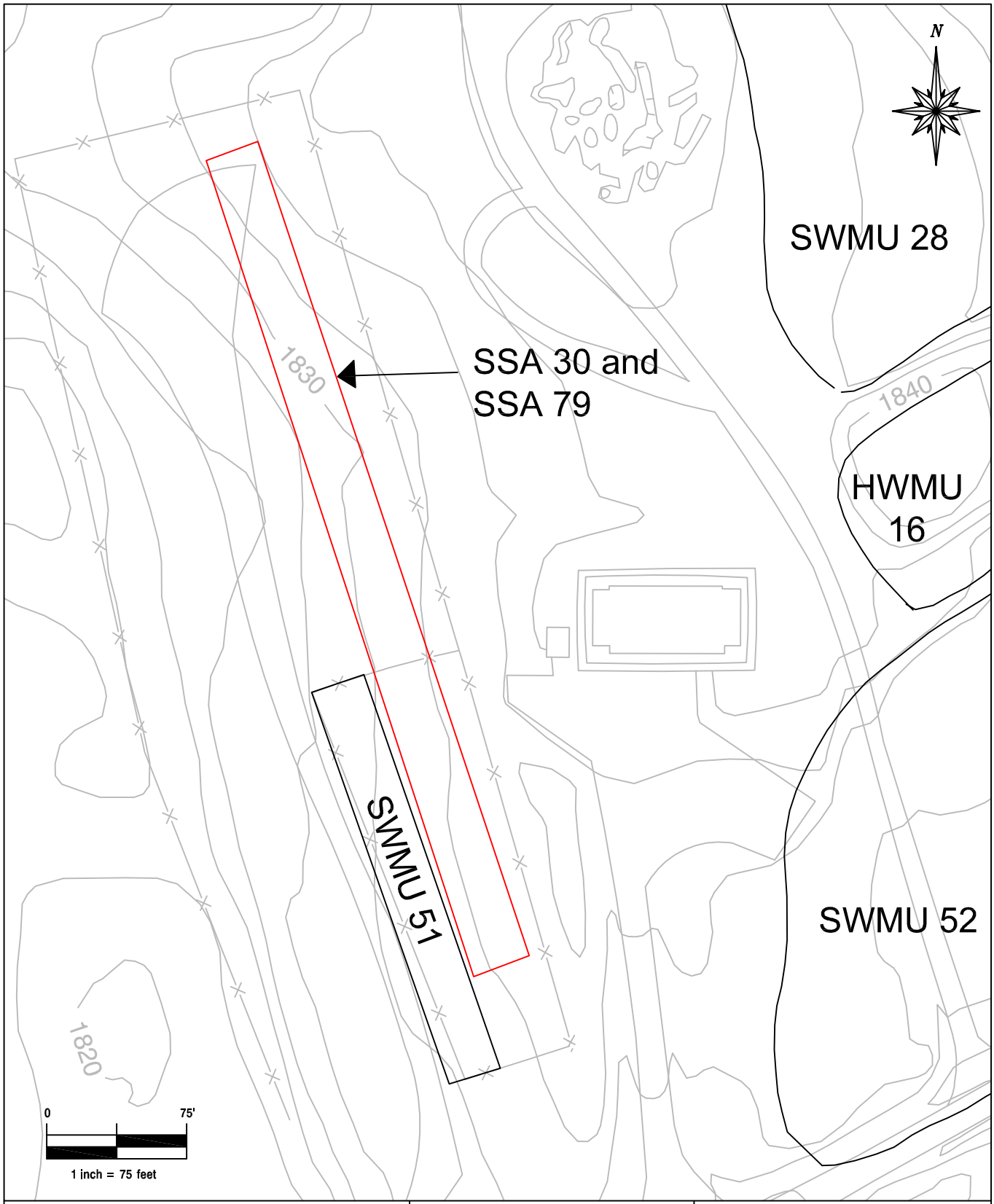

Legend

- Approximate SSA Boundary
- Topographic Contour
- Fence
- Approximate SWMU Boundary

FIGURE 3-1

Site Layout - SSA 30 and SSA 79

Date: March 2009	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 75 feet	File Name: Fig.3-1 SiteLayout

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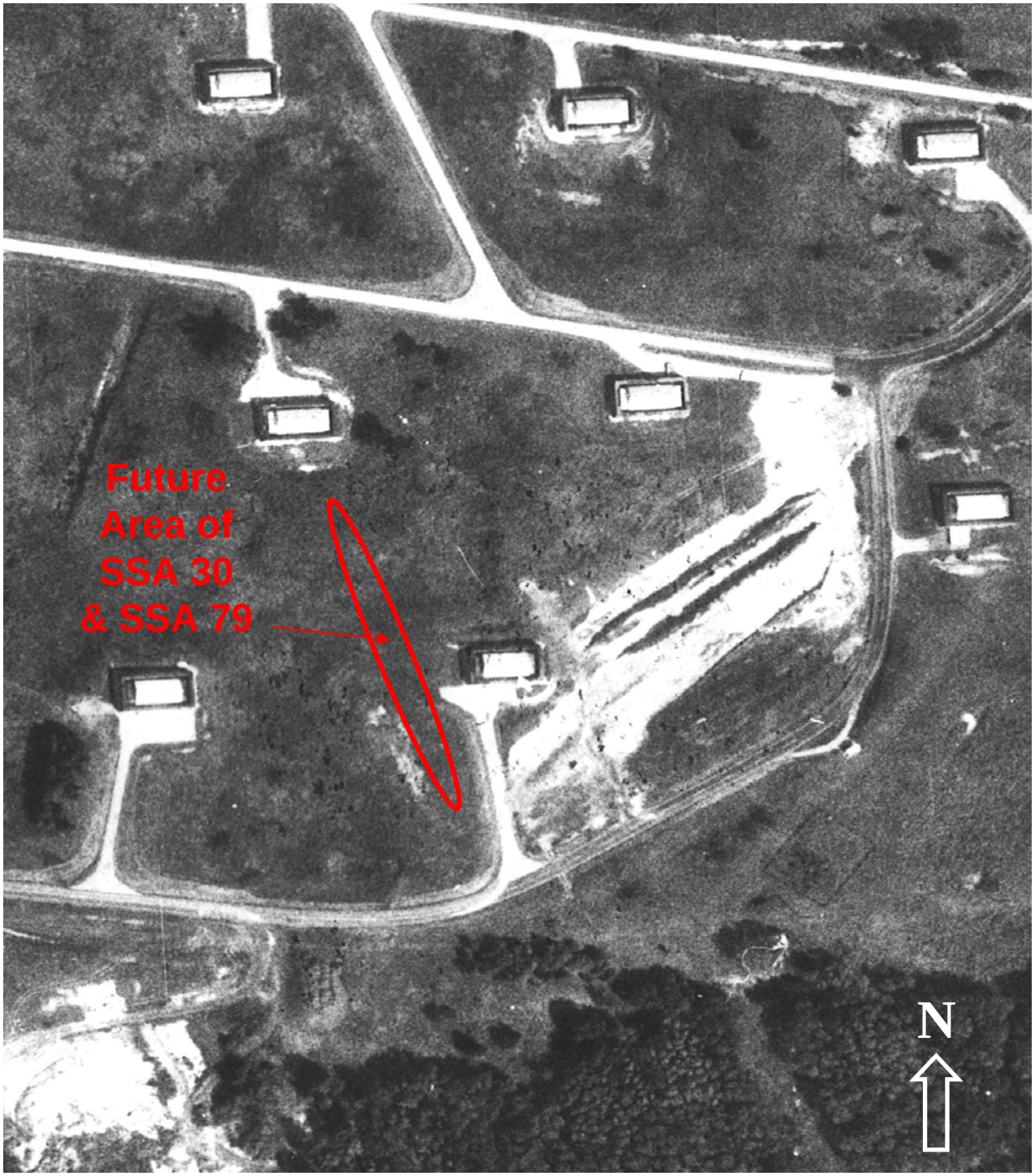
Radford Army Ammunition Plant
Radford, Virginia

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



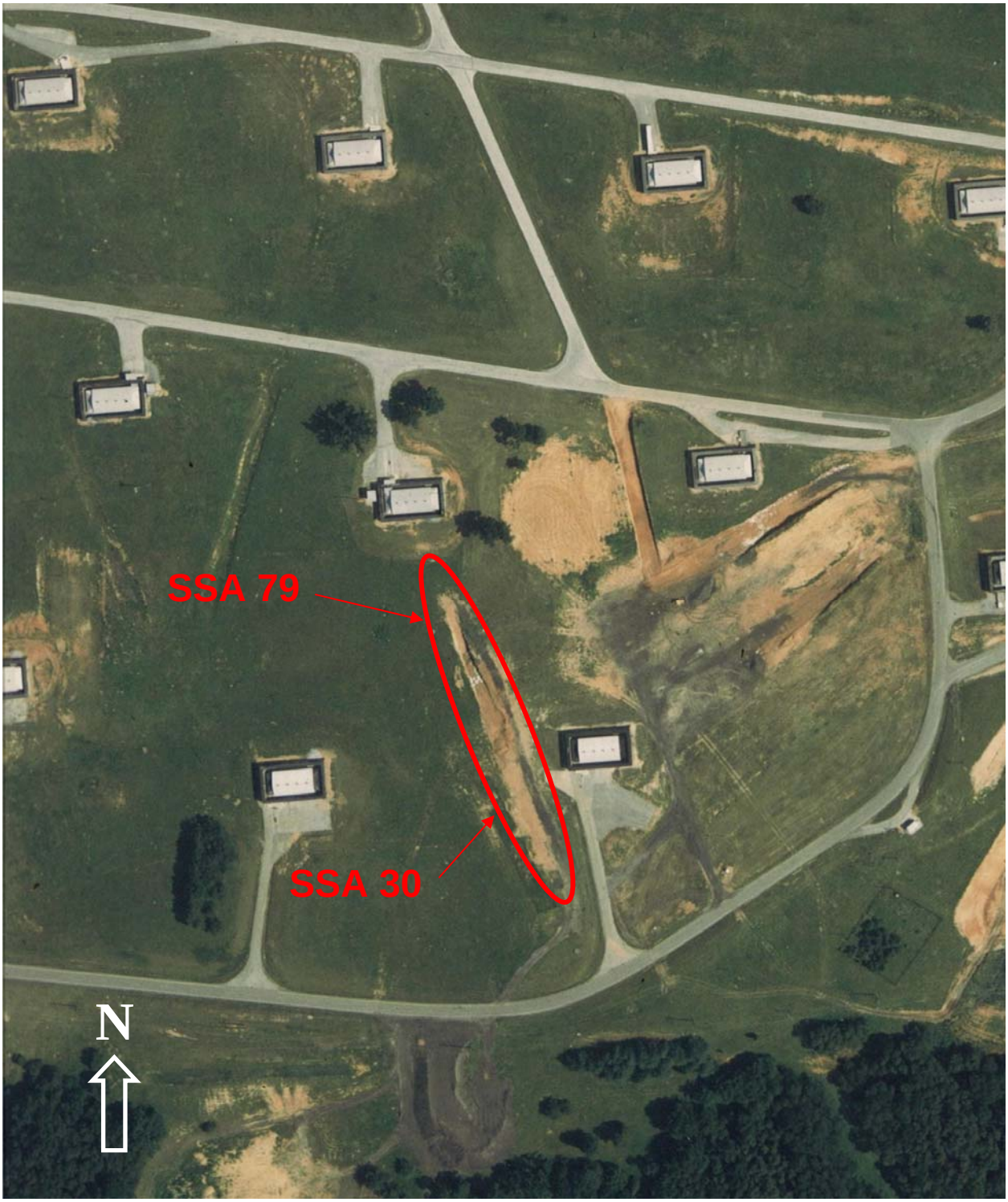
SSA 30 and SSA 79
AERIAL PHOTOGRAPH – 1971

FIGURE 3-2

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77

Date: *October 2008*	**Prepared by:** *HA/CLD*
Scale: *No Scale Implied*	**File Name:** *11657490*



SSA 30 and SSA 79
AERIAL PHOTOGRAPH – 1986

FIGURE 3-3

Date: *October 2008*

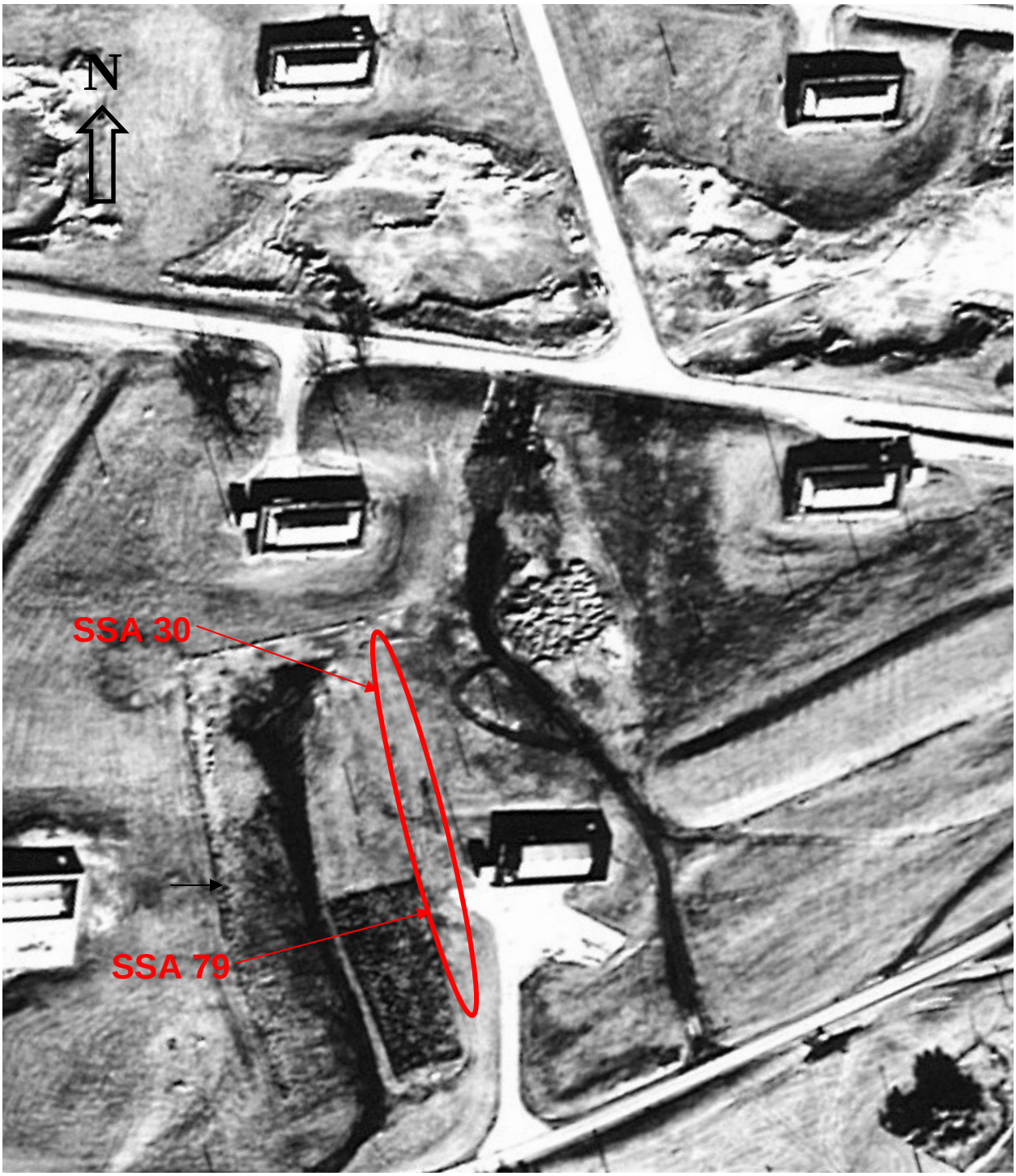
Prepared by: *HA/CLD*

Scale: *No Scale Implied*

File Name: *11657490*

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77



SSA 30 and SSA 79
AERIAL PHOTOGRAPH – 1990

FIGURE 3-4

Date: *October 2008*

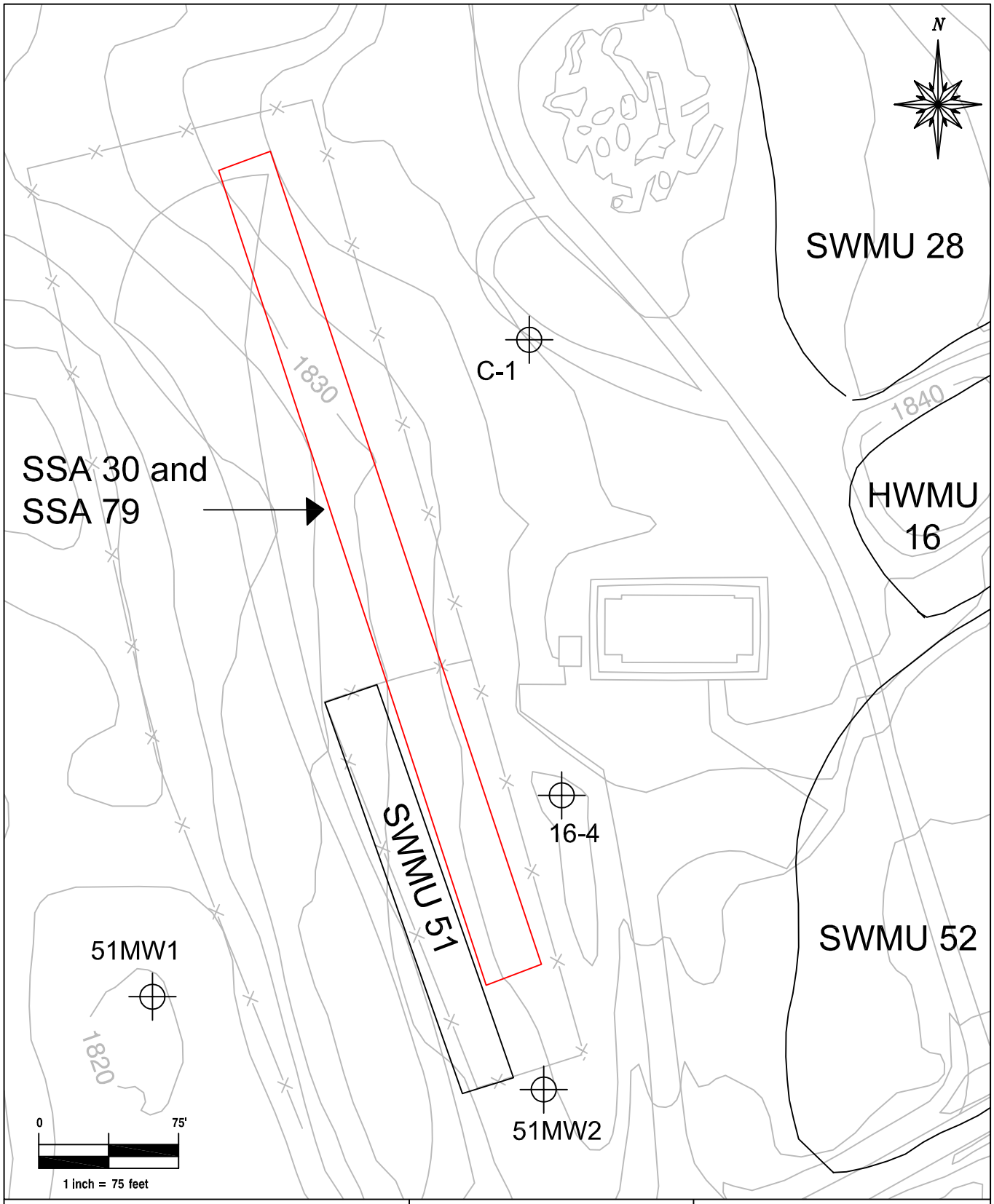
Prepared by: *HA/CLD*

Scale: *No Scale Implied*

File Name: *11657490*

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77



Legend

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

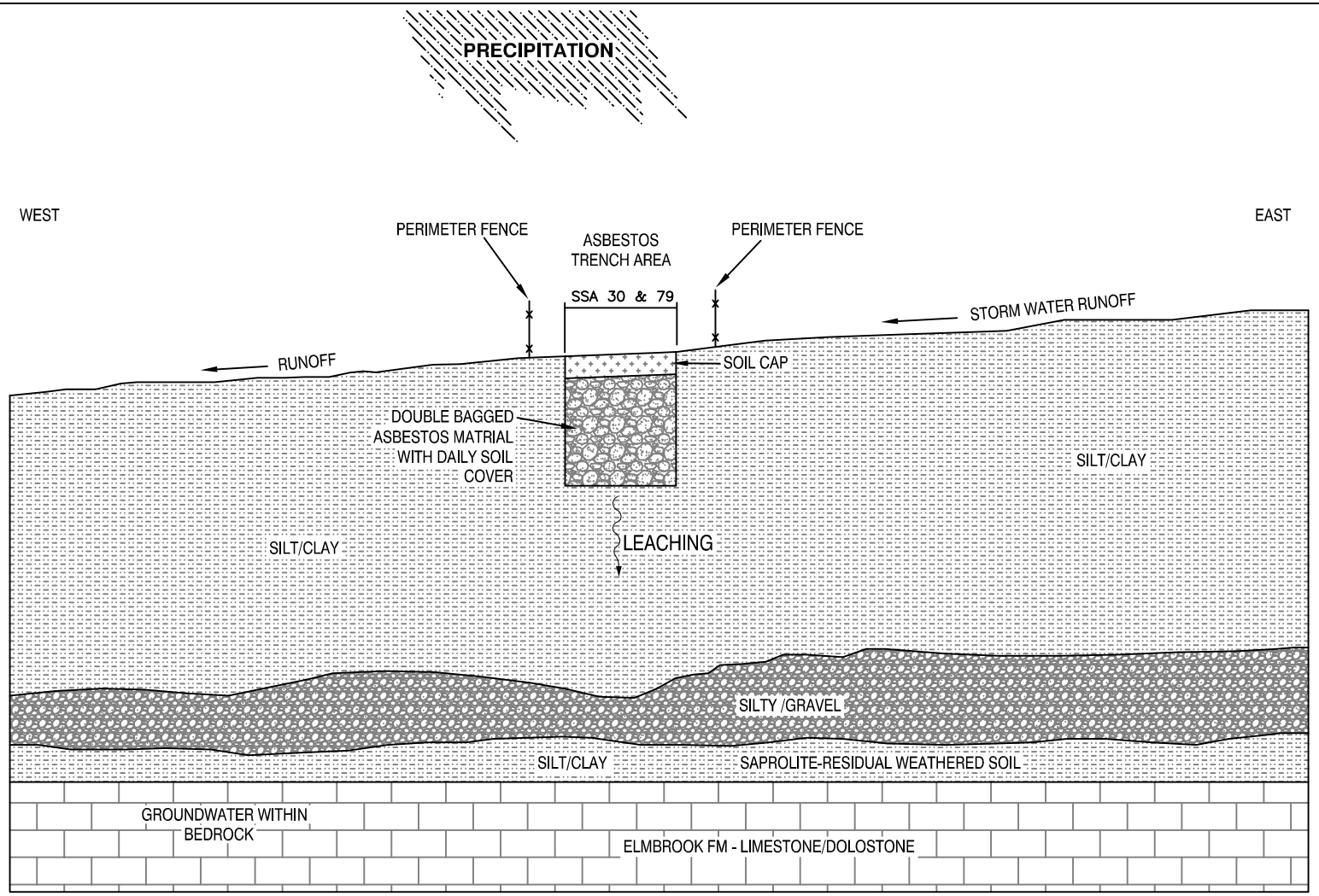
FIGURE 3-5

Previous Investigation -
SSA 30 and SSA 79

Date: March 2009	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 75 feet	File Name: Fig.3-5 Prev Invest

MWP Addendum 028 - SSP for
SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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



CONCEPTUAL DRAWING - NO SCALE IMPLIED

NO BEDROCK TOPOGRAPHY IMPLIED

FIGURE 3-6

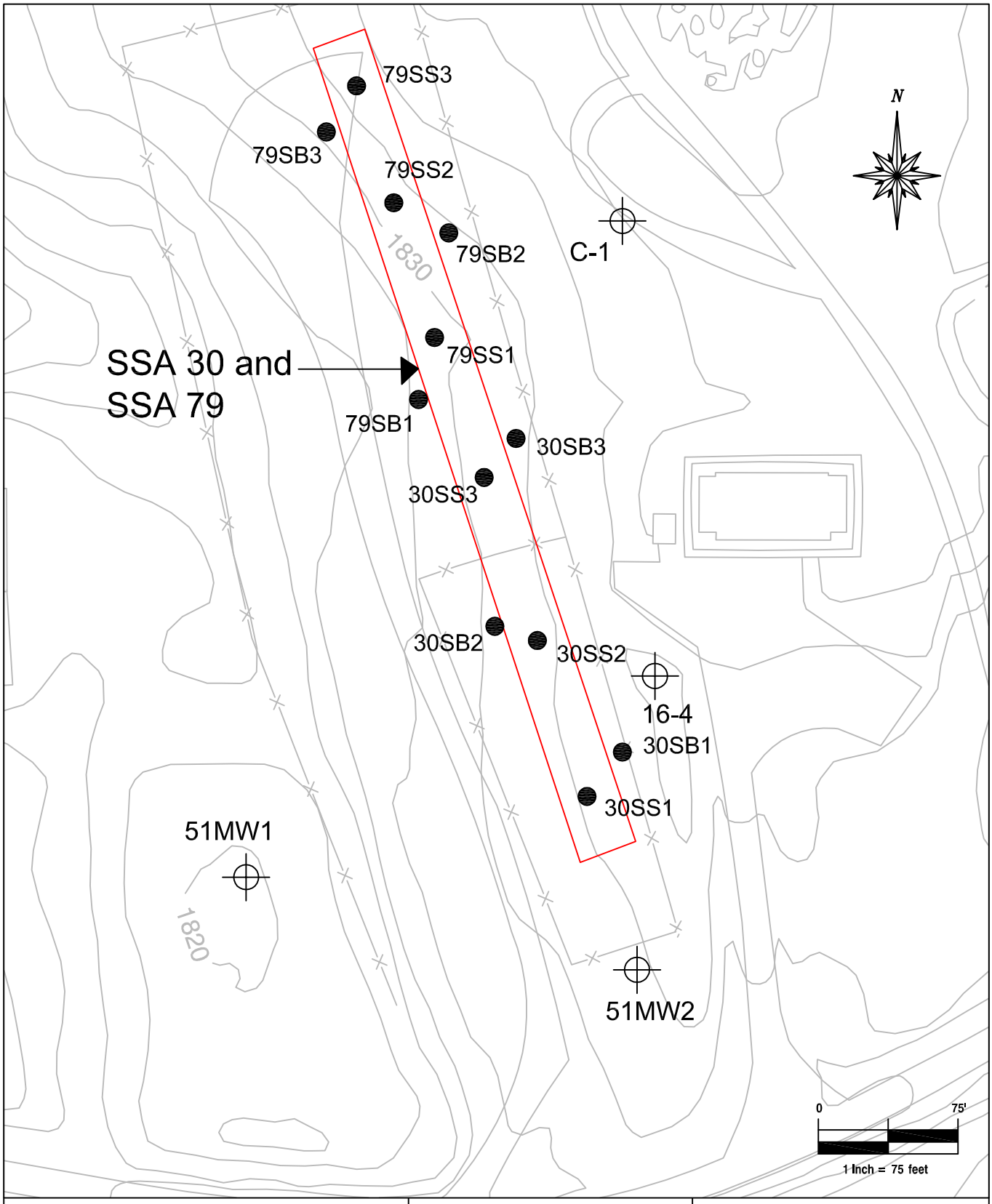
Conceptual Site Model - SSA 30 and SSA 79

Date: October 2008	URS Project #: 11657490
Prepared by: SS	Approved by: JOS
Scale: Not to Scale	File Name: Fig. 3-6

MWP Addendum 028 - SSP for SSAs 72, 30, 79, 60, and 77

Radford Army Ammunition Plant
Radford, Virginia

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



Legend

- Monitoring Well Location
- Approximate SSA Boundary
- Topographic Contour
- Fence
- Soil Boring Location

FIGURE 3-7

Proposed SSP Sample Locations
- SSA 30 and SSA 79

Date: October 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 75 feet	File Name: Fig.3-7 SSP Locs

MWP Addendum 028 - SSP for
SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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

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Table 3-1
Historical Groundwater Samples for SSA 30 and SSA 79 Area
Modified from Dames & Moore 1992 RFI Report for SWMUs 13, 17, 28, 51, and O
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Sample ID / Sample Date	CAS #	Adjusted Tap Water RBC	MCL	16-4 1/23/92 Result	51MW1 1/28/92 Result	51MW2 1/23/92 Result	C1 1/30/92 Result
VOCs (ug/L)							
1,1,1-Trichloroethane	71-55-6	910	200	<0.5	<0.5	<0.5	4.95
Carbon Disulfide	75-15-0	100	--	<0.5	<0.5	<0.5	1.13
Trichlorofluoromethane	75-69-4	130	--	6.51	<1.4	2.51	9.62
Explosives (ug/L)							
2,6-Dinitrotoluene	606-20-2	3.7	--	0.147	<0.074	0.126	<0.074
2,4/2,6 Dinitrotoluene Mixture	25321-14-6	0.099	--	0.147	<0.074	0.126	<0.074
Metals (ug/L)							
Barium	7440-39-3	730	2,000	113	9.72	11.5	42.7
Iron	7439-89-6	2,600	--	<38.8	41.4	<38.8	<38.8
Lead [(1)]	7439-92-1	15	--	1.41	<1.26	1.52	2.82
Manganese	7439-96-5	88	--	<2.75	3.58	<2.75	<2.75
SVOCs (ug/L)							
bis(2-ethylhexyl)phthalate	117-81-7	5	6	**8.55**	<4.8	<4.8	<4.8

Notes:

USEPA = U.S. Environmental Protection Agency

MCL = Maximum Contaminant Level

RBC = Risk-Based Concentration

USEPA Region III Risk-Based Concentration (RBC) values from the October 2008 Regional Screening Table

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

ug/L = Microgram Per Liter

TAL = Target Analyte List

VOC = Volatile Organic Compound

SVOC = Semi-Volatile Organic Compound

-- = No Risk Criteria Available

= Concentration Exceeds Adj. Tap Water RBC

bold = Concentration Exceeds MCL

[(1)] = Lead Action Level used

Table 3-2
Historical Groundwater Samples for SSA 30 and SSA 79 Area
Modified from Eastern Horseshoe 2006 Groundwater Data Summary Report (Shaw Environmental, Inc.)
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Sample ID				16-4				51MW1				51MW2			
Sample Date				4/10/06				4/11/06				4/10/06			
	CAS #	Adjusted Tap Water RBC	MCL	Result	LQ,VQ	MDL	RL	Result	LQ,VQ	MDL	RL	Result	LQ,VQ	MDL	RL
VOCs (ug/L)															
1,1,1-Trichloroethane	71-55-6	910	200	<1	U	0.5	1	<1	U	0.5	1	<1	U	0.5	1
1,1-Dichloroethane	75-34-3	2.4	--	<1	U	0.5	1	<1	U	0.5	1	<1	U	0.5	1
Chloroethane	75-00-3	2,100	--	<2	U	1	2	<2	U	1	2	<2	U	1	2
Methylene chloride	75-09-2	4.8	5	<5	U	1	5	<5	U	1	5	<5	U	1	5
Tetrachloroethene	127-18-4	0.11	5	<1	U	0.5	1	0.93	J, J	0.5	1	<1	U	0.5	1
Pesticides (ug/L)															
alpha-Chlordane [1]	5103-71-9	0.19	2	0.21		0.013	0.067	<0.066	U	0.013	0.066	<0.063	U	0.013	0.063
Heptachlor epoxide	1024-57-3	0.0074	0.2	0.015	J, J	0.013	0.067	<0.066	U	0.013	0.066	<0.063	U	0.013	0.063
Metals (ug/L)															
Aluminum	7429-90-5	3,700	--	236	, B	16	200	282	, B	16	200	100	J, B	16	200
Antimony	7440-36-0	1.5	6	3.2	J, B	2.2	5	3.6	J, B	2.2	5	<2.2	U	2.2	5
Barium	7440-39-3	730	2,000	149	J, J	0.5	200	45.3	J, J	0.5	200	40.8	J, J	0.5	200
Beryllium	7440-41-7	7.3	4	2	J, B	0.7	4	2	J, B	0.7	4	2.1	J, B	0.7	4
Chromium [2]	7440-47-3	5,500	100	0.74	J, J	0.5	10	0.59	J, J	0.5	10	1.3	J, J	0.5	10
Iron	7439-89-6	2,600	--	174	J, J	7.5	300	547		7.5	300	42.2	J, B	7.5	300
Lead [3]	7439-92-1	15	--	2	J, B	1.2	5	1.3	J, B	1.2	5	<1.2	U	1.2	5
Manganese	7439-96-5	88	--	5.1	J, J	0.2	15	60.6		0.2	15	1.8	J, B	0.2	15
Nickel	7440-02-0	73	--	<1.1	U	1.1	40	1.1	J, J	1.1	40	<1.1	U	1.1	40
Selenium	7782-49-2	18	50	<2.4	U	2.4	10	<2.4	U	2.4	10	<2.4	U	2.4	10
Vanadium	7440-62-2	26	--	0.7	J, B	0.6	50	<0.6	U	0.6	50	<0.6	U	0.6	50
Zinc	7440-66-6	1,100	--	0.91	J, J	0.8	20	3.4	J, J	0.8	20	2.1	J, J	0.8	20

Table 3-2
Historical Groundwater Samples for SSA 30 and SSA 79 Area
Modified from Eastern Horseshoe 2006 Groundwater Data Summary Report (Shaw Environmental, Inc.)
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Sample ID / Sample Date	CAS #	Adjusted Tap Water RBC	MCL	C1 4/12/06 Result	C1 4/12/06 LQ,VQ	MDL	RL
VOCs (ug/L)							
1,1,1-Trichloroethane	71-55-6	910	200	1.3	J	0.5	1
1,1-Dichloroethane	75-34-3	2.4	--	8.5		0.5	1
Chloroethane	75-00-3	2,100	--	4		1	2
Methylene chloride	75-09-2	4.8	5	8	, B	1	5
Tetrachloroethene	127-18-4	0.11	5	<1	U	0.5	1
Pesticides (ug/L)							
alpha-Chlordane (1)	5103-71-9	0.19	2	<0.063	U	0.013	0.063
Heptachlor epoxide	1024-57-3	0.0074	0.2	<0.063	U	0.013	0.063
Metals (ug/L)							
Aluminum	7429-90-5	3,700	--	57	J, B	16	200
Antimony	7440-36-0	1.5	6	2.6	J, B	2.2	5
Barium	7440-39-3	730	2,000	181	J, J	0.5	200
Beryllium	7440-41-7	7.3	4	1.9	J, B	0.7	4
Chromium (2)	7440-47-3	5,500	100	<0.5	U	0.5	10
Iron	7439-89-6	2,600	--	<7.5	U	7.5	300
Lead (3)	7439-92-1	15	--	<1.2	U	1.2	5
Manganese	7439-96-5	88	--	7.1	J, J	0.2	15
Nickel	7440-02-0	73	--	<1.1	U	1.1	40
Selenium	7782-49-2	18	50	2.8	J, J	2.4	10
Vanadium	7440-62-2	26	--	0.82	J, B	0.6	50
Zinc	7440-66-6	1,100	--	<0.8	U	0.8	20

Table 3-2
Historical Groundwater Samples for SSA 30 and SSA 79 Area
Modified from Eastern Horseshoe 2006 Groundwater Data Summary Report (Shaw Environmental, Inc.)
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Notes:

USEPA = U.S. Environmental Protection Agency
MCL = Maximum Contaminant Level
RBC = Risk-Based Concentration
USEPA Region III Risk-Based Concentration (RBC) values from the October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
ug/L = Microgram per Liter
TAL = Target Analyte List
VOC = Volatile Organic Compound
-- = No Risk Criteria Available

= Concentration Exceeds Adj. Tap Water RBC

bold = Concentration Exceeds MCL

(1) = Chlordane RBC used
(2) = Chromium III RBC used
(3) = Lead Action Level used

Laboratory Qualifiers:
U = Not detected.
A = J = The reported value is <MRL and >MDL and considered estimated.

Validation Qualifiers:
B = The analyte detected in the sample and the lab or field blank and considered non-detect.
J = Indicates an estimated value (1) due to QC non-conformance, or (2) concentration >MDL and <MRL. Reported value may not be accurate or precise.
L = Analyte present. Reported value may be biased low due to QC non-conformance.

4.0 SSA 60 RUBBLE PILE EAST OF ADMINSTRATION BUILDING (BUILDING 220)

4.1 SITE BACKGROUND AND ENVIRONMENTAL SETTING

4.1.1 Site Description and Topography

The rubble pile east of Administration Building 220 (SSA 60) is located in the southern portion of the MMA (Figure 1-1). SSA 60 is an approximate 1.5 acre fill area of demolition waste and construction waste material (Figure 4-1). Soil and gravel material were used to cover the fill material and level the area with an approximate 4% slope toward the west. The northern and eastern edges of fill material have steeper side slopes to the base of the fill area. Grass vegetation covers the fill area and side slopes. Maximum and minimum elevations of the site area are approximately 1,914 ft msl at the western edge of the site and 1,880 ft at the easternmost base of the fill area.

Structures at SSA 60 are limited to a meteorological tower constructed on the site in 1990 to monitor weather conditions and provide emergency response information. Aboveground power lines run along the western edge of the site adjacent to the main entry road to the plant area. In addition, a gravel area was added to the area to allow for access to the meteorological tower located at the site. Tanks and subsurface utilities are not located on or in the immediate vicinity of the site. Administrative Building 220 is located approximately 150 ft west of SSA 60 across the main entry road to the plant area. A site photographic log for SSA 60 is included in Appendix C.

4.2 SITE HISTORY

The rubble pile was created in 1985 to accept demolition waste (fill dirt and concrete slab materials) cleaned up from the remains of an explosion in the Nitroglycerin Area Number 1 and highway construction debris (fill dirt and blasted rock) from nearby Route 114 in the late 1980s. Soil and gravel were placed and compacted over the rubble pile and graded level with the intention of building a parking lot for Building 220 employees. The parking lot was not constructed. Fill activities ceased at the site in 1988. Pre 1985 topographic maps indicate that a narrow valley area between two ridges was filled at the site with fill depths likely greater than 20 ft in the center and eastern portions of the site area.

According the Virginia Solid Waste Management Regulations Title 9; VAC 20-80-60.D.7, the rubble pile site is conditionally exempt from the requirements of this chapter. The exemption states “landfilling of solid waste which includes only rocks, brick, block, dirt, broken concrete and road pavement, and which contain no paper, yard or wood wastes” is exempt from the regulation.

Figure 4-2 presents a 1990 aerial photograph of SSA 60 after fill activities had ceased and the meteorological tower had been constructed. A well defined drainage ditch is visible on the photograph extending from the easternmost base of fill area toward the east. A second drainage ditch appears to originate at the base of the fill area and merges with the main drainage channel less than 100 ft from the fill area. A later aerial photograph from 2002 shown on Figure 4-3 shows the same drainage features.

4.2.1 Surface Water

Surface water bodies, manholes, or catch basins are not located within SSA 60. Any surface water runoff that does not infiltrate into the subsurface at the site would flow toward the east across the site and down the steeper vegetated side slopes of the fill area. Runoff from the site that reaches the base of the fill slopes would potentially leave the site area via a drainage ditch that extends from the site down a valley approximately 600 ft before ending at an alluvial valley area that is enclosed on all sides by steep slopes and road embankments.

4.2.2 Soil

According to the *Soil Survey of Montgomery County, Virginia* (USDA 1985), the area of SSA 60 is underlain by Unison-Urban Land complex soil. This soil has moderate permeability and medium-to-strong acidity. Soil classification is not practical in urban land areas because the original soil has been physically altered or obscured. A typical profile of undisturbed Unison soil consists of a 15-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. In general, permeability is moderate in Unison soil, natural fertility is low, and organic matter content is low to moderate.

4.2.3 Geology

Subsurface investigations have not been previously conducted at the site. Bedrock of the Cambrian Age Elbrook Formation is mapped below SSA 60 (Bartholomew and Schultz 2000). Residual clayey soil from limestone/dolomite bedrock of Cambrian Age Elbrook Formation is expected to be present below fill material placed at the site. The Elbrook Formation in the site area is typically gray to dark gray, fine to medium grained limestone and dolomite, with laminar to medium beds for dolomite and medium beds for limestone. Outcrops of bedrock occur at higher elevations immediately south of the site.

4.2.4 Hydrogeology

Groundwater investigations have not been previously conducted at the site. Based on groundwater conditions investigated at similar areas of RFAAP, groundwater is expected to occur within fractures and voids of underlying bedrock. The depth to groundwater is expected to be greater than 75 ft below the fill material placed at SSA 60. The expected groundwater depth at SSA 60 of greater than 75 ft below the fill material is based on the assumption that potentiometric elevations in the upland area of the facility are similar for sites whose ground surface elevations are similar. SWMU 17 and SWMU 40 are located to the west of SSA 60 and have similar ground surface elevations to SSA 60 prior to filling (1,880 to 1,910 ft msl).

Select Groundwater Elevation Data – SWMU 17 and SWMU 40

Well ID	Location	Top of Casing at Measurement Point	Ground Surface Elevation (ft msl)	Depth to Groundwater (bgs)	Groundwater Elevation (12/10/07)
17MW2	SWMU 17	1905.88	1903.99	102.90	1801.09
17PZ1	SWMU 17	1906.90	1904.70	104.16	1800.54
40MW6	SWMU 40	1884.25	1882.61	98.68	1783.93

As shown in the above table, the depth to groundwater below the ground surface at SWMU 17 and SWMU 40 within relatively undisturbed areas is greater than 98 ft and therefore it has been conservatively assumed that the depth to groundwater below the fill material at SSA 60 is greater than 75 ft.

4.3 PREVIOUS INVESTIGATIONS

4.3.1 RCRA Facility Assessment – USEPA 1987

An assessment was conducted at SSA 60 (listed as Unit 60 in RFA) to evaluate potential hazardous waste or hazardous chemical releases and implement corrective actions, as necessary. The assessment consisted of a preliminary review and evaluation of available site information, personnel interviews, and a visual inspection of the site. Environmental samples were not collected at SSA 60 as part of the inspection. The RFA indicated that there were no documented releases from the unit.

4.4 CONCEPTUAL SITE MODEL (CSM)

A CSM for SSA 60 is presented on Figure 4-4. The site is located in the upland area outside the fenced area containing manufacturing operations at RFAAP. Rubble fill material consisting of demolition debris and highway construction debris has been placed within a former valley area to estimated maximum depths greater than 20 ft. Soil cover has been placed over the fill area to level the site. Grass covers the fill area and side slopes. Groundwater is expected to occur within fractures and voids of underlying bedrock at estimated depths greater than 75 ft below the fill material placed at SSA 60. A drainage ditch at the base of the fill area is expected to convey runoff from the site area during significant storm events. This drainage ditch leads to a valley area approximately 600 ft from the site that is surrounded on all sides by steep slopes associated with ridges and road embankments.

Fill material placed in rubble pile represents the potential constituent source at SSA 60. Material placed in the rubble pile reportedly consisted of demolition waste (fill dirt and concrete slab materials) from the remains of an explosion in the Nitroglycerin Area Number 1 and highway construction debris (fill direct and blast rock). The volume of material placed in the rubble pile is unknown. Potentially affected media at the site include:

- Surface and subsurface soil via placement of fill material;
- Surface soil/deposited material at the base of the fill area from stormwater runoff (erosion and mass transport) from the fill area;
- Sediment in the drainage ditch at base of fill area from stormwater runoff (erosion and mass transport) from the fill area;
- Subsurface soil via leaching of constituents from fill material place; and
- Groundwater via leaching of constituents released to subsurface soil.

Although current and likely future land-use scenarios are limited to industrial operations, both residential and industrial scenarios will be evaluated in the SSP human health screening (USEPA 2001).

SSA 60 is exclusively an upland habitat that lacks wetland or perennial surface water features. Therefore, soil represents the potential exposure medium for ecological receptors. 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*). Refer to Table 2-5 for wildlife receptor profiles.

4.5 DATA GAP ANALYSIS

Investigations have not been conducted to evaluate potential releases of hazardous constituents to environmental media. Related data gaps identified for the SSP investigation are discussed in the following sections.

4.5.1 Release Assessment to Surface Soil

An assessment of potential releases to surface soil has not been performed at SSA 60. This data gap will be filled by collecting surface soil samples from the fill area and at the base of the fill embankment where potential mass transport of material from the fill area would occur from stormwater runoff. Proposed field investigation activities are discussed in Section 4.6.1.

4.5.2 Release Assessment to Drainage Ditch

An assessment of potential releases to the drainage ditch located at the base of the fill area has not been performed at SSA 60. This data gap will be filled by collecting surface soil or sediment samples from the drainage ditch located at the base of the fill area. Proposed field investigation activities are discussed in Section 4.6.2.

4.5.3 Release Assessment to Subsurface Soil

An assessment of potential releases to subsurface soil has not been performed at SSA 60. This data gap will be filled by collecting subsurface soil samples below the fill material. Proposed field investigation activities are discussed in Section 4.6.3.

4.5.4 Groundwater

Given the lack of data at the site and anticipated significant depth to groundwater, potential releases to groundwater will be assessed by evaluating subsurface soil data and comparison of these data to USEPA soil-to-groundwater SSLs.

4.5.5 Other

Two representative samples of soil at the site (one surface sample and one subsurface sample) will be submitted for analysis of physical and geotechnical properties, as described in Section 4.6.4

4.5.6 Summary of Data Gaps

The data gap analysis completed for SSA 60 identified data gaps for evaluating potential releases to surface soil, subsurface soil, and the drainage ditch area from previous fill activities, and characterizing physical and geotechnical properties of site soil. The following table summarizes these identified data gaps and the completion plan to fill the data gaps.

SSA 60 - Summary of Data Gap Analysis and Completion Plan

DATA GAPS			COMPLETION PLAN
Item	**Physical**	**Chemical**	
Releases to Soil	Surface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect surface soil samples from fill area and at base of fill embankment
	Subsurface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect subsurface samples below fill material

DATA GAPS			COMPLETION PLAN
Item	**Physical**	**Chemical**	
Release to Drainage Ditch Soil/Sediment	Sediment	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Collect surface soil or sediment samples from drainage ditch area proximate to fill area
Releases to Groundwater	Subsurface Soil Samples	Use subsurface soil sample data	Compare subsurface soil data collected below fill material to soil-to-groundwater SSLs
Site-Wide Soil Characteristics	Physical / Geotechnical Properties	pH, total organic carbon, grain size, Atterberg Limits, and moisture content	Collect samples for geotechnical and physical property analysis.

4.6 PLANNED FIELD ACTIVITIES

The SSA 60 SSP field program is designed to address the data gaps identified in Section 4.5 and meet the SSP objectives identified in Section 1.1. The selection of the investigation areas and sample locations followed SOP 30.7 (Sampling Strategies, included in Appendix B) using biased sampling techniques to identify potential releases.

Sample analysis will be conducted consistent with the requirements of the MQAP and Section 6.0 of this WPA. Sample management and analytical methods are discussed in detail in Sections 6.4 and 6.5 of this WPA, respectively.

4.6.1 Surface Soil Sampling

Three surface soil samples, 60SS1, 60SS2, and 60SS3 will be collected from the fill area of SSA 60 to evaluate potential releases to surface soil and commingling of fill material with surface soil. Two additional surface soil samples, 60SS4 and 60SS5, will be collected at the base of the fill area embankment to evaluate potential overland mass transport of constituents from the fill area. Figure 4-5 shows the proposed sample locations. Surface soil samples will be collected from 0 to 0.5 ft bgs, with the exception of VOC samples, which will be collected from 0.5 to 1 ft bgs. Soil samples will be submitted for chemical analysis of the following parameters:

- TCL VOCs by SW-846 Method 8260B;
- TCL SVOCs by SW-846 Method 8270C (low level);
- TCL PCBs and TCL pesticides by SW-846 Methods 8082 and 8081A;
- Explosives by SW-846 Methods 8330 and 8332; and
- TAL inorganics by SW-846 Methods 6010/6020/7471A/9012A.

In addition, if evidence of burned material (i.e., ash) is apparent at one or more sample locations, then one soil sample from these locations will be submitted for analysis of TCL dioxin/furans by SW-846 Method 8290.

Surface soil samples will be collected following the procedures outlined in SOP 30.1 and 30.9 in Appendix B.

4.6.2 Drainage Ditch Sampling

Two soil/sediment samples, 60SE1 and 60SE2, will be collected from the drainage ditch located at the base of the fill area to evaluate potential mass transport of constituents from the fill area. Sediment samples will be collected from 0 to 0.5 ft bgs, with the exception of VOC samples, which will be collected from 0.5 to 1 ft bgs if sediment is present at a sufficient thickness. Figure 4-5 shows the proposed sample locations. Sediment samples will be submitted for chemical analysis of the same parameters as surface soil samples.

Sediment samples will be collected utilizing the hand auger method following the procedures outlined in SOP 30.4 and 30.9 in Appendix B.

4.6.3 Subsurface Soil Sampling

Two test pits, TP1 and TP2, will be excavated within the fill area to evaluate the nature and thickness of soil cover and fill material, and to collect subsurface soil samples below the fill material. Test pits will be performed at the locations shown on Figure 4-5 where the thickness of fill material is expected to be 10 ft or less. Test pits will be completed using a hydraulic track excavator consistent with the procedures outlined in SOP 20.4. The dimensions and depth of test pits will be dependent on the conditions encountered at each location. Test pit logs and photographic documentation will be completed for each location. Samples from the test pit will be screened for the presence of VOCs using a PID. Any excess soil and waste material excavated from the test pits will be placed into appropriate containers for offsite disposal as outlined as in Table 2-6. Completed test pits will be backfilled with clean fill material and compacted.

One subsurface soil sample ("B" sample) will be collected from each test pit location from soil present below the fill material. Soil samples will be submitted for chemical analysis of the same parameters as surface soil samples.

In the event that the test pits are unable to penetrate the fill material due to the nature of encountered fill material (rubble), two subsurface soil samples will be collected from alternative locations at the edge of the fill material at a depth interval immediately below the fill material.

4.6.4 Physical Soil Testing

Two representative soil samples (one surface and one subsurface) will be analyzed to characterize physical and geotechnical properties of site soil as outlined in Section 6.5.4:

- Grain-size analysis (ASTM D 422);
- Atterberg limits (ASTM D 4318);
- Soil moisture content (ASTM D 2216);
- Total organic carbon (Walkley-Black Method); and
- pH (ASTM D 4972).

Physical soil data will be used for qualitative soil screening evaluations as outlined in the USEPA SSP document (USEPA 2001) including calculation of site-specific soil screening levels for migration to groundwater, as required.

4.6.5 Surveying

Horizontal coordinates and ground surface elevations for soil samples and test pits will be obtained using a global positioning system (GPS) unit with submeter accuracy for horizontal measurements (+1 part per and million) and vertical measurements (+ 2 parts per million for vertical measurements).

4.6.6 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration (OSHA) and USEPA regulations regarding the identification, handling, and disposal of non-hazardous and hazardous IDM. Activities will be performed in accordance with the Installation safety rules, protocols, and SOP 70.1. Information on the expected nature (hazardous versus non-hazardous) of the materials that will be generated during the field investigations is summarized in Table 2-6.

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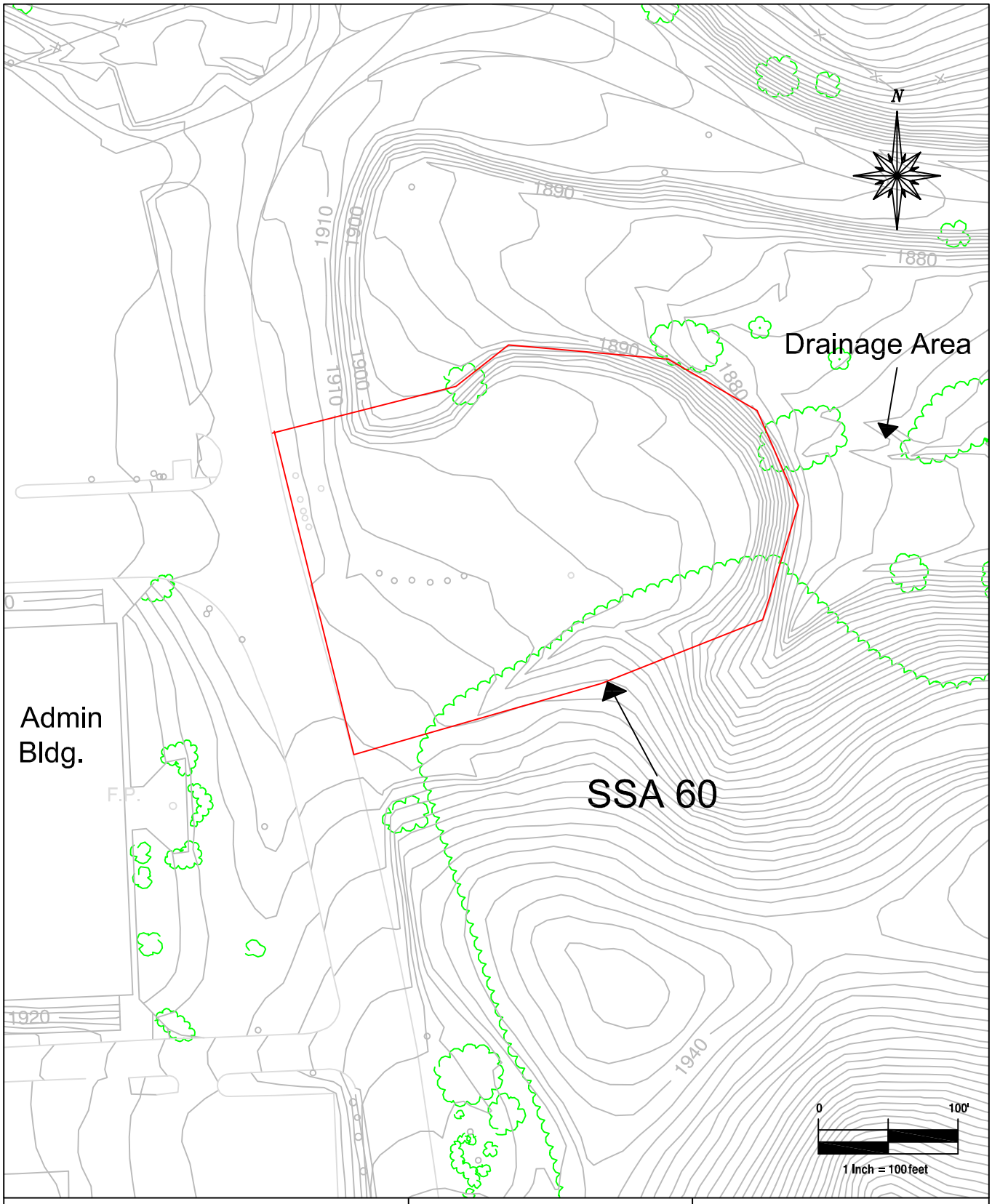

Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation

FIGURE 4-1

Site Layout - SSA 60

Date: October 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 100 feet	File Name: Fig.4-1 Site Layout

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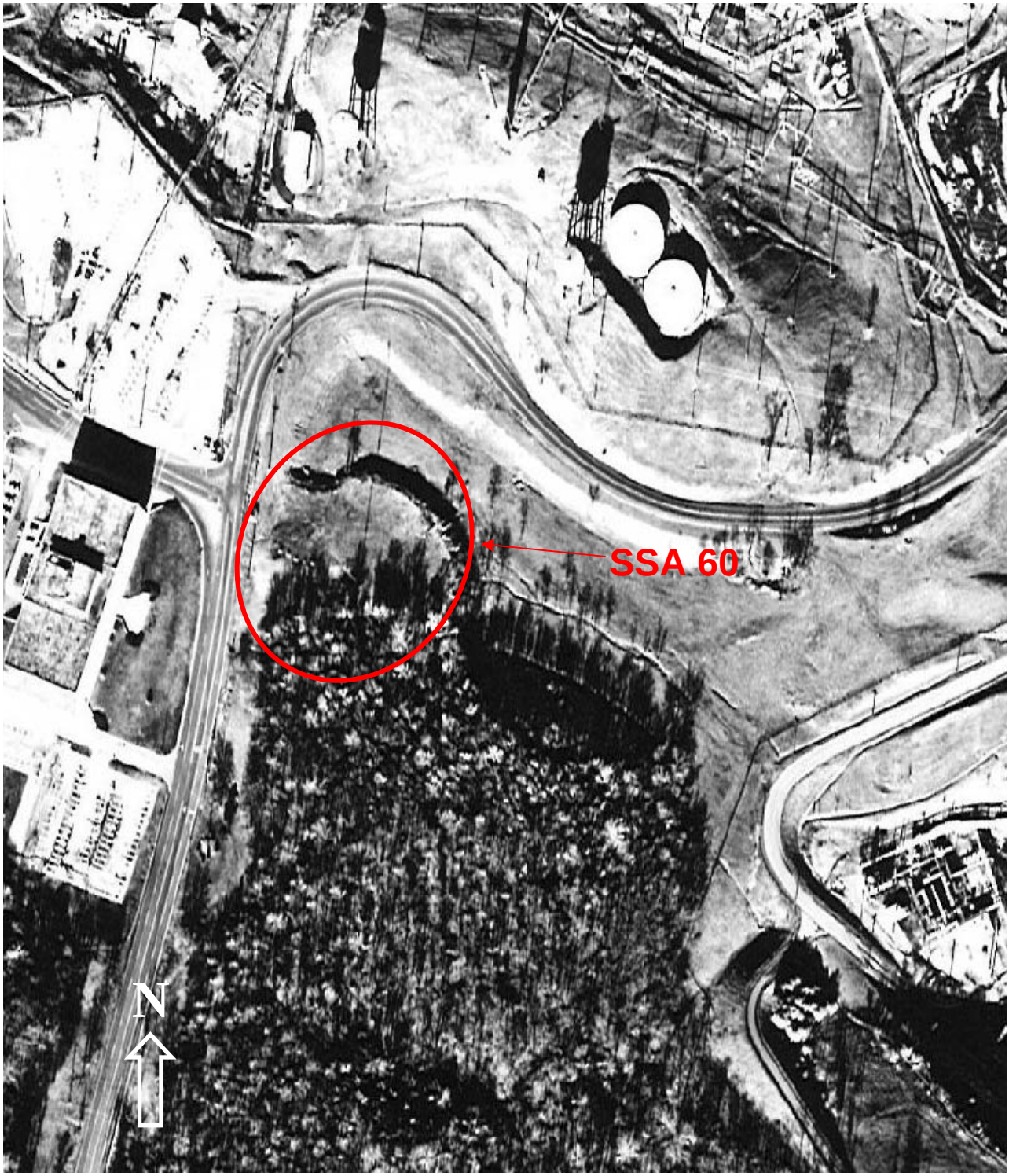

SSA 60 **AERIAL PHOTOGRAPH – 1990**	**FIGURE 4-2**
Date: *October 2008*	**Prepared by:** *HA/CLD*
Scale: *No Scale Implied*	**File Name:** *11657490*
	MWP Addendum 028 – **SSP for SSAs 18, 72, 30, 79, 60, and 77**

SSA 60 AERIAL PHOTOGRAPH – 2002		FIGURE 4-3
Date: *October 2008*	**Prepared by:** *HA/CLD*	**MWP Addendum 028 –** **SSP for SSAs 18, 72, 30, 79, 60, and 77**
Scale: *No Scale Implied*	**File Name:** *11657490*	

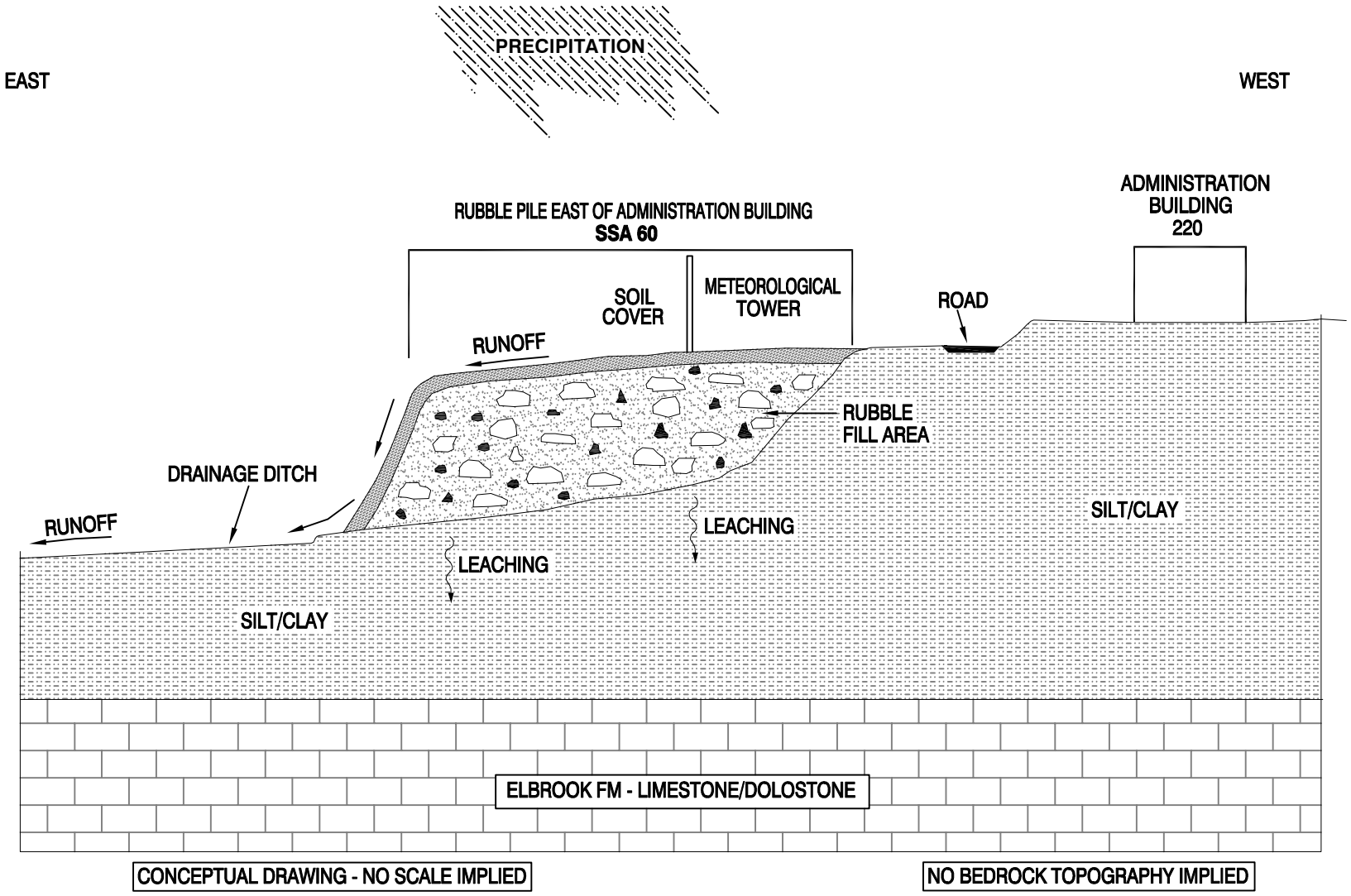

FIGURE 4-4

Conceptual Site Model - SSA 60

Date: October 2008	URS Project #: 11657490
Prepared by: SS	Approved by: JOS
Scale: Not to Scale	File Name: Fig. 4-4

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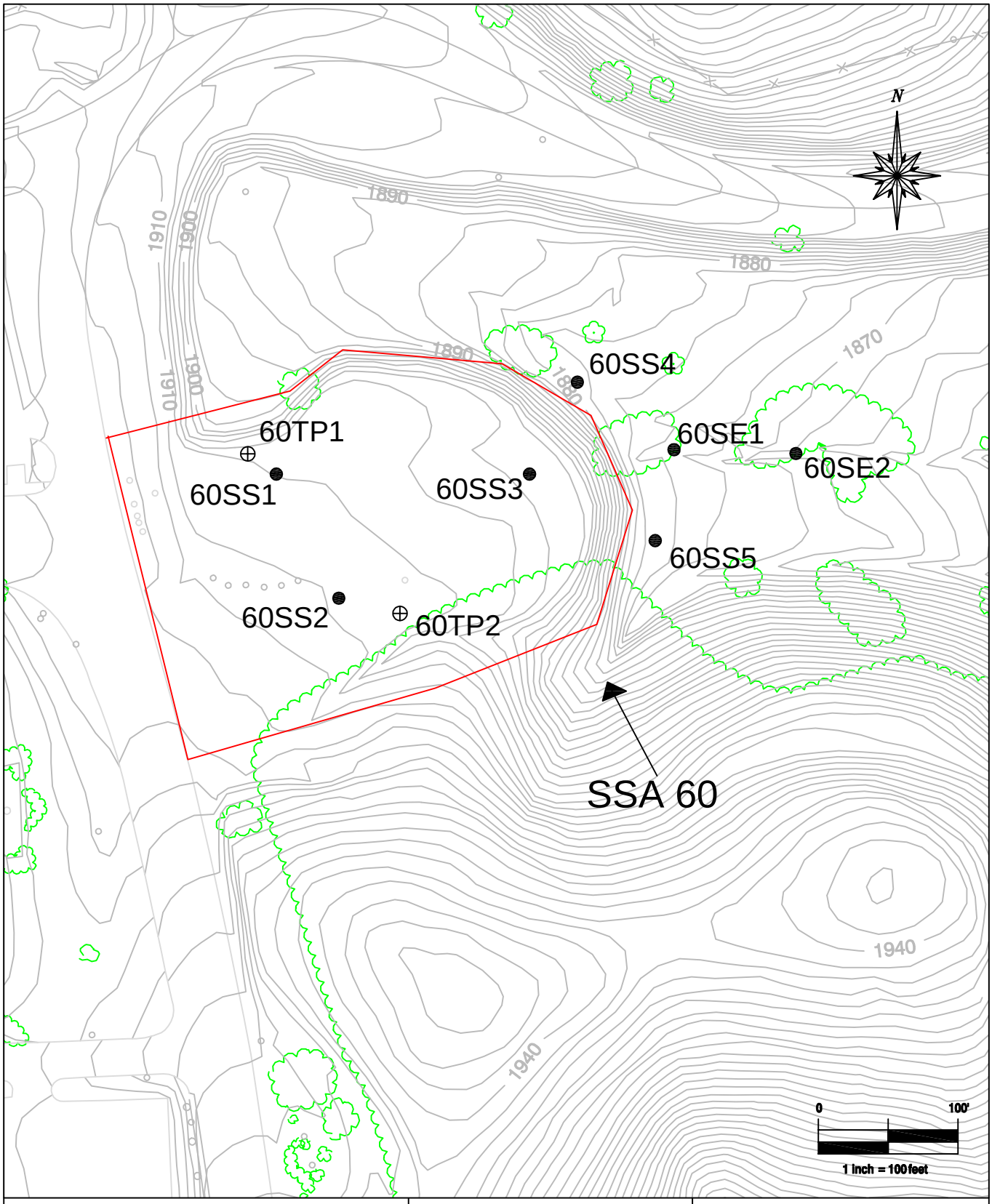

Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Soil Boring Location
- Test Pit Location

FIGURE 4-5

Proposed SSP Sample Locations - SSA 60

Date: October 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale:	File Name:

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5.0 SSA 77 GARBAGE INCINERATOR (BUILDING 7219)

5.1 SITE BACKGROUND

5.1.1 Site Description

The garbage incinerator (SSA 77) at Building 7219 is located in the southern part of the MMA at RFAAP (Figure 1-1). SSA 77 consists of a 29 ft by 25 ft concrete block/brick building with a 52 ft tall brick chimney formerly used to incinerate cardboard, paper products, wood, and other municipal waste materials. The building is located between the Shipping and Receiving Building 534 and Contaminated Scrap Burning Area (SWMU 17) in the southern portion of the MMA . Building 7219 is built into a hillside and has a basement and first floor (Figure 5-1). Paved asphalt roads encircle the building area. The first floor of the building is at grade with the asphalt road to the south of the building (approximately elevation 1,900 ft msl), while the basement is at grade with the asphalt road to the north of the building (approximate 1,890 ft msl). Grass covers the hillside area around Building 7219 between the asphalt pavement areas. A site photographic log for SSA 77 is included in Appendix C.

Equipment formerly contained in the building has been removed. A significant portion of the building roof has collapsed into the first floor of the building. Subsurface piping in the building area includes a sewer pipe extending from the southwest corner building to a partially aboveground, concrete septic tank approximately 30 ft north of the building. This pipe received water from a bathroom area and floor drains located on the charging floor (first floor). According to building plans, the sewer pipe is 4-inch diameter cast iron until it reaches the asphalt road area where the pipe is 6-inch diameter terracotta. This plan does not show a drainage field associated with the septic tank, contrasted with a drain field shown for a septic tank located west of the Shipping and Receiving Building.

Other subsurface utilities located in the site area include a 6-inch water line, which runs across the asphalt area approximately 30 ft south of Building 7219.

5.1.2 Site History

The garbage incinerator operated at the location of Building 7219 from the 1940s until 1974, when it was shutdown, rendered inactive, and equipment was removed. Building 7219 was reconstructed and improved in 1953. The basement floor of the building was the “firing floor” and contained the incinerator furnace and a bathroom area. The incinerator furnace was connected to the chimney by fire brick lined breeching. The first floor of the building was the “charging floor” where garbage was brought into the building for charging into the incinerator furnace via a charging throat. A heat recovery system was installed in the building and included water heater pipe coils at the incinerator furnace, hot water pipe, hot-water storage tank, and heat stove. The concrete floor of the first floor was sloped toward two six-inch diameter floor drains that were connected by 4-inch diameter cast iron pipes to the buildings sanitary line, which lead to a septic tank north of the building. A double sink area on the second floor also was connected to the sanitary system.

After incineration operations ceased in 1974, Building 7219 was then used to store rat bait and bee spray pesticides; however, these materials were removed in 1987 when the building’s roof began leaking. Building 7219 is currently inactive with no plans to reactivate.

Figures 5-2, 5-3, 5-4, and 5-5 are aerial photographs from 1949, 1962, 1971, and 1986 that show Building 7219 area. A small white rectangular object is visible in these photographs to the north of the building is likely a concrete vault associated with the building septic system.

5.1.3 Surface Water

Surface water bodies, manholes, or catch basins are not located in the immediate site area. Stormwater runoff would be expected to follow topography and flow across pavement surfaces and grass vegetated areas toward the north and SWMU 17.

5.1.4 Soil

According to the *Soil Survey of Montgomery County, Virginia* (USDA 1985), the area of SSA 77 is underlain by Unison-Urban Land complex soil. This soil has moderate permeability and medium-to-strong acidity. Soil classification is not practical in urban land areas because the original soil has been physically altered or obscured. A typical profile of undisturbed Unison soil consists of a 15-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. In general, permeability is moderate in Unison soil, natural fertility is low, and organic matter content is low to moderate.

5.1.5 Geology

Geologic and subsurface conditions have been assessed as part of investigations conducted in the SWMU 17 area immediately north and northeast of the site, which includes the Former Lead Furnace Area (FLFA). Deep borings were completed into bedrock at locations 150 ft east (wells 17PZ1 and 17MW2) and 85 ft north (well LFMW01) of the site (Figure 5-6). Numerous soil borings also were completed in the SWMU 17A/FLFA area. Gray brown argillaceous limestone of the Elbrook Formation underlies the site area. Depth to bedrock is expected to be less than 10 ft in the immediate area of SSA 77 given its ridge top location and shallow bedrock depth encountered in borings 17PZ1 and 17MW2. Residual soil weathered from bedrock is typically silt and clay (ML/CL). Sinkhole areas are located north site and bedrock in the site area has karst characteristics with clay filled weathered zones and voids.

Appendix D.3 includes several geologic cross-sections included in the Shaw Draft FLFA RFI/CMS Report (Shaw 2008a) illustrating subsurface conditions in the site area and boring logs for monitoring wells 17PZ1, 17MW2, and LFMW01.

5.1.6 Hydrogeology

A dye trace study conducted by Engineering Science, Inc. in 1994 at SWMU 17 identified a specific flow path connecting the SWMU 17A sinkhole to a spring in the New River (Appendix D.3). Dye placed in the injection point (INJ1) within this sinkhole traveled 4,800 ft to the spring in less than 24 hours. Groundwater in the site area occurs within bedrock in fractures and water saturated karst features. Recent static water levels measurements from wells in the site area have been in the range of 1,800 to 1,810 ft msl or approximately 90 to 100 ft below the elevation of the Building 7219 area. Groundwater flow toward the west-northwest was indicated by the Shaw groundwater measurements obtained for the FLFA RFI/CMS, which was the same direction as the preferential flow path identified by the dye trace study (Shaw 2008a). Appendix D.3 includes a groundwater flow map from the Draft Shaw FLFA RFI/CMS Report.

5.2 PREVIOUS INVESTIGATIONS

Environmental sampling specific to SSA 77 has not been conducted. Several investigations have been conducted at SWMU 17A and FLFA located immediately north of the site.

5.2.1 RCRA Facility Assessment – USEPA 1987

An assessment was conducted at SSA 77 (listed as Unit 77 in RFA) to evaluate potential hazardous waste or hazardous chemical releases and implement corrective actions, as necessary. The assessment consisted of a preliminary review and evaluation of available site information, personnel interviews, and

a visual inspection of the site. Environmental samples were not collected at SSA 77 as part of the inspection. The RFA did not identify any release history for the site.

5.2.2 Installation Assessment – USEPA 1992

EPIC under the direction of USEPA, performed an assessment of multiple SWMUs at RFAAP using selected aerial photographs from 1937 to 1986 (USEPA 1992). The photogeologic analysis was performed to locate waste management areas, identify the location of sinkholes that existed prior to the construction of the RFAAP, and map fracture traces. A specific assessment was not conducted for SSA 77; however, an assessment was conducted for adjacent SWMU 17 (burning areas). The aerial photographic analysis of SWMU 17 indicated that activity was noted from 1949 through 1986. Mounded material, containers, and possible stains were noted within the SWMU 17 area.

5.2.3 RCRA Facility Investigation - Dames & Moore 1992

The RFI conducted by Dames & Moore at SWMU 17 in 1992 included the installation of piezometer 17PZ1 approximately 150 ft east of Building 7219. Initially this piezometer was dry after installation. Later static water levels were approximately 90 ft bgs. Groundwater samples were not collected from this piezometer for this investigation.

5.2.4 RCRA Facility Investigation – Parsons Engineering Science 1996

As part of an RFI conducted at SWMU 17, Parsons collected groundwater samples from monitoring wells 17MW2 and 17PZ1 located approximately 150 ft east of Building 7219 for analysis of explosives, total metals, dissolved metals, TOC, and TOX. Explosives were not detected in these samples. Dissolved metals that were detected in the samples included barium and lead. The concentration of dissolved beryllium detected in 17MW2 (4.26 µg/L) and 17PZ1 (4.28 µg/L) were above the MCL of 4 µg/L. Dissolved barium was detected in sample 17MW2 (63.2 µg/L) and 17PZ1 (110 µg/L) at concentrations that were below the current adjusted T-RBC.

5.2.5 RCRA Facility Investigation/Corrective Measures Study (Draft) – Shaw 2008

This report presented the results of five previous investigations conducted at the FLFA by Shaw and others and included additional sampling of soil and groundwater in 2007 to complete the RFI/CMS Report. For purposes of the RFI/CMS and remedial actions, the FLFA has been defined as an approximate 0.78 acre area within the SWMU 17A Stage and Burn Area. The limits of this area extend to the northern edge of the asphalt road across from Building 7219. A small portion of the study area for the Building 7219 SSP, which includes several feet of below ground, terracotta sewer pipe and a septic tank, is located within the FLFA defined area.

Shaw conducted extensive sampling across the FLFA area to delineate the extent of lead, PCBs, dioxins, and other chemicals in soil. Lead was identified as the primary chemical of concern (COC) at the site driving corrective measures for soil under future industrial and residential scenarios. Dioxin/furans were identified as a secondary COC. The southwestern edge of the proposed residential remedial goal excavation area extends near the edge of the Building 7219 study area associated with the terracotta sewer pipe and septic tank. The recommended alternative for soil consists of soil excavation and offsite disposal with concentrations above residential remedial goals established for lead, dioxins, PCBs, arsenic, and copper. The FLFA surface soil data near the terracotta sewer pipe and septic tank indicated lead concentrations in surface soil below the residential action level of 400 mg/kg. One surface soil sample LSS04 collected along the asphalt road near the terracotta sewer pipe had dioxin concentrations above the residential and industrial RBC but lead concentrations below 400 mg/kg. Subsurface soil data was not collected in the areas near the Building 7219 study area. Appendix D.3 includes several figures showing sample results, the identified excavation areas for industrial and residential remedial goals. A table including the sample result from LSS04 is also included in this appendix.

In 2007, groundwater samples were collected from wells 17MW2, 17PZ1, and LMW01 located near Building 7219 as part of the RFI/CMS conducted at FLFA. Samples were analyzed for TCL organics, PAHs, explosives, herbicides, TAL metals, and perchlorate. Detected analyte results are summarized in Table 5-1 and included chloroform, tetrachloroethene, perchlorate, total metals, and dioxins. Chloroform, tetrachloroethene, perchlorate, and dioxins were detected at concentrations above their adjusted T-RBCs in one or more samples but below applicable MCLs (Table 5-1). Total aluminum and total iron also were detected in sample LMW01 collected from the sinkhole at SWMU 17 at concentrations above their adjusted T-RBCs; the higher concentrations were attributed in the RFI/CMS to elevated turbidity levels (greater than 900 units) in the sample.

5.3 CONCEPTUAL SITE MODEL (CSM)

A CSM for SSA 77 is presented on Figure 5-7. Building 7219 is located on a hillside overlooking the sinkhole at SWMU 17A. Depth to bedrock is expected to be less than 10 ft at the site with residual silt and clay soil overlying limestone bedrock. Groundwater is present within limestone bedrock at estimated depths of 90 to 100 ft bgs at the site.

Potential release sources would be related to historical garbage handling activities within and around the building area, potential releases from the sewer pipe and septic tank receiving wastewater from building floor drains, and waste by products associated with incineration including bottom ash, emission of flue gases and particulate matter. Post incinerator related constituent sources potentially would be related to storage of pesticides and rat bait in the building.

Potentially affected media at the site include:

- Surface soil from waste management activities in and around the building area and potential deposition of particulate matter from the incinerator chimney;
- Subsurface soil via leaching of any constituents released to surface soil;
- Subsurface soil from potential leaks in the wastewater sewer pipe (terracotta pipe) leading from the building to the septic tank;
- Subsurface soil from potential leaks from the septic tank or drain field area if present; and
- Groundwater via leaching of constituents released to subsurface soil.

Although current and likely future land-use scenarios are limited to industrial operations, both residential and industrial scenarios will be evaluated in the SSP human health screening (USEPA 2001).

The SSA 77 site area is exclusively an upland habitat that lack wetland and significant drainage features. Therefore, soil represents the potential exposure medium for ecological receptors. 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*). Refer to Table 2-5 for wildlife receptor profiles.

5.4 DATA GAP ANALYSIS

Investigations have not been conducted to evaluate potential releases of hazardous constituents to environmental media. Related data gaps identified for the SSP investigation are discussed in the following sections.

5.4.1 Release Assessment to Surface Soil

An assessment of potential releases to surface soil has not been performed at SSA 77. This data gap will be filled by collecting surface soil samples from around the building area. Proposed field investigation activities are discussed in Section 5.5.1

5.4.2 Release Assessment to Subsurface Soil

An assessment of potential releases to subsurface soil has not been performed at SSA 77. This data gap will be filled by collecting subsurface soil samples around the building area, adjacent to the sewer pipe, and adjacent to the septic tank. Proposed field investigation activities are discussed in Sections 5.5.2 and 5.5.3.

5.4.3 Groundwater

Potential releases to groundwater will be assessed by evaluating subsurface soil data and comparison of these data to USEPA soil-to-groundwater SSLs. Existing groundwater data for monitoring wells located in close proximity to the site (FLFA and SWMU 17 area) also will be used for the release evaluation.

5.4.4 Other

Two representative samples of soil at the site (one surface sample and one subsurface sample) will be submitted for analysis of physical and geotechnical properties, as described in Section 5.5.3.

5.4.5 Summary of Data Gaps

The data gap analysis completed for SSA 77 identified data gaps for evaluating potential releases to surface soil and subsurface soil from previous site activities, and characterizing physical and geotechnical properties of site soil. The following table summarizes these identified data gaps and the completion plan to fill the data gaps.

SSA 77 - Summary of Data Gap Analysis and Completion Plan

DATA GAPS			COMPLETION PLAN
Item	**Physical**	**Chemical**	
Releases to Soil	Surface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, TAL (including mercury and cyanide)and dioxin/furans	Collect surface soil samples around building area
	Subsurface Soil Samples	Chemical Data – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, and TAL inorganics (including mercury and cyanide)	Complete borings and collect subsurface samples around building area and adjacent to the sewer and septic tank
Releases to Groundwater	Subsurface Soil Samples	Use subsurface soil sample data	Compare subsurface soil data to soil-to-groundwater SSLs and evaluate existing groundwater data from the FLFA and SWMU 17 area
Site-Wide Soil Characteristics	Physical / Geotechnical Properties	pH, total organic carbon, grain size, Atterberg Limits, and moisture content	Collect samples for geotechnical and physical property analysis.

5.5 PLANNED FIELD ACTIVITIES

The SSA 77 SSP field program is designed to address the data gaps identified in Section 5.4 and meet the SSP objectives identified in Section 1.1. The selection of the investigation areas and sample locations followed SOP 30.7 (Sampling Strategies, included in Appendix B) using biased techniques to identify potential releases.

Sample analysis will be conducted consistent with the requirements of the MQAP and Section 6.0 of this WPA. Sample management and analytical methods are discussed in detail in Sections 6.4 and 6.5 of this WPA, respectively.

5.5.1 Soil Sampling in Building 7219 Area

Three direct push soil borings, 77SB1, 77SB2, and 77SB3, will be completed around the area of Building 7219 to evaluate for potential releases to surface and subsurface soil (Figure 5-8). Boring 77SB1 will be completed adjacent to western building entrance where waste material was brought into the building. Boring 77SB2 will be completed adjacent to the chimney area and northwest corner of the building where incinerator was located and sewer line runs adjacent to the building. Boring 77SB3 will be completed near the northeast corner of the building near the entrance to the basement firing floor.

Surface soil samples 77SB1A, 77SB2A, and 77SB3A will be collected from each of the borings at a depth of 0 to 0.5 ft bgs, with the exception of VOC samples, which will be collected from 0.5 to 1 ft bgs. Subsurface soil samples 77SB1B, 77SB2B, and 77SB3B will be collected from each of the borings at a depth interval of 4 to 6 ft bgs. Each of the soil samples will be submitted for chemical analysis of the following parameters:

- TCL VOCs by SW-846 Method 8260B;
- TCL SVOCs by SW-846 Method 8270C (low level);
- TCL PCBs and TCL pesticides by SW-846 Methods 8082 and 8081A;
- Explosives by SW-846 Methods 8330 and 8332; and
- TAL inorganics by SW-846 Methods 6010/6020/7471A/9012A.

Proposed dioxin sampling will focus on surface soil at the site due to the likely release mechanisms related to any surface spills of materials removed from the chimney cleanout and deposition of particulates from the chimney. Dioxin analysis is proposed at surface sample location 77SB2A adjacent to the chimney to evaluate potential releases from removal of residual material from the chimney cleanout and deposition of particulate matter from the chimney. Dioxin analysis is also proposed at surface sample location at 77SB3A located east/southeast of the chimney at the edge of the site area to evaluate releases due to deposition of particulate matter in the prevailing wind direction (westerly/northwesterly). These soil sample locations are considered the most appropriate locations to measure for potential releases of dioxins to surface soil at the site. Subsurface soil sampling for dioxins is not proposed due to the prevalent surface release mechanisms at the site.

Subsurface soil samples 77SB1B, 77SB2B, and 77SB3B are proposed to fill the identified data gap for evaluating releases to subsurface soil. A depth of 4 to 6 ft bgs was selected to provide a uniform release assessment to subsurface soil in the area of the incinerator building and chimney. Sample 77SB1B will assess potential releases from previous waste handling activities adjacent to the western building entrance. Sample 77SB2B will be collected below the depth of the sewer pipe and will assess potential subsurface releases from the sewer pipe and in the area where chimney cleanout occurred. Sample 77SB3B will assess potential releases near the northeast corner of the building near the entrance to the basement firing floor.

A four-foot, Geoprobe Macro-Core® sampling device will be used to collect soil samples continuously from each of the borings, as described in SOP 30.1, SOP 20.11, and SOP 30.9 in Appendix B. Soil core samples will be screened with a PID for the presence of VOCs. Borings logs will be prepared as outlined in SOP 10.3 in Appendix B.

5.5.2 Septic Tank Area

Three direct push borings, 77SB4, 77SB5, and 77SB6, will be completed in the septic tank area at the locations shown on Figure 5-8. Boring 77SB4 will be completed near the area where the terracotta pipe enters the tank. Borings 77SB5 and 77SB6 will be completed at distances 20 ft east and west of the concrete vault to evaluate for the presence of a drain field. Each boring will be completed to a maximum depth of 10 ft. Continuous soil cores will be collected, visually inspected, and screened with a PID for evidence of potential effects to the site. One subsurface soil sample will be collected from the boring and interval where visual identification of potential effects related to septic use is apparent (i.e., black staining, drain field trenches, odor, etc.). If visual identification of potential effects related to septic tank use or evidence of a drain field are not present, then the sample for chemical analysis will be collected from the boring completed adjacent to the septic tank at depth of 6 to 8 ft bgs, which is below the probable depth of the partially buried septic tank.

A four-foot, Geoprobe Macro-Core® sampling device will be used to collect soil samples continuously from each of the borings, as described in SOP 30.1, SOP 20.11, and SOP 30.9 in Appendix B. Soil core samples will be screened with a PID for the presence of VOCs. Borings logs will be prepared as outlined in SOP 10.3 in Appendix B.

5.5.3 Physical Soil Testing

Two representative soil samples (one surface and one subsurface) will be analyzed to characterize physical and geotechnical properties of site soil as outlined in Section 6.5.4:

- Grain-size analysis (ASTM D 422);
- Atterberg limits (ASTM D 4318);
- Soil moisture content (ASTM D 2216);
- Total organic carbon (Walkley-Black Method); and
- pH (ASTM D 4972).

Physical soil data will be used for qualitative soil screening evaluations as outlined in the USEPA SSP document (USEPA 2001) including calculation of site-specific soil screening levels for migration to groundwater, as required.

5.5.4 Surveying

Horizontal coordinates and ground surface elevations of soil borings and soil samples will be obtained using a global positioning system (GPS) unit with submeter accuracy for horizontal measurements (+1 part per and million) and vertical measurements (+ 2 parts per million for vertical measurements).

5.5.5 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration (OSHA) and USEPA regulations regarding the identification, handling, and disposal of non-hazardous and hazardous IDM. Activities will be performed in accordance with the Installation safety rules, protocols, and SOP 70.1. Information on the expected nature (hazardous versus non-hazardous) of the materials that will be generated during the field investigations is summarized in Table 2-6.

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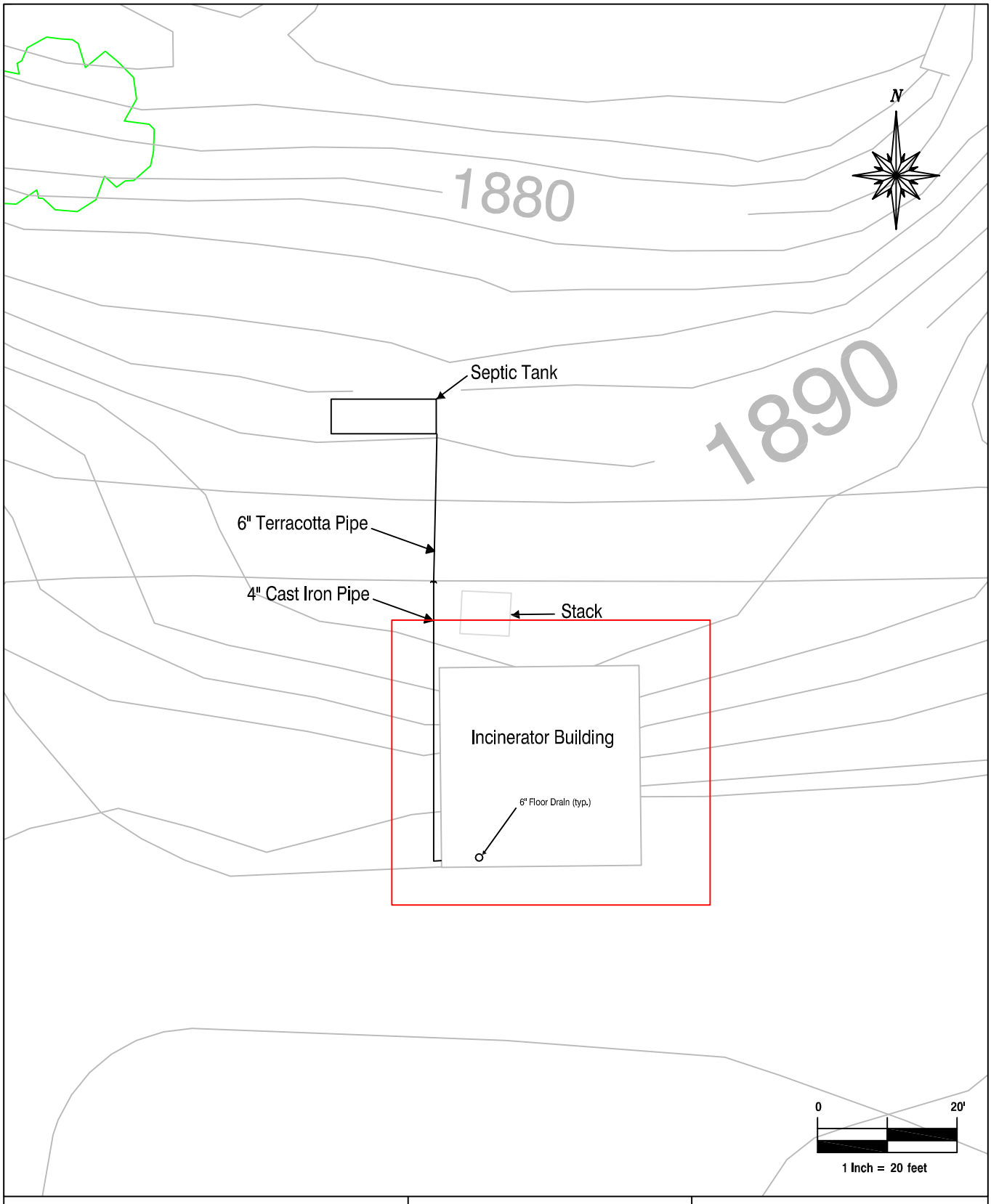

Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation
- Fence
- Aboveground Piping

FIGURE 5-1

Site Layout - SSA 77

Date: April 2008	URS Project #: 11656421
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 20 feet	File Name: Fig.5-1 SiteLayout

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SSA 77 AERIAL PHOTOGRAPH – 1949		FIGURE 5-2
Date: *October 2008*	**Prepared by:** *HA/CLD*	**MWP Addendum 028 –** **SSP for SSAs 18, 72, 30, 79, 60, and 77**
Scale: *No Scale Implied*	**File Name:** *11657490*	

SSA 77 AERIAL PHOTOGRAPH – 1962		FIGURE 5-3
Date: *October 2008*	**Prepared by:** *HA/CLD*	**MWP Addendum 028 –** **SSP for SSAs 18, 72, 30, 79, 60, and 77**
Scale: *No Scale Implied*	**File Name:** *11657490*	

SSA 77
AERIAL PHOTOGRAPH – 1971

FIGURE 5-4

Date: *October 2008*

Prepared by: *HA/CLD*

Scale: *No Scale Implied*

File Name: *11657490*

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77

SSA 77
AERIAL PHOTOGRAPH – 1986

FIGURE 5-5

Date: *October 2008*

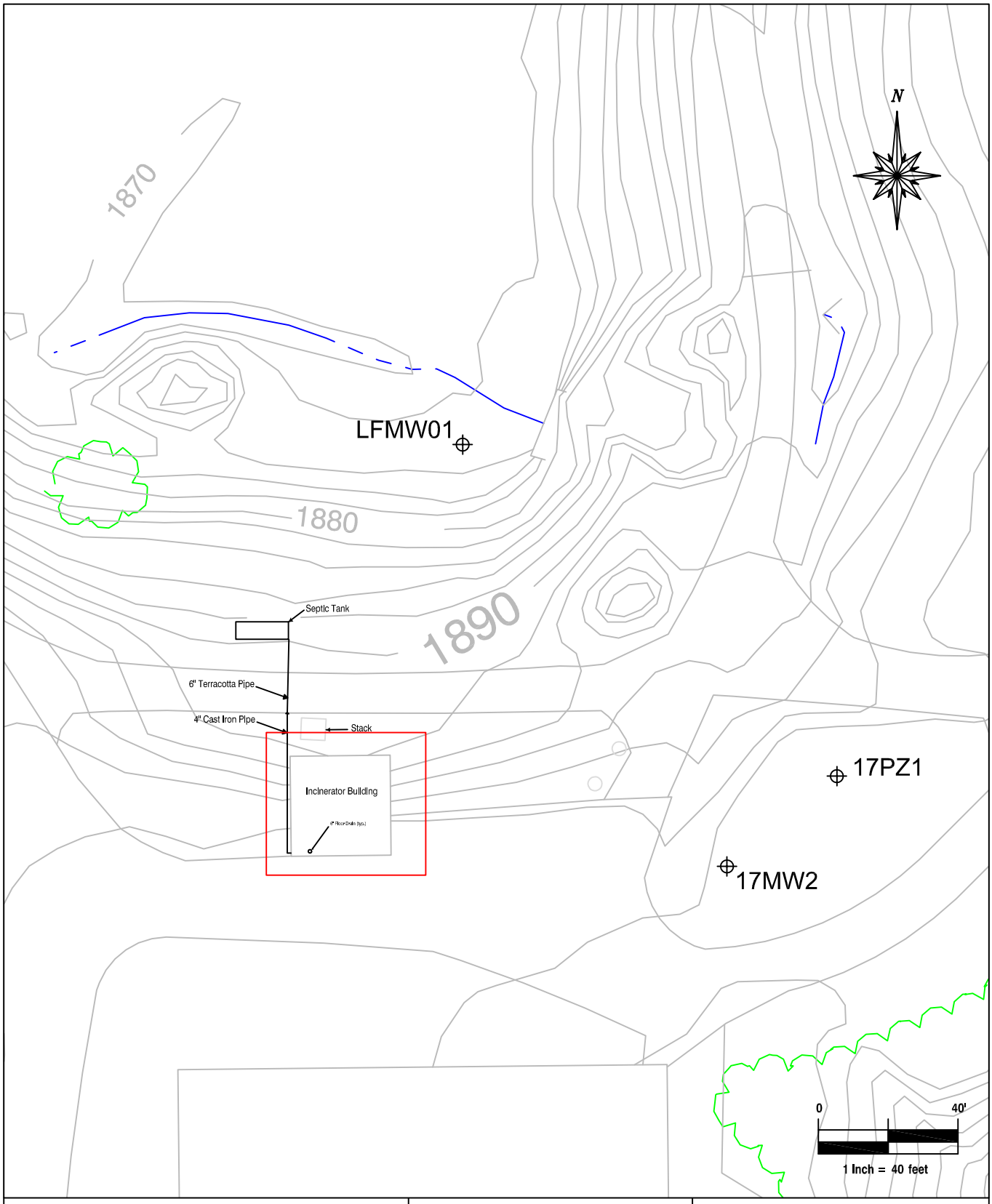
Prepared by: *HA/CLD*

Scale: *No Scale Implied*

File Name: *11657490*

MWP Addendum 028 –

SSP for SSAs 18, 72, 30, 79, 60, and 77



Legend

- Approximate SSA Boundary
- Topographic Contour
- Vegetation

FIGURE 5-6

Previous Investigation - SSA 77

Date: October 2008	URS Project #: 11656421
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 40 feet	File Name: Fig.5-6 Prev Invest

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant
Radford, Virginia

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

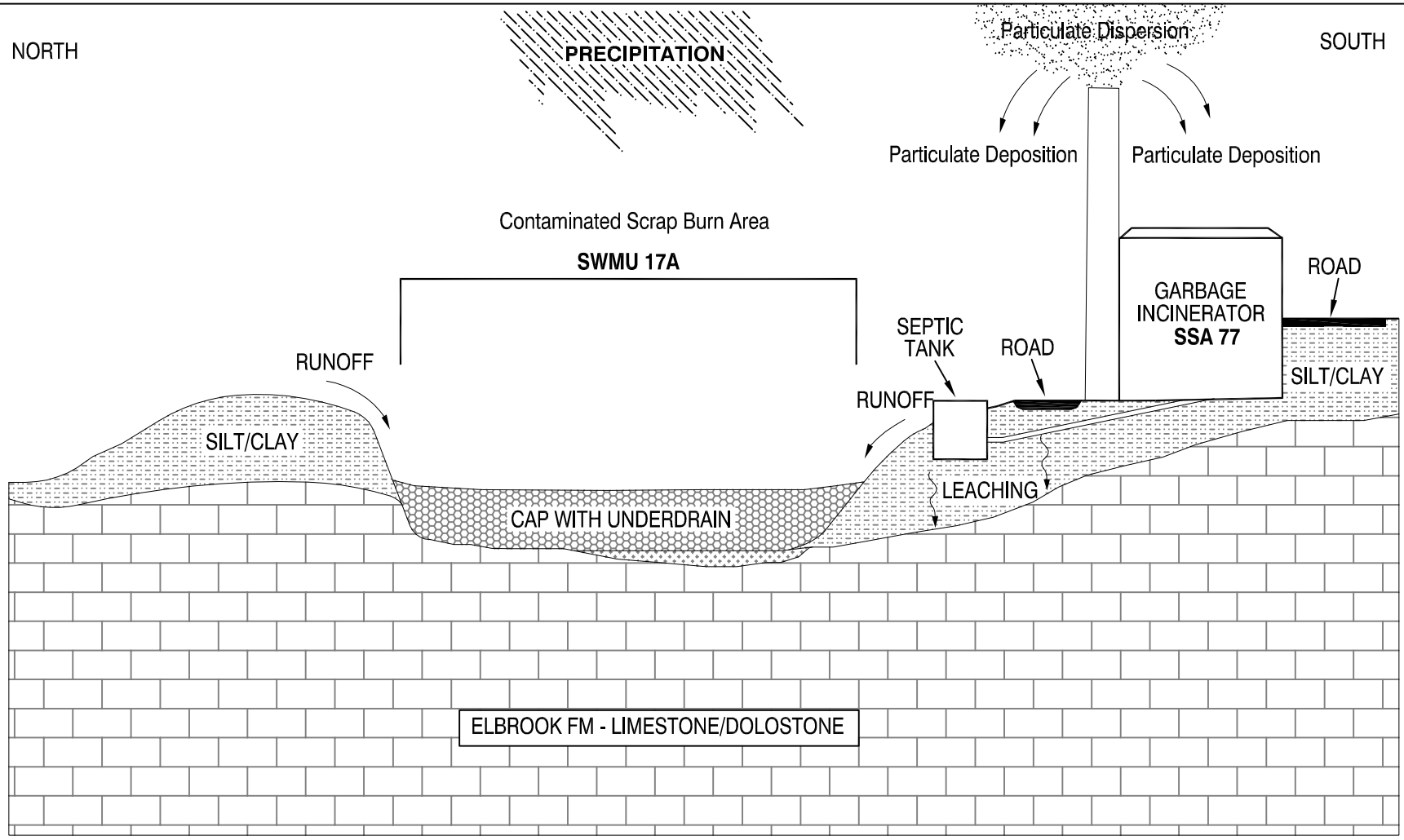


FIGURE 5-7

Conceptual Site Model - SSA 77

Date: October 2008	URS Project #: 11657490
Prepared by: SS	Approved by: JOS
Scale: Not to Scale	File Name: Fig. 5-7

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60 and 77

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Radford, Virginia

URS

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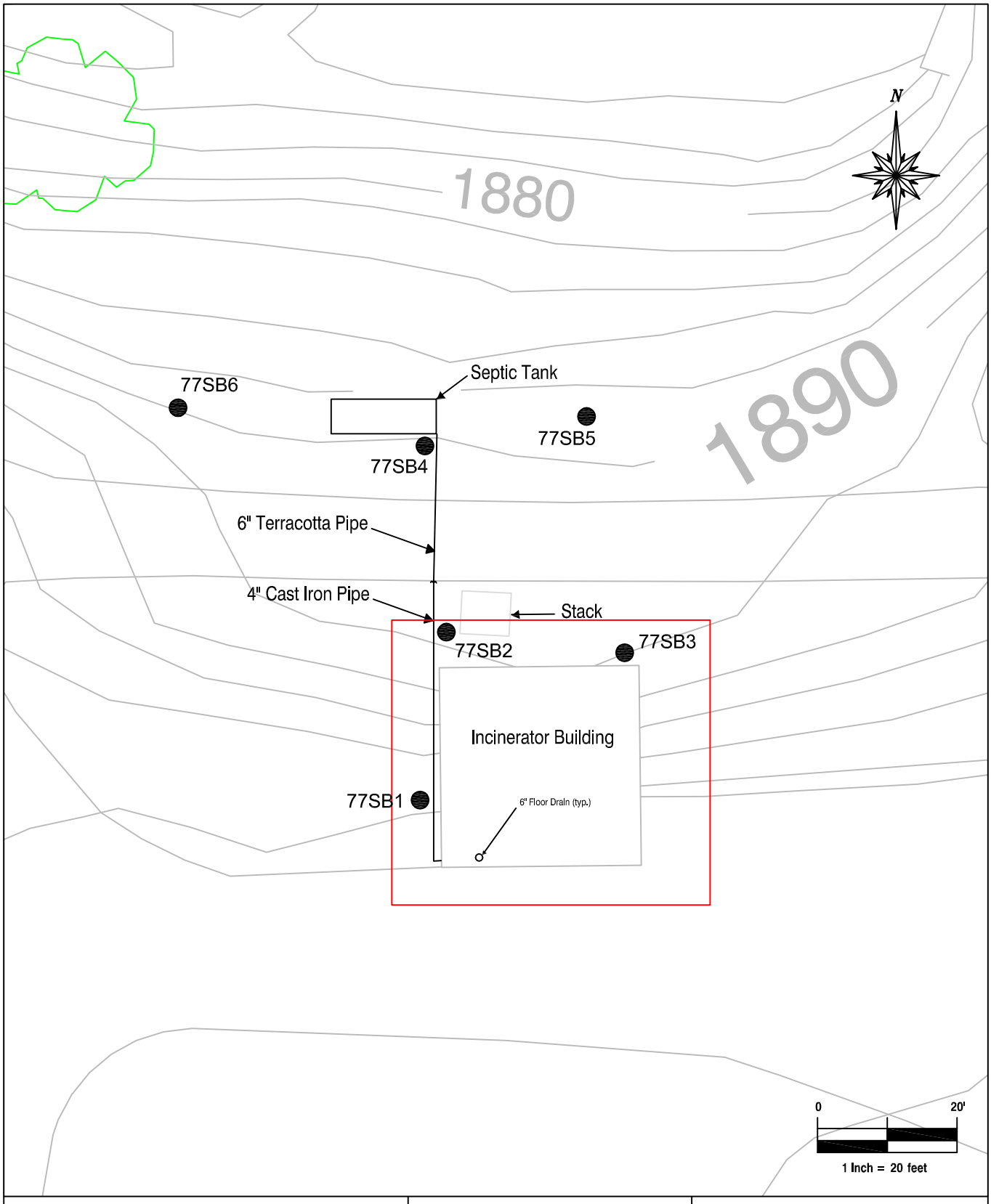
Richmond, Virginia 23230



Legend

- Approximate SSP Boundary
- Topographic Contour
- Vegetation
- Soil Boring Location

FIGURE 5-8

SSP Sample Locations - SSA 77

Date: October 2008	URS Project #: 11657490
Prepared by: DBC	Approved by: JOS
Scale: 1 inch = 20 feet	File Name: Fig.5-8 SSP Locs

MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, 77
Radford Army Ammunition Plant
Radford, Virginia

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

Table 5-1
Historical Groundwater Samples for SSA 77 Area
Modified from Former Lead Furnace Area - 2008 RFI/CMS Draft Report (Shaw Environmental, Inc.)
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Sample ID		Adjusted		LFMW01		MDL	RL	17PZ01		MDL	RL
Sample Date		Tap Water		8/21/07				8/21/07			
	CAS #	RBC	MCL	Result	LQ,VQ			Result	LQ,VQ		
VOCs (ug/L)											
Chloroform	67-66-3	0.19	80	<1	U	0.21	1	2.7		0.21	1
Tetrachloroethene	127-18-4	0.11	5	<1	U	0.25	1	<1	U	0.25	1
Toluene	108-88-3	230	1,000	<1	U	0.27	1	<1	U	0.27	1
Metals (ug/L)											
Aluminum	7429-90-5	3,700	--	9,320		79	200	296		79	200
Barium	7440-39-3	730	2,000	93	J, J	5	200	69.7	J, J	5	200
Beryllium	7440-41-7	7.3	4	1.9	J, B	1	4	1.2	J, B	1	4
Chromium [(1)]	7440-47-3	5,500	100	43		0.92	10	11		0.92	10
Cobalt	7440-48-4	1.1	--	4.6	J, J	1	50	<1	U	1	50
Copper	7440-50-8	150	1,300	6.9	J, J	1.2	25	<1.2	U	1.2	25
Iron	7439-89-6	2,600	--	10,100		15	300	<15	U	15	300
Lead [(2)]	7439-92-1	15	--	3.6	J, J	2.1	5	<2.1	U	2.1	5
Manganese	7439-96-5	88	--	78.3		1	15	5.3	J, J	1	15
Nickel	7440-02-0	73	--	30.5	J, J	1	40	6.4	J, J	1	40
Silver	7440-22-4	18	--	<0.77	U	0.77	10	<0.77	U	0.77	10
Vanadium	7440-62-2	26	--	20	J, J	1.1	50	<1.1	U	1.1	50
Zinc	7440-66-6	1,100	--	60.4		5	20	10	J, J	5	20
Dioxin/Furans (ng/L)											
Total 2,3,7,8-TCDD Equivalents		5.20E-04		7.89E-04				3.06E-06			
Misc. (ug/L)											
Perchlorate	14797-73-0	2.6	--	5.33		0.112	0.2	1.09		0.112	0.2

Table 5-1
Historical Groundwater Samples for SSA 77 Area
Modified from Former Lead Furnace Area - 2008 RFI/CMS Draft Report (Shaw Environmental, Inc.)
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Sample ID				17MW02			
Sample Date				8/21/07		MDL	RL
	CAS #	Adjusted Tap Water RBC	MCL	Result	LQ,VQ		
VOCs (ug/L)							
Chloroform	67-66-3	0.19	80	5.9		0.21	1
Tetrachloroethene	127-18-4	0.11	5	2.6		0.25	1
Toluene	108-88-3	230	1,000	<1	U	0.27	1
Metals (ug/L)							
Aluminum	7429-90-5	3,700	--	222		79	200
Barium	7440-39-3	730	2,000	54.4	J, J	5	200
Beryllium	7440-41-7	7.3	4	1.3	J, B	1	4
Chromium [(1)]	7440-47-3	5,500	100	29.5		0.92	10
Cobalt	7440-48-4	1.1	--	26.9	J, J	1	50
Copper	7440-50-8	150	1,300	7.9	J, J	1.2	25
Iron	7439-89-6	2,600	--	644		15	300
Lead [(2)]	7439-92-1	15	--	<2.1	U	2.1	5
Manganese	7439-96-5	88	--	12.8	J, J	1	15
Nickel	7440-02-0	73	--	18.1	J, J	1	40
Silver	7440-22-4	18	--	6.2	J, B	0.77	10
Vanadium	7440-62-2	26	--	1.5	J, J	1.1	50
Zinc	7440-66-6	1,100	--	11.9	J, J	5	20
Dioxin/Furans (ng/L)							
Total 2,3,7,8-TCDD Equivalents		5.20E-04		4.26E-06			
Misc. (ug/L)							
Perchlorate	14797-73-0	2.6	--	5.4		0.112	0.2

Notes:

USEPA = U.S. Environmental Protection Agency
MCL = Maximum Contaminant Level
RBC = Risk-Based Concentration
USEPA Region III Risk-Based Concentration (RBC) values from the October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
ug/L = Microgram Per Liter
ng/L = Nanograms Per Liter
TAL = Target Analyte List
VOC = Volatile Organic Compound
-- = No Risk Criteria Available

= Concentration Exceeds Adj. Tap Water RBC

bold = Concentration Exceeds MCL

(1) = Chromium III RBC used
(2) = Lead Action Level used

6.0 QUALITY ASSURANCE PLAN ADDENDUM

6.1 INTRODUCTION

This QAPA establishes function-specific responsibilities and authorities to ensure data quality for investigative activities at RFAAP. The project objectives will be met through the execution of the SOPs included in the MWP and appended to this document. The applicable SOPs are referenced below. Specific QC requirements include development of Data Quality Objectives (DQOs), performance of internal QC checks, and execution of appropriate analytical procedures during investigative activities. This QAPA is designed to be used in conjunction with the MQAP. Table 6-1 provides a list of general QA measures that will be implemented as specified in the MQAP.

The distribution list for submittals associated with this SSP is defined in the Facility Permit (USEPA, 2000a). At least three copies of draft documents and three copies of the final plans, reports, notifications, or other documents submitted as part of the SSP for SSAs 18, 72, 30, 79, and 77 is to be submitted to the USEPA Regional Administrator, and shall be sent Certified Mail, Return Receipt Requested, overnight mail, or hand-carried to:

USEPA Region III
RCRA General Operations Branch 3WC23
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

In addition, one copy each such submission shall be sent to:

Commonwealth of Virginia
Department of Environmental Quality
Waste Division
629 East Main Street
Richmond, Virginia 23219

Commonwealth of Virginia
Department of Environmental Quality
West Central Regional Office
Executive Office Park, Suite D
5338 Peters Creek Road
Roanoke, VA 24109

Moreover, one or more copies of each such submission shall be sent to:

Tom Meyer
USACE, Baltimore District
ATTN: CENAB-EN-HM (10000-G)
10 South Howard Street
Baltimore, Maryland 21203

U.S. Army Environmental Command
1 Rock Island Arsenal
Bldg 60, 3rd Fl, NW Wing, Room 320
(IMAE-CDN)
Rock Island, Illinois 61299

James McKenna
Radford Army Ammunition Plant
Route 114, Peppers Ferry Road
Building 220
Radford, Virginia 24141-0099

Dennis Druck
USACHPPM
5158 Blackhawk Road
ATTN: MCHB-TS-HER
Aberdeen Proving Ground, MD 21010-5403

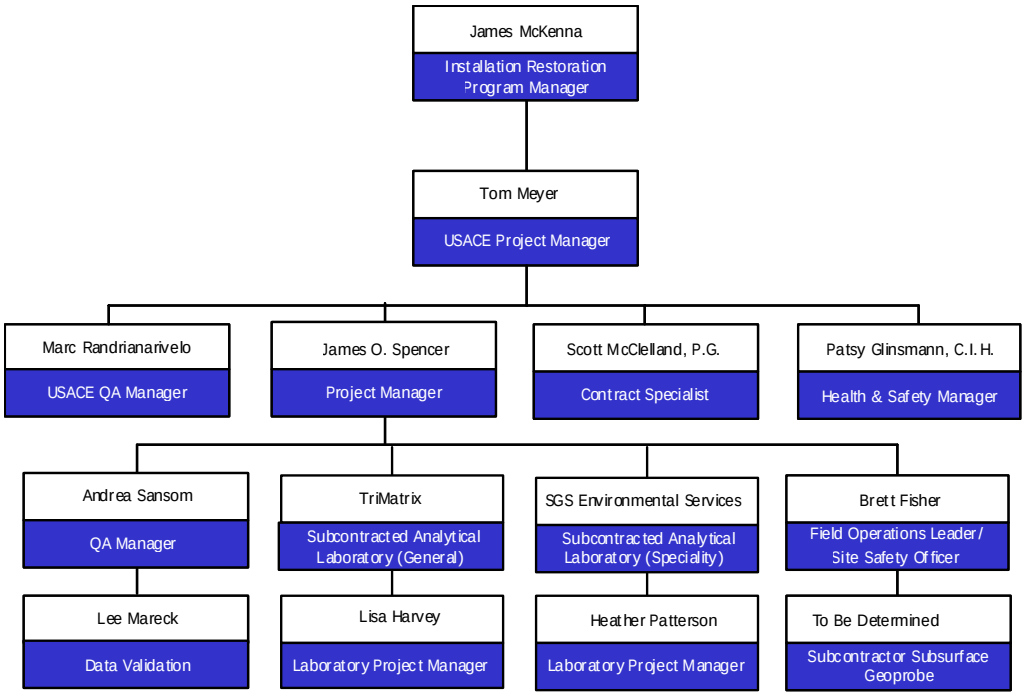
Rich Mendoza

6.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

6.2.1 Contractor and Subcontractor Responsibilities

Contractor and subcontractor personnel requirements for implementing the technical, quality, and health and safety programs are described in Section 2.1 of the MQAP. Figure 6-1 presents the identification and the organization of project management personnel.

Figure 6-1
Project Organizational Chart



6.2.2 Key Points of Contact

Table 6-2 provides the names and points of contact for URS personnel and subcontractors.

The Project Manager (PM) is responsible for ensuring that activities are conducted in accordance with contractual specifications, the Statement of Work (SOW), and approved work plans. The PM will also provide technical coordination with the Installation's designated counterpart. The PM is responsible for management of operations conducted for this project. In addition, the PM will ensure that personnel assigned the project, including subcontractors, will review the technical plans prior to initiation of each task associated with the project. The PM will monitor the project budget and schedule and will ensure availability of necessary personnel, equipment, subcontractors, and services. The PM will participate in the development of the field program, evaluation of data, reporting, and the development of conclusions and recommendations.

The Field Operations Leader will provide management of the field activities during the fieldwork. The Field Operations Leader is responsible for ensuring that technical matters pertaining to the field-sampling program are addressed. They will participate extensively in data interpretation, report writing, and preparation of deliverables, and will ensure that work is being conducted as specified in the technical plans. In addition, the Field Operations Leader is responsible for field QA/QC procedures and for safety-

related issues. Prior to initiation of field activities, the Field Operations Leader will conduct a field staff orientation and briefing to acquaint project personnel with the sites and assign field responsibilities.

The Health and Safety Manager will review and internally approve the HSPA that will be tailored to the specific needs of the project in the task specific addendum. In consultation with the PM, the Health and Safety Manager will ensure that an adequate level of personal protection exists for anticipated potential hazards for field personnel. On-site health and safety will be the responsibility of the SHSO who will work in coordination with the PM and the project Health and Safety Manager.

The QA Manager is responsible for ensuring that the QA procedures and objectives in the project-specific work plans are met, reviewing field and analytical data to ensure adherence to QA/QC procedures, and approving the quality of data prior to inclusion in associated reports. This may include the performance of field and laboratory audits during the investigation. In addition, the QA Manager will be responsible for the review, evaluation, and validation of analytical data for the project and will participate in interpreting and presenting analytical data. QC coordination is under the technical guidance of the QA Manager to direct the task leaders on a day-to-day or as-needed basis to ensure the application of QA/QC procedures.

The Data Validator is responsible for analytical data evaluation and review to provide information on analytical data limitations based on specific quality control criteria. Responsibilities of the Data Validator include establishing if data meet the project technical, quality control criteria, assessing the usability and extent of bias of data not meeting the specific technical, and quality criteria. The reviewer will establish a dialogue with the data users prior to and after review to answer questions, assist with interpretation, and to provide the validation reports.

The Contract Specialist is responsible for tracking funds for labor and materials procurement and oversight of the financial status of the project. Responsibilities include:

- Preparation of monthly cost reports and invoices;
- Administration of equipment rental, material purchases, and inventory of supplies;
- Administration and negotiation of subcontracts and interaction with the Administrative Contracting Officer and Procurement Contracting Officer on contract and subcontract issues; and
- Preparation of project manpower estimates and administration of contract documents.

6.3 QUALITY ASSURANCE OBJECTIVES

Quality assurance (QA) is defined as the overall system of activities for assuring the reliability of data produced. Section 6.1, of this WPA, references investigative, chemical, and regulatory measures associated with the QA Objectives of this project. Conformance with appended SOPs will ensure attainment of QA objectives. The system integrates 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 DQO process is a strategic planning approach to ensure environmental data is of the appropriate type, quantity, and quality for decision-making. Project-specific DQOs are included in Table 6-3 for investigative activities. The overall QA objective is to develop and implement procedures for sample and data collection, shipment, evaluation, and reporting that will allow reviewers to assess whether the field and laboratory procedures meet the criteria and endpoints established in the DQOs. DQOs are qualitative and quantitative statements that outline the decision-making process and specify the data required to

support corrective actions. DQOs specify the level of uncertainty that will be accepted in results derived from environmental data. *Guidance for the Data Quality Objectives Process* (USEPA 2006a), and *Systematic Planning: A Case Study for Hazardous Waste Site Investigations* (USEPA 2006b) formed the basis for the DQO process and development of RFAAP data quality criteria and performance specifications.

The objectives of the SSP are to assess: 1) whether releases of hazardous substances, pollutants, hazardous wastes, or hazardous constituents have occurred to the environment at the site, and 2) whether further investigation or action (i.e., risk assessment, RCRA Facility Investigation, interim action), or no further action (NFA) is appropriate at the site.

The DQO process consists of the seven steps specified below.

1. **State the Problem:** Define the problem to focus the study. Specific activities conducted during this process step include (1) the identification of the planning team and the primary decision-maker, (2) the statement of the problem, and (3) the identification of available resources, constraints, and deadlines.

    a) The planning team consists of the RFAAP, USACE, USEPA, Virginia Department of Environmental Quality (VDEQ), the RFAAP operating contractor, and URS; Relative to the implementation of this WPA, the primary decision-maker is RFAAP, in consultation with USACE, USEPA, VDEQ, the RFAAP operating contractor, and URS.

    b) The following project objectives have been identified:

        i) Assess whether releases of hazardous substances, pollutants, hazardous wastes, or hazardous constituents have occurred to the environment at the sites.

        ii) Complete human health and ecological SSP risk evaluations to assess whether further investigation or action (i.e., risk assessment, RCRA Facility Investigation, interim action), or NFA is appropriate at the sites.

        iii) Reach a decision regarding future action at the sites.

    c) The SSP project budget has been established, the project team has been identified, and a project schedule has been developed.

2. **Identify the Decision:** Define the decision statement that the study will attempt to resolve. Activities conducted during this step of the process involve (1) identification of the principal study question(s) and (2) definition of resultant alternative actions.

    a) Principal study questions include:

        i) What are the locations and nature of waste disposal areas at the site?

        ii) Have releases of hazardous substances, pollutants, hazardous wastes, or hazardous constituents have occurred to the environment at the sites?

        iii) Have hazardous constituents leached to subsurface soil at levels above background levels and human health risk SSP criteria?

iv) Do hazardous constituent concentrations in site media an unacceptable risk to human health or the environment considering current and planned future land uses?

b) The resultant alternative actions include:

i) If completion of the release assessment, human health SSP risk evaluation, and ecological SSP risk evaluation indicate that NFA is appropriate at the site, then the SSP Report will present this information.

ii) If it is concluded from human health and ecological SSP risk evaluations that further investigation or action is required at the site, then the SSP Report will present recommendations for additional investigations, further risk assessment, or other actions.

3. **Identify Inputs to the Decision**: Identify information inputs required for resolving the decision statement and assessing which inputs require environmental measures. This step of the process includes identification of the data that will be required to make the decision, identification of the information sources, identification of data required for establishment of study action levels, and confirmation of appropriate field sampling and analytical methods. The type of information that is needed to resolve the decision statement and the sources of this information include the following:

a) Results of an examination of site use, operational history, environmental setting, land use, and groundwater use and characteristics.

b) Details of a visual inspection of the site and site reconnaissance for ecological assessment.

c) Soil, sediment, test pit, and groundwater data.

d) Validated results of chemical and physical analyses performed on site soil, sediment, and groundwater samples.

e) Soil and sediment (human health) – residential RBCs, industrial RBCs, and soil to groundwater SSLs in the most recent version of the USEPA Regional Screening Table, lead action level, and RDA for iron.

f) Groundwater – tap water RBCs in the most recent version of the USEPA Regional Screening Table, Federal Maximum Contaminant Levels (MCLs), and Virginia Water Quality Standards in 9 VAC 25-260.

g) Soil and Sediment (ecological) – USEPA ecological screening levels.

h) Laboratory method detection limits s (MDLs) and reporting limits (RLs) for TCL organics, explosives, perchlorate (groundwater), and TAL inorganics.

4. **Define the Boundaries:** Define decision statement spatial and temporal boundaries. This step specifies (1) the spatial boundary, (2) the target population characteristics, applicable geographic areas and associated homogeneous characteristics, and (3) the constraints on sample collection.

a) Physical boundaries of the sites will be defined within the scope of the SSP by combining site historical data, previous site investigation findings, subsurface investigation data, geophysical surveys, and site reconnaissance completed for this WPA;

b) The media that will be investigated include surface soil, subsurface soil, sediment, and groundwater; and

c) Practical constraints that could interfere with sampling include weather, site vegetation, boring or test pit refusal on site debris, and equipment access to test pit and boring locations.

5. **Develop a Decision Rule:** Define (1) the parameters of interest, (2) the action levels, and (3) develop a decision rule.

   a) Parameters of interest include:

      i) TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives (including nitroglycerin and PETN [Pentaerythritol Tetranitrate]), TCL dioxin/furans, TAL metals, and chemical oxygen demand (COD), asbestos;

      ii) Physical soil characteristics including: grain size analysis, Atterberg Limits, moisture content, TOC, soil bulk density, and pH;

      iii) Depth to groundwater in existing site monitoring wells;

      iv) Groundwater characteristics and quality at selected sites.

   b) Action levels include:

      i) Action levels for risk screening include USEPA Region III RBCs, USEPA Region III ecological risk screening levels, USEPA soil migration to groundwater SSLs, MCLs, Virginia State Water Control Board Water Quality Criteria, as well as the background soil metals constituent concentrations as reported in the Facility-Wide Background Study Report;

      ii) In accordance with USEPA Region III guidance, RBCs for non-carcinogenic constituents will be adjusted downward to an HQ of 0.1 to ensure that chemicals with additive effects are not prematurely eliminated during screening; and

      iii) MDLs and RLs, as specified herein, will ensure that data quality is sufficient for its intended use. The selected laboratories are within the Contract Laboratory Program (CLP) network, the proposed laboratories have been validated by USACE for the selected SW-846 Test Methods, and it is assumed that sources of analytical errors will be small and known.

   c) c) Decision rules include:

      i) Constituents of potential concern will be identified by comparing maximum detected concentrations (or a 95% Upper Confidence Limit (UCL) if appropriate) to established action levels in order to decide the need for further evaluation, investigation, or response action;

      ii) Analytical laboratory decision rules are presented in this QAPA and the laboratory QAPs. These include specific action levels and decision rules based on accuracy and precision;

iii) Results of site activities will be used to refine the site conceptual model and will be used in the SSP evaluation.

6. **Specify Acceptable Limits on Decision Errors:** Specify the decision-maker's tolerable limits on decision errors. This step includes identification of (1) parameter range of interest, (2) decision errors, and (3) potential parameter values and probability tolerance for decision errors.

   a) MDLs and RLs are established for each analyte within the suite of parameters sought. MDLs and RLs below the action levels will ensure the data meet the DQOs. The contract laboratory will provide a CLP-like raw data package (Level IV). Data validation will be conducted based on this QAPA, the MQAP, the Department of Defense (DOD) Quality Systems Manual (QSM), and relevant USEPA Region III guidance.

   b) The main baseline condition decision error is to decide that the true mean concentration of a site-related constituent is below the action level for further study when in fact the mean concentration is above the action level and further action is needed (Type I, false rejection). Conversely, consequences of incorrectly deciding that the true mean concentration of a site-related constituent is above the action level when in fact the mean concentration is below the action level include spending un-necessary resources to study further or remediate a site with insignificant risk (Type II, false acceptance).

   c) Information from previous studies and physical features of each area was used to develop a field sampling plan design that allows for a low probability of decision error.

7. **Optimize Data Design:** Identify data collection activities commensurate with data quality specifications. This final step in the process consists of (1) reviewing DQO outputs and existing environmental data, (2) developing data collection and design alternatives, and (3) documentation of operational details and theoretical assumptions.

   a) DQO outputs will be reviewed based on the data collection activities; the validity of the data could be verified if necessary based on the review;

   b) Data collection is based upon site-specific characteristics and the end use of the data; and

   c) This addendum contains the proposed sampling design program based on the DQOs. Project documentation will be implemented in accordance with the MWP.

6.4 SAMPLE MANAGEMENT

Sample management objectives will be met through adherence to the sample identification procedures (identification convention), documentation requirements, and chain-of-custody procedures in the MWP.

6.4.1 Number and Type

Table 6-4 provides an itemization of the sample identifiers, sample depths (if applicable), and analytical parameters for environmental samples proposed during this investigation.

6.4.2 Sample Container, Preservation Method, and Holding Time Requirements

Table 6-5 identifies analytical parameters, container and preservation requirements, and holding times.

6.4.3 Sample Identification

Sample identification will consist of an alphanumeric designation related to the sampling location, media type, and sequential order according to the sampling event. The identification number will not consist of

more than thirty-two characters for entry into Environmental Restoration Information System (ERIS). Samples will be coded in the following order to ensure a unique identification.

- **Site Location Code**: The first two characters will be the SSA number (i.e., 18 for SSA 18).
- **Sample/Media Type:** The next two characters will be the sample/media types. In this case, the characters will be TP for test pits, SS for surface soil, SB for soil borings, SE for sediment, and GW for groundwater.
- **Sampling Location Number:** The next one or two characters will be the number of the sampling location (e.g., 3, 4, 5).
- **Sample Depth:** Surface samples (0 to 1 ft bgs) will be designated with an "A" after the boring number. Subsurface samples will be designated with a "B" following the boring number
- **Duplicate:** Duplicate samples will be identified with a "Dup" designation followed by a numeric designation corresponding to the sequence of duplicates collected (e.g., Dup-1). A record of the sample that corresponds to the duplicate will be kept in the field logbook. In this manner, duplicates will be submitted as blind duplicates, eliminating the potential for laboratory bias in analysis.

Sample Identification Examples:

1) A surface soil sample collected at a depth of 0 to 1 ft bgs at boring location four at SSA 18 would be identified as sample 18SB4A (for SSA 18, soil boring four, and "A" which stands for surface soil at that location).
2) QC Samples: QC samples will be identified by date (month, day, year), followed by QC sample type, and sequential order number at one digit. The QC sample types include Matrix Spike, Matrix Spike Duplicate (MS/MSD), Rinse Blank (R), and Trip Blank (T).

6.4.4 Documentation

SOPs 10.1 and 10.2 in Appendix B and Section 9.8 of the MQAP specify documentation protocols.

6.5 ANALYTICAL PROCEDURES

Laboratory analytical services will be subcontracted to the following laboratories:

- TriMatrix Laboratories Inc. – TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, explosives, TAL metals, asbestos, TOC, and waste characterization analysis; and
- SGS Analytical Services – TCL dioxin/furans.

Analytical methods and procedures that will be used for the SSP to be conducted at SSAs 18, 72, 30, 79, 60, and 77 are discussed in the following sections. MDLs and RLs for these methods are presented in Tables 6-6 through 6-13.

6.5.1 Organics

The following techniques will be used for analysis of organic constituents.

6.5.1.1 VOCs by SW-846 Test Method 8260B

The aqueous samples are prepared for analysis by purge-and-trap Method 5030 and the solid samples are prepared by purge-and-trap Method 5035. The volatile compounds are introduced into the gas chromatograph by the purge-and-trap method or by other methods (Section 1.2 of Method SW8260B). The analytes are introduced directly to a wide-bore capillary column or cryofocused on a capillary pre-

column before being flash evaporated to a narrow-bore capillary for analysis. The column is temperature-programmed to separate the analytes, which are then detected with a mass spectrometer (MS) interfaced to the gas chromatograph (GC). Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. (Wide-bore capillary columns normally require a jet separator, whereas narrow-bore capillary columns may be directly interfaced to the ion source.) Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

6.5.1.2 SVOCs by SW-846 Test Method 8270C

The samples are prepared for analysis by GC/MS using Method 3510C for aqueous media and Method 3540C for solid media, or other appropriate methods. The semi-volatile compounds are introduced into the GC/MS by injecting the sample extract into a GC with a narrow-bore fused-silica capillary column. The GC column is temperature-programmed to separate the analytes, which are then detected with a MS, connected to the gas chromatograph. Analytes eluted from the capillary column are introduced into the mass spectrometer via a direct connection. Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

6.5.1.3 Pesticides by SW-846 Test Method 8081A

A measured volume or weight of sample (approximately one liter for liquids, and two to 30 grams (g) for solids) is extracted using the appropriate matrix-specific sample extraction technique. Liquid samples are extracted at neutral pH with methylene chloride using Method 3520C (continuous liquid-liquid extractor), or other appropriate technique. Solid samples are extracted using Method 3540C (Soxhlet) or other appropriate technique. A variety of cleanup steps may be applied to the extract, depending on the nature of the matrix interferences and the target analytes. Suggested cleanups include alumina (Method 3610), Florisil (Method 3620), silica gel (Method 3630), gel permeation chromatography (Method 3640), and sulfur (Method 3660). After cleanup, the extract is analyzed by injecting a one-microliter (µL) sample into a gas chromatograph with a narrow- or wide-bore fused silica capillary column. The GC column is temperature-programmed to separate the analytes. An electron capture detector (ECD) or an electrolytic conductivity detector (ELCD) detects analytes eluted from the capillary column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

6.5.1.4 Herbicides by SW-846 Test Method 8151A

Method 8151 provides extraction, derivatization, and gas chromatographic conditions for the analysis of chlorinated acid herbicides in water, soil, and waste samples. Samples are extracted with diethyl ether and then esterified with either diazomethane or pentafluorobenzyl bromide. Organic acids, especially chlorinated acids, cause the most direct interference with the determination by methylation. Phenols, including chlorophenols, may also interfere with this procedure. The determination using pentafluorobenzylation is more sensitive, and more prone to interferences from the presence of organic acids or phenols than by methylation. The derivatives are assessed by gas chromatography with an electron capture detector (GC/ECD). The results are reported as acid equivalents. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

6.5.1.5 PCBs by SW-846 Test Method 8082

A measured volume or weight of sample (approximately one liter for liquids, and two to 30 g for solids) is extracted using the appropriate matrix-specific sample extraction technique. Aqueous samples are extracted at neutral pH using Method 3510C, or other appropriate technique. Solid samples are extracted using Method 3540C (Soxhlet) or other appropriate technique. Extracts for PCB analysis may be subjected to a sulfuric acid/potassium permanganate cleanup (Method 3665) or sulfuric acid cleanup (Method 3660B) designed specifically for these analytes. This cleanup technique will remove (destroy) many single component organochlorine or organophosphate pesticides. Therefore, Method 8082 is not applicable to the analysis of those compounds. Instead, use Method 8081. After cleanup, the extract is analyzed by injecting a 2 µL aliquot into a gas chromatograph with a narrow- or wide-bore fused silica capillary column. An ECD detects analytes eluted from the capillary column. Comparing and summing the response of at least three peaks within specified retention time windows to a five-point calibration curve accomplishes quantitation. The chromatographic data may be used to identify the seven Aroclors found in Section 1.1 of Method SW8082, individual PCB congeners, or total PCBs.

6.5.1.6 Explosives by SW-846 Test Methods 8330 and 8332

Test Methods 8330 and 8332 provide for the analysis of part per billion (ppb) levels of certain explosives residues in water, soil, and sediment matrices using high performance liquid chromatography (HPLC) using a UV detector. Before use of these methods, sample preparation techniques must be used. Two sample preparation techniques are available:

1) Low-Level Salting-out Method without Evaporation: Aqueous samples of low concentration are extracted by a salting-out extraction procedure with acetonitrile and sodium chloride. The small volume of acetonitrile that remains un-dissolved above the salt water is drawn off and transferred to a smaller volumetric flask. It is back-extracted by vigorous stirring with a specific volume of salt water. After equilibration, the phases are allowed to separate and the small volume of acetonitrile residing in the narrow neck of the volumetric flask is removed using a Pasteur pipette. The concentrated extract is diluted 1:1 with reagent grade water. An aliquot is separated on a C-18 reverse phase column, analyzed at 254 nanometers (nm), and confirmed on a cyanide (CN) reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

2) Soil and sediment samples are air dried at room temperature to a constant weight. Approximately 2g are extracted using acetonitrile in an ultrasonic bath for 18 hours. Five milliliters (mL) of supernatant is combined with five mL of calcium chloride solution and is shaken and left to stand for 15 minutes. The supernatant is prepared for analysis by filtering through a 0.45 micrometer (µm) Teflon filter. This extract is then separated on a C-18 reverse phase column, determined at 254 nm, and confirmed on a CN reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

6.5.2 Dioxins and Furans by SW-846 Test Method 8290

Method 8290 provides procedures for the identification and quantitative measurement of polychlorinated dibenzo-p-dioxins (tetra- though octa-chlorinated homologues; PCDDs) and polychlorinated dibenzofurans (tetra- though octa-chlorinated homologues; PCDFs) in a variety of environmental matrices and at part-per-trillion (ppt) to part-per-quadrillion (ppq) concentrations. A specified amount of sample is spiked with a solution containing specified amounts of each of the nine isotopically ($^{13}C_{12}$) labeled PCDDs/PCDFs. The sample is then extracted according to a matrix-specific extraction procedure.

The samples are prepared for analysis by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS) using the matrix specific extraction (refer to Method 8290) and analyte specific cleanup procedures (refer to Method 8290). A high-resolution capillary column (60 m DB-5, J&W Scientific, or equivalent) is used in this method. However, no single column is known to resolve isomers. In order to establish the concentration of the 2,3,7,8-TCDF (if detected on the DB-5 column), the sample extract must be reanalyzed on a column capable of 2,3,7,8-TCDF isomer specificity (e.g., DB-225, SP-2330, SP-2331, or equivalent). Quantitation of the individual congeners, total PCDDs and total PCDFs is achieved in conjunction with the establishment of a multipoint (five points) calibration curve for each homologue, during which each calibration solution is analyzed once. The identification of OCDD and nine of the fifteen 2,3,7,8- substituted congeners, for which a 13C-labeled standard is available in the sample fortification and recovery standard solutions, is based on their elution at their exact retention time (within 0.005 retention time units measured in the routine calibration) and simultaneous detection of the two most abundant ions in the molecular ion region. The remaining six 2,3,7,8-substituted congeners (i.e., 2,3,4,7,8-PeCDF; 1,2,3,4,7,8-HxCDD; 1,2,3,6,7,8-HxCDF; 1,2,3,7,8,9-HxCDF; 2,3,4,6,7,8-HxCDF, and 1,2,3,4,7,8,9-HpCDF), for which no carbon-labeled internal standards are available in the sample fortification solution, and other identified PCDD/PCDF congeners are identified by their relative retention times from the routine calibration data, and the simultaneous detection of the two most abundant ions in the molecular ion region. The identification of OCDF is based on its retention time relative to $^{13}C_{12}$-OCDD and the simultaneous detection of the two most abundant ions in the molecular ion region. Confirmation is based on a comparison of the ratios of the integrated ion abundance of the molecular ion species to their theoretical abundance ratios. A calculation of the toxicity equivalent concentration (TEQ) of each sample is made using international consensus toxicity equivalence factors (TEFs), and the TEQ is used to establish if the concentrations of target compounds in the sample are high enough to warrant confirmation of the results on a second GC column.

6.5.3 Metals

The following techniques will be used for analysis of inorganics.

6.5.3.1 Target Analyte List Metals by ICP SW-846 Test Method 6010B Series

Prior to analysis, samples are prepared by Method 3010A for aqueous media and Method 3050B for solid media, or other appropriate methods. When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved before analysis. This method describes multi-elemental determinations by Inductively Coupled Plasma (ICP) - Atomic Emission Spectroscopy (AES) using sequential or simultaneous optical systems and axial or radial viewing of the plasma. The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by radio frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and photosensitive devices monitor the emission line intensities.

Background correction is required for trace element determination. Background must be measured adjacent to analyte lines on samples during analysis. The position selected for the background-intensity measurement, on either or both sides of the analytical line, will be defined by the complexity of the spectrum adjacent to the analyte line. In one mode of analysis, the position used should be as free as possible from spectral interference and should reflect the same change in background intensity as occurs at the analyte wavelength measured. Background correction is not required in cases of line broadening where a background correction measurement would actually degrade the analytical result. The possibility of additional interferences named in Section 3.0 of Method 3050B should also be recognized and appropriate corrections made; tests for their presence are described in Section 8.5 of Method 3035B. Alternatively, users may choose multivariate calibration methods. In this case, point selections for background correction are superfluous since entire spectral regions are processed.

6.5.3.2 Mercury by SW-846 Test Methods 7470A (aqueous) and 7471A (solid)

Prior to analysis, the liquid, solid, or semi-solid samples must be prepared according to the procedure discussed in the method. Methods 7470A and 7471A, cold-vapor atomic absorption techniques are based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height or area) is measured as a function of mercury concentration. Quantitation is accomplished by comparing the response of the peak to a five-point calibration curve.

6.5.3.3 Target Analyte List Metals by ICP SW-846 Test Method 6020 Series

Inductively coupled plasma-mass spectrometry (ICP-MS) is applicable to the determination of sub-ppb concentrations of a large number of elements in water samples and in waste extracts or digests. Prior to analysis, samples that require total ("acid-leachable") values must be digested using appropriate sample preparation methods (such as Methods 3005-3051). Acid digestion prior to filtration and analysis is required for groundwater, aqueous samples, industrial waste, soil, sludge, sediment, and other solid waste for which total (acid-leachable) elements are required. When dissolved constituents are required, samples must be filtered and acid-preserved prior to analysis. No digestion is required prior to analysis for dissolved elements in water samples.

Method 6020 describes the multi-elemental determination of analytes by ICP-MS. The method measures ions produced by a radio frequency inductively coupled plasma. Analyte species originating in a liquid are nebulized and the resulting aerosol transported by argon gas into the plasma torch. The ions produced are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier. Interferences must be assessed and valid corrections applied or the data flagged to indicate problems. Interference correction must include compensation for background ions contributed by the plasma gas, reagents, and constituents of the sample matrix.

6.5.3.4 Cyanide by SW9012A

Samples will be analyzed for total cyanide by SW-846 Test Method 9012A, distillation followed by colorimetric analysis. Hydrocyanic acid (HCN) is released through reflux-distillation and absorbed in a scrubber containing sodium hydroxide solution. The cyanide ion is determined colorimetrically by converting it to cyanogen chloride (CNCl).

6.5.3.5 Asbestos by CARB Method 435 and USEPA Method 100.2

Soil samples will be analyzed for asbestos by State of California Air Resources Board Method 435. Samples are first examined for homogeneity and preliminary fiber identification at low magnification. Positive identification of suspect fibers is made by analysis of subsamples with the polarized light microscope. Quantitative analysis involves point counting.

Water samples will be analyzed for asbestos by USEPA Method 100.2. This method uses transmission light microscopy (TEM) to identify asbestos by morphology, selected area electron diffraction, and energy dispersive x-ray analysis. Known aliquots of the sample are filtered through a 0.1 to 0.22 micron pore mixed cellulose ester. A carbon extraction replica is prepared from a portion of the filter and is examined in the TEM at a magnification of 10,000 to 20,000X. Structures are classified according to the counting rules specified in the Chatfield polycarbonate filter protocol. Only asbestos structures greater than 10 microns in length are counted.

6.5.3.6 TOC by Walkley-Black Method

Soil samples will be analyzed for TOC by this method. This is a preferred method for TOC analyses of soil samples since the USEPA 9060 or 415.1 techniques designed for aqueous samples may leave unextracted organic carbon in the soil. Organic carbon is determined by an oxidation-reduction reaction in which potassium dichromate is added to a sample, followed by addition of concentrated sulfuric acid. Dichromate ($Cr_2O_7^{2-}$) oxidizes organic carbon to CO_2 in an acidic medium. The reduced dichromate is quantitatively related to oxidized organic carbon. Any remaining $Cr_2O_7^{2-}$ is reduced by Fe^{2+} from the ferrous sulfate titrant. The endpoint at which all $Cr_2O_7^{2-}$ has been reduced is indicated by the maroon color of an o-phenanthroline indicator.

6.5.4 Waste Samples

Samples of IDM will be characterized for disposal purposes by analyzing for the following parameters as discussed in the following sections:

- Toxicity Characteristic Leaching Procedure (TCLP) – Complete List (solid);
- TCLP metals (aqueous);
- Corrosivity (solid and aqueous);
- COD (aqueous);
- Explosives (solid);
- Reactivity (ATK internal visual method and percent explosive content); and
- Paint Filter Test (solid).

6.5.4.1 TCLP Extraction

For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8-µm glass fiber filter, is defined as the TCLP extract. For wastes containing greater than or equal to 0.5% solids, the liquid, if present, is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes. Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8-µm glass fiber filter. If compatible (i.e., multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration. Extracts are analyzed using the analytical methods described above.

6.5.4.2 Corrosivity by SW-846 Test Methods 9040B (aqueous) and 9045C (solid)

The corrosivity of a sample will be based on its pH. The pH of a liquid sample is either analyzed electrometrically using a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated using a series of standard solutions of known pH. For soil/solid waste samples, the sample is mixed with reagent water, and the pH of the resulting aqueous solution is measured.

6.5.4.3 Chemical Oxygen Demand by USEPA Test Method 410.4

Sample, blanks, and standards in sealed tubes are heated in an oven or block digester in the presence of dichromate at 150 degrees Celsius (^{o}C). After two hours, the tubes are removed from the oven or digester, cooled, and measured spectrophotometrically at 600 nm.

6.5.4.4 Reactivity

Reactivity of waste samples is assessed by analysis of the sample for explosives by SW-846 Methods 8330 and 8332. Waste material is considered potentially reactive when 10 percent or more explosives by weight are present. A qualitative assessment of samples may also be performed by visual and microscopic methods to identify typical crystalline structures characteristic of the propellants and explosives manufactured at the facility.

6.5.4.5 Paint Filter Test by SW-846 Test Method 9095B

This method is used to determine the presence of liquid in representative samples of waste and to determine compliance with 40 Code of Federal Regulations (CFR) 264.314 and 265.314. A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5 minute test period, the material is considered to contain free liquid.

6.5.5 Physical/Geotechnical Analysis

Soil samples for physical/geotechnical analysis will be submitted to URS' laboratory in Totowa, New Jersey for the analysis of the following parameters:

- Grain-size analysis (ASTM D 422);
- Atterberg limits (ASTM D 4318);
- Soil moisture content (ASTM D 2216);
- Total Organic Carbon (Walkley-Black Method); and
- pH (ASTM D 4972).

6.6 INTERNAL QUALITY CONTROL CHECKS

Internal QC components that will be used by URS during operations at RFAAP are presented below and in Section 8.0 of the MQAP. The internal quality components include the field QC samples and the laboratory QC elements to be followed. Rinse blanks, trip blanks, and field duplicates will be collected during the acquisition of environmental samples at RFAAP. Table 6-13 presents guidelines for the collection of QC samples that will be taken in conjunction with environmental sampling. Field QC acceptance criteria are summarized in Table 6-14.

6.6.1 Laboratory Quality Control Elements

The laboratory QC elements are summarized in Table 6-16. Specific laboratory analytical QC criteria and corrective actions are summarized in Tables 6-17 through 6-25 for the parameters specified in Section 6.5.

6.7 DATA COLLECTION AND VALIDATION

Non-CLP SW-846 Test Methods are proposed for analytical work for this WPA and analyses will be conducted by a National Environmental Laboratory Accreditation Program (NELAP) accredited analytical laboratory. Level IV CLP-like raw data will be provided along with the Form 1. Additional

discussion as to the laboratory deliverables may be found in Section 9.8.3 of the MQAP. Data will be made available to the USEPA upon request and presented in the SSP Report.

Data validation will be conducted on 100% of the data and documented based on the MQAP Section 9.5, USEPA SW-846 Test Method criteria, DOD QSM, and USEPA Region III guidance. Data qualifiers will follow the USEPA Region III Modifications to the USEPA National Functional Guidelines for Evaluating Inorganic Analysis and USEPA Region III Modifications to the USEPA National Functional Guidelines for Organic Data Review Multi-media, Multi-concentration (OLM01.0-OLM01.9). Verification for organic data will be performed at level M3 and the verification for inorganic data will be performed at level IM2.

Manual data validation will be conducted by an independent, third party data validator not directly associated with the field-sampling program. Ms. Andrea Sansom, Quality Assurance Manager, will oversee the performance of data validation functions. Data validation will be performed by knowledgeable and experienced individuals who can best perform evaluations within the necessary validation components. The data validator's qualifications will include experience with each of the elements required for the data verification and validation including ensuring that the measuring system meets the user's needs, assigning qualifiers to individual data values, assessing the relevancy of performance criteria, and concluding that data can proceed to quality assessment and reporting.

URS will direct the overall data management. Data management activities for the sampling program will be divided between URS, TriMatrix Laboratories and Paradigm Analytical Laboratories for Dioxin/Furan analyses. Each firm has the equipment needed to perform the required data management functions. The laboratory will perform data entry and manipulation operations associated with the analysis of raw analytical data and provisions of chemical analysis results by sampling location. These data will be transmitted to URS for evaluation and interpretation. In addition, URS will review boring logs and sample location maps.

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Table 6-1

Quality Assurance Measures Discussed in the MQAP

Quality Assurance Measure	Section in MQAP	SOP No. (MWP Appendix A and Appendix B of WPA 028)
Project Organization and Responsibilities	2.0	--
Lines of Authority	2.2	--
Chemical Data Measurements	3.2	--
Levels of Concern	3.3	--
Site Investigation	4.0/5.0	20.1, 20.2, 20.3, 20.4, 20.7, 20.8, 20.11, 30.1, 30.2, 30.6, 30.7, 30.9, 40.1, 40.2, 40.3, 50.1, 50.2, 70.1, 80.1
Documentation Requirements	5.6	10.1, 10.2, 10.3, 50.1
Chain-of-custody Requirements	5.7	10.4, 50.2
Calibration Procedures	7.0	90.1
Data Reduction, Validation, Reporting, and Management	9.0	--
Corrective Action	10.0	--
Quality Assessments	11.0	--

Table 6-2

Contractor and Subcontractor Key Points of Contact

Contractor	Key Point of Contact
Project Manager, James O Spencer Email: James_O_Spencer@URSCorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5420; Fax: 804.965.9764
Health and Safety Manager, Patsy Glinsmann Email: Patsy_Glinsmann@URSCorp.com	URS Group, Inc. 200 Orchard Ridge Drive, Suite 101 Gaithersburg, Maryland 20878 Tel: 301.258.9780; Fax: 301.869.8728
Quality Assurance Manager, Andrea Sansom Email: Andrea_Sansom@URSCorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5431; Fax: 804.965.9764
Data Validator, Lee Mareck Email: Lee_Mareck@URSCorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5444; Fax: 804.965.9764
Field Operations Leader and Site Health and Safety Officer, Brett Fisher Email: Brett_Fisher@URSCorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5430; Fax: 804.965.9764
Subcontractor	**Key Point of Contact**
Analytical Laboratory Services, General TriMatrix Laboratories, Inc. Email: HarveyLM@TriMatrixLabs.com	Lisa Harvey 5560 Corporate Exchange Court Grand Rapids, MI 49512 Tel: 616.975.4500; Fax: 616.940.4470
SGS Environmental Services, Inc. (SGS-Wilmington) Email: Heather.Patterson@sgs.com	Heather Patterson 5500 Business Drive Wilmington, NC 28405 Tel: 910.350.1903, Fax: 910.350.1557
Subsurface Exploration	To Be Determined

Table 6-3

Summary of Project Data Quality Objectives

DQO Element	Project DQO Summary
Problem Statement	• Assess whether releases of hazardous substances, pollutants, hazardous wastes, or hazardous constituents have occurred to the environment at the site. • Complete human health and ecological SSP risk evaluations to assess whether further investigation or action (i.e., risk assessment, RCRA Facility Investigation, interim action), or NFA is appropriate at the site. • Reach a decision regarding future action at the site.
Identify Decision/Study Question	<u>Principal Study Questions</u> • What are the locations and nature of waste disposal areas at the sites? • Have releases of hazardous substances, pollutants, hazardous wastes, or hazardous constituents occurred to the environment at the sites? • Have hazardous constituents leached to subsurface soil at levels above background levels and human health risk SSP criteria? • Do hazardous constituent concentrations in soil and groundwater pose an unacceptable risk to human health and the environment? <u>Resultant Alternative Actions</u> • If completion of the release assessment, human health SSP risk evaluation, and ecological SSP risk evaluation indicate that no further action is appropriate at the site, then the SSP Report will present this information. • If it is concluded from human health and ecological SSP risk evaluations that further investigation or action is required at the site, then the SSP Report will present recommendations for additional investigations, further risk assessment, or other actions.

Table 6-3

Summary of Project Data Quality Objectives

DQO Element	Project DQO Summary
Decision Inputs	• Results of an examination of site use, operational history, environmental setting, land use, and groundwater use and characteristics. • Details of a visual inspection of the site and site reconnaissance for ecological assessment. • Soil, sediment, test pit, and groundwater data. • Validated results of chemical and physical analyses performed on site soil and groundwater samples. • Soil (human health) – residential RBCs, industrial RBCs, and soil to groundwater SSL in the most recent version of the USEPA Regional Screening Table, lead action level, and RDA for iron. • Groundwater– tap water RBCs in the most recent version of the USEPA Regional Screening Table, MCLs, and Virginia Water Quality Standards in 9 VAC 25-260. • Soil and sediment (ecological) – USEPA ecological screening levels. • Laboratory MDLs and RLs for TCL organics, explosives, perchlorate (groundwater), TAL metals, and asbestos.
Study Boundaries	• Physical boundaries of the sites will be defined within the scope of the SSP by combining site historical data, previous site investigation findings, subsurface investigation data, geophysical surveys, and site reconnaissance completed for this WPA. • The media that will be investigated include surface soil, subsurface soil, sediment, and groundwater. • Practical constraints that could interfere with sampling include weather, site vegetation, boring refusal on site debris, and equipment access to test pit and boring locations.

Table 6-3

Summary of Project Data Quality Objectives

DQO Element	Project DQO Summary
Decision Rule	<u>Parameters of Interest</u> • TCL organics, TAL metals, explosives, and dioxin/furans. • Groundwater: pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and turbidity. • Physical soil: grain size, Atterberg limits, TOC, moisture content, and pH. • Depth to groundwater in existing site monitoring wells. • Groundwater characteristics and quality at selected sites. <u>Action Levels</u> • Action levels for risk screening include: USEPA Region III RBCs, USEPA Region III ecological screening levels, MCLs, Virginia Water Quality Criteria, and RFAAP background estimates for soil. • Laboratory MDLs and RLs. Low-level analytical methods have been selected to provide for the lowest achievable MDLs and RLs that, where possible, will achieve human health and ecological risk screening levels. <u>Decision Rules</u> • COPCs will be identified by comparing maximum detected concentrations (or a 95% Upper Confidence Limit (UCL) if appropriate) to established risk-based screening levels in order to decide the need for further evaluation, investigation, or response action. • Analytical laboratory decision rules are presented in this QAPA and the laboratory QAPs. These include specific action levels and decision rules based on accuracy and precision. • Results of site activities will be used to refine site conceptual models and will be used in the SSP evaluation.

Table 6-3

Summary of Project Data Quality Objectives

DQO Element	Project DQO Summary
Tolerable Limits on Decision Errors	• MDLs and RLs are established for each analyte within the suite of parameters sought and low-level analytical methods have been selected to provide for the lowest achievable MDLs that will achieve human health and ecological risk screening levels, when possible. The contract laboratory will provide a CLP-like data package for data validation. Data validation will be conducted based on the MWP QAP, USEPA national functional guidelines, and USEPA Region III modifications to the national functional guidelines. • The main baseline condition decision error is to decide that the true mean concentration of a site-related constituent is below the action level for further study when in fact the mean concentration is above the action level and further action is needed (Type I, false rejection). Conversely, consequences of incorrectly deciding that the true mean concentration of a site-related constituent is above the action level when in fact the mean concentration is below the action level include spending un-necessary resources to study further or remediate a site with insignificant risk (Type II, false acceptance). • Information from previous studies, physical features of the site area, and the geophysical survey conducted for this WPA were used to develop a field sampling plan design that allows for a low probability of decision error.
Optimize the Design for Obtaining Data	• DQO outputs will be reviewed based on the data collection activities; the validity of the data could be verified if necessary based on the review; • Data collection is based upon site-specific characteristics and the end use of the data; and • This addendum contains the proposed sampling design program based on the DQOs. Project documentation will be implemented in accordance with the MWP.

Table 6-4
Summary of Proposed Sample Identifiers, Depths, and Analytical Methods
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Chemical Analysis												Physical Analysis				
Sample ID	**Depth (ft bgs)**	**TAL Inorganics Including Mercury and Cyanide SW-846 Method 6020/6010B/7471A/9012A**	**Pesticides/PCBs SW-846 Method 8081A/8082**	**VOCs SW-846 Method 8260B**	**SVOCs SW-846 Method 8270C**	**Explosives/Nitroglycerin/ PETN SW-846 Method 8330m/8332**	**Dioxin/Furans SW-846 Method 8290[1]**	**Asbestos CARB 435 (Soil) EPA Method 100.2 (Water)**	**TCLP Full List**	**TCLP Metals**	**Chemical Oxygen Demand EPA Method 410.4**	**pH (corrosivity) SW-846 Method 9040B**	**Paint Filter Test SW-846 Method 9095**	**Grain Size ASTM D422**	**Atterburg Limits ASTM D4318**	**Moisture Content ASTM D2216**	**Total Organic Carbon Walkley-Black**	**pH ASTM D4972**
Soil																		
SSA 18 and SSA 72																		
18SB1A	0-1	X	X	X	X	X												
18SB1B	8-10	X	X	X	X	X								X	X	X	X	X
18SB2A	0-1	X	X	X	X	X								X	X	X	X	X
18SB2B	5-7	X	X	X	X	X												
18SB3A	0-1	X	X	X	X	X												
18SB3B	5-7	X	X	X	X	X												
18SB4A	0-1	X	X	X	X	X												
18SB4B	5-7	X	X	X	X	X												
18SB5A	0-1	X	X	X	X	X												
18SB5B	5-7	X	X	X	X	X												
18SB6B	5-7	X	X	X	X	X												
72SB1A	0-1		X															
72SB1B	8-10	X	X	X	X	X												
72SB2B	8-10	X	X	X	X	X												
72SB3B	6-8	X	X	X	X	X												
SSA 30 and SSA 79																		
30SS1	0-1	X	X	X	X	X		X										
30SS2	0-1	X	X	X	X	X		X										
30SS3	0-1	X	X	X	X	X		X										
30SB1B	16-18	X	X	X	X	X		X										
30SB2B	16-18	X	X	X	X	X		X										
30SB3B	16-18	X	X	X	X	X		X										
79SS1	0-1	X	X	X	X	X		X										
79SS2	0-1	X	X	X	X	X		X						X	X	X	X	X
79SS3	0-1	X	X	X	X	X		X										
79SB1B	16-18	X	X	X	X	X		X										
79SB2B	16-18	X	X	X	X	X		X						X	X	X	X	X
79SB3B	16-18	X	X	X	X	X		X										

Table 6-4
Summary of Proposed Sample Identifiers, Depths, and Analytical Methods
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Chemical Analysis												Physical Analysis				
Sample ID	**Depth (ft bgs)**	**TAL Inorganics Including Mercury and Cyanide SW-846 Method 6020/6010B/7471A/9012A**	**Pesticides/PCBs SW-846 Method 8081A/8082**	**VOCs SW-846 Method 8260B**	**SVOCs SW-846 Method 8270C**	**Explosives/Nitroglycerin/ PETN SW-846 Method 8330m/8332**	**Dioxin/Furans SW-846 Method 8290(1)**	**Asbestos CARB 435 (Soil) EPA Method 100.2 (Water)**	**TCLP Full List**	**TCLP Metals**	**Chemical Oxygen Demand EPA Method 410.4**	**pH (corrosivity) SW-846 Method 9040B**	**Paint Filter Test SW-846 Method 9095**	**Grain Size ASTM D422**	**Atterburg Limits ASTM D4318**	**Moisture Content ASTM D2216**	**Total Organic Carbon Walkley-Black**	**pH ASTM D4972**
SSA 60																		
60SS1	0-1	X	X	X	X	X	X[1]											
60SS2	0-1	X	X	X	X	X												
60SS3	0-1	X	X	X	X	X								X	X	X	X	X
60SS4	0-1	X	X	X	X	X												
60SS5	0-1	X	X	X	X	X												
60TP1B	10-12	X	X	X	X	X												
60TP2B	10-12	X	X	X	X	X								X	X	X	X	X
60SE1	0-1	X	X	X	X	X												
60SE2	0-1	X	X	X	X	X												
SSA 77																		
77SB1A	0-1	X	X	X	X	X	X											
77SB1B	4-6	X	X	X	X	X												
77SB2A	0-1	X	X	X	X	X	X							X	X	X	X	X
77SB2B	4-6	X	X	X	X	X								X	X	X	X	X
77SB3A	0-1	X	X	X	X	X												
77SB3B	4-6	X	X	X	X	X												
77SB4B	6-8	X	X	X	X	X												
77SB5B	6-8	X	X	X	X	X												
77SB6B	6-8	X	X	X	X	X												
QA/QC																		
Solid																		
DUP-1	TBD	X	X	X	X	X												
DUP-2	TBD	X	X	X	X	X												
DUP-3	TBD	X	X	X	X	X												
DUP-4	TBD	X	X	X	X	X												
MS/MSD	TBD	X	X	X	X	X												
MS/MSD	TBD	X	X	X	X	X												

Table 6-4
Summary of Proposed Sample Identifiers, Depths, and Analytical Methods
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Chemical Analysis												Physical Analysis				
Sample ID	**Depth (ft bgs)**	**TAL Inorganics Including Mercury and Cyanide SW-846 Method 6020/6010B/7471A/9012A**	**Pesticides/PCBs SW-846 Method 8081A/8082**	**VOCs SW-846 Method 8260B**	**SVOCs SW-846 Method 8270C**	**Explosives/Nitroglycerin/ PETN SW-846 Method 8330m/8332**	**Dioxin/Furans SW-846 Method 8290[1]**	**Asbestos CARB 435 (Soil) EPA Method 100.2 (Water)**	**TCLP Full List**	**TCLP Metals**	**Chemical Oxygen Demand EPA Method 410.4**	**pH (corrosivity) SW-846 Method 9040B**	**Paint Filter Test SW-846 Method 9095**	**Grain Size ASTM D422**	**Atterburg Limits ASTM D4318**	**Moisture Content ASTM D2216**	**Total Organic Carbon Walkley-Black**	**pH ASTM D4972**
QA/QC																		
Aqueous																		
EQB1	TBD																	
EQB2	TBD																	
Groundwater																		
SSA 30 and SSA 79																		
51MW1	22							X										
51MW2	21							X										
C1	25							X										
16-4	TBD							X										
DUP-5	N/A							X										
MS/MSD	N/A							X										
EQB3	N/A							X										
IDM																		
SSPIDM-SOIL	N/A					X			X			X	X					
60IDM-SOIL	N/A					X			X			X	X					
SSPIDM-WATER	N/A									X	X	X						

Notes:
USEPA = U.S. Environmental Protection Agency
X^1 = Up to 1 surface soil sample will be submitted for dioxin/furan analysis if burned material is encountered at sample locations.
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PCB = Polychlorinated Biphenyl
PETN = Pentaerythritol Tetranitrate
IDM = Investigative Derived Material

Table 6-5
Summary of Sample Container, Preservation Method, and Holding Time Requirements
MWP Addendum 028 - SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

PARAMETER	SAMPLE CONTAINER		PRESERVATION METHODS	HOLDING TIMES
	Quantity	Type		
SOLID SAMPLES				
TCL Volatile Organic Compounds	3	5-gram Encore samplers, zero headspace	Cool to 4 ± 2 °C; sodium bisulfate (low level), methanol (high level)	Must be analyzed within 48 hours or transferred to soil purge vial with preservative within 48 hours for analysis within 14 days
TCL Semivolatile Organic Compounds	1	500-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
TCL Pesticides	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 ºC	Extraction: 14 days Analysis: 40 days
TCL PCBs	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 ºC	Extraction: 14 days Analysis: 40 days
Explosives/Nitroglycerin/PETN	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
TAL Metals	1	250-mL wide mouth polyethylene container, Teflon®-lined cap	Cool to 4 ± 2 °C	Metals: 6 months Mercury: 28 days
TCL Dioxin/Furans	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 ºC	Extraction: 14 days Analysis: 40 days
Total Organic Carbon (TOC)	1	4 Oz glass container, Teflon®-lined cap	Cool to 4 ± 2 ºC	Analysis: 28 days
Asbestos	1	500-mL wide-mouth glass container, Teflon®-lined cap	--	Analysis: 6 months
SOLID WASTE CHARACTERIZATION				
TCLP VOCs	1	125-mL wide-mouth glass vial, Teflon®-lined cap	Cool to 4 ± 2ºC	Leaching: 14 days Analysis: 14 days
TCLP SVOCs (8270C, 8081A, & 8151A)	2	500-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 14 days Extraction: 7 days Analysis: 40 days
TCLP Metals	1	250-mL wide-mouth polyethylene container, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 6 months Analysis: 6 months Mercury analysis: 28 days
Explosives	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
Corrosivity, Paint Filter	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Corrosivity: 7 days Paint Filter: --
AQUEOUS SAMPLES				
TCL Volatile Organic Compounds	3	40-mL, glass vials, Teflon®-lined septum cap, zero headspace	HCl to pH < 2, Cool to 4 ± 2ºC	14 days
TCL Semivolatile Organic Compounds	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
TCL Pesticides	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
TCL PCBs	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Explosives/Nitroglycerin/PETN	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
TCL Dioxin/Furans	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Unflitered TAL Metals	1	500-mL, polyethylene container	HNO_3 to pH<2, Cool to 4 ± 2 °C	ICP: 6 months Mercury: 28 days
Perchlorate	1	125-mL, polyethylene container	Cool to 4 ± 2 °C	28 days
Asbestos	1	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Filter 48 hours Analysis: 7 days
AQUEOUS WASTE CHARACTERIZATION				
TCLP Metals	1	500-ml, polyethylene container	Cool to 4 ± 2 °C	Leaching: 6 months Analysis: 6 months Mercury analysis: 28 days
Corrosivity	1	125-mL, polyethylene container	Cool to 4 ± 2 °C	7 days
Chemical Oxygen Demand (COD)	1	250-mL, polyethylene container	H_2SO_4 to pH<2, Cool to 4 ± 2 °C	28 days

Notes:
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
TCLP = Toxicity Characteristic Leaching Procedure
COD = Chemical Oxygen Demand
PETN = Pentawrythritol Tetranitrate

TAL = Target Analyte List
TCL = Target Compound List
mL = milliliter
g = gram
ICP = Inductively Coupled Plasma

HNO_3 = Nitric Acid
H_2SO_4 = Sulfuric Acid
HCl = Hydrochloric Acid
°C = Degrees Celsius

Table 6-6
Summary of Analyte Detection Limits and Reporting Limits
TCL VOCs (by EPA Method 8260)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential				
Compound	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	c/n	RBC µg/L	Adjusted RBC µg/L	c/n	RBC mg/kg	Adjusted RBC mg/kg	c/n	RBC mg/kg	Adjusted RBC mg/kg	Aqueous Fresh Water µg/L	Sediment mg/kg
1,1,1-Trichloroethane	71-55-6	0.00020	0.002	0.110	1.0	--	n	9.1E+03	9.1E+02	ns	3.9E+04	3.9E+03	ns	9.0E+03	9.0E+02	1.1E+01	3.0E-02
1,1,2,2-Tetrachloroethane	79-34-5	0.00020	0.002	0.100	1.0	--	c	**6.7E-02**	**6.7E-02**	c	2.9E+00	2.9E+00	c	5.9E-01	5.9E-01	6.1E+02	1.4E+00
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.00033	0.005	0.140	1.0	--	n	5.9E+04	5.9E+03	nms	1.8E+05	1.8E+04	ns	4.3E+04	4.3E+03	--	--
1,1,2-Trichloroethane	79-00-5	0.00069	0.002	0.210	1.0	--	c	2.4E-01	2.4E-01	c	5.5E+00	5.5E+00	c	1.1E+00	1.1E+00	1.2E+03	1.2E+00
1,1-Dichloroethane	75-34-3	0.00019	0.002	0.076	1.0	--	c	2.4E+00	2.4E+00	c	1.7E+01	1.7E+01	c	3.4E+00	3.4E+00	4.7E+01	--
1,1-Dichloroethene	75-35-4	0.00037	0.002	0.140	1.0	--	n	3.4E+02	3.4E+01	n	1.1E+03	1.1E+02	n	2.5E+02	2.5E+01	2.5E+01	3.1E-02
1,2,3-Trichlorobenzene[1]	87-61-6	0.00021	0.002	0.130	2.0	--	n	8.2E+00	8.2E-01	ns	4.0E+02	4.0E+01	n	8.7E+01	8.7E+00	8.0E+00	8.6E-01
1,2,4-Trichlorobenzene	120-82-1	0.00024	0.002	0.160	2.0	7.0E+01	n	8.2E+00	8.2E-01	ns	4.0E+02	4.0E+01	n	8.7E+01	8.7E+00	2.4E+01	2.1E+00
1,2-Dibromo-3-chloropropane	96-12-8	0.00082	0.005	0.290	2.0	--	c	**3.2E-04**	**3.2E-04**	c	7.3E-02	7.3E-02	c	5.6E-03	5.6E-03	--	--
1,2-Dibromoethane	106-93-4	0.00084	0.003	0.220	1.0	--	c	**6.5E-03**	**6.5E-03**	c	1.7E-01	1.7E-01	c	3.4E-02	3.4E-02	--	--
1,2-Dichlorobenzene	95-50-1	0.00024	0.001	0.065	1.0	--	n	3.7E+02	3.7E+01	ns	1.0E+04	1.0E+03	ns	2.0E+03	2.0E+02	7.0E-01	1.7E-02
1,2-Dichloroethane	107-06-2	0.00030	0.001	0.150	1.0	--	c	1.5E-01	1.5E-01	c	2.2E+00	2.2E+00	c	4.5E-01	4.5E-01	1.0E+02	--
1,2-Dichloropropane	78-87-5	0.00092	0.003	0.100	1.0	5.0E+00	c*	3.9E-01	3.9E-01	c*	4.7E+00	4.7E+00	c*	9.3E-01	9.3E-01	--	--
1,3-Dichlorobenzene[2]	541-73-1	0.00024	0.001	0.120	1.0	--	c	4.3E-01	4.3E-01	c	1.3E+01	1.3E+01	c	2.6E+00	2.6E+00	1.5E+02	4.4E+00
1,4-Dichlorobenzene	106-46-7	0.00022	0.001	0.130	1.0	--	c	4.3E-01	4.3E-01	c	1.3E+01	1.3E+01	c	2.6E+00	2.6E+00	2.6E+01	6.0E-01
1-Chlorohexane	544-10-5	--	--	0.480	2.0	--	--	--	--	--	--	--	--	--	--	--	--
2-Butanone	78-93-3	0.00240	0.010	0.330	5.0	--	n	7.1E+03	7.1E+02	nms	1.9E+05	1.9E+04	ns	2.8E+04	2.8E+03	1.4E+04	--
2-Hexanone	591-78-6	0.00300	0.010	0.420	5.0	--	--	--	--	--	--	--	--	--	--	--	--
4-Methyl-2-pentanone	108-10-1	0.00190	0.010	0.380	5.0	--	n	2.0E+03	2.0E+02	ns	5.2E+04	5.2E+03	ns	5.3E+03	5.3E+02	1.7E+02	--
Acetone	67-64-1	0.00420	0.015	1.200	5.0	--	n	2.2E+04	2.2E+03	nms	6.1E+05	6.1E+04	n	6.1E+04	6.1E+03	1.5E+03	--
Benzene	71-43-2	0.00013	0.001	0.120	1.0	5.0E+00	c	4.1E-01	4.1E-01	c*	5.6E+00	5.6E+00	c*	1.1E+00	1.1E+00	3.7E+02	--
Bromochloromethane[3]	74-97-5	0.00013	0.001	0.200	1.0	--	c	1.1E+00	1.1E+00	c	4.6E+01	4.6E+01	c	1.0E+01	1.0E+01	--	--
Bromodichloromethane	75-27-4	0.00025	0.001	0.190	1.0	8.0E+01	c	1.1E+00	1.1E+00	c	4.6E+01	4.6E+01	c	1.0E+01	1.0E+01	--	--
Bromoform	75-25-2	0.00048	0.002	0.230	1.0	8.0E+01	c*	8.5E+00	8.5E+00	c*	2.2E+02	2.2E+02	c*	6.1E+01	6.1E+01	3.2E+02	6.5E-01
Bromomethane	74-83-9	0.00120	0.004	0.190	1.0	--	n	8.7E+00	8.7E-01	n	3.5E+01	3.5E+00	n	7.9E+00	7.9E-01	--	--
Carbon disulfide	75-15-0	0.00026	0.001	0.280	5.0	--	n	1.0E+03	1.0E+02	ns	3.0E+03	3.0E+02	ns	6.7E+02	6.7E+01	9.2E-01	8.5E-04
Carbon tetrachloride	56-23-5	0.00029	0.002	0.150	1.0	5.0E+00	c	2.0E-01	2.0E-01	c	1.3E+00	1.3E+00	c	2.5E-01	2.5E-01	1.3E+01	6.4E-02
Chlorobenzene	108-90-7	0.00020	0.001	0.120	1.0	1.0E+02	n	9.1E+01	9.1E+00	ns	1.5E+03	1.5E+02	n	3.1E+02	3.1E+01	1.3E+00	8.4E-03
Chloroethane	75-00-3	0.00035	0.002	0.200	1.0	--	n	2.1E+04	2.1E+03	ns	6.2E+04	6.2E+03	ns	1.5E+04	1.5E+03	--	--
Chloroform	67-66-3	0.00015	0.001	0.061	1.0	8.0E+01	c	1.9E-01	1.9E-01	c	1.5E+00	1.5E+00	c	3.0E-01	3.0E-01	1.8E+00	--
Chloromethane	74-87-3	0.00024	0.001	0.060	1.0	--	c	1.8E+00	1.8E+00	c*	8.4E+00	8.4E+00	c*	1.7E+00	1.7E+00	--	--
cis-1,2-Dichloroethene	156-59-2	0.00016	0.001	0.170	1.0	7.0E+01	n	3.7E+02	3.7E+01	ns	1.0E+04	1.0E+03	n	7.8E+02	7.8E+01	--	--
cis-1,3-Dichloropropene[4]	10061-01-5	0.00025	0.001	0.140	1.0	5.0E+00	c*	4.3E-01	4.3E-01	c*	8.4E+00	8.4E+00	c*	1.7E+00	1.7E+00	--	--
Cyclohexane	110-82-7	0.00069	0.500	0.140	5.0	--	n	1.3E+04	1.3E+03	ns	3.0E+04	3.0E+03	ns	7.2E+03	7.2E+02	--	--
Dibromochloromethane	124-48-1	0.00035	0.001	0.140	1.0	6.0E+01	c	8.0E-01	8.0E-01	c	2.1E+01	2.1E+01	c	5.8E+00	5.8E+00	--	--
Dichlorodifluoromethane	75-71-8	0.00033	0.002	0.170	1.0	--	n	3.9E+02	3.9E+01	n	7.8E+02	7.8E+01	n	1.9E+02	1.9E+01	--	--
Ethylbenzene	100-41-4	0.00012	0.001	0.130	1.0	7.0E+02	c	1.5E+00	1.5E+00	c	2.9E+01	2.9E+01	c	5.7E+00	5.7E+00	9.0E+01	1.1E+00
Isopropylbenzene	98-82-8	0.00012	0.001	0.120	1.0	--	n	6.8E+02	6.8E+01	ns	1.1E+04	1.1E+03	ns	2.2E+03	2.2E+02	2.6E+00	8.6E-02
Methyl acetate	79-20-9	0.00083	0.500	0.160	5.0	--	n	3.7E+04	3.7E+03	nms	1.0E+06	1.0E+05	ns	7.8E+04	7.8E+03	--	--
methyl tert-Butyl ether	1634-04-4	0.00023	0.001	0.096	1.0	--	c	1.2E+01	1.2E+01	c	1.9E+02	1.9E+02	c	3.9E+01	3.9E+01	1.1E+04	--
Methylcyclohexane	108-87-2	0.00080	0.500	0.150	5.0	--	--	--	--	--	--	--	--	--	--	--	--

Table 6-6
Summary of Analyte Detection Limits and Reporting Limits
TCL VOCs (by EPA Method 8260)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential				
Compound	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	c/n	RBC µg/L	Adjusted RBC µg/L	c/n	RBC mg/kg	Adjusted RBC mg/kg	c/n	RBC mg/kg	Adjusted RBC mg/kg	Aqueous Fresh Water µg/L	Sediment mg/kg
Methylene chloride	75-09-2	0.00400	0.015	0.051	1.0	--	c	4.8E+00	4.8E+00	c	5.4E+01	5.4E+01	c	1.1E+01	1.1E+01	9.8E+01	--
Styrene	100-42-5	0.00022	0.001	0.110	1.0	1.0E+02	n	1.6E+03	1.6E+02	ns	3.8E+04	3.8E+03	ns	6.5E+03	6.5E+02	7.2E+01	5.6E-01
Tetrachloroethene	127-18-4	0.00044	0.002	0.150	1.0	5.0E+00	c	**1.1E-01**	**1.1E-01**	c	2.7E+00	2.7E+00	c	5.7E-01	5.7E-01	1.1E+02	4.7E-01
Toluene	108-88-3	0.00040	0.002	0.072	1.0	1.0E+03	n	2.3E+03	2.3E+02	ns	4.6E+04	4.6E+03	ns	5.0E+03	5.0E+02	2.0E+00	--
trans-1,2-Dichloroethene	156-60-5	0.00023	0.001	0.160	1.0	1.0E+02	n	1.1E+02	1.1E+01	n	5.0E+02	5.0E+01	n	1.1E+02	1.1E+01	9.7E+02	1.1E+00
trans-1,3-Dichloropropene[4]	10061-02-6	0.00083	0.003	0.160	1.0	--	c*	4.3E-01	4.3E-01	c*	8.4E+00	8.4E+00	c*	1.7E+00	1.7E+00	--	--
Trichloroethene	79-01-6	0.00056	0.002	0.170	1.0	5.0E+00	c	1.7E+00	1.7E+00	c	1.4E+01	1.4E+01	c	2.8E+00	2.8E+00	2.1E+01	9.7E-02
Trichlorofluoromethane	75-69-4	0.00021	0.002	0.180	1.0	--	n	1.3E+03	1.3E+02	ns	3.4E+03	3.4E+02	n	8.0E+02	8.0E+01	--	--
Vinyl Chloride	75-01-4	0.00046	0.020	0.170	1.0	2.0E+00	c	**1.6E-02**	**1.6E-02**	c	1.7E+00	1.7E+00	c	6.0E-02	6.0E-02	9.3E+02	--
Xylenes	1330-20-7	0.00058	0.003	0.360	3.0	1.0E+04	n	2.0E+02	2.0E+01	ns	2.6E+03	2.6E+02	ns	6.0E+02	6.0E+01	1.3E+01	--

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
VOC = Volatile Organic Compound
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL
ns = n SL may exceed Csat
nms = n SL may exceed ceiling limit and Csat

[1] = 1,2,4-Trichlorobenzene RBCs used
[2] = 1,2-Dichlorobenzene RBCs used
[3] = Bromodichloromethane RBCs used
[4] = 1,3-Dichloropropene RBCs used

bold = MDL above screening criteria

Table 6-7
Summary of Analyte Detection Limits and Reporting Limits
TCL SVOCs (by EPA Method 8270C)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential			Aqueous Fresh Water	Sediment
Compound	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	c/n	RBC µg/L	Adjusted RBC µg/L	c/n	RBC mg/kg	Adjusted RBC mg/kg	c/n	RBC mg/kg	Adjusted RBC mg/kg	µg/L	mg/kg
1,1'-Biphenyl	92-52-4	0.0009	0.02	0.015	0.5	--	n	1.8E+03	1.8E+02	ns	5.1E+04	5.1E+03	ns	3.9E+03	3.9E+02	1.4E+01	1.2E+00
1,2,4,5-Tetrachlorobenzene	95-94-3	0.0010	0.33	0.024	2.0	--	n	1.1E+01	1.1E+00	n	1.8E+02	1.8E+01	n	1.8E+01	1.8E+00	3.0E+00	1.1E+00
2,2'-oxybis(1-Chloropropane)	108-60-1	0.0011	0.02	0.047	0.5	--	c	3.2E-01	3.2E-01	c	1.7E+01	1.7E+01	c	3.5E+00	3.5E+00	--	--
2,4,5-Trichlorophenol	95-95-4	0.0033	0.02	0.110	0.5	--	n	3.7E+03	3.7E+02	n	6.2E+04	6.2E+03	n	6.1E+03	6.1E+02	--	--
2,4,6-Trichlorophenol	88-06-2	0.0013	0.02	0.027	0.5	--	c**/n	6.1E+00	3.7E+00	c**/n	1.6E+02	6.2E+01	c**/n	4.4E+01	6.1E+00	4.9E+00	2.1E-01
2,4-Dichlorophenol	120-83-2	0.0022	0.03	0.015	0.5	--	n	1.1E+02	1.1E+01	n	1.8E+03	1.8E+02	n	1.8E+02	1.8E+01	1.1E+01	1.2E-01
2,4-Dimethylphenol	105-67-9	0.0057	0.03	0.330	1.0	--	n	7.3E+02	7.3E+01	n	1.2E+04	1.2E+03	n	1.2E+03	1.2E+02	--	2.9E-02
2,4-Dinitrophenol	51-28-5	0.0330	0.17	1.500	5.0	--	n	7.3E+01	7.3E+00	n	1.2E+03	1.2E+02	n	1.2E+02	1.2E+01	--	--
2,4-Dinitrotoluene	121-14-2	0.0041	0.07	0.210	1.0	--	n	7.3E+01	7.3E+00	n	1.2E+03	1.2E+02	n	1.2E+02	1.2E+01	4.4E+01	4.2E-02
2,6-Dinitrotoluene	606-20-2	0.0023	0.02	0.050	0.5	--	n	3.7E+01	3.7E+00	n	6.2E+02	6.2E+01	n	6.1E+01	6.1E+00	8.1E+01	--
2-Chloronaphthalene	91-58-7	0.0012	0.02	0.012	0.5	--	n	2.9E+03	2.9E+02	ns	8.2E+04	8.2E+03	ns	6.3E+03	6.3E+02	--	--
2-Chlorophenol	95-57-8	0.0006	0.02	0.016	0.5	--	n	1.8E+02	1.8E+01	n	5.1E+03	5.1E+02	n	3.9E+02	3.9E+01	2.4E+01	3.1E-02
2-Methylnaphthalene	91-57-6	0.0007	0.02	0.015	0.5	--	n	1.5E+02	1.5E+01	ns	4.1E+03	4.1E+02	n	3.1E+02	3.1E+01	4.7E+00	2.0E-02
2-Methylphenol	95-48-7	0.0022	0.03	0.140	0.5	--	n	1.8E+03	1.8E+02	n	3.1E+04	3.1E+03	n	3.1E+03	3.1E+02	1.3E+01	--
2-Nitroaniline	88-74-4	0.0023	0.07	0.120	1.0	--	--	--	--	--	--	--	--	--	--	--	--
2-Nitrophenol	88-75-5	0.0071	0.03	0.026	0.5	--	--	--	--	--	--	--	--	--	--	1.9E+03	--
3,3'-Dichlorobenzidine	91-94-1	0.0780	0.33	0.210	1.0	--	c	**1.5E-01**	**1.5E-01**	c	3.8E+00	3.8E+00	c	1.1E+00	1.1E+00	4.5E+00	1.3E-01
3-Nitroaniline	99-09-2	0.0110	0.03	0.130	1.0	--	c**/n	3.2E+00	1.1E+00	c**/n	8.2E+01	1.8E+01	n	1.8E+01	1.8E+00	--	--
4,6-Dinitro-2-methylphenol	534-52-1	0.0036	0.17	0.120	0.5	--	n	3.7E+00	3.7E-01	n	6.2E+01	6.2E+00	n	6.1E+00	6.1E-01	--	--
4-Bromophenyl-phenylether	101-55-3	0.0013	0.02	0.026	0.5	--	--	--	--	--	--	--	--	--	--	1.5E+00	1.2E+00
4-Chloro-3-Methylphenol	59-50-7	0.0021	0.02	0.021	0.5	--	--	--	--	--	--	--	--	--	--	--	--
4-Chloroaniline	106-47-8	0.0200	0.09	0.021	1.0	--	c	1.2E+00	1.2E+00	c*	3.2E+01	3.2E+01	c*	9.0E+00	9.0E+00	2.3E+02	--
4-Chlorophenyl-phenylether	7005-72-3	0.0005	0.02	0.016	0.5	--	--	--	--	--	--	--	--	--	--	--	--
4-Methylphenol	106-44-5	0.0013	0.03	0.160	0.5	--	n	1.8E+02	1.8E+01	n	3.1E+03	3.1E+02	n	3.1E+02	3.1E+01	5.4E+02	6.7E-01
4-Nitroaniline	100-01-6	0.0230	0.07	0.140	1.0	--	c*	3.2E+00	3.2E+00	c*	8.2E+01	8.2E+01	c**/n	2.3E+01	1.8E+01	--	--
4-Nitrophenol	100-02-7	0.0110	0.03	1.300	10.0	--	--	--	--	--	--	--	--	--	--	6.0E+01	--
Acenaphthene	83-32-9	0.0016	0.02	0.013	0.5	--	n	2.2E+03	2.2E+02	n	3.3E+04	3.3E+03	n	3.4E+03	3.4E+02	5.8E+00	6.7E-03
Acenaphthylene [1]	208-96-8	0.0010	0.02	0.012	0.5	--	n	1.1E+03	1.1E+02	n	1.7E+04	1.7E+03	n	1.7E+03	1.7E+02	--	5.9E-03
Acetophenone	98-86-2	0.0028	0.03	0.043	0.5	--	n	3.7E+03	3.7E+02	nms	1.0E+05	1.0E+04	ns	7.8E+03	7.8E+02	--	--
Anthracene	120-12-7	0.0025	0.02	0.014	0.5	--	n	1.1E+04	1.1E+03	nm	1.7E+05	1.7E+04	n	1.7E+04	1.7E+03	1.2E-02	5.7E-02
Atrazine	1912-24-9	0.0015	0.02	0.026	0.5	3.0E+00	c	2.9E-01	2.9E-01	c	7.5E+00	7.5E+00	c	2.1E+00	2.1E+00	1.8E+00	6.6E-03
Benzaldehyde	100-52-7	0.0260	0.09	0.051	0.5	--	n	3.7E+03	3.7E+02	nms	1.0E+05	1.0E+04	ns	7.8E+03	7.8E+02	--	--
Benzo(a)anthracene	56-55-3	0.0009	0.02	0.037	0.5	--	c	**2.9E-02**	**2.9E-02**	c	2.1E+00	2.1E+00	c	1.5E-01	1.5E-01	1.8E-02	1.1E-01
Benzo(a)pyrene	50-32-8	0.0012	0.02	0.023	0.5	2.0E-01	c	**2.9E-03**	**2.9E-03**	c	2.1E-01	2.1E-01	c	1.5E-02	1.5E-02	1.5E-02	1.5E-01
Benzo(b)fluoranthene	205-99-2	0.0010	0.02	0.040	0.5	--	c	**2.9E-02**	**2.9E-02**	c	2.1E+00	2.1E+00	c	1.5E-01	1.5E-01	--	--
Benzo(g,h,i)perylene [1]	191-24-2	0.0009	0.03	0.022	0.5	--	n	1.1E+03	1.1E+02	n	1.7E+04	1.7E+03	n	1.7E+03	1.7E+02	--	1.7E-01
Benzo(k)fluoranthene	207-08-9	0.0013	0.02	0.036	0.5	--	c	2.9E-01	2.9E-01	c	2.1E+01	2.1E+01	c	1.5E+00	1.5E+00	--	2.4E-01
Bis(2-chloroethoxy)methane	111-91-1	0.0008	0.02	0.016	0.5	--	n	1.1E+02	1.1E+01	n	1.8E+03	1.8E+02	n	1.8E+02	1.8E+01	--	--
Bis(2-chloroethyl)ether	111-44-4	0.0011	0.02	0.016	0.5	--	c	**1.2E-02**	**1.2E-02**	c	9.0E-01	9.0E-01	c	1.9E-01	1.9E-01	--	--
Bis(2-ethylhexyl)phthalate	117-81-7	0.0020	0.03	0.410	2.0	6.0E+00	c	4.8E+00	4.8E+00	c*	1.2E+02	1.2E+02	c*	3.5E+01	3.5E+01	1.6E+01	1.8E-01
Bis(2-chloroisopropyl) Ether	108-60-1	0.0011	0.02	0.047	0.5	7.0E+00	c	3.2E-01	3.2E-01	c	1.7E+01	1.7E+01	c	3.5E+00	3.5E+00	--	--
Butylbenzylphthalate	85-68-7	0.0010	0.03	0.029	1.0	--	c	3.5E+01	3.5E+01	c	9.1E+02	9.1E+02	c*	2.6E+02	2.6E+02	1.9E+01	1.1E+01

Table 6-7
Summary of Analyte Detection Limits and Reporting Limits
TCL SVOCs (by EPA Method 8270C)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential				
Compound	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	c/n	RBC µg/L	Adjusted RBC µg/L	c/n	RBC mg/kg	Adjusted RBC mg/kg	c/n	RBC mg/kg	Adjusted RBC mg/kg	Aqueous Fresh Water µg/L	Sediment mg/kg
Caprolactam	105-60-2	0.0230	0.09	0.140	1.0	--	n	1.8E+04	1.8E+03	nm	3.1E+05	3.1E+04	n	3.1E+04	3.1E+03	--	--
Carbazole	86-74-8	0.0005	0.02	0.018	0.5	--	--	--	--	--	--	--	--	--	--	--	--
Chrysene	218-01-9	0.0007	0.02	0.020	0.5	--	c	2.9E+00	2.9E+00	c	2.1E+02	2.1E+02	c	1.5E+01	1.5E+01	--	1.7E-01
Dibenz(a,h)anthracene	53-70-3	0.0036	0.03	0.026	0.5	--	c	**2.9E-03**	**2.9E-03**	c	2.1E-01	2.1E-01	c	1.5E-02	1.5E-02	--	3.3E-02
Dibenzofuran	132-64-9	0.0015	0.02	0.016	0.5	--	--	--	--	--	--	--	--	--	--	3.7E+00	4.2E-01
Diethylphthalate	84-66-2	0.0004	0.02	0.034	0.5	--	n	2.9E+04	2.9E+03	nm	4.9E+05	4.9E+04	n	4.9E+04	4.9E+03	2.1E+02	6.0E-01
Dimethylphthalate	131-11-3	0.0008	0.02	0.016	0.5	--	--	--	--	--	--	--	--	--	--	--	--
Di-n-butylphthalate	84-74-2	0.0024	0.02	0.380	2.0	--	n	3.7E+03	3.7E+02	n	6.2E+04	6.2E+03	n	6.1E+03	6.1E+02	1.9E+01	6.5E+00
Di-n-octylphthalate	117-84-0	0.0098	0.03	0.340	1.0	--	--	--	--	--	--	--	--	--	--	2.2E+01	--
Fluoranthene	206-44-0	0.0015	0.02	0.016	0.5	--	n	1.5E+03	1.5E+02	n	2.2E+04	2.2E+03	n	2.3E+03	2.3E+02	4.0E-02	4.2E-01
Fluorene	86-73-7	0.0016	0.02	0.011	0.5	--	n	1.5E+03	1.5E+02	n	2.2E+04	2.2E+03	n	2.3E+03	2.3E+02	3.0E+00	7.7E-02
Hexachlorobenzene	118-74-1	0.0034	0.02	0.019	0.5	1.0E+00	c	4.2E-02	4.2E-02	c	1.1E+00	1.1E+00	c	3.0E-01	3.0E-01	3.0E-04	2.0E-02
Hexachlorobutadiene	87-68-3	0.0011	0.02	0.018	0.5	--	c*	8.6E-01	8.6E-01	c*	2.2E+01	2.2E+01	c**/n	6.2E+00	6.1E+00	1.3E+00	--
Hexachlorocyclopentadiene	77-47-4	0.0025	0.02	0.130	0.5	5.0E+01	n	2.2E+02	2.2E+01	n	3.7E+03	3.7E+02	n	3.7E+02	3.7E+01	--	--
Hexachloroethane	67-72-1	0.0008	0.02	0.038	0.5	--	c**/n	4.8E+00	3.7E+00	c**/n	1.2E+02	6.2E+01	c**/n	3.5E+01	6.1E+00	1.2E+01	1.0E+00
Indeno(1,2,3-cd)pyrene	193-39-5	0.0022	0.03	0.014	0.5	--	c	2.9E-02	2.9E-02	c	2.1E+00	2.1E+00	c	1.5E-01	1.5E-01	--	1.7E-02
Isophorone	78-59-1	0.0008	0.02	0.031	0.5	--	c	7.1E+01	7.1E+01	c*	1.8E+03	1.8E+03	c*	5.1E+02	5.1E+02	--	--
Naphthalene	91-20-3	0.0019	0.02	0.023	0.5	--	c*	1.4E-01	1.4E-01	c*	2.0E+01	2.0E+01	c*	3.9E+00	3.9E+00	1.1E+00	1.8E-01
Nitrobenzene	98-95-3	0.0020	0.02	0.026	0.5	--	n	3.4E+00	3.4E-01	n	2.8E+02	2.8E+01	n	3.1E+01	3.1E+00	--	--
N-Nitrosodi-n-propylamine	621-64-7	0.0012	0.02	0.030	0.5	--	c	**9.6E-03**	**9.6E-03**	c	2.5E-01	2.5E-01	c	6.9E-02	6.9E-02	--	--
N-Nitrosodiphenylamine	86-30-6	0.0007	0.02	0.019	0.5	--	c	1.4E+01	1.4E+01	c	3.5E+02	3.5E+02	c	9.9E+01	9.9E+01	2.1E+02	2.7E+00
Pentachlorophenol	87-86-5	0.0037	0.02	0.190	1.0	1.0E+00	c	5.6E-01	5.6E-01	c	9.0E+00	9.0E+00	c	3.0E+00	3.0E+00	5.0E-01	5.0E-01
Phenanthrene [1]	85-01-8	0.0022	0.02	0.015	0.5	--	n	1.1E+03	1.1E+02	n	1.7E+04	1.7E+03	n	1.7E+03	1.7E+02	4.0E-01	2.0E-01
Phenol	108-95-2	0.0050	0.02	0.028	0.5	--	n	1.1E+04	1.1E+03	nm	1.8E+05	1.8E+04	n	1.8E+04	1.8E+03	4.0E+00	4.2E-01
Pyrene	129-00-0	0.0006	0.02	0.047	0.5	--	n	1.1E+03	1.1E+02	n	1.7E+04	1.7E+03	n	1.7E+03	1.7E+02	2.5E-02	2.0E-01

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
VOC = Volatile Organic Compound
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL
c**/n= carcinogenic where the n screening level (SL) <10x c SL; therefore, adjusted noncarcinogenic RBC value presented
ns = n SL may exceed Csat
nm = n SL may exceed ceiling
nms = n SL may exceed ceiling limit and Csat

[1] = RBC value for pyrene was used for these compounds

bold = MDL above screening criteria

Table 6-8
Summary of Analyte Detection Limits and Reporting Limits
TCL Pesticides (EPA Method 8081A)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential				
Compounds by Method 8081A	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	c/n	RBC µg/L	Adjusted RBC µg/L	c/n	RBC mg/kg	Adjusted RBC mg/kg	c/n	RBC mg/kg	Adjusted RBC mg/kg	Aqueous Fresh Water µg/L	Sediment mg/kg
4,4'-DDD	72-54-8	0.00004	0.0170	0.0019	0.01	--	c	2.8E-01	2.8E-01	c	7.2E+00	7.2E+00	c	2.0E+00	2.0E+00	1.1E-02	4.9E-03
4,4'-DDE	72-55-9	0.00004	0.0170	0.0027	0.01	--	c	2.0E-01	2.0E-01	c	5.1E+00	5.1E+00	c	1.4E+00	1.4E+00	--	3.2E-03
4,4'-DDT	50-29-3	0.00003	0.0170	0.0020	0.01	--	c*	2.0E-01	2.0E-01	c*	7.0E+00	7.0E+00	c*	1.7E+00	1.7E+00	1.0E-03	--
Aldrin	309-00-2	0.00022	0.0170	0.0079	0.02	--	c	**4.0E-03**	**4.0E-03**	c	1.0E-01	1.0E-01	c*	2.9E-02	2.9E-02	3.0E+00	2.0E-03
alpha-BHC	319-84-6	0.00002	0.0170	0.0019	0.01	--	c	1.1E-02	1.1E-02	c	2.7E-01	2.7E-01	c	7.7E-02	7.7E-02	--	6.0E-03
alpha-Chlordane[1]	5103-71-9	0.00004	0.0170	0.0021	0.01	--	c*	1.9E-01	1.9E-01	c*	6.5E+00	6.5E+00	c*	1.6E+00	1.6E+00	--	--
gamma-Chlordane[1]	5103-74-2	0.00003	0.0170	0.0021	0.01	--	c*	1.9E-01	1.9E-01	c*	6.5E+00	6.5E+00	c*	1.6E+00	1.6E+00	--	--
beta-BHC	319-85-7	0.00038	0.0170	0.0032	0.01	--	c	3.7E-02	3.7E-02	c	9.6E-01	9.6E-01	c	2.7E-01	2.7E-01	--	5.0E-03
delta-BHC[2]	319-86-8	0.00004	0.0170	0.0023	0.01	--	c	1.1E-02	1.1E-02	c	2.7E-01	2.7E-01	c	7.7E-02	7.7E-02	1.4E+02	6.4E+00
Dieldrin	60-57-1	0.00004	0.0170	0.0020	0.01	--	c	4.2E-03	4.2E-03	c	1.1E-01	1.1E-01	c	3.0E-02	3.0E-02	5.6E-02	1.9E-03
Endosulfan I[3]	959-98-8	0.00003	0.0170	0.0023	0.01	--	n	2.2E+02	2.2E+01	n	3.7E+03	3.7E+02	n	3.7E+02	3.7E+01	5.1E-02	2.9E-03
Endosulfan II[3]	33213-65-9	0.00003	0.0170	0.0018	0.01	--	n	2.2E+02	2.2E+01	n	3.7E+03	3.7E+02	n	3.7E+02	3.7E+01	5.1E-02	1.4E-02
Endosulfan sulfate[3]	1031-07-8	0.00004	0.0170	0.0033	0.01	--	n	2.2E+02	2.2E+01	n	3.7E+03	3.7E+02	n	3.7E+02	3.7E+01	--	5.4E-03
Endrin	72-20-8	0.00004	0.0170	0.0020	0.01	2.0E+00	n	1.1E+01	1.1E+00	n	1.8E+02	1.8E+01	n	1.8E+01	1.8E+00	3.6E-02	2.2E-03
Endrin aldehyde[4]	7421-93-4	0.00012	0.0170	0.0029	0.01	--	n	1.1E+01	1.1E+00	n	1.8E+02	1.8E+01	n	1.8E+01	1.8E+00	--	--
Endrin ketone[4]	53494-70-5	0.00004	0.0170	0.0033	0.01	--	n	1.1E+01	1.1E+00	n	1.8E+02	1.8E+01	n	1.8E+01	1.8E+00	--	--
gamma-BHC (Lindane)	58-89-9	0.00003	0.0170	0.0018	0.01	2.0E-01	c	6.1E-02	6.1E-02	c	2.1E+00	2.1E+00	c*	5.2E-01	5.2E-01	--	--
Heptachlor	76-44-8	0.00034	0.0170	0.0030	0.01	4.0E-01	c	1.5E-02	1.5E-02	c	3.8E-01	3.8E-01	c	1.1E-01	1.1E-01	3.8E-03	6.8E-02
Heptachlor epoxide	1024-57-3	0.00005	0.0170	0.0021	0.01	2.0E-01	c*	7.4E-03	7.4E-03	c*	1.9E-01	1.9E-01	c*	5.3E-02	5.3E-02	3.8E-03	2.5E-03
Methoxychlor	72-43-5	0.00007	0.0170	0.0052	0.02	4.0E+01	n	1.8E+02	1.8E+01	n	3.1E+03	3.1E+02	n	3.1E+02	3.1E+01	1.9E-02	1.9E-02
Toxaphene	8001-35-2	0.02200	0.1700	0.0670	0.30	3.0E+00	c	**6.1E-02**	**6.1E-02**	c	1.6E+00	1.6E+00	c	4.4E-01	4.4E-01	2.0E-04	1.0E-03

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL

[1] = Chlordane RBC value was used
[2] = alpha-BHC RBC value was used
[3] = Endosulfan RBC value was used
[4] = Endrin RBC value was used

bold = MDL above screening criteria

Table 6-9
Summary of Detection Limits and Reporting Limits
TCL PCBs (EPA Method 8082)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential			Aqueous Fresh Water	Sediment
Compound	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	C/N	RBC µg/L	Adjusted RBC µg/L	C/N	RBC mg/kg	Adjusted RBC mg/kg	C/N	RBC mg/kg	Adjusted RBC mg/kg	µg/L	mg/kg
Aroclor 1016	12674-11-2	0.0070	0.330	0.023	0.2	0.5	c**/n	9.6E-01	2.6E-01	c**/n	2.1E+01	3.7E+00	n	3.9E+00	3.9E-01	7.4E-05	--
Aroclor 1221	11104-28-2	0.0110	0.330	0.081	0.2	0.5	c	6.8E-03	6.8E-03	c	6.2E-01	6.2E-01	c	1.7E-01	1.7E-01	7.4E-05	--
Aroclor 1232	11141-16-5	0.0110	0.330	0.028	0.2	0.5	c	6.8E-03	6.8E-03	c	6.2E-01	6.2E-01	c	1.7E-01	1.7E-01	7.4E-05	--
Aroclor 1242	53469-21-9	0.0053	0.330	0.024	0.2	0.5	c	3.4E-02	3.4E-02	c	7.4E-01	7.4E-01	c	2.2E-01	2.2E-01	7.4E-05	--
Aroclor 1248	12672-29-6	0.0140	0.330	0.03	0.2	0.5	c	3.4E-02	3.4E-02	c	7.4E-01	7.4E-01	c	2.2E-01	2.2E-01	7.4E-05	--
Aroclor 1254	11097-69-1	0.0078	0.330	0.023	0.2	0.5	c*	3.4E-02	3.4E-02	c*	7.4E-01	7.4E-01	c**/n	2.2E-01	1.1E-01	7.4E-05	--
Aroclor 1260	11096-82-5	0.0056	0.330	0.02	0.2	0.5	c	3.4E-02	3.4E-02	c	7.4E-01	7.4E-01	c	2.2E-01	2.2E-01	7.4E-05	--
Aroclor 1262	37324-23-5	0.0057	0.330	0.045	0.2	0.5	--	--	--	--	--	--	--	--	--	--	--
Aroclor 1268	11100-14-4	0.0081	0.330	0.035	0.2	0.5	--	--	--	--	--	--	--	--	--	--	--

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits for PCBs Provided by TriMatrix
Method Detection and Reporting Limits for Perchlorate Provided by CAS Lab
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006

RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL
c**/n= carcinogenic where the n screening level (SL) <10x c SL; therefore, adjusted noncarcinogenic RBC value presented
bold = MDL above screening criteria

Table 6-10
Summary of Analyte Detection Limits and Reporting Limits
Explosives (EPA Methods 8330, 8330M, 8332)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels	
		Soil		Water			Tap Water			Soil Industrial			Soil Residential			Aqueous Fresh Water	Sediment
Compound by Method 8330	CAS Number	MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	MCL µg/L	C/N	RBC µg/L	Adjusted RBC µg/L	C/N	RBC mg/kg	Adjusted RBC mg/kg	C/N	RBC mg/kg	Adjusted RBC mg/kg	µg/L	mg/kg
1,3,5-Trinitrobenzene	99-35-4	0.074	2.5	0.045	5.0	--	n	1.1E+03	1.1E+02	n	2.7E+04	2.7E+03	n	2.2E+03	2.2E+02	--	--
1,3-Dinitrobenzene	99-65-0	0.076	2.5	0.071	5.0	--	n	3.7E+00	3.7E-01	n	6.2E+01	6.2E+00	n	6.1E+00	6.1E-01	--	--
2,4,6-Trinitrotoluene	118-96-7	0.15	2.5	0.1	5.0	--	c**/n	2.2E+00	1.8E+00	c**/n	7.9E+01	4.2E+01	c**/n	1.9E+01	3.6E+00	1.0E+02	9.2E-02
2,4-Dinitrotoluene	121-14-2	0.1	2.5	0.092	5.0	--	n	7.3E+01	7.3E+00	n	1.2E+03	1.2E+02	n	1.2E+02	1.2E+01	4.4E+01	4.2E-02
2,6-Dinitrotoluene	606-20-2	0.2	2.5	0.16	5.0	--	n	3.7E+01	3.7E+00	n	6.2E+02	6.2E+01	n	6.1E+01	6.1E+00	8.1E+01	--
2-Amino-4,6-dinitrotoluene	35572-78-2	0.22	2.5	0.24	5.0	--	n	7.3E+01	7.3E+00	n	2.0E+03	2.0E+02	n	1.5E+02	1.5E+01	1.5E+03	--
2-Nitrotoluene	88-72-2	0.17	2.5	0.28	5.0	--	c	3.1E-01	3.1E-01	c*	1.3E+01	1.3E+01	c*	2.9E+00	2.9E+00	--	--
3-Nitrotoluene	99-08-1	0.21	2.5	0.17	5.0	--	n	7.3E+02	7.3E+01	n	1.2E+04	1.2E+03	n	1.2E+03	1.2E+02	7.5E+02	--
4-Amino-2,6-dinitrotoluene	19406-51-0	0.3	2.5	0.22	5.0	--	n	7.3E+01	7.3E+00	n	1.9E+03	1.9E+02	n	1.5E+02	1.5E+01	--	--
4-Nitrotoluene	99-99-0	0.2	2.5	0.49	5.0	--	c*	4.2E+00	4.2E+00	c*	1.1E+02	1.1E+02	c**/n	3.0E+01	2.4E+01	1.9E+03	4.1E+00
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	2691-41-0	0.066	2.5	0.2	5.0	--	n	1.8E+03	1.8E+02	n	4.9E+04	4.9E+03	n	3.8E+03	3.8E+02	1.5E+02	--
Nitrobenzene	98-95-3	0.03	2.5	0.15	5.0	--	n	3.4E+00	3.4E-01	n	2.8E+02	2.8E+01	n	3.1E+01	3.1E+00	--	--
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	121-82-4	0.048	2.5	0.092	5.0	--	c	6.1E-01	6.1E-01	c	2.4E+01	2.4E+01	c*	5.5E+00	5.5E+00	3.6E+02	1.3E-02
Tetryl (Methyl-2,4,6-trinitrophenylnitramine)	479-45-8	0.065	2.5	0.15	5.0	--	n	1.5E+02	1.5E+01	n	2.5E+03	2.5E+02	n	2.4E+02	2.4E+01	--	--
Compound by Method 8330M																	
PETN	78-11-5	0.23	5.0	0.61	10.0	--	--	--	--	--	--	--	--	--	--	8.5E+04	--
Compound by Method 8332																	
Nitroglycerin	55-63-0	0.39	5.0	0.58	5.0	--	n	3.7E+00	**3.7E-01**	n	6.2E+01	6.2E+00	n	6.1E+00	6.1E-01	1.4E+02	--

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
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BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL
c**/n= carcinogenic where the n screening level (SL) <10x c SL; therefore, adjusted noncarcinogenic RBC value presented

bold = MDL above screening criteria

Table 6-11
Summary of Detection Limits and Reporting Limits
TAL Metals (EPA Methods 6010, 6020, 7470A, 7471A, 9012A)
Soil and Water Samples
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

		Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III BTAG Screening Levels		
		Soil		Water			Tap Water			Soil Industrial			Soil Residential			Aqueous Fresh Water	Soil	Sediment
Compound	CAS Number	MDL	Reporting Limit	MDL	Reporting Limit	MCL	C/N	RBC	Adjusted RBC	C/N	RBC	Adjusted RBC	C/N	RBC	Adjusted RBC			
		mg/kg	mg/kg	µg/L	µg/L	µg/L		µg/L	µg/L		mg/kg	mg/kg		mg/kg	mg/kg	µg/L	mg/kg	mg/kg
Aluminum	7429-90-5	2	10	20	50	--	n	3.7E+04	3.7E+03	nm	9.9E+05	9.9E+04	n	7.7E+04	7.7E+03	8.7E+01	1.0E+00	--
Antimony	7440-36-0	0.026	0.2	0.32	2	6.0E+00	n	1.5E+01	1.5E+00	n	4.1E+02	4.1E+01	n	3.1E+01	3.1E+00	3.0E+01	4.8E-01	2.0E+00
Arsenic	7440-38-2	0.026	0.5	0.24	5	1.0E+01	c	**4.5E-02**	**4.5E-02**	c	1.6E+00	1.6E+00	c*	3.9E-01	3.9E-01	5.0E+00	3.3E+02	9.8E+00
Barium	7440-39-3	0.33	1	2.1	10	2.0E+03	n	7.3E+03	7.3E+02	nm	1.9E+05	1.9E+04	n	1.5E+04	1.5E+03	4.0E+00	4.4E+02	--
Beryllium	7440-41-7	0.061	0.1	0.48	1	4.0E+00	n	7.3E+01	7.3E+00	n	2.0E+03	2.0E+02	n	1.6E+02	1.6E+01	6.6E-01	2.0E-02	--
Cadmium	7440-43-9	0.45	1	3	20	5.0E+00	n	1.8E+01	**1.5E+00**	n	8.1E+02	8.1E+01	n	7.0E+01	7.0E+00	2.5E-01	2.5E+00	9.9E-01
Chromium[1]	7440-47-3	0.8	5	9.1	50	1.0E+02	n	5.5E+04	5.5E+03	c	1.4E+03	1.4E+03	c	2.8E+02	2.8E+02	8.5E+01	7.5E-03	4.3E+01
Cobalt	7440-48-4	0.53	2	4.3	20	--	n	1.1E+01	**1.1E+00**	n	3.0E+02	3.0E+01	n	2.3E+01	2.3E+00	2.3E+01	1.0E+02	5.0E+01
Copper	7440-50-8	0.027	0.2	0.29	1	1.3E+03	n	1.5E+03	1.5E+02	n	4.1E+04	4.1E+03	n	3.1E+03	3.1E+02	9.0E+00	1.5E+01	3.2E+01
Cyanide	57-12-5	0.0667	0.1	2.3	10	2.0E+02	n	7.3E+02	7.3E+01	n	2.0E+04	2.0E+03	n	1.6E+03	1.6E+02	5.0E+00	5.0E-03	1.0E-01
Iron	7439-89-6	0.98	5	9.6	20	--	n	2.6E+04	2.6E+03	nm	7.2E+05	7.2E+04	n	5.5E+04	5.5E+03	3.0E+02	1.2E+01	2.0E+04
Lead[2]	7439-92-1	0.024	0.1	0.29	1	1.5E+01	n	1.5E+01	1.5E+01	n	8.0E+02	8.0E+02	n	4.0E+02	4.0E+02	2.5E+00	1.0E-02	3.6E+01
Manganese	7439-96-5	0.18	1	3.1	10	--	n	8.8E+02	8.8E+01	n	2.3E+04	2.3E+03	n	1.8E+03	1.8E+02	1.2E+02	3.3E+02	4.6E+02
Mercury	7439-97-6	0.0093	0.05	0.046	0.2	2.0E+00	n	6.3E-01	6.3E-02	ns	2.8E+01	2.8E+00	ns	6.7E+00	6.7E-01	1.0E-01	5.8E-02	1.8E-01
Nickel	7440-02-0	0.035	0.2	0.35	1	--	n	7.3E+02	7.3E+01	n	2.0E+04	2.0E+03	n	1.6E+03	1.6E+02	5.2E+01	2.0E+00	2.3E+01
Selenium	7782-49-2	0.028	0.5	0.3	5	5.0E+01	n	1.8E+02	1.8E+01	n	5.1E+03	5.1E+02	n	3.9E+02	3.9E+01	1.0E+00	1.8E+00	2.0E+00
Silver	7440-22-4	0.0093	0.1	0.061	0.5	--	n	1.8E+02	1.8E+01	n	5.1E+03	5.1E+02	n	3.9E+02	3.9E+01	3.2E+00	9.8E-06	1.0E+00
Thallium	7440-28-0	0.0068	0.1	0.05	0.2	2.0E+00	n	2.4E+00	2.4E-01	n	6.6E+01	6.6E+00	n	5.1E+00	5.1E-01	8.0E-01	1.0E-03	--
Vanadium	7440-62-2	0.032	0.1	0.27	1	--	n	2.6E+02	2.6E+01	n	7.2E+03	7.2E+02	n	5.5E+02	5.5E+01	2.0E+01	5.0E-01	--
Zinc	7440-66-6	0.49	5	7.6	10	--	n	1.1E+04	1.1E+03	nm	3.1E+05	3.1E+04	n	2.3E+04	2.3E+03	1.2E+02	1.0E+01	1.2E+02

Notes:

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TAL = Target Analyte List
MDL = Method Detection Limit
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RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL
ns = n SL may exceed Csat
nms = n SL may exceed ceiling limit

bold = MDL above screening criteria

[1] = Chromium III Tap Water RBC used
[2] = Lead criteria are Action Levels; see USEPA Region III guidance

Table 6-12
Summary of Detection Limits, Reporting Limits, and Risk Screening Criteria
for TCL Dioxin/Furans (EPA Method 8290)
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations									USEPA Region III Draft BTAG Screening Levels	
		Soil		Water													
		MDL pg/g	Reporting Limit pg/g	MDL ng/L	Reporting Limit ng/L	ng/L	C/N	Tap Water RBC ng/L	Adjusted Tap Water RBC ng/L	C/N	Soil RBC (Industrial) pg/g	Adjusted Soil RBC (Industrial) pg/g	C/N	Soil RBC (Residential) pg/g	Adjusted Soil RBC (Residential) pg/g	Aquatic Fresh Water ng/L	Sediment mg/kg
2,3,7,8-TCDD	1746-01-6	0.119	1	0.00086	0.01	3.00E+01	c*	5.2E-01	5.2E-01	c*	1.8E+01	1.8E+01	c*	4.5E+00	4.5E+00	3.1E-06	--
1,2,3,7,8-PeCDD	40321-76-4	0.278	5	0.00252	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,7,8-HxCDD	39227-28-6	0.422	5	0.00722	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,6,7,8-HxCDD	57653-85-7	0.413	5	0.0034	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,7,8,9-HxCDD	19408-74-3	0.265	5	0.0039	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,6,7,8-HpCDD	35822-39-4	0.413	5	0.0058	0.05	--	--	--	--	--	--	--	--	--	--	--	--
OCDD	3268-87-9	0.91	10	0.00645	0.1	--	c	1.7E+03	1.7E+03	c	6.1E+04	6.1E+04	c	1.5E+04	1.5E+04	--	--
2,3,7,8-TCDF	51207-31-9	0.103	1	0.00150	0.01	--	c	5.2E+00	5.2E+00	c	1.3E+02	1.3E+02	c	3.7E+01	3.7E+01	--	--
1,2,3,7,8-PeCDF	57117-41-6	0.319	5	0.00296	0.05	--	c	1.7E+01	1.7E+01	c	4.4E+02	4.4E+02	c	1.2E+02	1.2E+02	--	--
2,3,4,7,8-PeCDF	57117-31-4	0.318	5	0.00697	0.05	--	c	1.7E+00	1.7E+00	c	4.4E+01	4.4E+01	c	1.2E+01	1.2E+01	--	--
1,2,3,4,7,8-HxCDF	70648-26-9	0.481	5	0.00548	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,6,7,8-HxCDF	57117-44-9	0.138	5	0.00478	0.05	--	--	--	--	--	--	--	--	--	--	--	--
2,3,4,6,7,8-HxCDF	60851-34-5	0.308	5	0.00426	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,7,8,9-HxCDF	72918-21-9	0.299	5	0.00586	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.563	5	0.00234	0.05	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.562	5	0.00411	0.05	--	--	--	--	--	--	--	--	--	--	--	--
OCDF	39001-02-0	0.709	10	0.00640	0.1	--	c	1.7E+03	1.7E+03	c	4.4E+04	4.4E+04	c	1.2E+04	1.2E+04	--	--

Notes:

CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by SGS
pg/g = Picogram Per Gram
ng/L = Nanogram Per Liter
USEPA = U.S. Environmental Protection Agency
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

-- = No Risk Criteria Available
c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL

bold = MDL above screening criteria

Table 6-13
Summary of Detection Limits, Reporting Limits, and Risk Screening Criteria
for Asbestos (CARB 453 and EPA Method 100.2)
MWP Addendum 028 - SSP at SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels	
		Soil		Water											
		MDL	Reporting Limit	MDL	Reporting Limit			Tap Water RBC	Adjusted Tap Water RBC		EPA Soil Action Level		EPA Soil Action Level	Aquatic Fresh Water	Sediment
		% by W	% by W	MFL	MFL	MFL	C/N	MFL	MFL	C/N	% by W	C/N	% by W	MFL	% by W
Asbestos	Varies	0.25	0.25	0.2	0.2	7.00E+00	--	--	--	--	1.0E+00	--	1.0E+00	--	--

Notes:

CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by Trimatrix
MFL = million fibers per liter
USEPA = U.S. Environmental Protection Agency
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2006
Sediment - BTAG Sediment Screening Values, 2006
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from October 2008 Regional Screening Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

-- = No Risk Criteria Available
c/n = Carcinogenic/Noncarcinogenic status per EPA RBC Table (October 2008)
c = Carcinogenic
n = Non-Carcinogenic
c*= carcinogenic where the n screening level (SL) <100x c SL

bold = MDL above screening criteria

Table 6-14
Field Quality Control Samples

Control	Purpose of Sample	Collection Frequency
Field Duplicate	Ensure precision in sample homogeneity during collection and analysis	10% of field samples per matrix
Rinse Blank	Ensure the decontamination of sampling equipment has been adequately performed; to assess cross contamination and/or incidental contamination to the sample container	1 per 20 samples per matrix per sample technique
Temperature Blank	Verify sample cooler temperature during transport	1 temperature blank per cooler
Trip Blank	Assess if cross contamination occurs during shipment or storage with aqueous VOC samples	1 trip blank per cooler containing aqueous VOC samples

Table 6-15
Field Quality Control Elements Acceptance Criteria

Item	DQO	Parameter	Frequency of Association	Criteria Goal
Field Duplicate	P	Metals	1 per 10 samples	RPD ≤ 20% Aqueous; difference ± RL* RPD ≤ 35% Solid; difference ± 2xRL*
		Organics	1 per 10 samples	RPD ≤ 40% Aqueous; difference ± RL* RPD ≤ 60% Solid; difference ± 2xRL*
Trip Blank	A,R	VOCs in water	1 per cooler with aqueous VOCs	No target analytes detected greater than the RL
Rinse Blank	A,R	Entire	1 per 20 samples per matrix per equipment type	No target analytes detected greater than the RL
Chain of Custody Forms	R	Entire	Every sample	Filled out correctly to include signatures; no missing or incorrect information.
Representative Sampling Forms	R	Entire	Every sample	Filled out correctly to include signatures; no missing or incorrect information.
Field Logbook	R	Entire	Every sample	Filled out correctly to include analytical parameters; map file data; and applicable coding information.
Field Instrument Calibration Logs	A	Entire	Every measurement	Measurements must have associated calibration reference

Legend: A = Accuracy C = Comparability R = Representativeness P = Precision

*The difference will be evaluated when either of the field duplicate results is less than the reporting limit.

Table 6-16
Analytical Quality Control Elements of a Quality Assurance Program

Item	DQO	Parameter	Frequency of Association	Criteria Requirement
Analytical Method	C	Entire	Each analysis	Method analyses based on USEPA methods as defined in Section 2.5
Chemical Data Packages	C	Entire	Each lot/batch	Pass peer review and formal QA/QC check.
Laboratory Chain of Custody	R	Entire	Each lot/batch	Custody of sample within laboratory fully accounted for and documented
Laboratory System Controls	A,C,P, R	Entire	During laboratory operations	No deficiencies
Holding Time	A,C,P, R	Entire	Each analysis	No deficiencies (USEPA Region III Modifications)
Method Blanks	A,R	Entire	Each lot/batch	No target analyte detected in the method blanks greater than RL
Laboratory Control Spike	A	Entire	Each lot/batch	Must meet criteria as defined in Tables 6-17 through 6-25
Matrix Spikes and Duplicates	A,P	Entire	Each lot/batch	Must meet criteria as defined in Tables 6-17 through 6-25
Surrogates	A	Entire	Organic fractions, including QC samples	Must meet criteria as defined in Tables 6-17 through 6-25
Serial dilution	A	Metals	Inorganic Fractions, Each lot/batch	Must meet criteria as defined in Table 6-20

Legend: A = Accuracy C = Comparability R = Representativeness P = Precision

Table 6-17
Quality Control Method Criteria for Volatile Organic Compounds by USEPA SW-846 Method 8260B

Procedure	Frequency	Acceptance Criteria		Corrective Action
Initial Calibration 5-pt curve (linear) 6-pt curve (2^o order)	Set-up, major maintenance, or for drift correction	RRF > 0.10/0.30 for SPCCs RSD ≤ 30% for CCCs response factors RSD for analytes ≤ 15% or r>0.995 (linear) or r^2>0.99 (2^o order)		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Initial Calibration Verification	Immediately following initial calibration	A second source full compliment target list with a percent recovery = 75-125%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Every 12 hours	RRF > 0.10/0.30 for SPCCs %Difference for RF of CCCs ±30% from initial calibration. Mean for analytes ≤ 20% as no individual target exceeds 40%D		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Method Blank	Every day/batch.	No target analytes greater than one half of the RL		Document source of contamination. Re-analysis is required for positive results associated with blank contamination.
Tuning BFB	Prior to calibration and every 12 hours	Must meet tuning criteria		Re-tune, re-calibrate, and re-analyze affected sample analyses.
Laboratory Control Spike	Every batch	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Internal Standards	Every sample	Recommended Standards fluorobenzene chlorobenzene-d_5 1,4-dichlorobenzene-d_4	Retention time ±30 seconds of mid point of initial calibration Area changes within a factor of two (-50% to +100%)	Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples associated with standards outside criteria. A third analytical run may be required at a dilution.
Surrogate	Every sample	Recommended Standards Toluene-d_8 4-Bromofluorobenzene 1,2-Dichloroethane-d_4 Dibromofluoromethane	Laboratory generated control limits not to exceed those listed in the current version of the DOD QSM	If surrogate compounds do not meet criteria, there should be a re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 per matrix	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 6-18
Quality Control Method Criteria for Semi-volatile Organic Compounds by USEPA SW-846 Method 8270C

Procedure	Frequency	Acceptance Criteria		Corrective Action
Initial calibration 5-pt curve (linear) 6-pt curve (2^o order)	Set-up, major maintenance, or for drift correction	RRF > 0.05 for SPCCs RSD ≤30% for CCC compounds RSD for target analytes ≤ 15% or r>0.995 (linear) or r^2>0.99 (2^o order)		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment target list with a percent recovery = 80-120%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	12 hours	RRF > 0.05 for SPCCs %Difference for RF of CCCs ±30% from initial calibration Mean for analytes ≤ 20% as no individual target exceeds 40%D		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Tuning DFTPP	12 hours	Must meet tuning criteria.		Re-tune, re-calibrate, and re-analyze affected sample analyses.
Method Blank	Per extraction batch	No target analytes greater than one half of the RL		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	Every batch	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DoD QSM	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Internal Standards	Every sample	Recommended Standards phenanthrene-d10 chrysene-d12 perylene-d12 1,4-dichlorobenzene-d4 naphthalene-d8 acenaphthalene-d10	Retention time ±30 seconds of mid point of initial calibration Area changes within a factor of two (-50% to +100%)	Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples associated with standards outside criteria. A third analytical run may be required at a dilution.
Surrogate Spikes	Every sample	Recommended Standards nitrobenzene-d_5 2-fluorobiphenyl p-terphenyl-d14 phenol-d5 2,4,6-tribromophenol 2-fluorophenol	Laboratory generated control limits not to exceed limits listed in the current version of the DoD QSM	If two base/neutral or acid surrogates are out of specification, or if one base/neutral or acid extractable surrogate has a recovery of less than 10%, then there should be a re-extraction and re-analysis to confirm that the non-compliance is due to sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 samples per matrix	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DoD QSM	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 6-19
Quality Control Method Criteria for Explosives by USEPA SW-846 Methods 8330 and 8332

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Initial Calibration Curve 5-pt curve (linear) 6-pt curve (2o order)	Set-up, major maintenance, or for drift correction for each column used for analysis	%RSD <20% or r>0.995 (linear) or r2>0.99 (2o order)		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment of target list with a percent recovery = 80-120%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Every ten samples or twelve hours	%D ± 15% of the response factor from the initial curve. The mean may be used as long as no individual target exceeds 30%D		Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria.
Method Blank	1 per batch	No target analytes detected greater than one half of the RL		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	1 per batch	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Surrogate Spikes	Every sample	<u>Standards</u> A similar compound that is not expected to be found at the site	Laboratory generated control limits not to exceed limits listed in the current version of the DOD QSM	If surrogate compounds do not meet criteria, there should be a re-extraction and re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 samples per matrix	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.
Target Analyte Confirmation	Every positive detection	RPD $\leq$ 40%		Report the higher of the two concentrations unless a positive bias is apparent and qualify.

Table 6-20
Quality Control Method Criteria for Target Analyte List Metals by USEPA SW-846 Methods 6020/ 6010B/7471A/ 7470A/ 9012A

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Tune (MS)	Daily	Analyzed a minimum of four times with RSD < 5% for analytes in the solution.		Sample analysis cannot begin until this criterion is met.
Mass Calibration (MS)	Daily	Difference < 0.1 amu from true value.		Adjust to the correct value.
Resolution Check (MS)	Daily	Peak width <0.9 amu at 10% peak height		Sample analysis cannot begin until this criterion is met.
Initial Calibration Curve (MS, ICP, Hg, & CN)	Daily, major maintenance, or to correct drift.	MS & ICP Option 1: 1-standard and a blank with a low level standard at RL.	Low level check standard ± 20%.	The standards for that element must be re-prepared and re-analyzed again.
		MS & ICP Option 2: 3-standards and a blank	r > 0.995 for each element	
		Hg – 5-standards and a blank	r > 0.995	
		CN – 6 standards and a blank	r > 0.995	
Distilled Standards (CN)	Once per calibration	One high and one low distilled standard within ± 10% of the true value		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification (MS, ICP, Hg, & CN)	Immediately following initial calibration.	MS & ICP - A second source full compliment of target list with a percent recovery = 90-110%		Sample analysis cannot begin until this criterion is met.
		Hg – A second source full compliment of target list with a percent recovery = 80-120%		
		CN - A second source full compliment of target list with a percent recovery = 85-115%		
Initial Calibration Blank (MS, ICP, Hg, & CN)	Immediately following initial calibration verification.	No target analytes detected at concentration above 2 X MDL.		Sample analysis cannot proceed until this criterion is met.
Interference Check (MS & ICP)	Beginning of each sample analytical run.	Recovery ±20% of true value.		Terminate the analysis, correct the problem, re-calibrate, re-verify the calibration, and reanalyze associated samples.
Continuing Calibration Check (MS, ICP, Hg, & CN)	Every 10 samples and end of analytical run.	MS & ICP - Recovery ±10%.		Reanalyze; if the CCV fails again, stop analysis, the problem corrected, the instrument recalibrated, and the calibration re-verified prior to continuing sample analyses.
		Hg - Recovery ±20%.		
		CN - Recovery ±15%.		
Continuing Calibration Blank (MS, ICP, Hg, & CN)	Every 10 samples and end of analytical run.	No target analytes detected at concentration above 2 X MDL.		Sample sequence should not continue until this criterion is met. Demonstrate "clean". Affected samples will be reanalyzed.
Preparation Blank (MS, ICP, Hg, & CN)	1 per batch per matrix	No target analytes detected at concentration above one half of the RL.		Document source of contamination. Re-digestion/re-analysis is required for positive results associated with blank contamination, unless DQOs are still met.

Table 6-20 (Continued)
Quality Control Method Criteria for Target Analyte List Metals by USEPA SW-846 Methods 6020/ 6010B/7471A/ 7470A/ 9012A

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Laboratory Control Sample (MS, ICP, Hg, & CN)	1 per batch per matrix	Standards Full compliment target list.	80-120% recovery Soil use generated limits	Recoveries indicating a low bias require a redigestion/ reanalysis. Recoveries indicating a high bias require a redigestion/ reanalysis for associated positive field samples. Qualify data biased high or biased low as appropriate.
Matrix Spike and Duplicate or Sample Duplicate (MS, ICP, Hg, & CN)	1 per 20 samples per matrix	Standards Full compliment target list.	75-125% recovery; ICP & Hg: RPD≤25%; CN: RPD≤20%; MS: [analyte]>100xIDL -RPD≤20%; Soil use generated limits	Qualify associated data biased high or biased low as appropriate.
Post Digestion Spike (PDS) (MS & ICP)	1 per 20 samples per matrix	Standards Full compliment target list.	75-125% recovery	
Serial Dilution (MS & ICP)	1 per 20 samples per matrix	Used to assess new matrices	For sample results > 5x RL for ICP or > 20x RL for MS, %D between diluted and undiluted sample result ≤10%.	Chemical or physical interference indicated. Investigate to identify cause.
Internal Standards (MS)	Every Analytical Sequence	Standards & Blanks	80-120% of initial calibration intensity	Terminate the analysis, correct the problem, re-calibrate, re-verify the calibration, and reanalyze associated samples.
		Samples	30-120% of initial calibration intensity	Reanalyze at consecutive five fold dilutions until criteria is met.

Table 6-21
Quality Control Method Criteria for Pesticides, Herbicides, and PCBs by USEPA SW-846 Methods 8081A, 8082, and 8151A

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Initial calibration curve 5-pt curve (linear) 6-pt curve (2o order)	Set-up, major maintenance	%RSD<20% or r>0.995 (linear) or r2>0.99 (2o order)		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment of target list with a percent recovery = 85-115%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Bracketing samples	%D recovery ± 15% of the response factor from the initial curve or mean with no individual peak >30%		Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria.
Endrin/4,4-DDT Breakdown	Bracketing samples	endrin degradation ≤15%. 4,4-DDT degradation ≤15%.		If criterion is not met, system must be deactivated and the affected samples reanalyzed.
Instrument Blank	After continuing calibration and highly contaminated samples.	No target analytes detected greater than one half the RL.		Demonstrate "clean". Affected samples will be reanalyzed.
Method Blank	Per extraction batch	No target analytes detected greater than one half the RL.		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	Per extraction batch	<u>Standards</u> Full target list for 8081A and a mix of 1016 & 1260 for 8082	Laboratory generated control limits not to exceed limits listed in the current version of DOD QSM	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Surrogate Spikes	Every sample	<u>Standards</u> TCMX and DCB	Laboratory generated control limits not to exceed limits listed in the current version of DOD QSM	Investigate to assess cause, correct the problem, and document actions taken; re-extract and re-analyze sample. Specific method cleanups may be used to eliminate or minimize sample matrix effects. If still out, qualify.

Table 6-21 (Continued)
Quality Control Method Criteria for Pesticides, Herbicides, and PCBs by USEPA SW-846 Methods 8081A, 8082, and 8151A

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Matrix Spike and Duplicate	1 per 20 samples per matrix	Standards Full target list for 8081A and a mix of 1016 & 1260 for 8082	Laboratory generated control limits not to exceed limits listed in the current version of DOD QSM	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. Specific method cleanups may be used to eliminate or minimize sample matrix effects.
Target Analyte Confirmation	Every positive detection	RPD $\leq$ 40%		Report the higher of the two concentrations unless a positive bias is apparent and qualify.

Table 6-22
Quality Control Method Criteria for Asbestos by CARB Method 435 and USEPA Method 100.2

Procedure	Frequency of QC Procedure	Acceptance Criteria	Corrective Action
Alignment Check	Daily	Equipment in alignment	Realign equipment before analysis of samples.
Camera Check	Weekly	95%	Repair camera before analysis of samples
Method Blank	1 per prep series or 10%	<0.01 MFL > 10 µm	Re-prep and analyze whole batch after source of contamination is found and eliminated.
Duplicate Count	One per 100 or more samples	2X Poisson Standard Deviation	If duplicate results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.
Replicate Count	One per 100 or more samples	1.5X Poisson Standard Deviation	If replicate results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 6-23
Quality Control Method Criteria for Total Organic Carbon by Walkley-Black Method (Argonomy, Methods of Soil Analysis 29-3.5.2)

Procedure	Frequency of QC Procedure	Acceptance Criteria	Corrective Action
Calibration (Titration Method)	Before Processing Samples a titration blank must be analyzed	0.5+/- 0.05N	If the titrant normality is not within the QC limit, clean the burette and remake the titrant solution and/or the 1N K2Cr2O7.
Laboratory Duplicate	1 per 20 samples or batch per matrix	RPD = 20%	If the RPD is out side the QC limit, it should be noted in the lab narrative.
Method Blank	1 per 20 samples or batch per matrix	No target analytes detected greater than the RL.	Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Sample	1 per 20 samples per matrix	Laboratory generated control limits not to exceed recovery limits of 64-128%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Matrix Spike and Duplicate	1 per 20 samples per batch, per matrix	Laboratory generated control limits not to exceed recovery limits of 68-142%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 6-24
Quality Control Method Criteria for Chemical Oxygen Demand by USEPA Method of Chemical Analysis for Water and Wastes Method 410.4

Procedure	Frequency of QC Procedure	Acceptance Criteria	Corrective Action
Initial calibration curve 5-pt curve	Major maintenance, instrument modification, per manufacturer's specifications	r>0.995 (linear) or r>0.99 (2^o order)	Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	Recovery ±10% of true value	Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standards. If the ICV fails a second time, initial calibration must be repeated.
Continuing Calibration Check	Every 10 samples, end of analytical run	Recovery ±10% of true value	Sample analysis cannot proceed until this criterion is met. Reanalyze CCC. If the CCC fails second time, the analysis must be terminated, the problem corrected, the instrument re-calibrated, and the calibration re-verified prior to continuing sample analyses.
Continuing Calibration Blank	Every 10 samples, end of analytical run	No target analytes detected greater than the RL.	If not within criteria, terminate the analysis, correct the problem, re-calibrate, and reanalyze each sample analyzed since the last acceptable CCB.
Method Blank	1 per 20 samples or batch per matrix	No target analytes detected greater than the RL.	Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Sample	1 per 20 samples per matrix	Laboratory generated control limits not to exceed recovery limits of 60-140% or RPD of 30%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Matrix Spike and Duplicate	1 per 20 samples per batch, per matrix	Laboratory generated control limits not to exceed recovery limits of 60-140% or RPD of 30%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 6-25
Quality Control Method Criteria for Dioxin/Furans by USEPA SW-846 Method 8290

Procedure	Frequency	Acceptance Criteria		Corrective Action
Initial calibration 5-pt	Set-up, major maintenance, or for drift correction	RSD ≤20% for standard compounds RSD ≤30% for reference compounds		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Continuing Calibration Check	12 hours	%Difference within s ±30% for reference compounds And ≤ 20% for standard compounds		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Internal standards	Every sample	Are all percent recoveries within 40-135%		Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with internal standards outside criteria.
Tuning	12 hours	Must meet tuning criteria.		Re-tune, re-calibrate, and re-analyze affected sample analyses.
Method Blank	Per extraction batch	No target analytes greater than one half of the RL		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	Every batch	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DoD QSM	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Matrix Spike and Duplicate	1 per 20 samples per matrix	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits listed in the current version of the DoD QSM	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

7.0 HEALTH AND SAFETY PLAN ADDENDUM

7.1 INTRODUCTION

This site-specific HSPA was developed to provide the requirements for protection of site personnel, including government employees, URS personnel, regulators, subcontractors, and visitors, which are expected to be involved with soil boring advancement/sampling at the site screening areas.

This HSPA addresses project-specific hazards, which include physical hazards, biological hazards, and chemical hazards, as identified in Section 7.2.2, below.

This addendum addresses site-specific training, personal protective equipment (PPE), and air monitoring requirements. General health and safety issues that are also applicable to this scope of work are addressed in Master Health and Safety Plan, as shown in Table 7-1.

URS, subcontractor personnel, and site visitors will read this HSPA and will be required to follow its protocols as minimum standards. This HSPA is written for the site-specific conditions at SSAs 18, 72, 30, 79, 60, and 77 and must be amended if conditions change. A copy of this HSPA will be available at each work site.

The contractor will provide a safe work environment for personnel involved in RFAAP investigative activities. The contractor will emphasize the importance of personnel injury and illness prevention at the work site.

7.2 TRAINING PLAN

Training will be used to review important topics outlined in this addendum and to inform URS personnel and subcontractor personnel of the hazards and control techniques associated with facility-wide conditions.

Site personnel will be informed of the specific PPE that will be worn during field activities. This includes, at a minimum, steel-toed boots, safety glasses (with side shields), gloves, and hardhat. Each field person will also have a respirator on the site, in the event that an emergency occurs and a respirator is necessary for site evacuation, or if the use of a respirator is necessary based on air monitoring results. Prior to initiation of fieldwork, the staff will be required to review the manual *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2005). Additional training, which will be conducted during daily safety "tailgate" meetings, will include emergency and evacuation procedures, general safety rules, and use of automobiles. Written documentation of safety briefings will be kept on the site.

7.2.1 Hazard Information Training

Hazard information training will be presented to URS and subcontractor personnel to provide a description of the Hazardous, Toxic, and Radioactive Waste (HTRW) with the potential to be found at the site screening areas. Training will also be provided on the potential biological, chemical, and physical hazards to be found at the Installation. The URS SHSO will conduct this training based on information provided by the operating contractor.

7.2.2 Project-Specific Hazard Analysis

The following hazards must be recognized and controlled during applicable investigative activities:

(1) Physical Hazards

- Cold stress – refer to Section 3.2.2 of the MHSP;
- Falls, open excavation, confined-space entry;
- Noise from heavy equipment;
- Cuts, abrasions, and lacerations;
- Manual lifting – refer to Section 3.2.4 of the MHSP;
- Slips, trips, and falls associated with walking through heavily vegetated areas – refer to Section 6.1.1 of the MHSP;
- Heavy equipment – refer to Section 6.1.2.1 of the MHSP; and
- MMA – overhead power lines.

(2) Biological Hazards (refer to Section 3.3 of the MHSP)

- Insect bites and stings;
- Tick bites;
- Snake, rodent, or other animal bites; and
- Dangerous plants.

(3) Chemical Hazards

- Potential exposure to toxic chemicals; and
- Potential exposure to dangerous fumes in case of a nearby release or spill of acids, resulting in the creation of a fume cloud.

7.2.3 Hearing Conservation Training

Site personnel involved in heavy equipment operation in addition to other operations involving exposure to noise levels greater than 85 decibels on the A-weighted scale Decibels on the A-Weighted Scale (dBA) eight-hour time-weighted average (TWA) shall be trained according to 29 CFR 1910.95. This training shall address the effects of noise on hearing, the purpose, advantages, disadvantages, and selection of hearing protection devices, and the purpose and explanation of Audiometric test procedures.

7.2.4 Hazard Communication Training

In order to comply with the requirements of the OSHA Hazard Communication (HAZCOM) Standard, 29 CFR 1910.1200, URS will have a written HAZCOM Program in place. The written hazard communication program addresses training (including potential safety and health effects from exposure), labeling, current inventory of hazardous chemicals on the site, and the location and use of Material Safety Data Sheets. The SHSO will arrange HAZCOM training for site personnel at the time of initial

site assignment. Whenever a new hazardous substance is introduced into the work area or an employee changes job locations where new chemicals are encountered, supplemental HAZCOM training shall be scheduled and presented. HAZCOM training shall be documented by the SHSO using a HAZCOM Employee Training Record. This documentation and the URS HAZCOM Program will be maintained on the site for the duration of the project, and later incorporated in the employees' personal training file.

7.2.5 Confined Space Entry Training

Confined space entry training will not be required for fieldwork, as there will be no confined spaces entered during this investigation.

7.3 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

The minimum and initial level of PPE for these activities will be Level D. The initial selection of PPE is based on a hazard assessment, including the review of existing analytical data and related toxicological information with respect to the proposed field activities. PPE assignments are subject to change based upon site conditions and task variation. The SHSO will review the required level of protection and safety equipment for each task with the sampling crew. The decisions on which protective level is most appropriate will be made by the SHSO.

In accordance with 29 CFR 1910.134, URS personnel working on the site will be required to participate in the written URS respiratory protection program. Personnel slated for fieldwork will have a qualitative fit test performed at least once per year or more frequently as required by law. Site personnel will be trained on the use, limitations, maintenance, inspection, and cleaning of respirators.

7.4 MONITORING PLAN

During sampling activities, the SHSO will monitor the site initially and periodically for potentially hazardous airborne constituents or physical hazards. The SHSO will use a PID to detect volatile organic vapors. SOP 90.1 describes the calibration of the PID that the SHSO will conduct daily. The action levels for volatile organic compounds at sustained concentrations in the breathing zone are as follows:

PID Readings	Action
Background plus 5 parts per million (ppm)	Investigate
Five ppm to 25 ppm	Upgrade to Level C (full face air-purifying respirator with organic vapor/acid gas cartridges), and investigate
Greater than 25 ppm	Suspend work, depart area, and investigate
ppm = Parts Per Million	

7.5 EMERGENCY RESPONSE PLAN

Emergency response will follow the protocols set fort in MHSP, Section 10.0. Table 7-2 presents the current emergency telephone numbers applicable to activities performed at RFAAP.

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Table 7-1
Health and Safety Issues Discussed in the MHSP

Health and Safety Issue	Section in MHSP
Site Safety and Health Documentation	1.4
Safety Statement	1.5
Health and Safety Personnel and Responsibilities	2.1
Hazard Assessment and Hazard Control	3.0
Training Plan	4.0
Medical Surveillance Plan	5.0
Site Safety and Control	6.0
PPE	7.0
Personnel and Equipment Decontamination	8.0
Monitoring Plan	9.0
Emergency Response and Contingency Plan	10.0

Table 7-2
Emergency Telephone Numbers

Contact	Telephone Number
Emergency Response Services	
Installation Fire Department**	16 (on post)
Installation Security Police**	7325 (on post) (540) 639-7325 (off post)
Installation Safety Department**	7294 (on post) (540) 639-7294 (off post)
Installation Spill Response**	7323, 7324 or 7325 (on post) (540) 639-7323, 7324, or 7325 (off post)
Installation Medical Facility** (RFAAP Hospital)	7323 or 7325 (on post) (540) 639-7323 or 7325 (off post)
Local Police Department	911
New River Valley Medical Center	(540) 731-2000 - General Telephone Number
National Poison Control Center	(800) 222-1222
National Response Center	(800) 424-8802
Regional USEPA Emergency Response	(215) 814-9016
Chemical Manufacturers Association Chemical Referral Center	(800) 262-8200

Directions from the Main Gate:

New River Valley Medical Center
2900 Lamb Circle
Christiansburg, VA 24073

Take Route 114 toward Radford to first traffic light. Take U.S. Route 11 South and go across the bridge over the New River. Turn left after crossing the bridge, continue to Virginia Route 177 South, and turn right. Proceed on VA 177 South and cross over Interstate 81. New River Valley Medical Center is on the left.

** These telephone numbers are referenced from *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2005).

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WORK PLAN ADDENDUM 028

SITE SCREENING PROCESS AT SITE SCREENING AREAS 18, 72, 30, 79, 60, AND 77

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

FINAL
JUNE 2009

URS

CONTRACT NO.
W91238-07-D-0006
DELIVERY ORDER NO.
DA01

APPENDIX A
SSP GUIDANCE DOCUMENT

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1.0 INTRODUCTION

The Radford Army Ammunition Plant (RFAAP) is an active military installation located in the mountains of southwest Virginia, and covers approximately 4,080 acres in Montgomery and Pulaski County, Virginia.

The United States Environmental Protection Agency (USEPA) issued a RCRA Corrective Action Permit to Alliant Ammunition and Powder Company (Alliant) and the U.S. Department of the Army (Army) on October 31, 2000. Within the RCRA Corrective Action permit is a listing of 31 identified Site Screening Areas (SSAs) which are to be investigated in accordance with this EPA approved Site Screening Process (SSP). Should additional SSAs be identified at RFAAP, a site screening will need to be completed in accordance with this SSP.

This SSP has been developed as the central document describing how site screening will be applied to the RFAAP. Overall, the SSP is devised to expedite investigations of SSAs at RFAAP to determine what level of evaluation is appropriate for these identified areas. The SSP will help determine whether there have been releases of hazardous substances, pollutants, contaminants, hazardous wastes, or hazardous constituents to the environment from an SSA, and determine whether an SSA should proceed further through the RFI process, be the subject of an interim removal action or be considered for no further action.

Once a SSA is identified, the following five distinct tasks will be undertaken:

- Performance of a Desktop Audit and site visit to determine the scope of the SSP site-specific Work Plan(s);
- Development of an SSP site-specific Work Plan outlining a Sampling and Analysis Plan as well as a risk screening plan (human health and ecological, as appropriate) for EPA approval;
- Performance of SSP field work in accordance with the approved SSP Work Plan;
- Evaluation of SSP data and completion of pre-remedial risk screening; and
- Determination of the need for further investigation of the SSA, an interim removal action at the SSA or preparation of a No Further Action Decision Document, per the RCRA Corrective Action permit, based on results of the SSP and risk screening.

The following sections detail these SSP tasks.

2.0 SITE VISIT AND DESKTOP AUDIT

The purpose of the Desktop Audit is to evaluate and document, through review of existing information, if operations at the SSA(s) have resulted in the release of hazardous substances, pollutants, contaminants, hazardous wastes or hazardous constituents to the environment. The Desktop Audit process includes a search of all documents related to operations at the SSA as well as interviews with personnel knowledgeable about the site. Available information for each SSA, including location and a site map, description of past and current land uses, and a description of releases and associated cleanups, will form the basis for the Desktop Audit. Other information sources will include the administrative record and other local, state and federal documentation containing information pertinent to the site.

Typical existing information that will be examined during the Desktop Audit will include site use, ownership and operational history, groundwater and surface water use and characteristics, soil exposure characteristics, and air exposure pathways. This information can be obtained from maps, publications by the United States Geological Survey (USGS) and state geological surveys, regional databases and geographic information systems, and aerial photography. On the basis of information collected during the Desktop Audit, a list of chemicals potentially stored, handled, released, or disposed at each SSA will be compiled.

In addition to the Desktop Audit, a site visit will be conducted at each SSA. The site visit will include a visual inspection of the SSA to aid in site characterization, including identifying potential contaminant sources; chemical migration pathways; potential human and ecological receptors; and receptor exposure pathways. Additionally, potential media to be sampled and sampling locations will be identified for the SSP.

Results of the Desktop Audit and site visit will be presented in a summary report. Included in the report will be an SSA-specific Conceptual Site Model (CSM) depicting potential contaminant sources, environmental and exposure pathways of concern, and potential human and ecological receptors. The CSM will maximize the usability of analytical data derived from site characterization efforts for subsequent risk assessments, and will form the basis for any additional data collection to support the human health and ecological risk screening. These results will be used in formulating the SSP Work Plan, including the need for human health and ecological risk screening.

3.0 DEVELOPMENT OF SITE SCREENING INSPECTION SAMPLING AND ANALYSIS STRATEGY

A site-specific Work Plan will be developed for each SSA investigated under the SSP. The Work Plans will reference the Desktop Audit Summary, providing a detailed description of historical information, SSA conditions, results of previous investigative work and results of the site visit. The Work Plans will also present a Sampling and Analysis Plan (SAP) that describes the number, types and locations of samples to be collected, sample analyses, and the rationale for the sampling plan. The purpose of sample collection and analysis will be to assess the presence or absence of hazardous substances, contaminants, hazardous wastes, or hazardous constituents, and to provide data for performing human health and ecological risk screening in order to evaluate if there is a potential threat to human health or the environment at the SSA.

Media sampled during the SSP will be identified based upon Desktop Audit and site visit findings, and approval of the USEPA Region III.

Potential media of interest in the SSP may include surface soil (0 to 1 feet below ground surface [bgs] 0-6 inches for constituents other than VOCs, 6-12 inches for VOCs), subsurface soil, groundwater, surface water, sediment, and animal and plant tissue (e.g., fish). Where appropriate, geophysical techniques will be used to aid in placement of groundwater and soil sample locations and to confirm and delineate suspected buried waste material identified during the Desktop Audit and site visit. Field screening for explosives using immunoassay-type sampling kits can be performed at SSAs (a complete list of all explosive compounds and respective detection limits using this method will be included in the Work Plan). However, immunoassay-type analytical data cannot be used for risk screening, unless it can be shown through confirmation sampling and analysis that the results of the field test kits are of equivalent precision and accuracy to standard methods of analysis.

Groundwater samples collected during SSP investigations may be obtained via direct push techniques (DPT) or from groundwater monitoring wells, depending on site conditions and data needs. For groundwater samples collected from monitoring wells, only unfiltered organic and metals results will be considered in the assessments (except in circumstances where monitoring wells do not produce samples with sufficiently low solids for a reasonable risk screening to be performed). For DPT groundwater samples, only the filtered metals and unfiltered organic results will be considered in the assessment. Groundwater parameters measured during field activities should include pH, Eh, dissolved oxygen, specific conductance, temperature, salinity, and turbidity, as appropriate, depending on the medium- and SSA-specific conditions.

All environmental media samples collected during the SSP will be analyzed for the full suite of Contract Laboratory Procedure (CLP) constituents and other constituents based on the findings of the Desktop Audit including additional analytes requested by EPA. The analytical target list will include Target Compound List (TCL) volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs) and dioxins, and Target Analyte List (TAL) inorganic chemicals, including cyanide. Based on past uses of specific SSAs for explosives treatment, and the results of field screening immunoassay methods, it may be necessary to analyze specific samples for nitramine/nitroaromatic compounds. Depending on the history of the SSA and other available information, it may be necessary to

analyze specific samples for perchlorates. Soil samples should be analyzed for physical properties (e.g., bulk density, grain size, specific gravity, percent moisture, and total organic carbon [TOC]), as necessary.

Analytical methods used in the SSP will generally be USEPA CLP/Standard Methods and/or SW-846 Methods. Polynuclear aromatic hydrocarbons (PAHs) and pesticides/PCBs may be analyzed using low detection methods. For example, the National Oceanographic and Atmospheric Administration (NOAA) Status and Trends Methods (USEPA Method No. 1668 [GC/MS, congener standards]; USEPA, 1995d) will be used to meet PCB method detection limits (MDLs) required for the human health and ecological risk screening. An analysis of risk-based concentrations (RBCs) and Biological Technical Assistance Group (BTAG) screening levels relative to analytical reporting limits (RLs) will be conducted as part of Work Plan preparation to ensure that RLs do not exceed screening concentrations (to the greatest extent practicable).

CLP laboratory analytical data will be subjected to data validation in accordance with the Innovative Approaches for Validation of Organic and Inorganic Data, as amended by USEPA Region III (USEPA, 1995a). Section 5 describes the data validation and data evaluation process that will be used in the SSP.

4.0 PERFORMANCE OF FIELD WORK

All SSP field work at SSAs will be performed in accordance with the Master Project Plans for RFAAP and the SSA-specific SSP Work Plan described in Section 3.0 above. The Master Project Plan, including a Field Sampling Plan, Quality Assurance Project Plan, and Health and Safety Plan, addresses the full range of potentially applicable activities that could be required throughout the SSP.

5.0 DATA VERIFICATION, VALIDATION AND USABILITY ASSESSMENT

5.1 Data Verification

Data will be verified in accordance with USEPA Region III Innovative Approaches for Data Validation (USEPA, 1995). Verification for organic data will be performed at Manual Level M2 and the verification for inorganic data will be performed at Manual Level IM1 (if a determination is made that an SSA does require a RFI and formal baseline risk assessment, the existing SSP data will be re-validated at the M3 and IM2 level, respectively). Particular emphasis will be placed on holding time compliance, equipment calibration, spike recoveries, and blank results, although all required elements of the verification process will be considered. The analytical results for nonCLP parameters will be verified based on the Region III Modifications to the National Functional Guidelines further modified to reflect the acceptance specifications of the referenced method to the extent that those specifications differ from those in the Region III Modifications to the National Functional Guidelines. Data qualifiers will be assigned based on the results of verification findings. Laboratory deliverable packages will be equivalent to USEPA CLP deliverable packages, containing complete quality control (QC) summary reports, quality assurance (QA) documentation, and raw data.

Data qualifiers provide information pertaining to the degree of confidence to be considered relative to the presence (or absence) of reported chemicals, and also identify numerical results considered to be less accurate and/or precise than is normal for the method. A list of the data qualifiers that may be applied during the verification effort and their definitions are presented below.

Data Qualifier Codes	
J	The analyte was positively identified. The associated result is the approximate concentration of the analyte in the sample.
K	The analyte was detected. Reported value may be biased high.
R	Serious analytical problems were encountered and quality control criteria were not met. The data point is rejected. The analyte may or may not be present in the sample.
N	Tentative identification. Consider present. Special methods may be needed to confirm its presence or absence in future sampling efforts
L	The analyte was detected. Reported value may be biased low.
U	The analyte was analyzed for, but not detected above the reported quantitation limit.
UL	The analyte was not detected. The reported quantitation limit is approximate and may be lower.
UJ	The analyte was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.
B	The analyte was analyzed for, but was not detected substantially above the level reported in the laboratory or field blanks.

Data tables must report non-detects with the following format: < xx, where xx is the sample reporting limit (but not the method detection limit, the instrument detection limit, the contract detection limit, etc.). Thus, all data tables will have either a blank to show that a constituent was not analyzed, a number to show the numeric value of the detected constituent, or a less than symbol followed by the sample reporting limit. The usual data qualifiers will be added as necessary. A data validation report with hand annotated Form 1s will be prepared to present data validation findings.

5.2 Data Validation and Usability Assessment

Data that are compliant with the minimum specifications of the subject analytical methods, still may not provide sufficient qualitative and/or quantitative quality to make decisions at the requisite statistical confidence. To assess risks associated with chemicals of potential concern (COPCs) at a SSA, data of known quality must be used (USEPA, 1992a). An understanding of analytical data quality is necessary for evaluation of uncertainties related to the data, and consideration of these uncertainties in the decision-making process for the SSAs. To facilitate this goal, data from the SSPs will be evaluated for quality and usability prior to its use in the human health and ecological risk screening.

Guidance such as Guidance for the Data Quality Objective Process (EPA QA/G-4, 1994), Guidance for the Data Quality Assessment Process (EPA QA/G-9, 2000), Risk Assessment Guidance for Superfund, Volume I (USEPA, 1989), and Guidance for Data Usability in Risk Assessment (USEPA, 1992a) will be used to evaluate data for usability in the human health and ecological risk screening. Data will be evaluated for quality based on information in the data verification report. Specifically, data will be evaluated for appropriateness of analytical methods and qualifiers, significant blank contamination, and tentatively identified compounds (TICs). Further, and perhaps more importantly, biases and variability inherent in the data will be assessed in relation to the relative interval between the risk screening level and the reported concentration. Additionally, given that a statistical relationship can be defined between variability, the number of samples in a given data set, and the statistical confidence with which a given conclusion may be drawn, the sampling plan and reported results will be evaluated in relationship to the DQOs established during the planning process.

All validated data that is not qualified and data that is qualified with J, L, K, U, UL, UJ, and B will be used to identify COPCs in the risk screening process, unless the inherent limitations of the analytical method and/or matrix effects obviate this use. Data qualified as rejected (i.e., R) will not be used in COPC identification.

Analytical results for the essential nutrients, calcium, sodium, potassium, and magnesium, in both solid and aqueous media, will not be considered in the assessments. All other metals, including iron, and all organic chemicals, including laboratory contaminants not disqualified in the data verification and validation processes, will be considered in the COPC identification process if detected at least once in environmental samples at an SSA.

5.3 Tentatively Identified Compounds

Chemical analysis to identify and quantify organic compounds is performed with gas chromatography-mass spectrometry (GC-MS) methods. The GC-MS instrument is calibrated for a series of target analytes using chemical standards of known concentration and purity. Quantification of these target analytes is performed against specific internal standards as identified in the respective method. Identification of these target analytes is based on a comparison of the unknown analyte to the chemical standards used during calibration based on the analyte's retention time and mass spectra.

Chromatographic peaks in volatile/semivolatile fractions analyses that are not target analytes, surrogates, or internal standards are potential Tentatively Identified Compounds (TICs). TICs must be qualitatively identified by a National Institute of Standards and Technology (NIST) mass spectral library search and the identification assessed by the data reviewer. For each sample, the laboratory conducts a mass spectral search of the NIST library and report the possible identity for the 10 VOC and/or 20 SVOC largest fraction peaks that are not surrogates, internal standards, or target compounds, but that have an area or height greater than 10 percent of the area or height of the nearest internal standard. TIC results are reported for each sample on the Organic Analyses Data Sheet (Form I - VOC-TIC or SVOC -TIC)

TICs will be reported and included in the COPC identification based upon the degree of match, evidence of similar pattern, analyst professional judgment, availability of toxicity data (e.g., IRIS, HEAST, or NCEA reference doses and/or slope factors), and consultation with EPA Region III (see Section 6.1.1.1). The top 20 TICs will be reported by name and CAS Registry number and may be quantified. Quantification of TICs will be based on input from EPA staff. Positive identification and quantification of TICs will be accomplished by acquiring the appropriate standards and calibrating the GC-MS for the tentatively identified compounds. TICs that lack toxicity data will be discussed in the uncertainty section of the screening risk assessment results.

6.0 SCREENING PROCEDURES

Human health and ecological screening procedures will be performed as a part of the SSP. Section 6.1 presents the methodology for the human health screening procedures and Section 6.2 presents the methodology for the ecological risk screening .

6.1 Human Health Screening Procedures

Human health screening procedures will be conducted in accordance with the USEPA Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989 and 1991b) and USEPA Region III guidance (USEPA, 1991c, 1993a, and 1998a) with modifications. The purpose of the screening step is to evaluate site data with respect to conservative criteria so that sites requiring no further action can be eliminated from further consideration. This process will also be used to identify sites requiring further evaluation to proceed through additional steps. The conceptual site model (CSM) developed in Section 2.0 will be used to identify those media that are associated with identified exposure pathways. If potential current and future exposure pathways associated with a particular medium are determined to be incomplete, then it may not be necessary to carry that medium through the screening process, given approval by EPA.

The screening procedure will involve the following steps:

1. Identification of COPCs and Cumulative Risk Screening

2. Chemical-Specific Screening for Lead and Iron

3. Comparison to Soil Screening Levels (SSLs)

4. Comparison to ARARs

5. Background Comparisons

These steps are described in the following sections.

6.1.1 Identification of COPCs and Cumulative Risk Screening

6.1.1.1 Identification of COPCs for Human Health Cumulative Risk Screening

As stated previously, chemicals detected at least once in environmental samples at an SSA will be evaluated in the COPC identification stage of the human health screening. The essential nutrients calcium, sodium, potassium, and magnesium; chemicals disqualified in the validation process; and TICs not positively identified, will be eliminated as COPCs.

COPCs will be identified by comparing maximum detected concentrations (MDCs) in a specific medium with chemical-specific risk-based screening criteria, unless the data display the statistical properties required to calculate a valid 95% upper confidence limit (UCL). If this is the case, then the 95% UCL will be employed. Chemicals with MDCs exceeding risk-based

criteria will be identified as COPCs and will be carried through to the cumulative risk screening step of the assessment.

Soil and Sediment. COPCs in surface and subsurface soil and sediment will be identified by comparing MDCs (or a 95% UCL if appropriate) in these media to Risk-Based Concentrations (RBCs) in the most recent version of the USEPA Region III Risk-Based Concentration Table for soil ingestion using the residential and industrial scenarios (USEPA 2000).

For soils and sediments that are exposed a significant portion of the year (i.e., > 6 months/year), screening levels shall correspond, or be adjusted to correspond, to an increased cancer risk of 1 x 10-6 and a noncancer Hazard Quotient (HQ) of 0.1. COPCs can be identified if the MDCs (or a 95% UCL if appropriate) are greater than the screening values for the ingestion and/or inhalation pathways. For sediments that are not exposed, comparisons to adjusted soil screening levels may be used to decide on the need for further evaluation (e.g., quantitative risk assessment), further investigation or response action.

Groundwater and Surface Water. COPCs in groundwater and surface water will be identified by comparing MDCs (or a 95% UCL if appropriate) of chemicals in these media to RBCs in the most recent version of the USEPA Region III Risk-Based Concentration Table for tap water (USEPA 2000), and to federal and state Maximum Contaminant Levels (MCLs) for groundwater and surface water used as a source of drinking water.

For groundwater, as well as surface water that may be a source of drinking water, RBC screening levels shall correspond, or be adjusted to correspond, to an increased cancer risk of 1 x 10-6 and a noncancer Hazard Quotient (HQ) of 0.1. For other surface water, comparisons to adjusted groundwater screening levels may be used to decide on the need for further evaluation (e.g., quantitative risk assessment), further investigation, or response action. Note that all ground water is considered a source of drinking water unless deemed non-potable (i.e., Class III).

Fish. COPCs in fish will be identified by comparing MDCs (or a 95% UCL if appropriate) of chemicals in fish tissue samples to screening level RBCs for fish in the USEPA Region III Risk-Based Concentration Table (USEPA, 2000). Screening levels shall correspond, or be adjusted to correspond, to an increased cancer risk of 1 x 10-6 and a noncancer Hazard Quotient (HQ) of 0.1.

Chemicals Lacking RBCs

For chemicals lacking Region III published RBCs, but having available associated toxicity data that are peer-reviewed, risk assessors will obtain information from the following sources, which are listed in order of preference: USEPA's Integrated Risk Information System (IRIS), Health Effects Assessment Summary Tables (HEAST), and provisional values from the National Center for Environmental Assessment (NCEA). From these sources, the Army will make a good faith effort to propose alternative screening values, for EPA concurrence.

Summary. In summary, a detected chemical will be retained as a COPC for a specific medium if the MDC (or a 95% UCL if appropriate) is greater than the corresponding screening criteria described above.

6.1.1.2 Cumulative Risk Screening

The cumulative risk screening process will consist of calculating ratios between the maximum exposure point concentrations (EPCs) of COPCs in an environmental medium and the corresponding USEPA Region III residential and industrial RBCs. COPCs are those chemicals brought forward from the COPC identification step (see Section 6.1.1.1). Carcinogenic and noncarcinogenic effects will be evaluated for exposure to chemicals in each environmental medium sampled.

6.1.1.2.1 Estimation of Exposure Point Concentrations

For purposes of this screening process, maximum detected concentrations (MDCs) (or a 95% UCL if appropriate) will be considered in the cumulative risk screening as representative exposure point concentrations (EPCs) for the SSA as a conservative measure. The selection of the MDC for the exposure point concentration in most cases is motivated by the recognition that in many cases when the number of samples is small, the alternative approach reverts to the maximum detected concentration because the calculated 95% UCL exceeds the MDC.

6.1.1.2.2 Human Health Effects - Carcinogens

The potential for carcinogenic risk will be evaluated by estimating excess cancer risk for each COPC. Using the maximum EPC and the respective screening level RBC value, excess residential and industrial cancer risk can be estimated using the following formula:

$$Excess\,Cancer\,Risk = TR\frac{Max.EPC_i}{RBC_i}$$

Where:

TR	=	The target lifetime cancer risk of 1x10-6
EPCi	=	EPC of COPCi detected in soils and fish (mg/kg) or water (g/L)
RBCi	=	RBC for COPCi in soils and fish (mg/kg) or water (g/L) based on carcinogenic effects at the TR stated above

Finally, the cumulative residential and industrial excess cancer risk is estimated for each SSA. The cumulative excess cancer risk for exposure to multiple COPCs is estimated using the following equation:

$$Cumulative\ Excess\ Cancer\ Risk = \sum \left[TR\ x \frac{Max.EPC_i}{RBC_i} \right]$$

In accordance with 40 Code of Federal Regulations (C.F.R.) 300.430, carcinogenic risk within the benchmark range of 1x10-4 (1 cancer case in 10,000) to 1x10-6 (1 cancer case in 1,000,000) is generally considered acceptable. The following statement is from 40 C.F.R. 300.430 (2000): "For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10-4 to 10-6 using information on the relationship between dose and response. The 10-6 risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure."

Multiplying the EPC/RBC ratio by USEPA's point of departure risk level, 10-6, results in an excess cancer risk estimate for the COPC. Excess cancer risk estimates for all COPCs will be summed to account for potential carcinogenic effects associated with multiple chemical exposures (USEPA, 1989) for each medium. The results of cumulative risk screening will be evaluated as follows:

- If the calculated cumulative excess cancer risk is greater than or equal to 1×10^{-5} for any of the medium, then a quantitative risk assessment would be performed for the SSA, or

- If the calculated cumulative excess cancer risk is: 1) below 1×10^{-5} for all media; and 2) no other screening criteria, as defined by this document, have been exceeded, then no further action (NFA) would be recommended for the SSA.

6.1.1.2.3 Human Health Effects - Noncarcinogens

The potential for adverse noncarcinogenic health effects will be evaluated by calculating a residential and industrial HQ for each COPC. Using the maximum EPC and a respective noncarcinogenic RBC, a residential or industrial HQ can be estimated with the following formula:

$$HQ = THQ \frac{Max.EPC_i}{RBC_i}$$

Where: THQ = The target HQ of 0.1
EPCi = EPC of COPCi detected in soils and fish (mg/kg) or groundwater (g/L)
RBCi = RBC for COPCi in soils and fish (mg/kg) or Groundwater (g/L) based on noncarcinogenic effects at the THQ stated above.

Finally, the cumulative residential and industrial non-carcinogenic hazard index (HI) for exposure to multiple COPCs is estimated as follows:

$$Cumulative\ Noncarcinogenic\ HI = \sum \left[THQ\, x \frac{Max.EPC_i}{RBC_i} \right]$$

Per USEPA guidance for a Baseline Risk Assessment, when the HI exceeds 1, there is a potential for adverse noncarcinogenic health effects (USEPA, 1989). Generally, the more the HI exceeds unity, the greater the potential for adverse health effects. Additionally, when the HI exceeds 1, and multiple chemicals contribute to the exceedance, the HI is segregated on the basis of toxic effects and target organs (i.e., hepatic, renal, respiratory, cardiovascular, gastrointestinal, hematological, musculoskeletal, dermal, ocular effects, neurological, reproductive, developmental, and immune system).

For the cumulative risk screening procedure, HI segregation will involve obtaining the most recent and reliable noncarcinogenic health effects data for COPCs, such as data in the Integrated Risk Information System database (EPA) and databases developed by the Agency for Toxic Substances and Disease Registry (ATSDR). Health effects will be considered for only chronic exposure to COPCs. For COPCs with multiple target organs, the organ that the chemical primarily targets will be considered in hazard segregation.

The results of the cumulative hazard screening will be evaluated as follows:

- In accordance with Region III guidance for risk screening, if the cumulative noncarcinogenic HI for a SSA, computed by this method, is greater or equal than 0.5 for any target organ, then a quantitative risk assessment would be performed for the SSA, or

- If the cumulative noncarcinogenic HI for an SSA, computed by this method, is: 1) less than 0.5 for all target organs; and 2) no other screening criteria, as defined by this document, have been exceeded, then NFA would be recommended for the SSA.

6.1.1.3 Uncertainty Analysis

Uncertainties associated with the cumulative risk screening will be qualitatively evaluated to determine the accuracy of the approach. Factors that may contribute to uncertainty include the use of RBC age-adjusted ingestion and inhalation rates, the use of toxicity information provided by NCEA when RBCs are not available, and the level of uncertainty due to a lack of dermal risk estimates. Uncertainty in the assessment could also arise if health-based RBCs are less than analytical method detection limits.

Uncertainty is associated with the use of RBCs and SSLs because they do not consider dermal uptake. The Site Screening Process is geared towards a risk-based identification of COPCs and preliminary assessment of human and ecological risks that is objective and quantitative. As such, it hinges on the availability of appropriate, risk-based screening levels. No such levels have been identified for dermal exposures to soil, sediment, water or air. Given the conservative nature of the screening process (e.g., use of MDC for exposure point concentrations, use of residential screening level RBCs for soil and groundwater), it is considered very unlikely that omission of

dermal exposures in the risk screening process will result in failure to identify a SSA that would require further investigation or response. To guard against this possibility, contaminant concentrations at all SSAs that pass the risk screening will be scrutinized for the occurrence of contaminants that are known to be easily absorbed through the skin, and if necessary, dermal risks for selected contaminants will be calculated in accordance with USEPA's Dermal Exposure Guidance (USEPA, 1992c, 1997a). These dermal risks may be added to the Cumulative Excess Cancer Risk or Cumulative Noncarcinogenic HI computed above.

6.1.2 Chemical-Specific Screening for Lead and Iron

6.1.2.1 Lead

If lead concentrations in soil are greater than 400 mg/kg (USEPA, 1994a), or lead concentrations in groundwater or surface water are greater than 15 g/L (USEPA 1996b), then potential risk associated with lead will be evaluated using the IEUBK model (USEPA, 1994b). The model will be run using site-specific input parameters based on SSP findings and consultation with USEPA Region III. If the percentage of children expected to have blood lead levels of 10 micrograms per deciliter (μg/dL) or greater exceeds 5%, then further investigation or response action will be required for the SSA.

6.1.2.2 Iron

If iron concentrations in soil or water result in an HQ of 0.5 or greater, then a "margin of exposure" evaluation will be performed. Risks from exposure to iron will be characterized by comparing estimated iron intake to the recommended dietary allowance (RDA) and concentrations known to cause adverse effects in children (NCEA, 1996).

6.1.3 Comparison to Soil Screening Levels (SSLs)

USEPA's Soil Screening Guidance (USEPA, 1996a) will be used as the source of information for three types of SSLs, which address:

- Chemical migration of VOCs from subsurface soil to air;
- Chemical migration of contaminants from soil to air via fugitive dust; and
- Chemical migration of contaminants from soil to groundwater.

MDCs (or a 95% UCL if appropriate) of chemicals found in soil and sediment will be compared to screening levels for leaching of contaminants to groundwater, i.e., soil-to-groundwater screening levels (USEPA, 1996a). Many soil-to-groundwater screening values can be found in the USEPA Region III RBC Tables. A dilution attenuation factor (DAF) of 20 may be used unless groundwater is considered to be shallow. In this case, a site-specific DAF should be calculated. Chemicals found at concentrations exceeding soil-to-groundwater screening levels will be evaluated in a qualitative manner to assess the need for further assessment, investigation, or response action. Geotechnical information such as Total Organic Carbon (TOC), pH, groundwater characteristics, etc., will be an integral part of the qualitative evaluation. In

particular, the SSL comparison will be evaluated with respect to its application to site conditions, such as the karst environment which is present throughout RFAAP. Based on the qualitative evaluation, and other relevant information, a recommendation will be made as to whether further evaluation, investigation, or response action should take place for the SSA.

6.1.4 Comparison to ARARs

MDCs (or a 95% UCL if appropriate) of chemicals found at each SSA will be compared to Applicable or Relevant and Appropriate Requirements (ARARs), including, but not limited to: federal and Virginia Maximum Contaminant Levels (MCLs) under the Safe Drinking Water Act, federal Ambient Water Quality Standards under the Clean Water Act, Virginia Water Quality Criteria, Virginia AST/UST TPH guidance level for soil (100 mg/kg) and Virginia AST/UST TPH guidance level for groundwater (1 mg/L) (VDEQ, 1995). Chemicals which are found at concentrations greater than ARARs will be identified. If an MDC (or a 95% UCL if appropriate) is greater than one or more ARARs, a recommendation will be made as to whether further evaluation, investigation, or response action should take place for the SSA. EPA may decide that further evaluation, investigation or response action is required at a SSA, based upon consultation with the Commonwealth if State ARARs are involved.

6.1.5 Background Comparison

As a final step in the human health screening process, MDCs of chemicals identified as COPCs will be compared to the EPA-approved site-specific background concentrations shown in the following table. This table includes inorganic chemicals whose 95% upper tolerance limit (UTL) are greater than residential RBC values and are based on the inorganic background data collected at RFAAP.

Facility-Wide Point Estimates for Soil

[Units in mg/kg]

Chemical	Minimum Concentration	Maximum Concentration	95% UTL of the Mean
Aluminum	3,620	47,900	40,041
Arsenic	1.2	35.9	15.8
Chromium	6.3	75.8	65.3
Iron	7,250	67,700	50,962
Manganese	16.7	2,040	2,543
Thallium	1.3	5	2.11
Vanadium	12.2	114	108

Based on the background comparison, and other relevant information, a recommendation will be made as to whether further investigation or response action is warranted at each SSA.

6.1.6 Summary of Human Health Risk Screening Procedures

The results of each screen will be summarized. If COPCs have been identified, in a particular medium, the SSA will be subject to further evaluation, such as a quantitative risk assessment. The results of the SSP will also be used to further refine the CSM.

6.2 Ecological Risk Screening Procedures

The USEPA Risk Assessment Forum (1992) recommended a general framework for conducting ecological risk assessments (ERAs). The Forum framework is presented in Figure 6-1. USEPA has since refined the framework and prepared ERA guidance (USEPA 1997). The approach taken for the SSA ecological screening at RFAAP follows the ERA eight-step approach in the USEPA guidance. Other guidance documents which may be consulted during the ecological risk screening process include the USEPA Region III BTAG ERA guidelines (USEPA 1995b), and the Tri-Service Procedural Guidelines for ERAs, Volume 1 (Wentsel et al, 1996).

The eight-step process is summarized in Figure 6-2. Since this is an ecological risk screen, the process focuses on Steps 1 and 2. These steps are intended to provide a foundation of information pertaining to ecological resources and potential interactions with site-related contamination in order that risk managers can make conservative decisions regarding ecological risks at individual SSAs.

The following steps will be followed for the ecological risk screening :

Site Reconnaissance

Problem Formulation

Exposure Assessment

Ecological Effects Assessment

Risk Characterization

Figure 6-1 Ecological Risk Assessment Framework (USEPA, 1997)

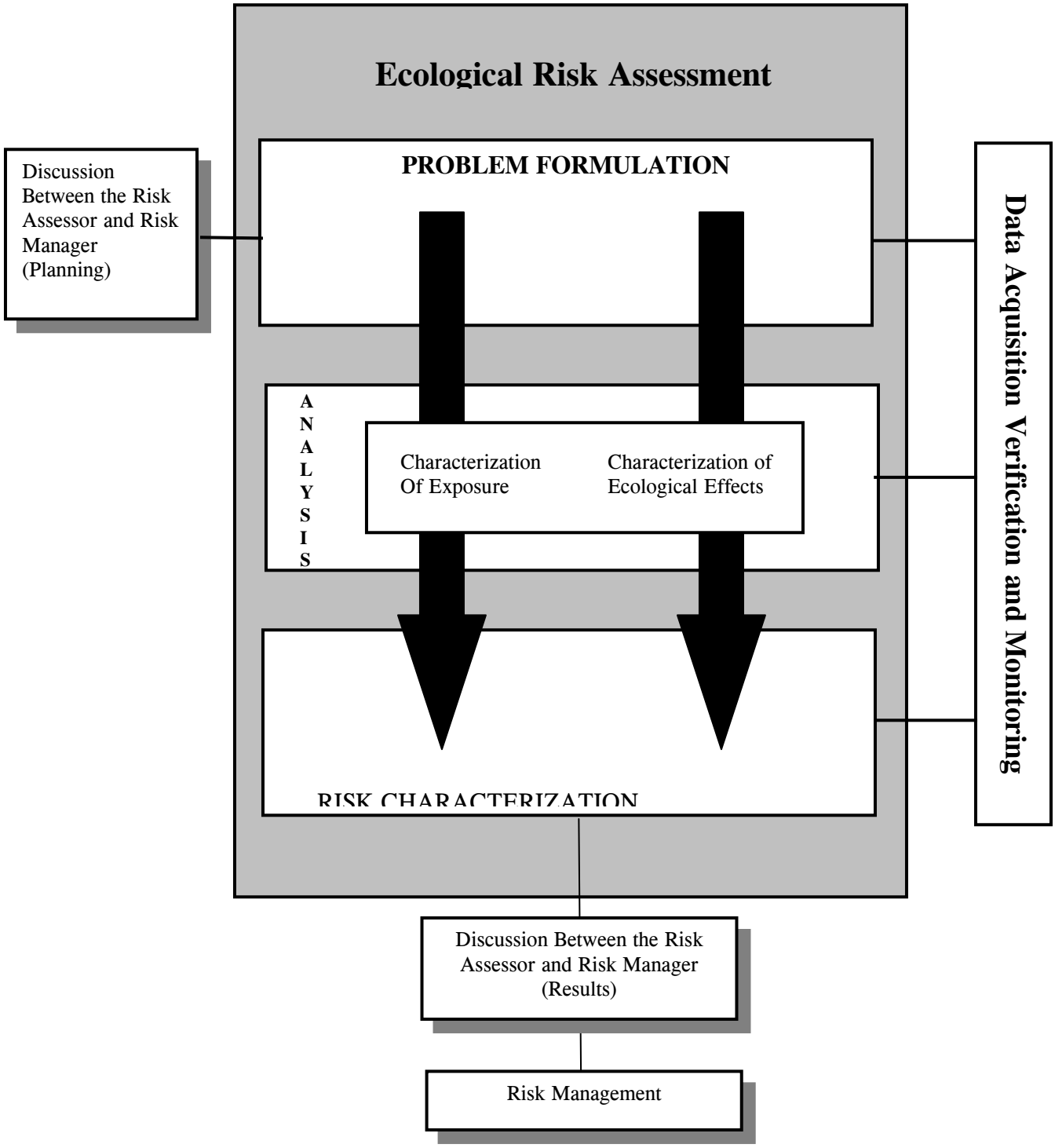
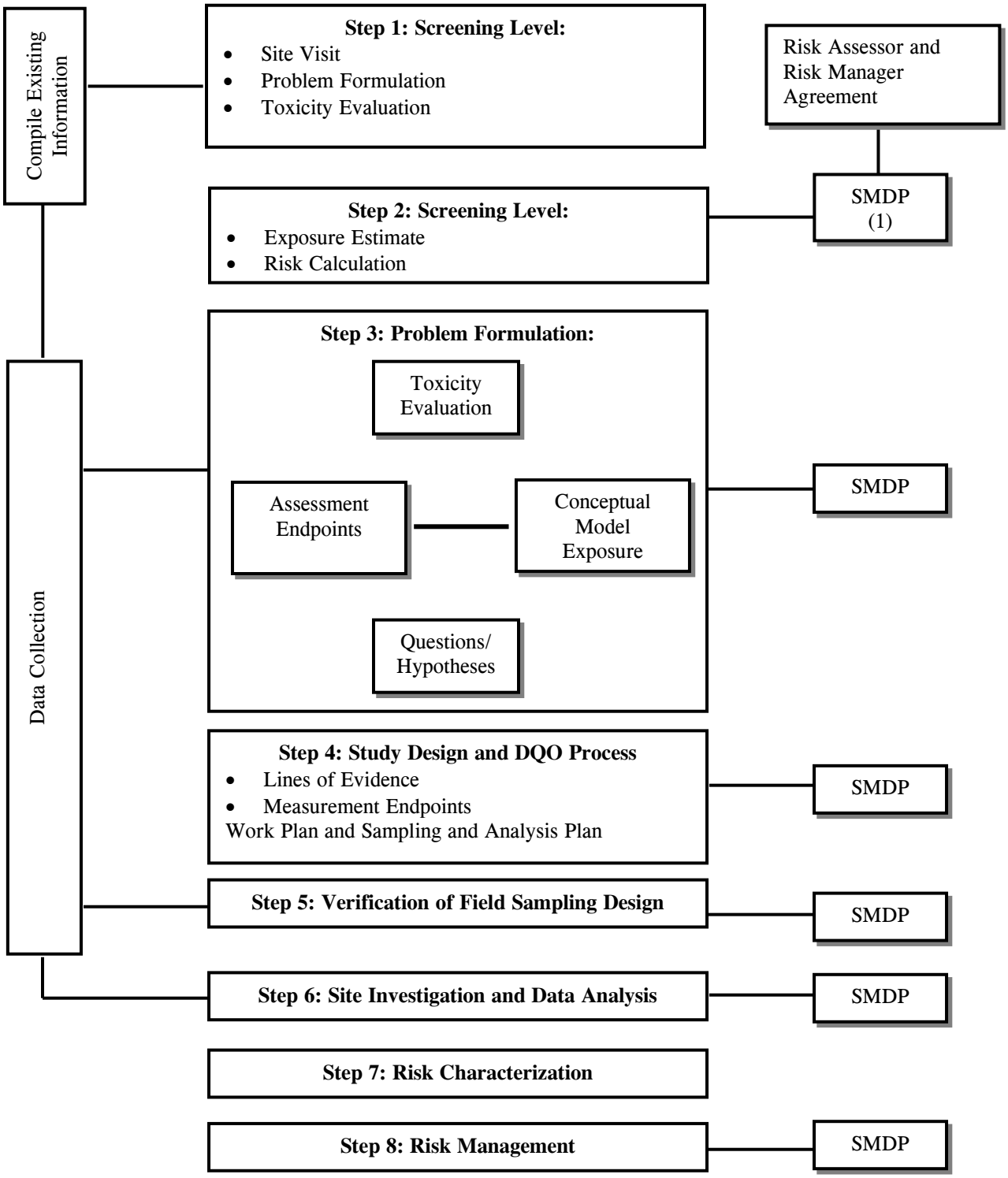


Figure 6-2 Eight-Step Ecological Risk Assessment Process for Superfund (USEPA, 1997)



The ecological risk screening will provide conclusions and recommendations regarding ecological risk at the site. The Army will use these data to make ecological risk management recommendations for each SSA. The scientific/management decision point reached from the ecological risk screening will include one of the following:

- There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the SSA 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.

6.2.1 Problem Formulation

Problem formulation is the first phase of a ecological risk screening and discusses the goals, breadth, and focus of the screening. It involves the collection and analysis of existing data to the greatest extent possible. Problem formulation includes general descriptions of RFAAP SSAs, with emphasis on size of the SSAs, proximity to operational areas and/or sensitive habitats, and the habitats and ecological receptors present. This phase also involves characterization of site contaminants, contaminant sources, migration routes, and an evaluation of complete routes of contaminant exposure to important ecological receptors. Assessment and measurement endpoints that will be evaluated are also selected. Finally, a conceptual model is developed that describes how contaminants associated with the sites in question may come into contact with ecological receptors. Much of this step will have been completed during the site reconnaissance, the review of historical information, and the development of the work plan, as discussed in Sections 2.0 and 3.0, respectively.

The following sections provide more detailed descriptions of the steps involved in the development of the problem formulation component of the ecological risk screening.

6.2.1.1 Site Characterization

The objectives of this step are to initially identify and characterize the site(s) ecological resources, and to preliminarily describe the nature and extent of chemical contamination at the site(s) in question. Information pertaining to site land-use (past, current and future), size, proximity to operable areas and/or sensitive habitats, and habitats and ecological resources will be developed during the site characterization. The SSP is a screening level process that will be used to determine if a site should proceed further through the RFI stage. As such, detailed field sampling and quantitative analysis of biota will not be performed during the SSP. If contamination is identified which may impact ecological receptors, a recommendation in the SSP report would include biota sampling.

This step will actually begin with the site visit discussed in Section 2.0. Information about local ecological resources (including threatened and endangered species) will also be obtained from maps of the study area, available scientific literature, and federal and state agencies (e.g., U.S.

Fish and Wildlife Service, Virginia Department of Game and Inland Fisheries, Department of Natural Heritage database, etc.). The site characterization will also describe likely contaminant sources, release mechanisms, complete migration pathways, the fate of chemicals resulting from site-related activities, as well as important ecological resources that could be adversely affected by these chemicals.

6.2.1.2 Identification of Chemicals of Potential Ecological Concern

COPCs will be identified by comparison of maximum site concentrations to approved Region III BTAG screening values and/or by simple food-web modeling. Initial screening of analytical data will be conducted using general screening values considered protective of all wildlife. Chemicals with MDCs (or a 95% UCL if appropriate) exceeding screening values and/or chemicals for which no screening values are available will be initially identified as COPCs to be carried through to the risk characterization step of the ecological risk screening. Values may be derived from sources such as, Federal and state standard Ambient Water Quality Criteria, Ontario Ministry of the Environment LEL values for freshwater habitats (Ontario Ministry of Environment and Energy, 1993), Great Lakes Research TEL values (Smith et al., 1996) for freshwater habitats, and EPA and ORNL surface soil screening levels (USEPA, 2000b and Will and Suter, 1995a).

6.2.1.3 Identification of Exposure Pathways and Potential Receptors for Analysis

The pathways by which ecological receptors may be exposed to COPCs at the site(s) will be identified along with the receptor groups that could be adversely affected by these chemicals. Several potential exposure pathways may exist at the site(s). For example, terrestrial vegetation may be exposed to contaminants via direct aerial deposition and root translocation, although aerial deposition is highly variable and difficult to quantify. Terrestrial animals may be exposed to soil contaminants through ingestion of contaminated food items and by incidentally ingesting soil while grooming fur, preening feathers, digging, grazing close to the soil, or feeding on items to which soil has adhered (such as roots and tubers). Terrestrial animal receptors may also come into contact with contaminants in surface water by using surface water for drinking water, although this exposure route represents a negligible portion of total exposure for most receptors.

Aquatic and semi-aquatic organisms at the RFAAP may be exposed to contaminants via direct contact with surface water and sediments, incidental ingestion of surface water and sediments, and consumption of contaminated food items. Aquatic and semi-aquatic organisms may also be exposed to constituents from contaminated groundwater that flows into surface water.

For purpose of the SSA ecological risk screening, exposure pathways representing important and likely meaningful routes of contaminate uptake will be assessed for appropriate receptor groups. If sufficient information exists to examine more obscure exposure routes (e.g. aerial deposition or inhalation) or if the assessment of an exposure route will substantially contribute to the risk understanding (e.g. drinking water) it will be examined to assess whether it warrants the evaluation.

Based on the identification of site-specific habitats, food webs, COPCs, and exposure pathways, recommendations will be made for species or species groups to be selected for evaluation in the risk screening. These may include the following receptor groups:

- For terrestrial systems: terrestrial plants, terrestrial invertebrates, reptiles and amphibians, invertebrate-eating birds (e.g., robin), invertebrate-eating mammals (e.g., shrew), carnivorous mammals (e.g. red fox), and carnivorous birds (e.g., red-tailed hawk) may be included. In addition, plant-eating mammals (e.g., rabbit), and omnivorous mammals (e.g. raccoon) may be included.

- For aquatic systems: aquatic plants, benthic invertebrates, fish, reptiles and amphibians, fish-eating birds (e.g. great blue heron), and fish-eating mammals (e.g. mink) may be included.

6.2.1.4 Identification of Assessment and Measurement Endpoints

One of the major tasks in screening problem formulation is the selection of assessment and measurement endpoints. An assessment endpoint is defined as "an explicit expression of actual environmental values that are to be protected" (USEPA, 1992d). Measurement endpoints are "measurable ecological characteristics that are related to the valued characteristic chosen as the assessment endpoint" (USEPA 1992d). Measurement endpoints serve as tools for ranking and evaluating environmental values that are to be protected. While declines in populations and shifts in community structure can be quantified, studies of this nature are generally time-consuming and difficult to interpret. However, measurement endpoints indicative of observed effects on individuals are relatively easy to measure in laboratory toxicity studies and can be related to the site specific assessment endpoint.

Toxicity data and assessment endpoints shall be discussed with BTAG, and agreed upon, in accordance with the USEPA Guidance (USEPA 1997). This step also includes the development of a conceptual site model (CSM) and identification of the specific objectives and scope of the ecological risk screening. The CSM is designed to diagrammatically identify potentially exposed receptor populations and applicable exposure pathways, based on the physical nature of the site and the potential contaminant source areas. Generally, a separate CSM will be developed for each SSA because the contaminant source, migration pathways, assessment and measurement endpoint, and exposure pathways are site-specific. However, in appropriate cases, more than one SSA can be included in a single CSM if, for example, there are common exposure and/or migration pathways.

6.2.2 Exposure Assessment

This section of the ecological risk screening includes identification of contaminant concentration data used to represent ecological exposure in various media. For each exposure pathway selected for quantitative evaluation, conservative exposure point concentrations (EPCs) will be used and the receptor specific exposure will be quantified. EPCs will be estimated using environmental sampling data either alone or in conjunction with simple environmental fate and transport models.

The food chain modeling will be performed in accordance with current USEPA CERCLA guidance for ecological risk assessment, and use conservative exposure parameter values (maximum ingestion rate, minimum body weight, 100% bioavailability) (USEPA, 1993b). The ecological exposure assessment will consist of two phases. The first, most conservative, phase will be based on conservative exposure assumptions such as:

Maximum analytical results for each medium of concern used as EPCs; and

Site use factor equals 1

The second phase will be based on conservative yet more realistic exposure assumptions such as:

- Site use factor determined based on the size of the SSA, proximity to operational areas and/or sensitive habitats, the quality of habitat present, and behavior of important ecological receptors; and

- Use of average body weight and average intake for selected wildlife receptors.

6.2.3 Ecological Effects Assessment

This step in the ecological risk screening develops toxic reference values (TRVs) for ecological receptors, to be used in the risk characterization. Acknowledging that data pertaining to ecological risk characterization is continually being updated, the Army shall consult with EPA on the most-up-to-date and appropriate data sources, when reaching this stage in the screening process. The toxicity of COPCs to terrestrial and aquatic organisms will be summarized using relevant toxicity data for the selected receptor species. The TRVs to be used in the evaluation of potential adverse effects to terrestrial and aquatic species will be derived from the literature, where possible.

In food web modeling, calculated doses will be compared to toxicological thresholds (no observed adverse effect levels [NOAELs] and lowest observed adverse effect levels [LOAELs]). The Army shall develop TRVs for wildlife receptors derived from NOAELs and LOAELs taken from various literature sources. BTAG will review these values and may provide technical assistance in selecting wildlife derived NOAELs and LOAELs. Only EPA and BTAG approved TRVs will be used in identifying COPCs at SSAs.

6.2.4 Risk Characterization

This step compares exposure point contaminant concentrations with benchmark concentrations protective of ecological receptors. The ratio of the maximum contaminant concentration to the benchmark value is called the HQ or Ecological Effects Quotient (EEQ), and is defined as follows:

$$EEQ = Emax/TRV$$

Where: EEQ = Ecological Effects Quotient for contaminant (unitless)

Emax = Maximum Concentration for contaminant (mg/L or mg/kg)

TRV = Toxicity Reference Value for contaminant (mg/L or mg/kg)

When the ratio of the maximum concentration to its respective benchmark value exceeds 1.0, further assessment may be needed. The EEQ value should not be construed as being probabilistic; rather, it is a numerical indicator of the extent to which a maximum concentration exceeds or is less than a benchmark. When EEQ values exceed 1.0, it is an indication that ecological receptors are potentially at risk based on conservative exposure assumptions.

The preliminary risk characterization will be based on the conservative preliminary exposure assumptions. A major part of the risk characterization is the interpretation of the preliminary estimates of risk in light of the conservative assumptions and uncertainties (see Section 6.2.5).

Additional evaluation of site-specific data may be necessary to confirm with greater certainty whether ecological receptors are actually at risk at the site, especially since most benchmarks are based on conservative exposure assumptions. A refined estimate of EEQs will be made using the refined exposure factors (Section 6.2.2). The results of the conservative and refined risk estimates will be evaluated in light of the uncertainties of the risk assessment process (Section 6.2.5). Furthermore, other factors, such as low frequency of detection, may mitigate potential risks for a COPC with an elevated EEQ value.

6.2.5 Uncertainty Analysis

When the above steps are completed, the results are interpreted and the uncertainties associated with the ecological risk screening are addressed. General uncertainties associated with the ecological risk screening will be qualitatively evaluated to determine the conservatism of the approach. For example, uncertainty in this site screening could arise if ecological based criteria are less than analytical method detection limits. In addition, background screening will be performed at this stage to aid in risk management decisions. Maximum detected concentrations of inorganic constituents may be compared to background values (see Section 6.1.4) to assist in assessing whether or not potential ecological risk is associated with site-related conditions.

7.0 SITE SCREENING PROCESS REPORT

Results of the desktop audit, nature and extent determination (if available), and the human health and ecological screening procedures will be presented in an SSP Report for each SSA with a recommendation for future action. The EPA will review the SSP Report for each SSA and based on results of the screening procedures, a decision will be made as to whether each SSA should be recommended for no further action, or for further action. A need for further action will be based on but not limited to the following: historical use of the SSA, history of documented release (if any), analytical data from the SSA, and the overall weight of the evidence. In general, further action at an SSA may be required under the following circumstances:

- Cumulative Excess Cancer Risk (CECR) greater than 1x10-5
- HI greater than 0.5 per target organ
- Maximum Detected Concentration > SSL for chemical migration from soil to ground water or other screening values (e.g., Virginia AST/UST TPH guidance level for soil; Virginia State and Federal MCLs, Virginia AST/UST TPH guidance level for ground water; or Federal and State Ambient Water Quality Criteria for surface water)
- Ecological risk considerations per Section 6.2

If none of the above circumstances occur, EPA may recommend no further action and memorialize this recommendation in a Decision Document.

If any of the above circumstances occur, further action may be required. Further action may consist of one or more of the following:

- Interim Removal Action, followed by sampling to confirm that risks have been reduced to acceptable levels
- Focused RFI (including additional sampling)
- RFI/CMS

8.0 DISPUTE RESOLUTION

Disputes arising during the course of the SSP shall be resolved using the dispute resolution procedures of the RCRA Corrective Action Permit, Part I, C.

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APPENDIX B

STANDARD OPERATING PROCEDURES

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Standard Operating Procedures

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**
20.3	Well and Boring Abandonment
20.4	Test Pits
20.6	Ground-Penetrating Radar Surveys
20.7	Resistivity and Electromagnetic Surveys
20.11	Drilling Methods and Procedures
30.0	**SAMPLING**
30.1	Soil Sampling
30.2	Groundwater Sampling
30.4	Sediment Sampling with Scoop or Tube Sampler
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	Water 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 10.2
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:

    $1\ EV = [\pi R_w^2 h_w + 0.30p(R_s^2 - R_w^2)h_s] * (0.0043)$

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

$0.0043 = gal/in^3$

and filter pack porosity is assumed as 30%, or

Volume in casing =
$(0.0043\ gal/in^3)(p)(12\ in/ft)(R_c^2)(W_h)$

Where:

R_c = radius of casing in inches, and
W_h = water column height in feet

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Wh)(0.30)

(if Wh is less than the length of the sandpack), or

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Sh)(0.30)

(if Wh is greater than the length of the sandpack).

where:

Rb = 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-μm).

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 IDENTIFICATON

If one-half or more of the material will pass a No. 200 sieve (75 μm), 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 dilatency, 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:

Description	Criteria
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:

Description	Criteria
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:

Blow Count	Relative Density for Sand
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:

Blow Count	Consistency for Clays	Description
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:

Modifiers	Descriptions
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:

Description	Criteria
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:

Description	Criteria
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 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:

RQD = [Σ length of intact core pieces > 100 mm (4-inches)] x 100%/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:

AEG Fracturing	Spacing
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:

Hardness	Criteria
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).*

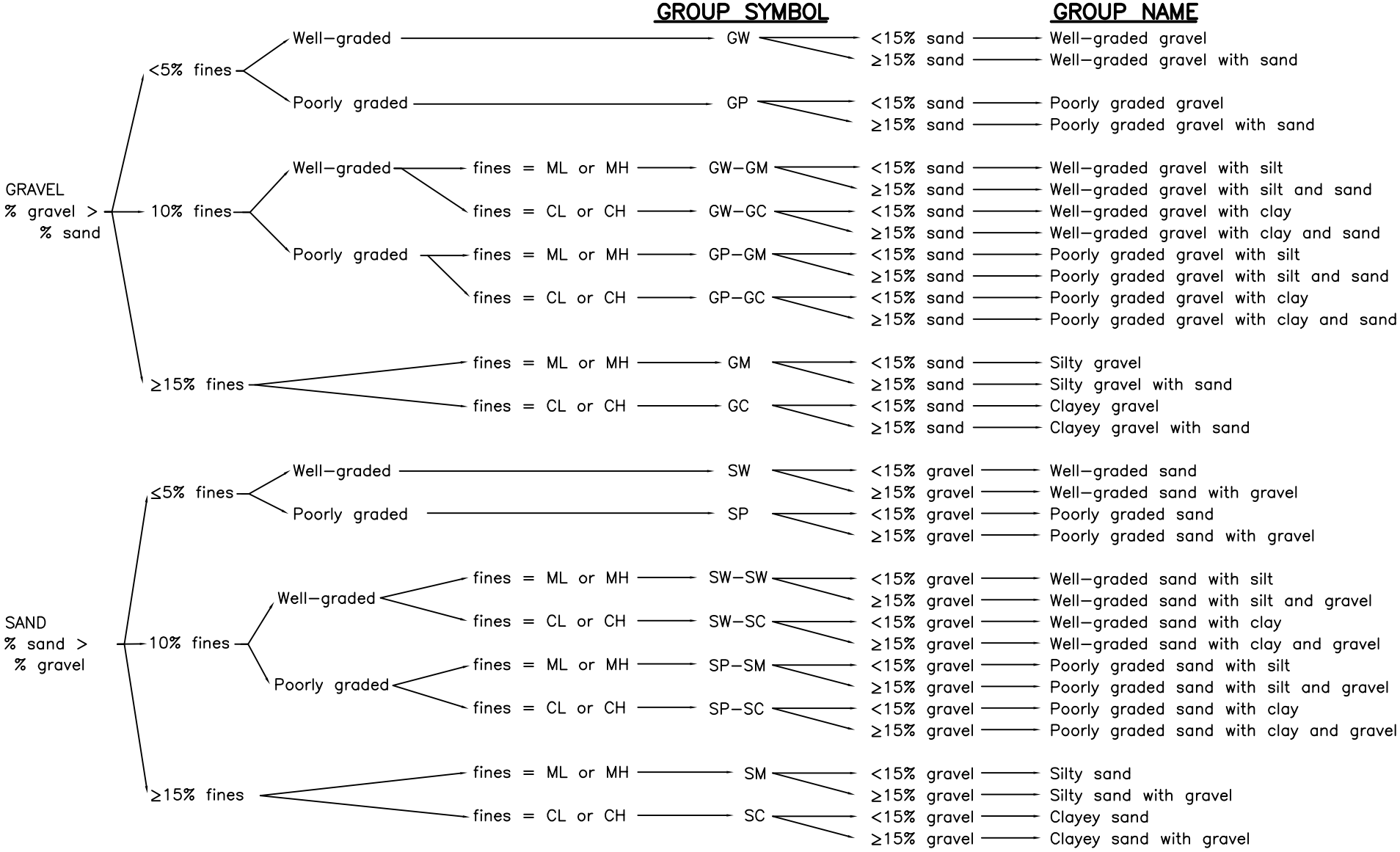
ASTM Standard D 5434-03. 2003. *Guide for Field Logging of Subsurface Explorations of Soil and Rock.*

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%.

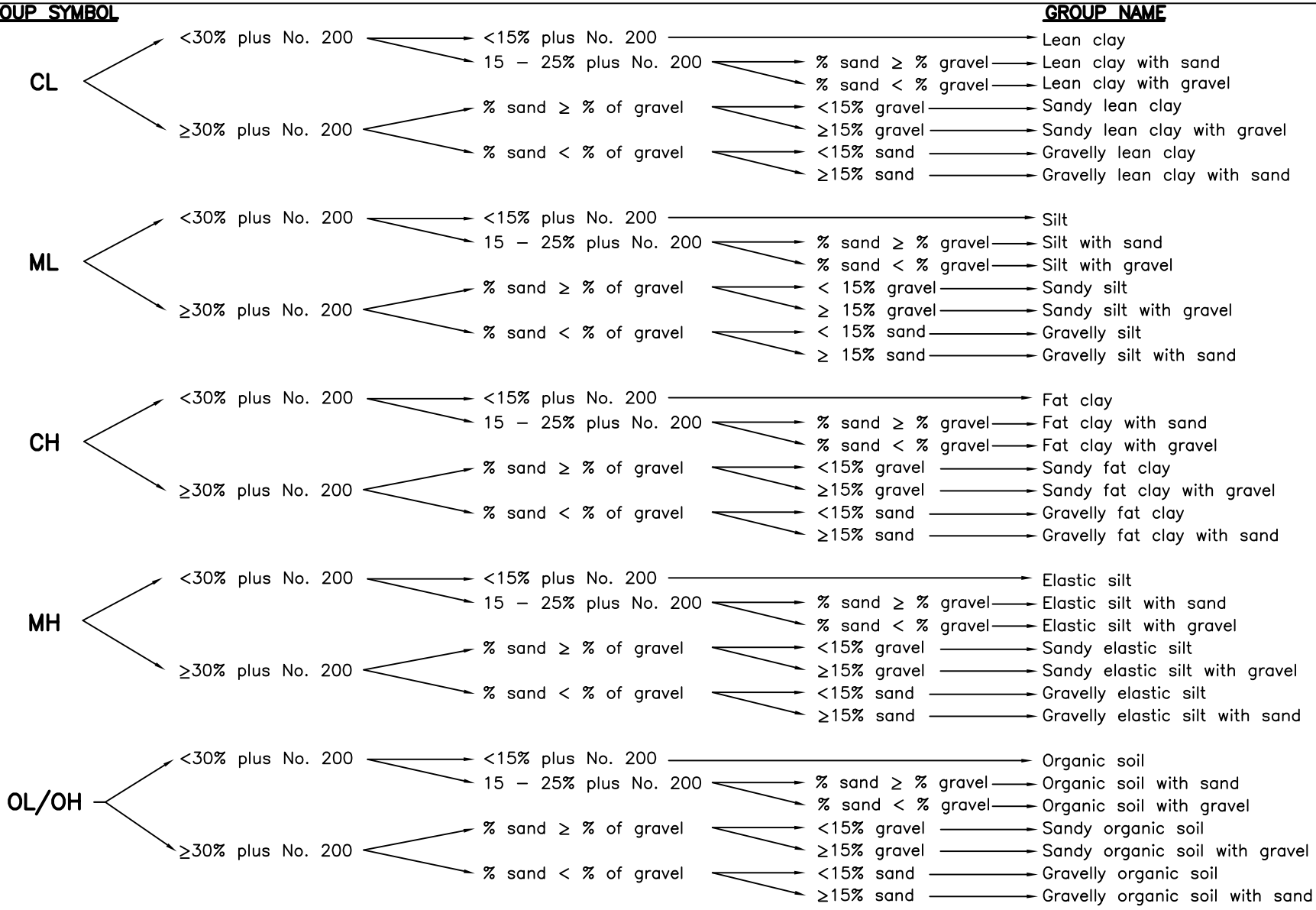
SOURCE: ASTM D 2488

Radford Army Ammuntion 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*



NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

SOURCE: ASTM D 2488

Radford Army Ammuntion Plant		FIGURE 10.03b
Date: *October 2007*	**Prepared By:** *DBC/TLD*	**FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS**
Scale: *N.T.S.*	**File Name:** *SOP Figure 10.03b_Fine*	

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	Comp	Grab										Subtotal	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 20.3
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.

<u>General Considerations</u>

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 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 to12 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 20.6
GROUND-PENETRATING RADAR SURVEYS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide a general description and technical management guidance concerning the use of Ground-Penetrating Radar (GPR) Surveys.

2.0 MATERIALS

- Work plans;
- Field logbook;
- Site maps;
- GPR and associated equipment;
- Data Sheets;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan.

3.0 PROCEDURE

3.1 DESCRIPTION OF METHODS

3.1.1 Theory and Principles of Operation

Commercially available Ground-Penetrating Radar (GPR) equipment operates on the principle of time-domain reflectometry, in which the differences in strength and the time delay between a transmitted electromagnetic pulse and its reflection from an object are measured. The time delay (t) is directly related to the propagation velocity of the electromagnetic waves (v) and to the distance between the transmitter and the object (D) as follows:

$$t = \frac{2D}{v}$$

Because surface GPR is normally used at or near the surface of the ground, the distance (D) corresponds directly to the depth of the buried targets that reflect the radar signals.

The strength of a radar signal is a complex function of the distance traveled through the medium, the dielectric constant, the magnetic permeability, and the electrical conductivity. Radar signals are attenuated rapidly in materials with a high dielectric constant. The attenuation of radar signals in subsurface media is a strong function of the mineralogy and the water content. Thus, materials such as dry sands and gravels are least absorptive of radar signals, whereas wet clays are highly absorptive. The absorptive properties of the medium limit the penetration depth, i.e., and the depth at which targets can be detected.

In operation, the GPR repetitively transmits short-duration (typically 5-10 nanosecond) pulses of high-frequency (typically 50 GHz) electromagnetic energy through a transmitting antenna that is moved along the

ground surface at a constant speed. Reflected pulses are detected by a receiving antenna at a location corresponding to the distance traveled by the antenna during the transmission and reflection of the pulse, at which point another pulse is transmitted. At a typical antenna speed of 2 miles per hour (3 ft per second), a complete transmit/receive cycle occurs about every 2 inches along the path of the antenna.

Radar antennas are available that operate at frequencies centered on 50, 80, 120, 300, 500, and 900 MHz and 1 GHz. Whereas the higher frequencies are able to detect smaller targets, the penetration depth is roughly inversely proportional to frequency. Thus, each GPR survey requires an analysis of the trade-off between resolution and depth of penetration so that the optimal frequency can be selected.

The strength of a radar reflection is a function of the composition, size, shape, and depth of the target. Reflections are strong from objects exhibiting large differences in dielectric constant from the surrounding medium and that are large in size compared with the radar signal wavelength.

3.1.2 General Applicability

GPR signals are reflected from any interface that corresponds to an abrupt change in dielectric constant. Therefore, both metallic and nonmetallic objects (including voids), as well as changes in geologic structure, can be detected by this method. Because of the higher frequencies used, target resolution is considerably improved over seismic or resistivity sounding methods. However, the high frequencies also result in strong attenuation of the signals, particularly in clay materials with high moisture content. At 100 MHz, the useful penetration depth in clay soil with 20% moisture content is about 3 feet, whereas in dry clay or sand with 20% moisture the penetration depth extends to about 30 feet. By changing the frequency of the antenna, greater or lesser depths of penetration can be accomplished.

GPR can be a powerful method for locating and mapping buried drums, wooden objects, foundations, non-containerized wastes, underground utilities, and any other artifacts (including historical artifacts) at a site. Depending on whether sufficient penetration can be achieved, the method can also be used to map saturated zones and bedrock contours and locate sinkholes or fracture systems. GPR has also been used to map contaminants indirectly, both polar and non-polar.

3.1.3 Instrumentation

The standard array of GPR instrumentation consists of transmitting and receiving antennas, which are pulled along the ground; a control unit, containing power supply and signal processing circuitry, which is connected to the antenna by a cable; and an oscillograph or analog tape recorder. The system can be vehicle-mounted, and the transmitter can be connected via radio link to the signal processing and recording equipment. Systems have been modified to include digitizing, onsite computer processing, and digital, graphic display equipment.

3.2 DATA ACQUISITION

3.2.1 Field Procedures

Establishing a grid of parallel survey lines across the site and moving the radar antenna along each of these lines perform GPR surveys. A suitable means must be provided for determining the location of the radar unit along each of the lines and for documenting this information on the recording medium. Typical systems measure the time and velocity of antenna motion, or determine the position of the antenna by synchronization signals from the wheels or tracks of the vehicle used to tow the antenna or by means of an electronic marking device.

Depending on the data quality objectives and site conditions, different frequency antennas are needed. The GRP contractor will beta-test all methods in one small representative area to verify that the selected

antennas produce reasonable, defensible data. In the event selected antennas or the GPR method does not meet the project's data quality objectives, the antennas and method will be eliminated from the survey.

To assess the depth of anomalies noted on radar traces, it is necessary to convert the travel time data that are actually recorded. The velocity of electromagnetic waves in the subsurface medium at the site is determined at a particular site by excavation to observed targets or known test targets and measuring their depths. The velocity should be determined at several points in the area of interest. Another method to determine the depth to a target is by assessing the velocity of the medium. This can be accomplished by performing wide-angle, reflection/refraction measurements, known as WARR. Separating the transmitter and receiver portions of the antenna at a constant rate over a known distance and recording the refraction pattern accomplish this. By determining the slope of the refraction pattern, a velocity can be obtained.

Electronic data generated during GPR surveys shall backed up at the end of every data for both field and processed data. A backup of all hard copy data shall also be maintained.

3.2.2 Data Format

Reflected radar signals are electronically processed and displayed as an intensity-modulated time spectrum, where the time corresponds to target depth as described above. The series of signals corresponding to the reflected pulses as the antenna moves along a path forms a three-dimensional data set containing distance of traverse, depth, and intensity information.

Typically, the data are recorded on magnetic tape and/or displayed on an X-Y oscillograph, with distance displayed along the X-axis, time (depth) displayed along the Y-axis, and the intensity given by the degree of darkness of the trace. In a typical survey, a series of parallel tracks are traversed by the GPR, and the series of resulting oscillograph traces thus provide XYZ location information on, as well the intensity of reflection from targets of interest.

Although much of the data obtained in a GPR survey are automatically recorded by the instrumentation, additional information to unambiguously identify and interpret each trace should be recorded on standard data sheets. As a minimum, the data sheet should contain the following information:

- Project name, number and location;
- Company or organization;
- Date and time of day;
- Operator's name;
- Line and trace designation (also recorded directly on the signal recording medium);
- Receiving levels and filter settings;
- Antenna frequency(s);
- Direction and speed of antenna movement;
- Weather and temperature;
- Relative soil moisture content and soil type;
- Site map coordinates at the beginning and end of the trace. At least one point in the survey must be tied into the state plane coordinate system for follow-on work;
- Notes, remarks, or comments; and

- Electromagnetic velocity in the subsurface medium at the nearest calibration point.

3.3 DATA INTERPRETATION

Except for those systems that provide extensive data processing, interpretation of anomalies in GPR traces requires considerable subjective evaluation by a qualified geophysicist. Extensive experience is essential to distinguish target reflections from inherent system noise and interferences. In many cases, the anomalies from targets of interest are small compared with varying reflections from the antenna system, the ground surface, geologic perturbations, and other interferences. Similarly, an acceptable interpretation of target depth from travel time data requires knowledge of geophysical and geological characteristics across the site. A radar antenna transmits a "cone" rather than a thin beam of electromagnetic energy. Therefore, reflections are obtained from objects not directly below the antenna. As the antenna moves across the plane of an object, reflections are obtained for a considerable distance along the antenna path. The signal travel times vary during this process, corresponding to the distance between the antenna and the object. A discrete spherical target, therefore, will exhibit a hyperbolic reflection pattern on the radar trace, with the apex of the hyperbola corresponding to the location and depth of the object. Multiple or odd-shaped targets or targets of considerable size (compared with the radar wavelength) will exhibit complex reflection patterns consisting of overlapping hyperbolas. Thus, a true "picture" of subsurface objects is not obtained, and experience is necessary to translate the complex tracings into information on target depths size or shape.

Radar signals can be digitized which permits digital recording, computer processing and enhanced display of the location and intensity data. Typical computer processing includes removing extraneous signal interferences, changing hyperbolic reflection patterns to signals more representative of the size or shape of targets, color-coding of intensity data, blocking of data sets to correspond to the site map, and map-view displays of targets at a given depth.

3.4 APPLICATIONS MANAGEMENT

3.4.1 Prerequisites

Appropriate planning of GPR surveys requires an understanding of the geohydrological and geophysical characteristics of the site. The type and structure of soils and geologic formations should be indicated. The description of the site should include the depth, size, and shape and type of potential targets to be detected, as well as obstructive site features such as terrain and underground structures. Additionally, existence of and depth to known buried objects should be listed and mapped, and electromagnetic sources of interference to the survey should be considered.

3.4.2 Work Planning and Scheduling

If possible, GPR surveys should be performed concurrently (if warranted) with other geophysical surveys and in advance of excavation or drilling at a site. Radar data complements information from other geophysical methods such as, electromagnetic induction, seismic refraction, magnetometry, terrain conductivity, and resistivity, in arriving at an interpretation of subsurface geohydrologic features and buried waste materials.

The time and effort required to perform GPR surveys varies greatly depending on the sophistication of the available equipment and the complexity of the site. Assuming a two-person team, simple hand-operated radar systems can cover from ¼ to ½ acre per day for the survey, proper documentation, and simple interpretation. Vehicle-mounted systems with automatic data recording and processing can cover from 2 to 5 acres per day. Sophisticated data processing, detailed interpretations, and high-quality displays require considerable computer usage and approximately twice the time required for the actual field survey.

The specific objectives of the GPR survey should be defined in work plan addenda and should include the following elements:

- Type of survey (level of detail) to be accomplished, and area to be covered;
- Type, depth, size, and composition of targets of interest;
- Locational accuracy required;
- Schedule limitations;
- Degree of sophistication required for data presentation and interpretation;
- Specific deliverables required; and
- Logistics.

3.4.3 Quality Control (QC)

3.4.4 General

Because of the specialized nature of the method and the highly subjective interpretations needed to process the data, GPR surveys are subject to misapplication, erroneous interpretation, and collection of inadequate or incomplete data. This susceptibility to misuse requires that an adequate quality control program be established. Quality control aspects common to most geophysical field programs include the following:

- Program management personnel (i.e., the project geologist or geophysicist, RI leader, or site manager) with technical expertise in the subject for preparation of statements of work, proposal reviews, work plans, and reports.
- Defined scope of work, specifications, and data validation procedures.
- Defined field quality control procedures.
- No data should be rejected from a data set without appropriate justification; field data sheets should contain all observed data and the conditions that could affect data validation.
- All field data parameters 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 RI/FS contractor's files.
- Properly calibrated instruments provide an added measure of data validity and permit 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 and should be recorded in the field. These real-time quality control procedures aid field personnel in correction of noise sources, validating suspected external sources, and early detection of problems that may jeopardize the survey objectives.

3.4.5 Calibration

The determination of target depth from travel time measurements requires calibration of the instrumentation for these two parameters. Travel time is calibrated periodically in the field by using a secondary-standard, previously calibrated pulse generator to produce timing marks directly on the radar trace. The travel time to

a target is determined by the position of the target reflection along the timing marks. This calibration should be performed several times daily, and each radar trace should be referenced to the most recent calibration. Calibration of the radar traces for depth determination may be performed as follows:

- For reconnaissance surveys or for surveys where lateral resolution is more important than depth, the traces can be roughly calibrated by estimating the velocity of electromagnetic materials in the media at the site. The crudeness of the calibration is evidenced by considering that the velocity can vary by more than an order of magnitude, depending on the soil/rock properties and the moisture content.
- For surveys requiring reasonable resolution of target depth, the travel time to targets of known depths must be determined at each site. A radar trace is made over the known targets, and the reflection patterns then provide direct depth-calibration points on the trace. Sites with uniform lithology may require only a few depth calibrations, but generally, it is necessary to perform these calibrations at several locations and at several depths throughout the area of interest because dielectric constants may vary across the site. Each radar trace should be referenced to the calibration most representative of the trace coordinates at the site. The preferred method is to use buried objects of known depth as calibration targets or to excavate to detected objects and measure the depth. A less desirable (but often necessary) procedure is to bury standard targets at various depths within the area of interest.
- WARR measurements should be made on a daily basis at various positions at the site, especially in areas where subsurface conditions may vary greatly.

3.4.6 Daily Quality Control

All radar traces and interpreted data sets should be accompanied by quality control data that indicate the level of quality of the data. Periodic replicate measurements should be made so that measurement precision can be established. Time and/or depth calibrations should be performed on a daily basis.

A calibration that yields significant changes in instrument parameters or travel time may indicate the need for repetition of data or increased density of travel time calibrations in the area of interest. Graphical data should be reviewed during the field activities to determine data quality, and whether the survey results appear to be consistent with geophysical knowledge of the site.

3.5 HEALTH AND SAFETY CONSIDERATIONS

All procedures for hazardous waste site entrance, traverse, and egress that apply to general field operations also apply to GPR surveys. The GPR survey consists of traversing the site on foot or in vehicles, and the extent of the activities results in considerable periods of time during which personnel are exposed to any adverse conditions that may exist. An appropriate level of protection against these risks must be planned and provided.

Hand-towed GPR systems involve physical activity (particularly on sloping or rough terrain) that is much more strenuous than when vehicle-mounted systems are used. Precautions must be taken against exposure to heat or cold in accordance with the type of activity that is planned. Extreme weather conditions will have an adverse effect on the time required to complete a survey, thereby increasing the duration of personal exposure to the elements and to hazardous site conditions.

3.6 POTENTIAL PROBLEMS AND LIMITATIONS

A wide-variety of problems may be encountered during GPR surveys. Problems can be expected to arise in the following areas:

3.6.1 Limitations Inherent to Geophysical Methods

A basic limitation of geophysical methods is that a given set of data cannot always be associated with a particular set of subsurface conditions. In general, surface geophysical measurements alone cannot provide a complete assessment of subsurface conditions. When appropriately integrated with other information from subsurface borings, borehole geophysics, etc., GPR 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.

3.6.2 Planning and Execution

Rarely is a survey accomplished exactly according to the original plan. Site features not previously specified and other variations can occur that force changes in the details of the approach. However, the objectives of the survey, the general methodology, the amount and quality 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.

3.6.3 Material Properties Contrast

It may be difficult to identify a particular subsurface boundary or feature if the subsurface materials have an insufficient velocity contrast or gradual boundary.

3.6.4 Noise and Interferences

Measurements can be severely affected by both natural and man-made sources of interference. Sources of system noise that degrade the quality of radar traces include improper spacing of antennas above ground, improper cable placement, location of antennas too close to other system components, and facility instrument operation. Because reflections are obtained from any object with a dielectric constant differing from the surroundings, large masses of buried or surface rocks, metal, debris, wet soil, or aboveground structures can mask targets of interest. Some antennas are not shielded on top, and similar interfering reflections will be obtained from overhead objects such as trees, power lines, and buildings. The site personnel must recognize the limitations posed by these obstructions and take steps to minimize the interferences.

Topographic and geologic features can also interfere with acquisition of high-quality target detection data. Small depressions in the ground surface, the presence of boulders, clay lenses, and moist soil zones affect both the detectability of a target and determination of its depth from the travel time.

Sources of electromagnetic energy in the vicinity, such as radio or television transmitters or navigational radar antennas, can result in spurious signals in the radar traces. In some cases, these problems can be minimized by judicious selection of radar and/or data communications frequency and by scheduling the surveys during periods of transmission inactivity.

3.6.5 Weather Conditions

Because water is a good absorber of radar signals, wet weather has a very serious effect on the ability to perform GPR surveys. Physical difficulties in executing a survey over wet terrain also may be expected. The field activities should be planned, if possible, during periods when dry weather can be expected. Schedules for surveys should account for the probability that moist soil conditions will exist.

3.6.6 Technical Difficulties

Preventable difficulties include equipment malfunction or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the geophysical characteristics of the site

are not as initially conceptualized. Early recognition and response by technical management can minimize the effect of any problems. Interim, real-time scrutiny of the data by the site geophysicists 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, change performers, or cancel a survey, as appropriate.

4.0 REFERENCES

Discussion of various geophysical survey techniques and applications can be found in the following:

ASTM Standard D 6429-99. 1999. *Standard Guide for Selecting Surface Geophysical Methods.*

ASTM Standard D 6432-99. 1999. *Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation.*

Benson, Richard C., Robert A Glaccum and Michael R. Noel. *Geophysical Techniques for Sensing Buried Wastes and Waste Migration*, Technos, Inc., Miami, FL, contract No. 68-03-3050, USEPA Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Costello, Robert L. 1980. *Identification and Description Geophysical Techniques*, Report No. DRXTH-TE-CR-80084, US Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD; Defense Technical Information System Number ADA 123939.

McKown G. L., G. A. Sandness, and G. W. Dawson, 1980. *Detection and Identification of Buried Waste and Munitions*, Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, VA.

Olhoeft, Gary R. 1989. *Geophysics Advisor Expert System: Version 1.0*, Interagency Agreement DW 14932497, USEPA EMSL, Las Vegas, NV.

USACE. 1995. *Geophysical Exploration for Environmental and Engineering Investigations.* EM 1100-1-19802. 31 August.

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:

$$\textit{1,000}\ \text{milliohm per meter} = \frac{1}{\text{ohm-meter}}$$

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:

Sampling depth = 1.5 (coil spacing) (Vertical Dipole)
= 0.75 (coil spacing) (Horizontal Dipole)

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:

ASTM Standard D 6429-99 (2006). 2006. *Standard Guide for Selecting Surface Geophysical Methods.*

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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 are 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 addition 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 ampler 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 to 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

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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 20.3.

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 ($\leq$ 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;
  - ±3% for specific conductance;
  - ±10 mV for oxidation/reduction potential (Eh); and
  - ±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-though 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 be 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:

  $1\ EV = (p R_w^2 h_w) + (0.30p(R_s^2 - R_w^2)h_w) * (0.0043)$

  If the water table lies above the top of the sand pack use this equation:

  $1\ EV = [(p R_w^2 h_w) + (0.30p(R_s^2 - R_w^2)h_s)] * (0.0043)$

  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

  $0.0043\ gal/in^3$
  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;
  - ±3% for specific conductance;

- ±10 mV for oxidation/reduction potential (Eh); and
- ±10% for turbidity and dissolved oxygen.

- Three calculated eVs of water in the 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-though 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 be 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. R*equirements 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 30.4
SEDIMENT SAMPLING WITH SCOOP OR TUBE SAMPLER

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for obtaining representative sediments sampling using a scoop or hand corer.

Sediments include solid matter derived from rocks or biological materials that are suspended in, or settled from, water. This procedure can be applied to the collection of sediment samples from areas of deposition such as streams, rivers, ditches, lakes, ponds, and lagoons.

SOP 30.5 describes two methods of grab sampling (Ekman and Ponar) that are suitable for sampling surface or deep sediments. SOP 30.12 describes a method of sampling deep sediments by using a Vibracore sampler.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Photoionization detector (PID) or other appropriate monitoring instruments as specified in site-specific health and safety plan;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Stainless steel bowls;
- Stainless steel or polytetrafluoroethylene (PTFE) scoops, trowels, spoons, and knives;
- Hand core sediment sampler, liners (optional) and extensions;
- Hand auger with buckets, rods, and T-handles;
- Rubber boots/waders;
- Decontamination equipment and supplies (SOP 80.1);
- Plastic sheeting;
- Utility knife;
- Boat or other stable work platform, and personal flotation devices, as applicable; and
- Personal protective equipment and clothing (PPE) as specified in site-specific health and safety plan.

3.0 PROCEDURE

The water content of the sediment may vary greatly. Likewise, the sediments themselves may range from very soft to dense. It may be necessary to use a variety of equipment to obtain the required samples, even at a single site.

3.1 CONSIDERATIONS

Factors that determine the type of sediment water sampler used are primarily related to project objectives of surficial versus subsurface samples, site constraints of the water depth, sampling and sediment conditions, and cost-effectiveness of the sampler.

The most appropriate method(s) of sample collection and the appropriate depths of sampling (sampling strategies) will be specified in the work plan addendum based on site-specific conditions and data quality objectives (DQOs).

3.2 DOCUMENTATION

Sediment sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2. This information should include a description of the water body characteristics (size, depth, flow, etc.) and nature of sediments.

Sampling locations should be marked on a site map. Describe each location and place a numbered stake above the visible high water mark on the bank closest to the sampling location and/or mark adjacent trees with surveyor's flagging. The descriptions must be adequate to allow the sampling station to be relocated at some future date by someone other than the original sampling crew.

3.3 SAMPLE LOCATION AND TIMING

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected upstream. In addition, if surface water samples are to be collected at the same locations as the sediment samples, the surface water samples must be collected first. Sampling should be conducting using appropriate sampling devices that minimize disturbance and sample washing as the sample is retrieved through the liquid column.

In general, sediment 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 volatile organic compounds (VOCs), extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any location are site-specific and are specified in work plan addenda.

3.4 LOCATION

For all samples, mark the sampling location on a site map. Photograph (optional, recommended) and describe each location, and place a numbered stake above the visible high water mark on the bank closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at some future date.

3.5 GENERAL PROCEDURES

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of work plan addenda and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Document sample location and conditions appropriately in the field logbooks and on site maps.
4. Collect surface water sample as described in the work plan addenda and SOP 30.3, as necessary.
5. Collect sediment sample using the appropriate sampling device as described in the following sections.

3.6 SCOOP OR TROWEL METHOD

The scoop or trowel method is a very accurate procedure for collecting representative samples, but is limited to sampling exposed sediments or sediments in surface water less than 6-inches deep, with nominal flow.

1. Insert scoop or trowel into material and remove sample.
2. 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.
3. The method of collection for VOC samples 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 and sampling conditions.
4. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.
5. 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.
6. 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. Secure the cap of each container tightly. Sample container requirements are specified in work plan addenda.
7. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

3.7 TUBE SAMPLER

Tube samplers are a simple and direct method for obtaining sediment samples. The tube sampler is forced into the sediment and then withdrawn and the sample collected. Non-cohesive sediments may limit the effectiveness of this type of sampler.

1. Ensure that the corers and (optional) liners are properly cleaned.
2. Gradually force the corer into the sediment.
3. Carefully retrieve the tube sampler.
4. Remove the sediment core from the tube sampler and place core on a clean working surface.
5. Begin sampling with the acquisition of any discrete sample(s) for analysis of VOCs, with as little disturbance as possible. VOC samples will not be composited or homogenized.
6. The method of collection for VOC samples 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 and sampling conditions.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.

8. 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.
9. 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. Secure the cap of each container tightly. Sample container requirements are specified in work plan addenda.
10. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

3.8 HAND AUGER AND TUBE SAMPLER

In general, the use of a hand auger and tube sampler will allow for sampling deeper sediments than possible with the tube sampling method described in Section 3.7. A potential disadvantage of using this method is that it limited to use for water bodies of limited depth and hand augers may not be an effective method for penetrating soft sediments since the borehole may collapse prior to sampling.

1. Attach the auger bucket to a drill rod extension and attach the T-handle to the drill rod.
2. Begin drilling with the auger. Periodically remove accumulated sediment from the bucket.
3. After reaching the desired depth, slowly and carefully remove the auger from the boring.
4. Remove the auger bucket from the drill rod(s) and replace with a clean thin-wall tube sampler.
5. Remove the sediment core from the tube sampler and place core on a clean working surface.
6. Carefully lower the tube sampler down the borehole and gradually force it into the sediment, avoiding scraping the borehole sides.
7. Carefully retrieve the tube sampler and unscrew the drill rod(s).
8. Begin sampling with the acquisition of any discrete sample(s) for analysis of VOCs, with as little disturbance as possible. VOC samples will not be composited or homogenized.
9. The method of collection for VOC samples 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 and sampling conditions.
10. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.
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. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

3.9 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 4700-91 (2006). 2006. *Standard Guide for Soil Sampling from the Vadose Zone.*

ASTM Standard D 5633-04. 2004. *Standard Practice for Sampling with a Scoop.*

USEPA. 1987. *A Compendium of Superfund Field Operations Methods.* EPA/540/P-87/001.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

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 heterogenous 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 0-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 4ºC 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 determining 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^{c}Alary, 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_2SO_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.

4.0 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.

5.0 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 contaminates 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.

Procedure	Frequency
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 regu-

larly 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 through 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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APPENDIX C
PHOTOGRAPHIC LOG

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PHOTO 1: SSA 18 – Unit 18a Building 4434 and Unit 18e Concrete Clarifiers

PHOTO 2: SSA 18 – Unit 18e Concrete Clarifiers

PHOTO 3: SSA 18 – Unit 18g Concrete Discharge Station

PHOTO 4: SSA 18 – Unit 18c Lime Silos

PHOTO 5: SSA 18 – Unit 18d Neutralization Tanks

PHOTO 6: SSA 18 – Unit 18f Steel Wastewater Surge Tank

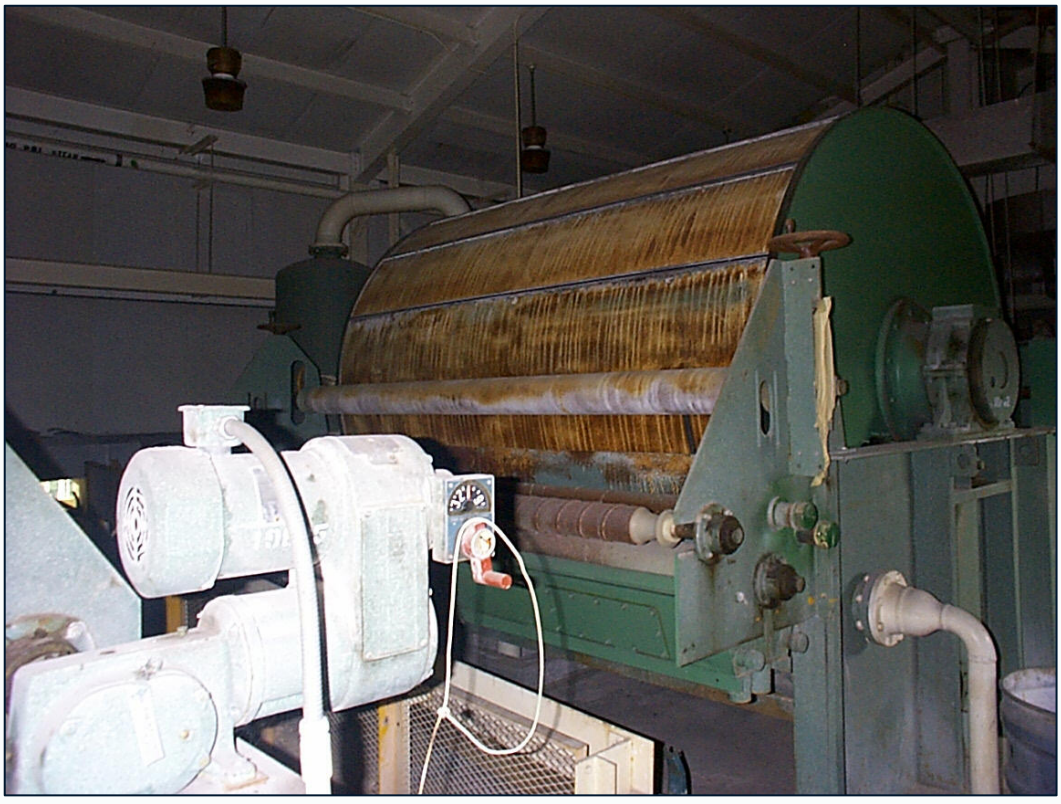

PHOTO 7: SSA 18 – Unit 18b Vacuum Drum Filter

PHOTO 8: SSA 72 – Oleum Plant Acidic Wastewater Sump

PHOTO 9: SSA 72 – Oleum Plant Acidic Wastewater Sump

PHOTO 10: SSA 30 and 79 – Asbestos Disposal Trenches 1&2

PHOTO 11: SSA 60 – Rubble Pile East of Administrative Building 220

PHOTO 12: SSA 77 – Garbage Incinerator from West

PHOTO 12: SSA 79 – Garbage Incinerator from East

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APPENDIX D

PREVIOUS INVESTIGATION INFORMATION

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APPENDIX D.1

SSA 18 AND SSA 72

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DRILLING LOG FOR SB-01

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/18/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe

Drilling Method (s) Direct push

Bit Size (s) 2-INCH Auger Size (s) _____

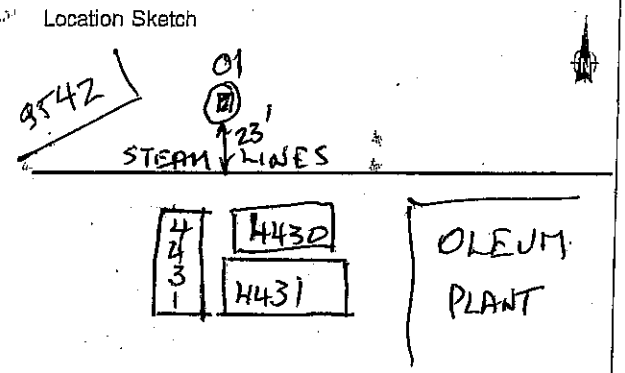
Auger/Split Spoon Refusal _____

Total Depth of Borehole is _____

Total Depth of Corehole is _____

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB01		CL, SL			100%				SILTY, MICACEOUS, clay 10YR 4/3
2										CLAY as above
3										at base 10YR 6/6 SANDY
4			CL, SL, SD							
5			CL, SL			100%				Clay, silty, 10 YR 6/6 uniform
6										
7										
8			CL, SL, S			100%				Clay, silty, sandy
9			CL, SL							Clay, silty, trace fn sand, micaceous uniform
10										
11										
12			CL, SL							Clay as above
13										
14										
15			S, SL							Sand, v. fine, silty micaceous

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
											SB-01
			SD, SL								sand as above
16			CL, SL								silty clay, w fn. sand. micaceous
17											
18											
19			GR, S								GR, S
20											TD. 20 ft.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DRILLING LOG FOR SB-02

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA.

Date Started/Finished 04/17/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe

Drilling Method (s) Direct push

Bit Size (s) 2INCH Auger Size (s) _____

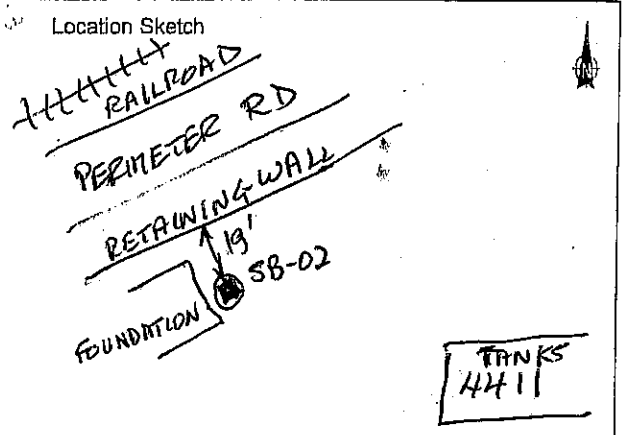
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	~~Core~~ Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB02 0-4'		FILL GR	N/A		63%		N/A	N/A	CLAY 10YR 6/6 Yellow-brown silty
2			CL, SL							
3										
4			CL, SL			88%				Clay, as above
5										
6										
7										
8			CL, SL			88%				Clay, as above trace v. fn. sd.
9										
10										
11										increasing v. fn. sd
12						100%				CL as above
13										
14			S, SL							S, very fine, silty 10YR 6/6
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-02
16	ATK-SUB=SB-02		S, SL.				90%				Sand, very fine, silty, micaceous 10YR 6/6
17											
18											
19											
20											TD 20ft. bgs.
21											
22											
23											
24											
25											
26											
27											
28											
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DRILLING LOG FOR SB-03

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA.

Date Started/Finished 04/18/07

Drilling Company BHT - ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) GEOPROBE®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

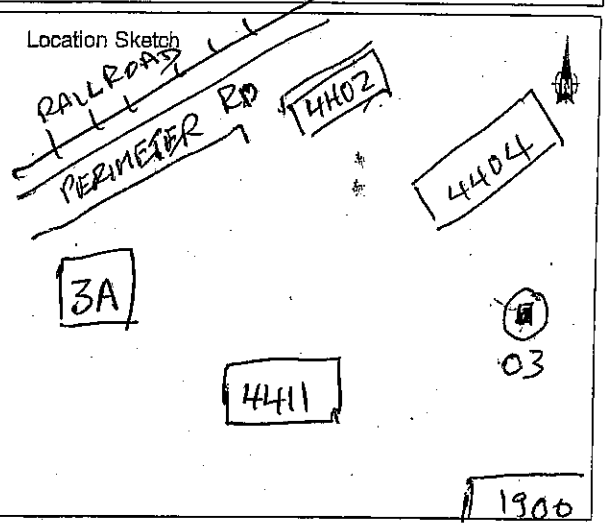
Auger/Split Spoon Refusal ~~N/A~~ HA 19.5ft.

Total Depth of Borehole Is ~~20ft~~ 19.5ft HA

Total Depth of Corehole Is ~~20ft~~ 19.5ft HA.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1–4	ATK-SS-SB03	N/A	CL, SL	N/A		100%		N/A	N/A	Clay, silty light brown 10YR 6/6
5–8			CL, SL			100%				Clay, as above
9–12			CL, SL			100%				Clay as above dark mottles and concretions at 9ft bgs
13–15			CL, SL			100%				Clay, as above, fr. v. fr. sand

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-03
16											
17	ATK-SUB-SB03		S, SL, CL				88%				Sand, silty, clayey, 10YR 6/6
18											
19											Quartz Pebble at 19.5 FT
20											Refusal at 19.5 ft bgs
21											
22											
23											
24											
25											
26											
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28											
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DRILLING LOG FOR SB-04'

Project Name RADFORD ARM

Site Location RADFORD, VA.

Date Started/Finished 04/17/07

Drilling Company BMT ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

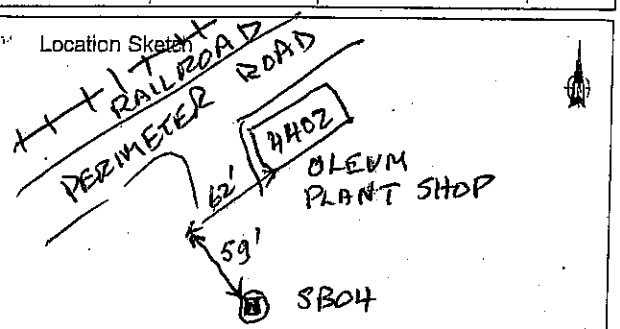
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft.

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB04		FILL GR CL, SL	N/A		100%		N/A	N/A	Clay 10YR 6/6 Light brown silty.
2										
3										
4										
5			CL, SL			100%				Clay, silty as above grading to silt, clayey
6										
7			SL, CL							
8										
9			CL, SL			100%				Clay, silty. 10YR/6/6 Light brown
10										
11										
12										
13			CL, SL			100%				Clay silty, as above
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-04
					N/A				N/A	N/A	
16											
17	ATK-SUB-SB04		CL, SL				100%				CL, SL As above
18											
19											
20			S, SL 10YR 6/6								S, v fn, silty T.D. 20 FT bgs.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
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DRILLING LOG FOR SB-05

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 02/20/07

Drilling Company BAT ENTECH

Driller's Name Tim Lee

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) GeoProbe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

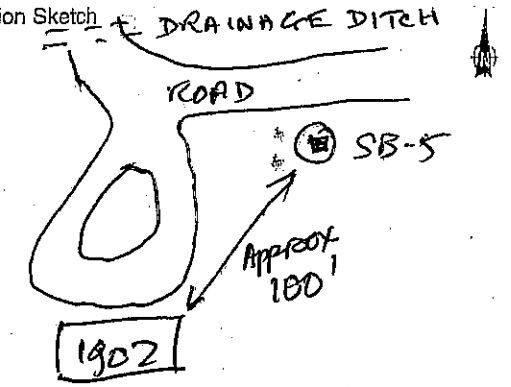
Auger/Split Spoon Refusal 15 ft bgs

Total Depth of Borehole is 15 ft

Total Depth of Corehole is 15 ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
	ATK-SS-SB05		CL,SL			100%				8" Brown silty clay topsoil
1										CLAY, silty, lt brn 10YR 6/6 fragment of coal? at 2' bgs.
2										
3										
4			CL,SL			100%				Clay silty as above
5			CL,GR,S,S							Clay, gravel sand & silt
6			CL,SL							Clay, silty, lt. brn
7			CL,GR,S,SL							Clay, gravel, sand & silt
8			CL,SL			100%				Clay, silty, occasional pebble. Cobble at 8'4"
9										
10										
11										
12	ATK-SUB-SB05		CL,SL			100%				CLAY, as above
13			CL,GR							Clay gravel 8 inches
14			CL	Dolostone?		100%				CLAY to 14'10" T.D. Refusal at 15 ft bgs
15										

DRILLING LOG FOR SB-06

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/18/07

Drilling Company BMT - ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ADDIS

Geologist's Signature Hussein Addis.

Rig Type (s) GeoProbe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

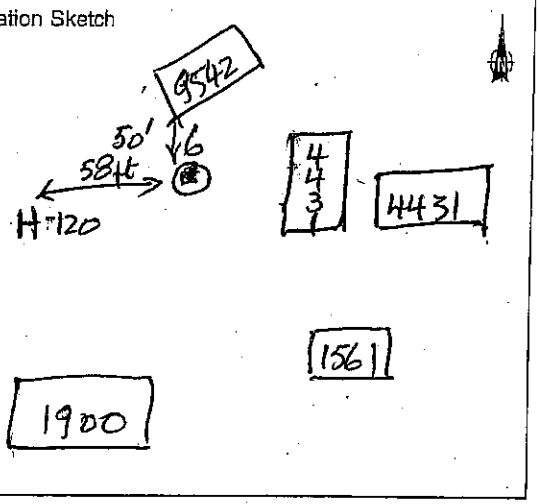
Auger/Split Spoon Refusal ~~N/A~~ 19.5 ft HA

Total Depth of Borehole Is ~~20 ft~~ 19.5 ft HA

Total Depth of Corehole Is ~~20 ft~~ 19.5 ft HA.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	~~Penetration Times~~ N/A	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB06		CL, SL	FILL GR CL FILL?		100%				GR fill to 4" Poss clay fill to 12"
2										Clay, silty, 10YR 6/6 soft, carbonaceous? streaks
3										
4										
5			CL SL			100%				Clay, silty, light brown 10YR 6/6
6										
7										
8										
9			CL, SL			100%				Clay silty as above trace fine sand, mica. 1" layer of sand and qtz pebbles 9' - 9'1"
10										
11										
12										
13			SD, SL, CL			75%				Sand, silty, clayey micaceous 10YR 6/6
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-06
16			S, SL				75%				Very fine silty sand micaceous. 10YR 6/6 Quartz pebble 19.5ft
17											
18											
19											
20											T.D. 19.5ft
21											
22											
23											
24											
25											
26											
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31											
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45											

DRILLING LOG FOR SB-07

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA

Date Started/Finished 04/19/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) GEOPROBE®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

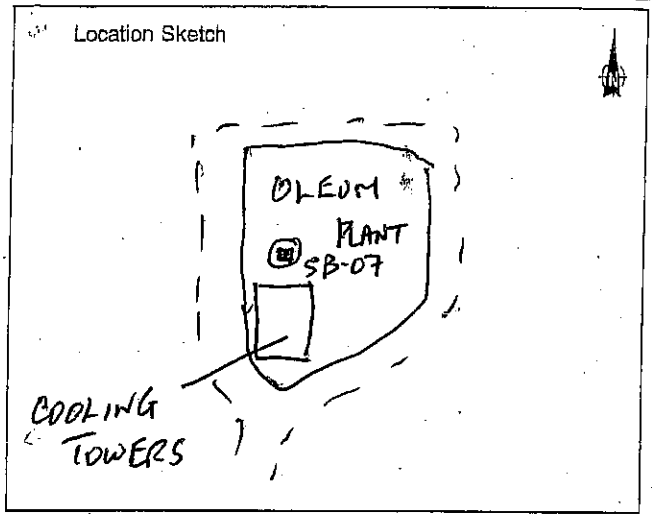
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
	FTK-		GR, CL			100%				FILL, gravel & clay
1	SS-		CL, SL							1-2.5' CL, SL DOM. 10YR 6/6
2	SB07									
3			CL							CL, SOFT, PLASTIC DOM. 10YR 4/3
4			CL, SL			100%				Clay, silty, becoming siltier with depth. 10YR 6/6
5										
6										
7										
8			CL, SL			100%				CLAY as above
9										
10			S. SL							Sand, silty, v. fine 10YR 6/6
11										
12			S. SL							Sand, as above
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-07
16			S, SL, CL				80%				Sand, silty clayey. moderate 10YR 6/6
17											
18											
19											
20											T.D. 20 ft.
21											
22											
23											
24											
25											
26											
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DRILLING LOG FOR SB-08

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/20/07

Drilling Company BMT-ENTECH

Driller's Name Tim Lee

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) GEOPROBE ®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

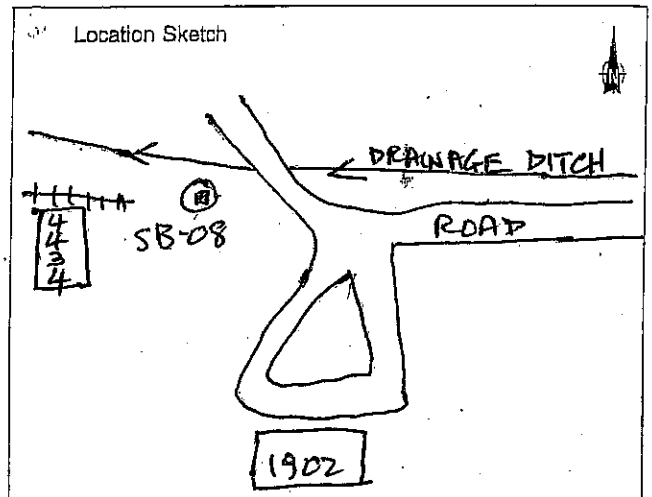
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20 ft

Total Depth of Corehole Is 20 ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB08		CL, SL			100%				2 inches "topsoil" Remainder, silty clay, lt. brn, firm 10YR 6/6
2										
3										
4			CL, SL			100%				8" silty clay as above
5			CL. SL							Silty clay, 10YR 4/3 mid to gray brn.
6										
7										
8			CL, SL			100%				Silty clay lt. brn 10YR 6/6 black carbonaceous flecks 9.5'-12'
9										
10										
11										
12			CL, SL			100%				Silty clay as above w mica, tr. fine sand
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-08
16	ATK-SUB-SB08		CL, SL, S				100%				Clay, silty, sandy 10YR 6/6
17			SL, S, CL								Silt, sandy, clayey 10YR 6/6
18											
19			S, SL								Sand, silty 10YR 6/6
20											T.D. 20ft.
21											
22											
23											
24											
25											
26											
27											
28											
29											
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DRILLING LOG FOR SB-09

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/19/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ADDIS

Geologist's Signature Hussein Addis

Rig Type (s) GEOPROBE (R)

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

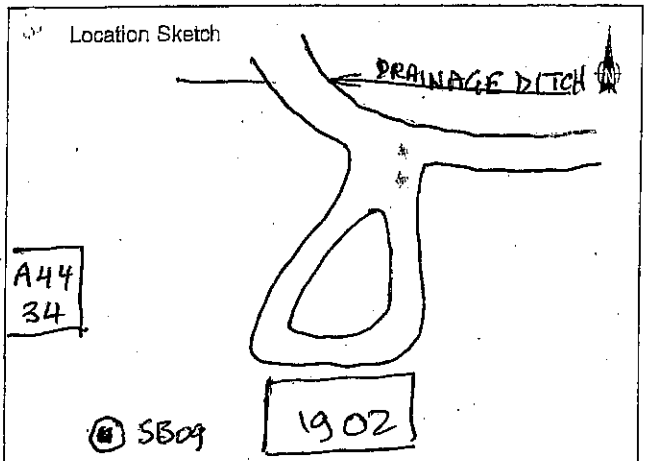
Auger/Split Spoon Refusal N/A.

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB09		CL,SL			100%				Clay, silty, light brown 10YR 6/6, firm, very uniform.
2										
3										
4			CL,SL			100%				Clay, as above
5										
6										
7										
8			CL,SL			100%				Clay, as above
9										
10										
11										
12						100%				Clay, as above
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
											SB-09
16			CL,SL								clay, asphalt
17											
18											
19			S,SL								Sand, very fine silty 10YR6/6
20											TD. 20ft.
21											
22											
23											
24											
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28											
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DRILLING LOG FOR SB-10

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA.

Date Started/Finished 04/18/07

Drilling Company BIT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

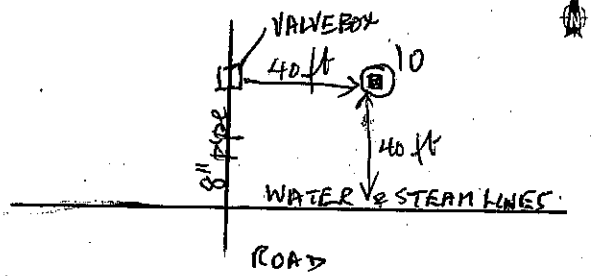
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft bgs

Total Depth of Corehole Is 20ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



OLEUM PLANT

4429

Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB10		CL, SL			100%				6inches "topsoil" 2" sand Clay, silty, trace fn sd micaceous, uniform 10YR 6/6
2										
3										
4			CL, SL			100%				Clay, as above
5										
6										
7										
8			SL, CL			100%				Silty, clayey, trace fn sand, micaceous 10YR 6/6
9										
10										
11										
12			SL, CL			100%				Silt as above
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-10
16	ATK-SUB-SB10		S, SL				100%				Sand, v. fine silty, micaceous occasional qtz. pebble damp/moist 10YR 6/6
17											
18											
19											
20											TD. 20 ft.
21											
22											
23											
24											
25											
26											
27											
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45											

DRILLING LOG FOR SB-11

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/18/07

Drilling Company BMT - ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

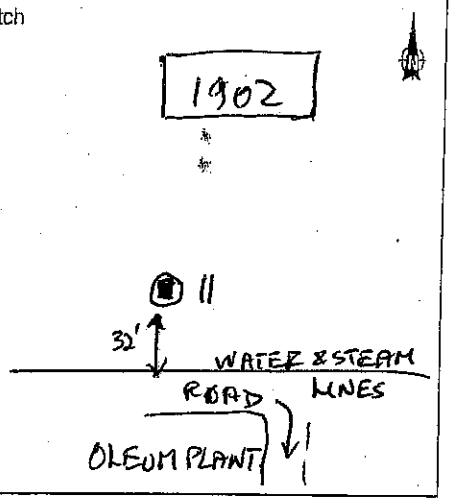
Auger/Split Spoon Refusal N/A

Total Depth of Borehole is 20ft

Total Depth of Corehole is 20ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB11		GR FILL			90%				Blackgravel, "topsoil" 6"
2			CL							Clay soft, wet, plastic to firm at 3'-4' 10YR 4/3 to 10YR 6/6
3										
4			CL, SL			80%				Clay, silty, trace v.fn Sd. uniform 10YR 6/6
5										
6										
7										
8			SL, CL, S,			100%				Silt, clayey, sandy micaceous uniform 10YR 6/6
9										
10										
11										
12			SL, CL, S							Silt, as above
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-11
16											
17	ATK-SUB-SB11		SL, S				100%				Silt, sandy
18			S, SL								Sand, fn, silty trouble 10YR 6/6
19											
20											TD. 20ft.
21											
22											
23											
24											
25											
26											
27											
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DRILLING LOG FOR SB-12

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA.

Date Started/Finished 04/18/07

Drilling Company BMT-ENTECH

Driller's Name Tim Lee

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe ®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

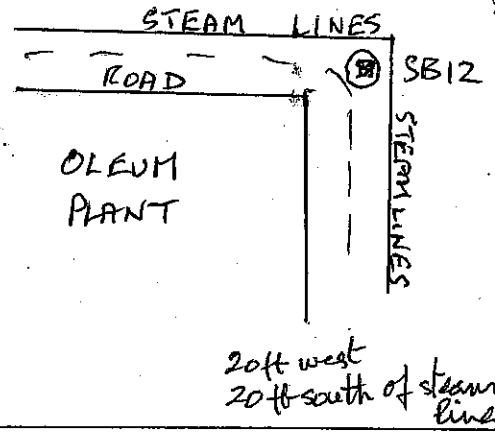
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB12		GR			100%				GRAVEL FILL
2			CL,SL							Clay, silty, w trace gravel. 10YR 6/6
3										
4			CL,SL			100%				Clay, silty lt brn uniform 10YR 6/6
5										
6										
7										
8			CL,SL			100%				Clay as above
9										
10										
11										
12			S,SL,CL			100%				Sand, silty, clayey (loam) uniform 10YR 6/6
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
											SB-12
16											
17	RTK-SOB-SB12		S, SL, CL				100%				Sand, v. fine silty, clayey loam, very uniform 10YR 6/6
18											
19											
20											20ft T.D.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
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39											
40											
41											
42											
43											
44											
45											

DRILLING LOG FOR SB-13

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/19/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

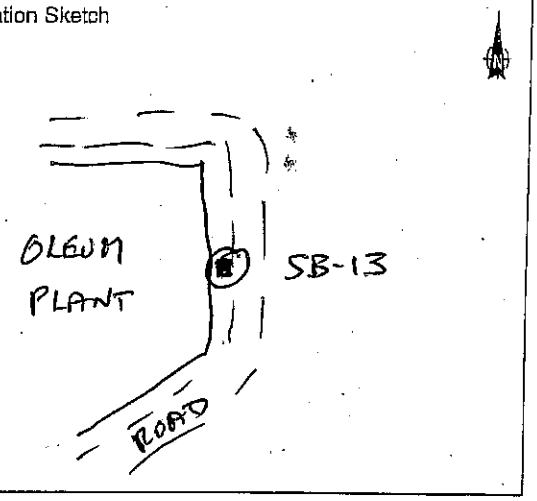
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
			GR							GRAVEL FILL
1	ATK		CL, SL			50%				CL, silty, firm
2	SS-									10YR 6/6
3	SB13									
4			CL, SL							
5						100%				CL as above
6										
7			S, SL							Sand, silty, v. fn, micaceous
8										
9			CL, SL			100%				Clay, silty w trace fine sand
10										10YR 6/6
11			S, SL, CL							Sand, silty, v. fn clayey, micaceous
12										
13			S, SL, CL			100%				Sand, as above pebble at 15'8"
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-13
16											
17	ATK-SUB-SB13		S				100%				Sand, silty, v. fine, dajey micaceous
18			CL, S, SL								Sandy, silty, clay loam, micaceous
19											10YR 6/6
20											T.D. 20FT
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DRILLING LOG FOR SB-14

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 04/18/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe (R)

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

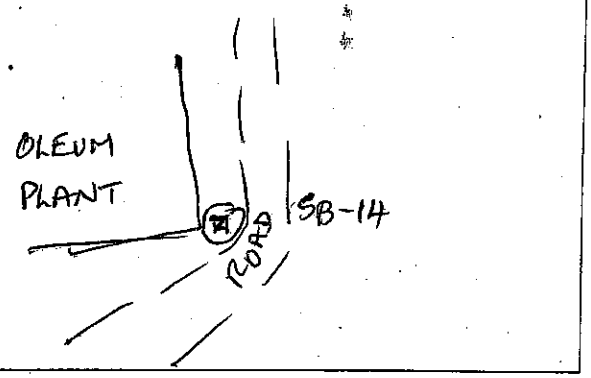
Auger/Split Spoon Refusal _____

Total Depth of Borehole Is _____

Total Depth of Corehole Is _____

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1			GR			RBNE 0%				FILL, GRAVEL
2			GR, CL							FILL GRAVEL & CLAY
3	ATK-SS-SB14		CL			100%				CLAY, SOFT, WET, MID BROWN 10YR 4/3
4			CL, SL							Clay, silty, soft wet, as above but 10YR 6/6 color change
5						100%				
6										
7										
8			CL, SL							Clay, silty w. isolated gravel, black streaks.
9						100%				
10										
11										
12			CL, SL							Clay, silty 10YR 6/6 uniform.
13						100%				
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-14
16											
17	ATK-SUB-SB-14		CL, SL				75%				Clay, silty as above soft, wet
18											
19											
20											T.D. 20ft.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
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41											
42											
43											
44											
45											

DRILLING LOG FOR SB-15

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA

Date Started/Finished 04/19/2007

Drilling Company BTT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis.

Rig Type (s) GEOPROBE®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

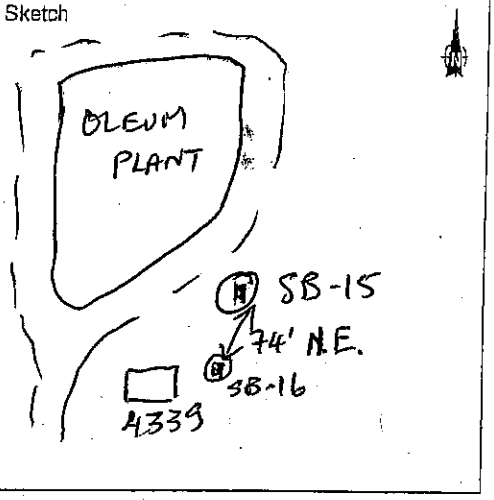
Auger/Split Spoon Refusal 7ft bgs - MOVED OVER

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB15		CL, SL			80%				Clay, silty with occasional small pebbles. 10YR 6/6
2										
3										
4										
5	NO SAMPLE		CLAY as above			NOT Measured				No sample taken for description. Quartz pebble
6										
7				Refusal						Refusal
8										DROVE PREPROBE to 8' Ft south.
9			CL, SL			100%				8-12' CL, SL
10										Uniform, Lt BRN
11										10YR 6/6
12										
13			CL, SL, S			100%				Clay, silty sandy, (loam) Lt. BRN
14										10YR 6/6
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
			S, SL, CL								SB-15 Sand, silty clayey
16	ATK-SUB-SB15		S, SL				80%				Sand, silty fine/dle Pebbles at 19'-2"-19'4" ?JASPER. 2" layer gravel
17											
18											
19				2" gravel							
20			S, SL								T.D. 20 ft
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
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39											
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41											
42											
43											
44											
45											

DRILLING LOG FOR SB-16

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA

Date Started/Finished 04/19/2007

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ADIS

Geologist's Signature Hussein Adil

Rig Type (s) GEOPROBE®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

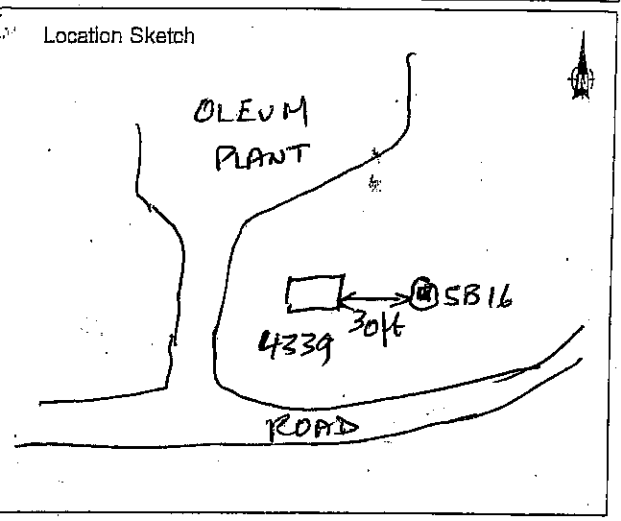
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20 ft

Total Depth of Corehole Is 20 ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB16		CL, SL			100%				6" Topsoil w. grass Clay, silty 10YR 4/3 to 10YR 6/6 brown and light brown
2										
3										
4										
5			CL, SL			100%				Clay, silty, poss coal frags. at 5'6" and 7'6" bgs
6										
7										
8										
9			CL, SL and SL, CL			100%				clayey silt to silty clay, mica flakes
10										
11										
12										
13			SL, CL			100%				Silt, clayey, tr. fine sand. micaceous 10YR 6/6
14										
15			CL, SL							clay, silty 10YR 6/6

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
			CL, SL								SB-16
16											CLAY, silty as above
17			S, SL				90%				Sand, silty
18				pebble						Quartz pebble →	
19			S, SL								Sand, silty fine 10YR 6/6
20											T.D. 20ft
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
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36											
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38											
39											
40											
41											
42											
43											
44											
45											

DRILLING LOG FOR SB-17

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA

Date Started/Finished 04/19/2007

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) GEOPROBE®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

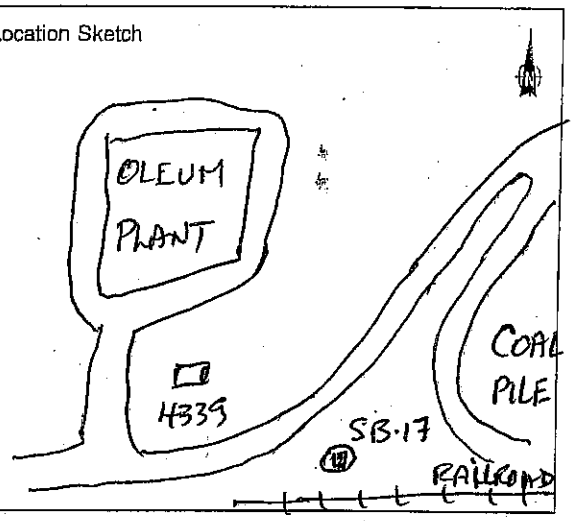
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20 FT

Total Depth of Corehole Is 20 FT

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB17		CL, SL			100%				Topsoil sq grass roots Clay, silty 10YR 4/3 and 10YR 6/6
2										
3										
4			CL, SL			100%				Clay, silty, tr. Sand
5										
6			S, SL, CL							Sand, tr, silty, clayey loam 10YR 6/6
7										
8			S, SL, CL			100%				As above
9										
10										
11										
12			S, SL, CL			100%				As above
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-17
16											
17	ATK-		S, SL				100%				Sand, silty.
18	SUB-										10YR 6/6
19	SB-17										Uniform.
20											T.D. 20ft.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
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41											
42											
43											
44											
45											

DRILLING LOG FOR SB-18

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA.

Date Started/Finished 04/19/2007

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ADIS

Geologist's Signature Hussein Adis

Rig Type (s) GEOPROBE ®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) N/A

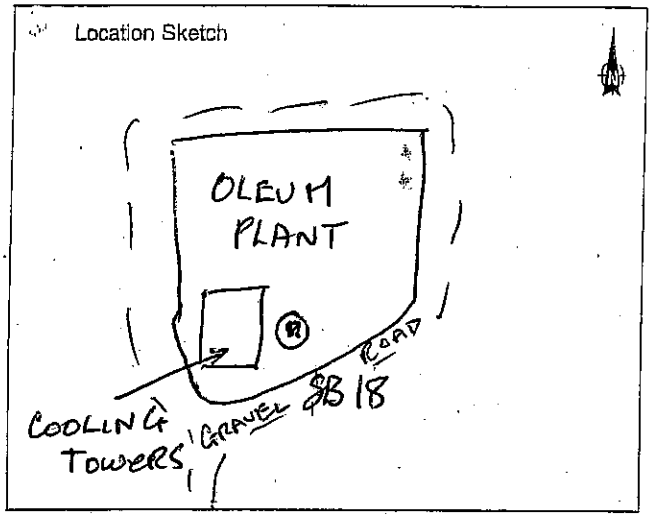
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20 ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
			GR			100%				GRAVEL FILL
1	ATK-		CL,SL							Clay, silty, 10YR 6/6
2	SS-									
3	SB18									
4										CLAY as above 10YR 4/3
			CL,SL							CLAY as above
5						100%				CLAY, SILTY, 10YR 6/6
6										
7										
8										
9			CL,SL,S			100%				Clay, silty, sandy micaceous 10YR 6/6
10										
11										
12			CL,SL,S	GR		100%			GRAVEL	CLAY, as above
13									one inch	
			S,SL,CL							Sand, silty, clayey, micaceous, 10YR 6/6
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments SB-18
16	ATK-SUB-SB18		S, SL, CL				80%				Sand, silty clayey, micaceous 10YR 6/6
17											
18											
19											
20											T.D. 20ft.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
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44											
45											

DRILLING LOG FOR SB-19

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA

Date Started/Finished 04/18/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) Geoprobe®

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

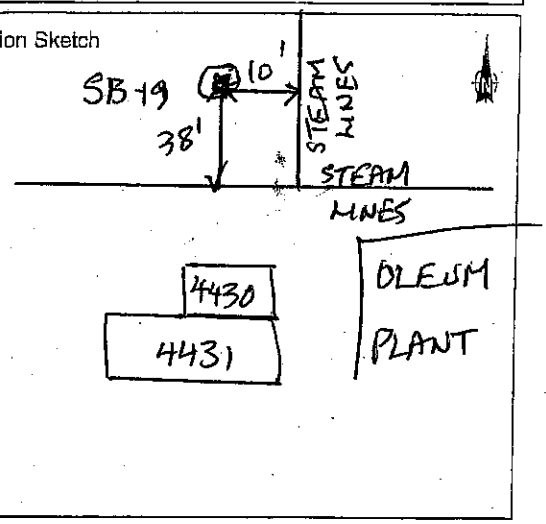
Auger/Split Spoon Refusal ✓

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft.

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB19		CL, SL			100%				Clay, silty, micaceous 10YR 4/3 grading to 10YR 6/6
2										
3										
4			CL, SL			100%				Clay, silty, micaceous 10YR 6/6 uniform
5										
6										
7										
8			CL, SL			100%				Clay as above
9										
10			S, SL							Sand, silty, micaceous w. few quartz pebbles
11										
12			SL, CL			100%				Silt, micaceous, clayey.
13										
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
			GR.								SB-19
			SL, CL								GRAVEL, quartz
16			S, SL				100%				SL, CL as above
17											S, v. coarse, silty w few quartz pebbles
18											
19			SL, CL								SL, CL, micaceous
20											T.D. 20 ft bgs.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

DRILLING LOG FOR SB-20

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD VA.

Date Started/Finished 04/20/07

Drilling Company BMT-ENTECH

Driller's Name TIM LEE

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) GEOPROBE

Drilling Method (s) DIRECT PUSH

Bit Size (s) 2-INCH Auger Size (s) _____

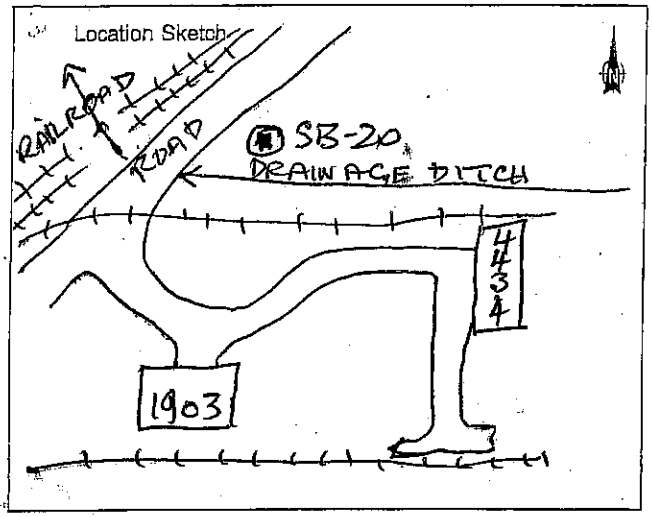
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 20ft

Total Depth of Corehole Is 20ft

Water Level (TOIC)		
Date	Time	Level(Feet)

Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB20		CL, SL			100%				4 INCHES BRN topsoil Silty clay w/ thfrags of ? dolostone
2			GR							GRAVEL/cobbles? dolostone
3			CL, SL							Clay, silty, BRN, 10YR 4/3
4			CL, SL			100%				Clay, silty as above grading to
5										Clay, silty, 10YR 6/6
6										
7										
8			CL, SL			100%				Clay silty as above
9										Some isolated gravel frags.
10										
11			SL, CL, S							Silty, clayey w/ fn Sand
12			S, SL, CL			100%				Sand, silty, clayey micaceous, becoming
13										less clayey
14										
15										

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
											SB-20
16	ATK-SUB-SB20		S, SL, CL				90%				Sand, silty, trace clay friable 10YR 6/6
17											
18											
19											
20											T.D. 20ft.
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
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40											
41											
42											
43											
44											
45											

Borehole Record for MW-01 (RFAAP)

- Drilling Log
- Narrative Lithologic Description
- Well Development Record
- Well Development -- Parameter Measurements
- Investigation - Derived Waste Inventory Sheet

DRILLING LOG FOR MW-01

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 05/03/07 - 05/03/07

Drilling Company BEDFORD WELL DRILLING Co

Driller's Name STEPHEN RIPLEY

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) INGERSOLL RANDT3W TRUCK MOUNTED

Drilling Method (s) MR ROTARY

Bit Size (s) 6INCH Auger Size (s) N/A

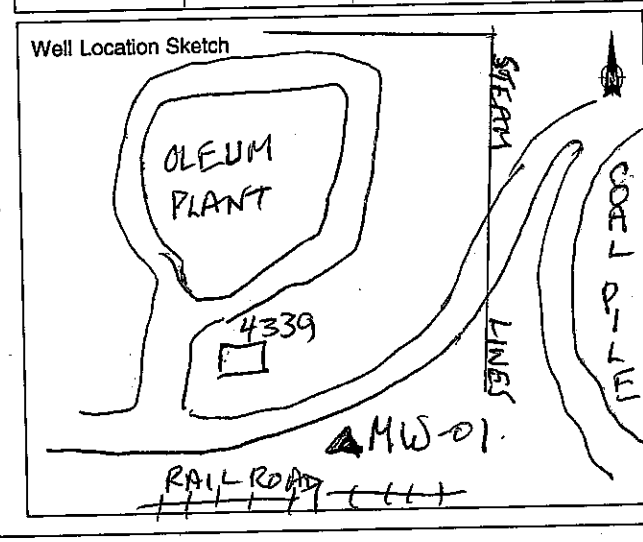
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 50ft

Total Depth of Corehole Is 20ft (SB-17)

Water Level (TOIC)		
Date	Time	Level(Feet)
05/08/07	1550	47.35

Well Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB17		CL, SL			100%				
2										
3										
4						100%				
5										
6			S, SL, CL							
7										
8						100%				
9										
10										
11										
12						100%				
13										
14										
15										

RFAAP MW-01

SCREENED WELL

Stick-up 3.0 ft

Top of Grout _____ ft

Top of Seal at 3 ft

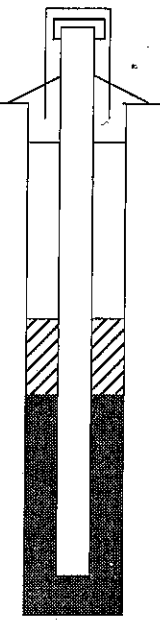
Top of Sand Pack 36 ft

Top of Screen at 40 ft

Bottom of Screen at 50 ft

Bottom of Hole at 50 ft

Bottom of Sandpack at 50 ft



Lock Number _____

Inner Casing Material PVC

Inner Casing Inside Diameter 4 inches

GROUND SURFACE

Quantity of Material Used:

Bentonite Pellets 8 x 50 lbs

Cement ± 150 lbs at surface

Borehole 8 inches Diameter

Cement/ Bentonite _____

Grout _____

Screen Slot Size 0.01"

Screen Type _____

☑ PVC _____

☐ Stainless Steel _____

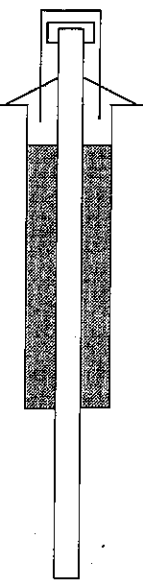
Pack Type/Size:

☑ Sand _____

☐ Gravel _____

☐ Natural _____

OPEN-HOLE WELL



Stick-up _____ ft

Inner Casing Material _____

Inner Casing Inside Diameter _____ inches

Outer Casing Diameter _____ inches

Borehole Diameter _____ ft

Bedrock _____ ft

Bottom of Rock Socket/ Outer Casing _____ ft

Bottom of Inner Casing _____ ft

Corehole Diameter _____

Bottom of Corehole _____ ft

NOTE: See pages 136 and 137 for well construction diagrams

Depth-ft.	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
	Lithology to 20 ft based on SB17			
1	Topsoil w grass roots 4 inches	○	○	○
2	0.4" to 4.0 ft. clay, silty, 10YR 4/3 and 10YR 6/6	○	○	○
3	light brown to mid brown.	○	○	○
4		○	○	○
5	4.0 - 6.0 Clay, silty, trace sand	○	○	○
6		○	○	○
7	6.0 - 16.0 Sand, silty, clayey, fine grained (loam)	○	○	○
8	light brown 10YR 6/6	○	○	○
9		○	○	○
10		○	○	○
11		○	○	○
12		○	○	○
13		○	○	○
14		○	○	○
15		○	○	○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
16											MW-01
17	ATK-		S, SL				100%				RFAAP
18	SUB-										
19	SB17										
20											
21			S								
22											
23											
24											
25											
26			GR								
27											
28			S								
29											
30											
31											
32											
33											
34											
35			ROCK								
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

Depth(feet).	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
	RFAAFMW-01			
16				
17	16.0 - 20.0 Sand, silty, uniform 10YR 6/6			
18	light brown			
19				
20	Corehole (SB-17) total depth 20.0 ft.			
21	Cuttings from air rotary from 20.0 - 50.0 ft.			
22	20.0 to 26.0 Becoming sandier.			
23				
24				
25				
26				
27	Driller notes cobbles 26.0" to 28.0" approx.			
28				
29	Sand below cobbles			
30				
31				
32				
33				
34	Driller notes water in overburden			
35	Bedrock 34 - 35.0" below ground approx.			
36	Since no water in hole: drilled to 50 ft.			
37	Hard, dark grey ? dolostone Cambrian			
38	Elbrook Formation shown on geologic map.			
39				
40				
41				
42				
43				
44				
45	Driller notes fracture at approx 45 ft bgs, water in hole			

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
46			ROCK								RFAAP MW-01
47											
48											
49											
50											T.D. 50ft bgs
51											
52											
53											
54											
55											
56											
57											
58											
59											
60											
61											
62											
63											
64											
65											
66											
67											
68											
69											
70											
71											
72											
73											
74											
75											

Depth(feet)	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-01	Moisture Content: Dry	Moist	Wet
46		○	○	○
47	Hard, dark grey ? dolostone to 50.0".	○	○	○
48		○	○	○
49		○	○	○
50	Total depth of borehole 50'0"	○	○	○
51		○	○	○
52		○	○	○
53		○	○	○
54		○	○	○
55		○	○	○
56		○	○	○
57		○	○	○
58		○	○	○
59		○	○	○
60		○	○	○
61		○	○	○
62		○	○	○
63		○	○	○
64		○	○	○
65		○	○	○
66		○	○	○
67		○	○	○
68		○	○	○
69		○	○	○
70		○	○	○
71		○	○	○
72		○	○	○
73		○	○	○
74		○	○	○
75		○	○	○

Depth(feet)	Sample Number	Blows on Sampler		Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
77												
78												
79												
80												
81												
82												
83												
84												
85												
86												
87												
88												
89												
90												
91												
92												
93												
94												
95												
96												
97												
98												
99												
100												
101												
102												
103												
104												
105												

Borehole Record for MW-02 (RFAAP)

- Drilling Log
- Narrative Lithologic Description
- Well Development Record
- Well Development -- Parameter Measurements
- Investigation - Derived Waste Inventory Sheet

DRILLING LOG FOR MW-02

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 05/01/07 - 05/01/07

Drilling Company BEDFORD WELL DRILLING Co.

Driller's Name MICHAEL R MONAGHAN

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis.

Rig Type (s) INGERSOLL RAND T3W TRUCK MOUNTED

Drilling Method (s) AIR ROTARY

Bit Size (s) 10 INCH / 6 INCH Auger Size (s) _____

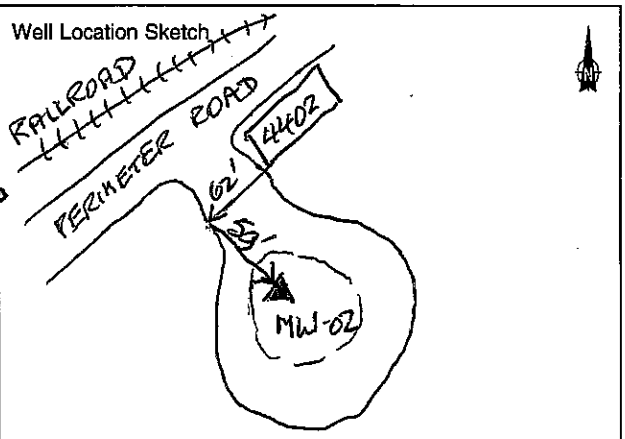
Auger/Split Spoon Refusal N/A

Total Depth of Borehole Is 50 feet

Total Depth of Corehole Is N/A. SB-04 = 20ft

Water Level (TOIC)		
Date	Time	Level(Feet)
05/02/07	1125	34ft BTOIC approx
05/07/07	1140	36.6ft BTOIC

Well Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
			GR			100%				GRAVEL FILL 6 inches
1	ATK-SS-SB-04		CL, SL							
2										
3										
4						100%				
5										
6										
7			SL, CL							
8			CL, SL			100%				
9										
10										
11										
12						100%				
13										
14										
15										

RFAAP MW-02

SCREENED WELL

Stick-up 2.1 HA 2.0 ft

Top of Grout 2 ft

Top of Seal at 2 ft

Top of Sand Pack 36 ft

Top of Screen at 39.5 ft

Bottom of Screen at 49.5 ft

Bottom of Hole at 50 ft

Bottom of Sandpack at 50ft

Lock Number _____

Inner Casing Material PVC

Inner Casing Inside Diameter 4 inches

GROUND SURFACE

Quantity of Material Used:

Bentonite Pellets 400lbs

Cement ~150lbs at surface

Borehole Diameter 12" inches to 3ft
8 inch to 50ft

Cement/ Bentonite _____

Grout _____

Screen Slot Size 0.01"

Screen Type _____

☑ PVC _____

☐ Stainless Steel _____

Pack Type/Size:

☑ Sand _____

☐ Gravel _____

☐ Natural _____

OPEN-HOLE WELL

Stick-up _____ ft

Inner Casing Material _____

Inner Casing Inside Diameter _____ inches

Outer Casing Diameter _____ inches

Borehole Diameter _____ ft

Bedrock _____ ft

Bottom of Rock Socket/ Outer Casing _____ ft

Bottom of Inner Casing _____ ft

Corehole Diameter _____

Bottom of Corehole _____ ft

NOTE: See pages 136 and 137 for well construction diagrams

Depth-ft.	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
	0'-20' from SB-04 log			
1	0.6"-4' Clay 10YR 6/6 Light brown, silty	○	○	○
2		○	○	○
3		○	○	○
4	4-7' clay, silty, as above	○	○	○
5		○	○	○
6		○	○	○
7	7'-8' silt, 10YR 6/6 light brown clayey	○	○	○
8	8'-12 clay, silty, as above	○	○	○
9		○	○	○
10		○	○	○
11		○	○	○
12	12'-16' clay, silty, as above	○	○	○
13		○	○	○
14		○	○	○
15		○	○	○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
16			CL, SL								RFAAP HW-02
17	ATK-SUB-SB04						100%				
18											
19											
20			S, SL								
21			S, SL								BEGINNING AIR ROTARY 10" Bit
22											
23											
24											
25											
26											
27			CL								
28			ROCK								Top of bedrock
29											
30											
31											
32											Drilled w. 6" bit
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

Depth(feet).	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-02	Moisture Content: Dry / Moist / Wet
16		○ ○ ○
17	16' - 19'4" Clay, silty, 10YR, 6/6 Light brown, as above	○ ○ ○
18		○ ○ ○
19		○ ○ ○
20	19'4" to 20' Sand, very fine, silty 10 YR/6/6	○ ✓ ○
21	Note: bottom of Geoprobe borehole SB-04 at 20 ft bgs.	○ ○ ○
22	cutting becoming increasingly sandy with depth	○ ○ ○
23		○ ○ ○
24		○ ○ ○
25		○ ○ ○
26		○ ○ ○
27		○ ○ ○
28	Light gray clay immediately above bedrock.	○ ○ ○
29	Rock, hard, dark gray, ?dolostone? Cambrian Elbrook	○ ○ ○
30	Formation on geologic map.	○ ○ ○
31		○ ○ ○
32		○ ○ ○
33		○ ○ ○
34		○ ○ ○
35		○ ○ ○
36		○ ○ ○
37		○ ○ ○
38		○ ○ ○
39		○ ○ ○
40		○ ○ ○
41		○ ○ ○
42	Driller notes "soft spot", possibly a fracture at 42' bgs.	○ ○ ○
43		○ ○ ○
44		○ ○ ○
45		○ ○ ○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
46			ROCK								RFAAF MW-02
47											
48											
49											
50											BOTTOM OF BOREHOLE 50ft
51											
52											
53											
54											
55											
56											
57											
58											
59											
60											
61											
62											
63											
64											
65											
66											
67											
68											
69											
70											
71											
72											
73											
74											
75											

Depth(feet)	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-02	Moisture Content: Dry	Moist	Wet
46		○	○	○
47		○	○	○
48		○	○	○
49	Hard, dark grey ?dolostone to bottom of hole at 50ft bgs	○	○	○
50		○	○	○
51		○	○	○
52		○	○	○
53		○	○	○
54		○	○	○
55		○	○	○
56		○	○	○
57		○	○	○
58		○	○	○
59		○	○	○
60		○	○	○
61		○	○	○
62		○	○	○
63		○	○	○
64		○	○	○
65		○	○	○
66		○	○	○
67		○	○	○
68		○	○	○
69		○	○	○
70		○	○	○
71		○	○	○
72		○	○	○
73		○	○	○
74		○	○	○
75				

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
77											
78											
79											
80											
81											
82											
83											
84											
85											
86											
87											
88											
89											
90											
91											
92											
93											
94											
95											
96											
97											
98											
99											
100											
101											
102											
103											
104											
105											

Borehole Record for MW-03(RFAAP)

- Drilling Log
- Narrative Lithologic Description
- Well Development Record
- Well Development -- Parameter Measurements
- Investigation - Derived Waste Inventory Sheet

DRILLING LOG FOR MW-03

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 05/02/07 - 05/02/07

Drilling Company BEDFORD WELL DRILLING Co.

Driller's Name MICHAEL F. MONAGHAN

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) INGERSOLL RAND T3W TRUCK MOUNTED

Drilling Method (s) AIR ROTARY

Bit Size (s) 6 inch Auger Size (s) ✓

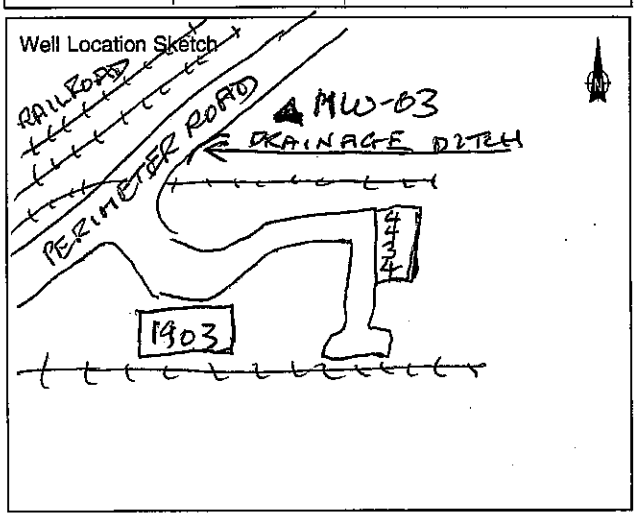
Auger/Split Spoon Refusal N/A.

Total Depth of Borehole Is 34 ft.

Total Depth of Corehole Is 20 ft (SB-20)

Water Level (TOIC)		
Date	Time	Level(Feet)
05/07/07	1400	26.46 btoc

Well Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB-20		CL, SL			100%				
2			GR							
3			CL, SL							
4										
5						100%				
6										
7										
8										
9						100%				
10										
11										
12			SL, CL, S							
13			S, SL, CL			100%				
14										
15										

REAAP MW-03

SCREENED WELL

Stick-up 2.1 ft

Top of Grout _____ ft

Top of Seal at 3 ft

Top of Sand Pack 21 ft

Top of Screen at 24 ft

Bottom of Screen at 34 ft

Bottom of Hole at 33.4 HA ft

Bottom of Sandpack at 34 ft

Lock Number _____

Inner Casing Material PVC

Inner Casing Inside Diameter 4 inches

GROUND SURFACE

Quantity of Material Used:

Bentonite Pellets 600 lbs

Cement N/A

Borehole 8 inches Diameter

Cement/ Bentonite 200 lbs

Grout _____

Screen Slot Size 0.01 "

Screen Type _____

☑ PVC _____

☐ Stainless Steel _____

Pack Type/Size:

☑ Sand _____

☐ Gravel _____

☐ Natural _____

OPEN-HOLE WELL

Stick-up _____ ft

Inner Casing Material _____

Inner Casing Inside Diameter _____ inches

Outer Casing Diameter _____ inches

Borehole Diameter _____ ft

Bedrock _____ ft

Bottom of Rock Socket/ Outer Casing _____ ft

Bottom of Inner Casing _____ ft

Corehole Diameter _____

Bottom of Corehole _____ ft

NOTE: See pages 136 and 137 for well construction diagrams

Depth-ft.	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
	0-20ft from SB-20 log			
1	4 inches brown topsoil. 0-2' silty clay with fragments of ?dolostone	○	○	○
2		○	○	○
3	2.0-2.8' gravel with cobble of ?dolostone.	○	○	○
4	2.8 - 4.0' clay, silty, brown 10YR 4/3	○	○	○
5	4.0 -8.0' clay, silty, as above	○	○	○
6	grading to clay, silty 10YR 6/6.	○	○	○
7		○	○	○
8	Clay, ~~of~~ HA as above, some isolated gravel fragments	○	○	○
9		○	○	○
10		○	○	○
11		○	○	○
12	11'-4"-12.0 Silt, clayey with fine sand.	○	✓	○
13	12-0 to 16.0 Sand, silty, clayey, micaceous			
14	becoming less clayey 10YR 6/6	○	✓	○
15		○	✓	○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
16											RFAAP
17	ATK-SUB-SB-20		SL, CL				90%				MW-03
18											
19											
20											Depth of core
21			S								
22											
23											
24											
25											
26			GR								
27											
28			ROCK								
29											
30											
31											
32											
33											
34											Total depth 34ft
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

Depth(feet).	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-03	Moisture Content Dry / Moist / Wet
16	sand, very fine, silty, micaceous	○ ✓ ○
17	sandy, silty, trace clay, friable 10YR 6/6	○ ✓ ○
18		○ ✓ ○
19		○ ✓ ○
20	Geoprobe borehole total depth 20 ft.	○ ✓ ○
21	Cuttings from air rotary 20 - 25.5 ft	○ ○ ○
22	increasingly sandy	○ ○ ○
23		○ ○ ○
24		○ ○ ○
25		○ ○ ○
26	25.5 - 28' driller reports cobbles/gravel	○ ○ ○
27		○ ○ ○
28		○ ○ ○
29	28.0' top of bedrock. Dark grey? dolostone.	○ ○ ○
30	Cambrian, Elbrook Formation from geologic	○ ○ ○
31	map.	○ ○ ○
32		○ ○ ○
33		○ ○ ○
34	Bottom of hole 34'	○ ○ ○
35		○ ○ ○
36		○ ○ ○
37		○ ○ ○
38		○ ○ ○
39		○ ○ ○
40		○ ○ ○
41		○ ○ ○
42		○ ○ ○
43		○ ○ ○
44		○ ○ ○
45		○ ○ ○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
46											
47											
48											
49											
50											
51											
52											
53											
54											
55											
56											
57											
58											
59											
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61											
62											
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64											
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67											
68											
69											
70											
71											
72											
73											
74											
75											

Borehole Record for MW-04 (RFAAP)

- Drilling Log
- Narrative Lithologic Description
- Well Development Record
- Well Development -- Parameter Measurements
- Investigation - Derived Waste Inventory Sheet

DRILLING LOG FOR MW-04

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 05/02/07 - 05/02/07

Drilling Company BEDFORDWELL DRILLING CO

Driller's Name MICHAEL F. MONAGHAN

Geologist's Name HUSSEIN ALDIS

Geologist's Signature Hussein Aldis

Rig Type (s) INGERSOLL RAND T3W TRUCKMOUNTED

Drilling Method (s) AIR ROTARY

Bit Size (s) 6 INCH Auger Size (s) —

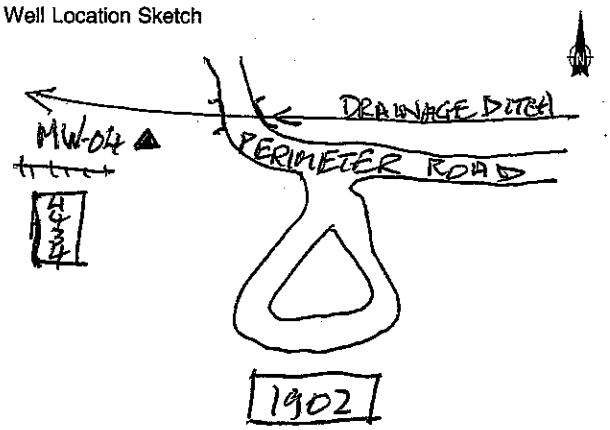
Auger/Split Spoon Refusal N/A.

Total Depth of Borehole is 33 feet

Total Depth of Corehole is 20ft (SB-08)

Water Level (TOIC)		
Date	Time	Level(Feet)
05/08/07	0945	28.95 btoc

Well Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB08		CL,SL			100%				
2										
3										
4										
5						100%				
6										
7										
8										
9						100%				
10										
11										
12										
13						100%				
14										
15										

RFAAP MW-04

SCREENED WELL

Stick-up 2.4 ft

Top of Grout _____ ft

Top of Seal at 3 ft

Top of Sand Pack 18.5 ft

Top of Screen at 20.5 ft

Bottom of Screen at 30.5 ft

Bottom of Hole at 33 ft

Bottom of Sandpack at 30.5

Lock Number _____

Inner Casing Material PVC

Inner Casing Inside Diameter 4 inches

GROUND SURFACE

Quantity of Material Used:

Bentonite Pellets 12x50 lbs

Cement at surface ≈ 200 lbs

Borehole 6 inches Diameter

Cement/ Bentonite _____

Grout _____

Screen Slot Size 0.01"

Screen Type _____

☑ PVC

☐ Stainless Steel

Pack Type/Size:

☑ Sand

☐ Gravel

☐ Natural

OPEN-HOLE WELL

Stick-up _____ ft

Inner Casing Material _____

Inner Casing Inside Diameter _____ inches

Outer Casing Diameter _____ inches

Borehole Diameter _____ ft

Bedrock _____ ft

Bottom of Rock Socket/ Outer Casing _____ ft

Bottom of Inner Casing _____ ft

Corehole Diameter _____

Bottom of Corehole _____ ft

NOTE: See pages 136 and 137 for well construction diagrams

Depth-ft.	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
	Lithology to 20 ft from SB-08			
1	2-inches of "topsoil" 0-4' silty clay, light brown, for in	○	○	○
2	10YR 6/6	○	○	○
3		○	○	○
4	4.0 - 4'8" Silty clay as above.	○	○	○
5	4'-8" - 8.0' Silty clay, mid to grey brn 10YR 4/3	○	○	○
6		○	○	○
7		○	○	○
8		○	○	○
9	8 - 9.5 Silty clay, light brown 10YR 6/6	○	○	○
10	9.5 - 12.0 silty clay, as above w/ carbonaceous flecks	○	○	○
11		○	○	○
12		○	○	○
13	12.0 - 16.0 Silty clay, light brown with mica and trace of fine sand.	○	○	○
14		○	○	○
15		○	○	○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
16											RFAAP
17	ATK-SUB-SB08		CL, SL, S				100%				MW-04
18			~~CL, SL, S~~ HA S2, S, CL								
19		HA	SL, SL, CL								
20			S								Bottom of corehole
21											
22											
23											
24											
25											
26											
27											
28											
29											
30			ROCK								TOP OF BEDROCK
31											
32											
33											TD. 33ft
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

Depth(feet).	NARRATIVE LITHOLOGIC DESCRIPTION RFFAP MW-04	Moisture Content Dry	Moist	Wet
	Lithology from 35-08 to 20'			
15	15.0-16.0 Silty clay, as above	○	○	○
16	clay, silty, sandy, light brown 10YR 6/6 16.0-17.0	○	○	○
17	17.0-19.0 Silt, sandy, clayey, 10YR 6/6	○	○	○
18		○	○	○
19	Sand, silty light brown 10YR 6/2 19-20.0 ft.	○	✓	○
20	Bottom of core at 20.0.	○	✓	○
21	Cuttings from air rotary to T.D. at 33 ft bgs.	○	✓	○
22		○	✓	○
23	Increasingly sandy to bedrock at 30 ft. bgs.	○	✓	○
24		○	✓	○
25		○	✓	○
26		○	✓	○
27	Fine to medium sand 27-28' approx.	○	✓	○
28	Driller indicates water at around 28'-27'	○	○	✓
29	Bedrock at 30 ft bgs. Dark grey ? dolostone.	○	○	○
30	Cambrian Elbrook Formation according to	○	○	○
31	geologic map.	○	○	○
32	Drillhole advanced to 33 feet bgs. Hole collapsing.	○	○	○
33		○	○	○
34		○	○	○
35		○	○	○
36		○	○	○
37		○	○	○
38		○	○	○
39		○	○	○
40		○	○	○
41		○	○	○
42		○	○	○
43		○	○	○
44		○	○	○
45				

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
46											
47											
48											
49											
50											
51											
52											
53											
54											
55											
56											
57											
58											
59											
60											
61											
62											
63											
64											
65											
66											
67											
68											
69											
70											
71											
72											
73											
74											
75											

Borehole Record for MW-05 (RFAAP)

- Drilling Log
- Narrative Lithologic Description
- Well Development Record
- Well Development -- Parameter Measurements
- Investigation - Derived Waste Inventory Sheet

DRILLING LOG FOR MW-05

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA.

Date Started/Finished 05/02/07 - 05/02/07

Drilling Company BEDFORD WELL DRILLING CO.

Driller's Name MICHAEL F. MONAGHAN

Geologist's Name Hussein Aldis

Geologist's Signature Hussein Aldis

Rig Type (s) INGERSOLL RAND T3W TRUCK MOUNTED

Drilling Method (s) AIR ROTARY

Bit Size (s) 6 inch Auger Size (s) N/A

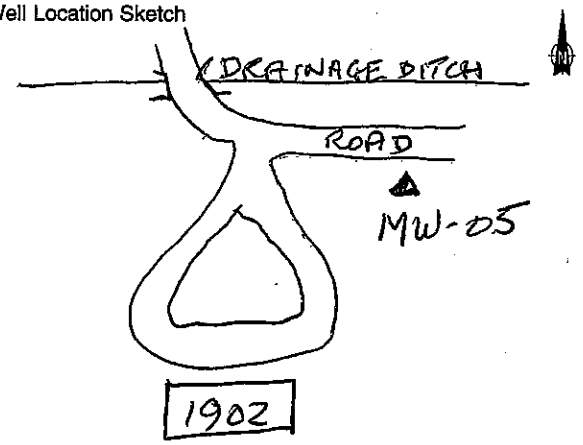
Auger/Split Spoon Refusal —

Total Depth of Borehole Is 25 feet

Total Depth of Corehole Is HA 15 20ft (SB-05)

Water Level (TOIC)		
Date	Time	Level(Feet)
05/08/07	0825	20.39 bTOC

Well Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB05		CL, SL			100%				
2										
3										
4										
5			CL, GR, S, SL			100%				
6			CL, SL							
7			CL, GR, S, SL							
8										
9			CL, SL			100%				
10										
11										
12										
13	ATK-SS-SB05		CL, SL			100%				
14			CL, GR							
15			CL	ROCK						Bottom of CORE

RFAAP MW-05

SCREENED WELL

Stick-up 2.4 ft

Top of Grout _____ ft

Top of Seal at 3 ft

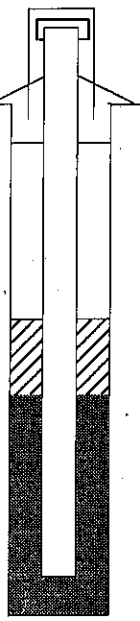
Top of Sand Pack 13 ft

Top of Screen at 13.6 ft

Bottom of Screen at 23.6 ft

Bottom of Hole at 25 ft

Bottom of Sandpack at 25



Lock Number _____

Inner Casing Material PVC

Inner Casing Inside Diameter 4 inches

GROUND SURFACE

Quantity of Material Used:

Bentonite Pellets 9 x 50 lbs

Cement ~150 lbs at surface

Borehole _____ inches Diameter

Cement/ Bentonite _____

Grout _____

Screen Slot Size 0.01"

Screen Type _____

☑ PVC _____

☐ Stainless Steel _____

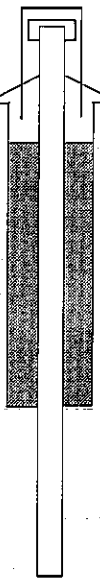
Pack Type/Size:

☑ Sand _____

☐ Gravel _____

☐ Natural _____

OPEN-HOLE WELL



Stick-up _____ ft

Inner Casing Material _____

Inner Casing Inside Diameter _____ inches

Outer Casing Diameter _____ inches

Borehole Diameter _____ ft

Bedrock _____ ft

Bottom of Rock Socket/ Outer Casing _____ ft

Bottom of Inner Casing _____ ft

Corehole Diameter _____

Bottom of Corehole _____ ft

NOTE: See pages 136 and 137 for well construction diagrams

Depth-ft.	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
1	0-8" silty clay "topsoil"	○	○	○
2	0.8" – 4.0 ft Clay, silty light brown 10YR 6/6	○	○	○
3	fragment of ? coal at 2.0 ft.	○	○	○
4		○	○	○
5	Clay, gravel, sand and silt 5.0 – 5'6"	○	○	○
6	5'-6" to 6'6" clay, silty, light-brown 10YR 6/6	○	○	○
7	6'-6" to 8.0" clay, gravel, sand and silt.	○	○	○
8	8'0" to 12-0" clay, silty, light brown, occasional	○	○	○
9	pebble. Cobble at 8'-4".	○	○	○
10		○	○	○
11		○	○	○
12		○	○	○
13	Clay, silty, as above 12.0" to 13'0"	○	○	○
14	13'0" to 13'8" clay and gravel	○	○	○
15	Clay silty to 14'10" 14'10"-15'0" Dark gray ? dolostone	○	○	○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
16			ROCK								RFAAP MW-05 FRACTURE ZONE 16.0-20.0 ft.
17			CL, SL								
18											
19											
20			ROCK								
21											
22											
23											
24											
25											T.D. 25.0
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

Depth(feet).	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-05	Moisture Content Dry / Moist / Wet
16	15'0" to 16.0 Dark gray ?dolostone bedrock	○ ○ ○
17	16.0" to 20.0 Fracture zone ? mud and water	○ ○ ○
18		○ ○ ○
19		○ ○ ○
20		○ ○ ○
21	20.0" to 25'0" Dark grey ?dolostone bedrock.	○ ○ ○
22	Cambrian Elbrook Formation according to	○ ○ ○
23	the geologic map.	○ ○ ○
24		○ ○ ○
25		○ ○ ○
26		○ ○ ○
27		○ ○ ○
28		○ ○ ○
29		○ ○ ○
30		○ ○ ○
31		○ ○ ○
32		○ ○ ○
33		○ ○ ○
34		○ ○ ○
35		○ ○ ○
36		○ ○ ○
37		○ ○ ○
38		○ ○ ○
39		○ ○ ○
40		○ ○ ○
41		○ ○ ○
42		○ ○ ○
43		○ ○ ○
44		○ ○ ○
45		○ ○ ○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
46											
47											
48											
49											
50											
51											
52											
53											
54											
55											
56											
57											
58											
59											
60											
61											
62											
63											
64											
65											
66											
67											
68											
69											
70											
71											
72											
73											
74											
75											

Borehole Record for MW-06 (RFAAP)

- Drilling Log
- Narrative Lithologic Description
- Well Development Record
- Well Development -- Parameter Measurements
- Investigation - Derived Waste Inventory Sheet

DRILLING LOG FOR MW-06

Project Name RADFORD ARMY AMMUNITION PLANT

Site Location RADFORD, VA

Date Started/Finished 05/03/07 - 05/03/07

Drilling Company Bedford Well Drilling Co.

Driller's Name Stephen Ripley

Geologist's Name Hussein Aldis

Geologist's Signature Hussein Aldis.

Rig Type (s) Ingersoll Rand T3W Truck Mounted

Drilling Method (s) AIR ROTARY

Bit Size (s) 6 inch Auger Size (s) N/A.

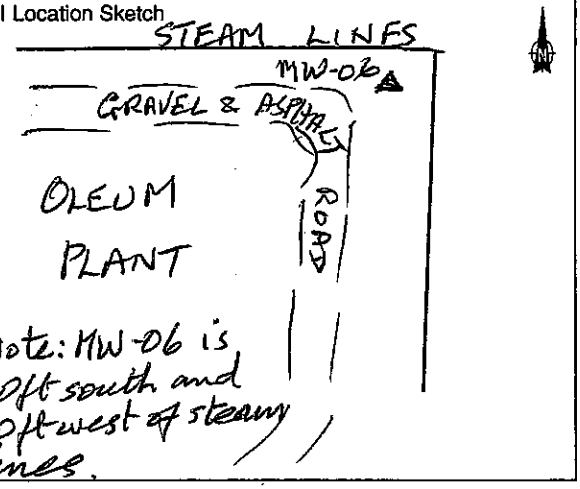
Auger/Split Spoon Refusal N/A.

Total Depth of Borehole Is 80ft bgs.

Total Depth of Corehole Is 20ft (SB-12)

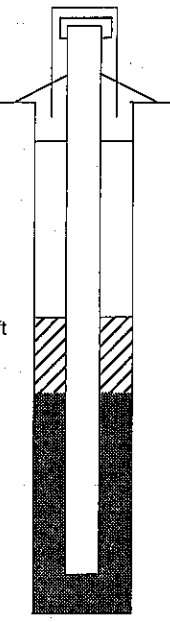
Water Level (TOIC)		
Date	Time	Level(Feet)
05/08/07	1400	410.14ft

Well Location Sketch



Depth(Feet)	Sample Number	Blows on Sampler	Soil Components Rock Profile CL SL S GR	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
1	ATK-SS-SB-12		GR			100%				Approx 4 inches gravel fill at surface
2			CL, SL							
3										
4										
5						100%				
6										
7										
8										
9						100%				
10										
11										
12			S, SL, CL							
13						100%				
14										
15										

RFAAP MW-06



SCREENED WELL

Stick-up 3.0 ft

Top of Grout _____ ft

Top of Seal at 3 ft

Top of Sand Pack 66 ft

Top of Screen at 72 ft

Bottom of Screen at 82 ft

Bottom of Hole at 82 ft

Bottom of Sandpack at 82 ft

Lock Number _____

Inner Casing Material PVC

Inner Casing Inside Diameter 4 inches

GROUND SURFACE

Quantity of Material Used:

Bentonite Pellets 17x50 lbs

Cement 2/50 lbs at surface

Borehole 6 inches Diameter

Cement/ Bentonite _____

Grout _____

Screen Slot Size 0.01"

Screen Type _____

☑ PVC _____

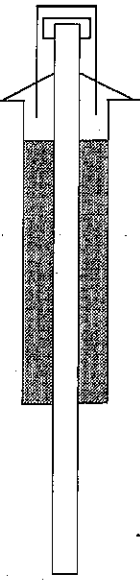
☐ Stainless Steel _____

Pack Type/Size:

☑ Sand _____

☐ Gravel _____

☐ Natural _____



OPEN-HOLE WELL

Stick-up _____ ft

Inner Casing Material _____

Inner Casing Inside Diameter _____ inches

Outer Casing Diameter _____ inches

Borehole Diameter _____ ft

Bedrock _____ ft

Bottom of Rock Socket/ Outer Casing _____ ft

Bottom of Inner Casing _____ ft

Corehole Diameter _____

Bottom of Corehole _____ ft

NOTE: See pages 136 and 137 for well construction diagrams

Depth-ft.	NARRATIVE LITHOLOGIC DESCRIPTION	Moisture Content: Dry	Moist	Wet
	Lithology for 20ft is based on SB-12			
1	4 inches of gravel fill at surface	○	○	○
2	0.4" - 12 ft, Clay, silty, light brown 10YR 6/6	○	○	○
3		○	○	○
4		○	○	○
5		○	○	○
6		○	○	○
7		○	○	○
8		○	○	○
9		○	○	○
10		○	○	○
11		○	○	○
12		○	○	○
13	12.0 - 16.0 Sand, silty, clayey, uniform, light brown 10YR 6/6.	○	○	○
14		○	○	○
15		○	○	○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
16							100%				REAAP MW-06
17	RTK-		SSL, CL				100%				
18	SUB-										
19	SB12										
20											TD. for SB-12
21			S								
22											
23											
24											
25											
26											
27											
28			GR								
29											
30			ROCK								
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

Depth(feet).	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-06	Moisture Content Dry Moist Wet
16		○ ○ ○
17	Sand, silty, very fine, clayey, very uniform	○ ○ ○
18	10YR 6/6	○ ○ ○
19		○ ○ ○
20	Bottom of SB-12 at 20 ft. 2 HA	○ ○ ○
21	Drilling with air rotary to 80 feet. Cuttings only	○ ○ ○
22	Becoming sandier to approx. 28 ft bgs	○ ○ ○
23		○ ○ ○
24		○ ○ ○
25		○ ○ ○
26		○ ○ ○
27		○ ○ ○
28		○ ○ ○
29	Driller estimates gravel from 28.0 ft to 30.0 ft bgs	○ ○ ○
30		○ ○ ○
31	Bedrock at 30' Hard dark grey, ?dolostone	○ ○ ○
32	Cambrian Elbrook Formation from geologic map.	○ ○ ○
33	Drilled dry to 75'	○ ○ ○
34		○ ○ ○
35		○ ○ ○
36		○ ○ ○
37		○ ○ ○
38		○ ○ ○
39		○ ○ ○
40		○ ○ ○
41		○ ○ ○
42		○ ○ ○
43		○ ○ ○
44	.75 ft, HA	○ ○ ○
45	Note: Driller says soft spot at ~~75~~ ft bgs is fracture	○ ○ ○

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
46			ROCK								RFAAP MW-06
47											
48											
49											
50											
51											
52											
53											
54											
55											
56											
57											
58											
59											
60											
61											
62											
63											
64											
65											
66											
67											
68											
69											
70											
71											
72											
73											
74											
75											

Depth(feet)	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-06	Moisture Content: Dry	Moist	Wet
46	Bedrock, hard dark grey ? dolostone	○	○	○
47	to 82 feet bgs. Very few fractures	○	○	○
48		○	○	○
49		○	○	○
50		○	○	○
51		○	○	○
52		○	○	○
53		○	○	○
54		○	○	○
55		○	○	○
56		○	○	○
57		○	○	○
58		○	○	○
59		○	○	○
60		○	○	○
61		○	○	○
62		○	○	○
63		○	○	○
64		○	○	○
65		○	○	○
66		○	○	○
67		○	○	○
68		○	○	○
69		○	○	○
70		○	○	○
71		○	○	○
72		○	○	○
73		○	○	○
74	Suspected fracture at 75ft bgs cuts dust.	○	○	○
75				

Depth(feet)	Sample Number	Blows on Sampler	Soil Components CL SL S GR	Rock Profile	Penetration Times	Run Number	Core Recovery	RQD	Fracture Sketch	HNu/OVA (ppm)	Comments
77			ROCK								RFAAP MW-06
78											
79											
80											
81											
82											T.D. 82ft
83											
84											
85											
86											
87											
88											
89											
90											
91											
92											
93											
94											
95											
96											
97											
98											
99											
100											
101											
102											
103											
104											
105											

Depth (feet)	NARRATIVE LITHOLOGIC DESCRIPTION RFAAP MW-06	Moisture Content Dry / Moist / Wet
77		○ ○ ○
78	Hard, dark grey ? dolostone, very few	○ ○ ○
79	fractures.	○ ○ ○
80		○ ○ ○
81		○ ○ ○
82	Bottom of hole at 82 feet bgs	○ ○ ○
83		○ ○ ○
84		○ ○ ○
85		○ ○ ○
86		○ ○ ○
87		○ ○ ○
88		○ ○ ○
89		○ ○ ○
90		○ ○ ○
91		○ ○ ○
92		○ ○ ○
93		○ ○ ○
94		○ ○ ○
95		○ ○ ○
96		○ ○ ○
97		○ ○ ○
98		○ ○ ○
99		○ ○ ○
100		○ ○ ○
101		○ ○ ○
102		○ ○ ○
103		○ ○ ○
104		○ ○ ○
105		○ ○ ○

APPENDIX D.2

SSA 30 AND SSA 79

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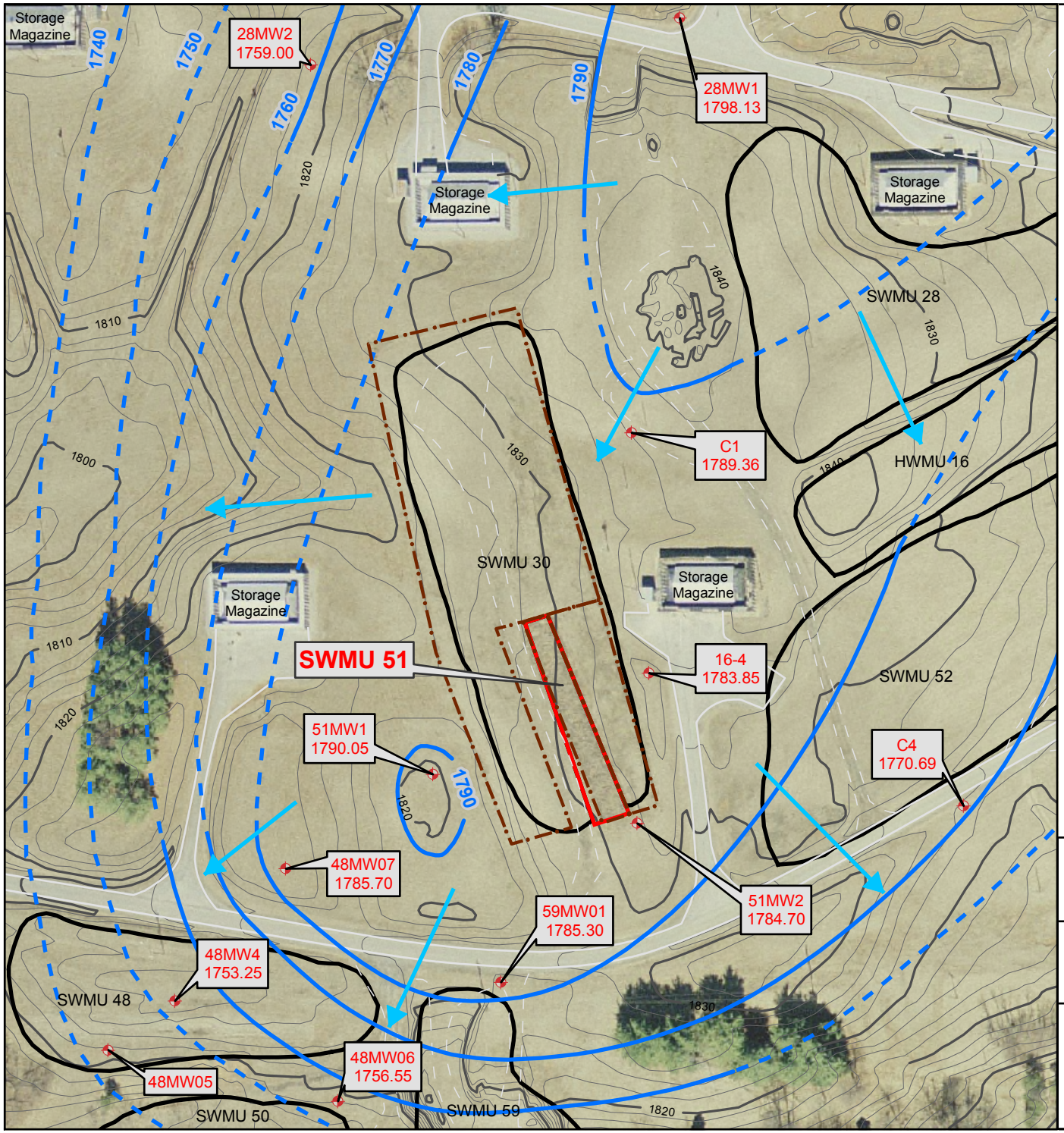

LEGEND

- Monitoring Well Location
- Dirt Road
- Paved Road
- 10 ft Contour Line
- Groundwater Contour
- Inferred Groundwater Contour
- Groundwater Flow Direction
- Fence Line
- SWMU 51 Boundary
- Other SWMU/HWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Water levels for wells 48MW4, 48MW06, 48MW07, and 59MW01 were measured in Aug 2007. Water levels for the remainder of the wells were measured in April 2006.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 2-12
SWMU 51 Groundwater Contour Map

Radford Army Ammunition Plant,
Radford, VA

GIS File: RFAAP_008_Fig2-12_SWMU51_GW_Contours.mxd (5/16/2008 11:11:22 AM)

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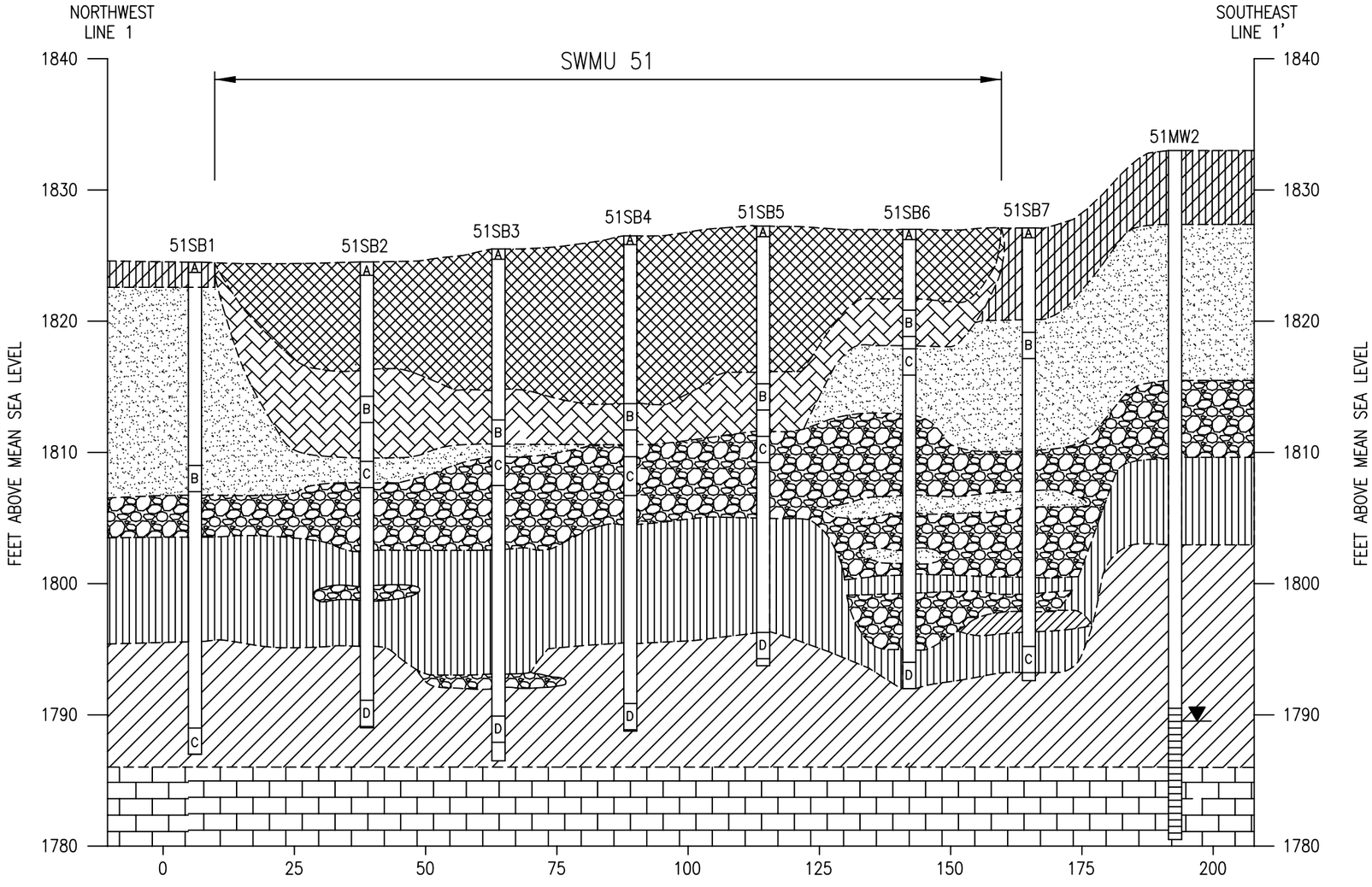


LEGEND

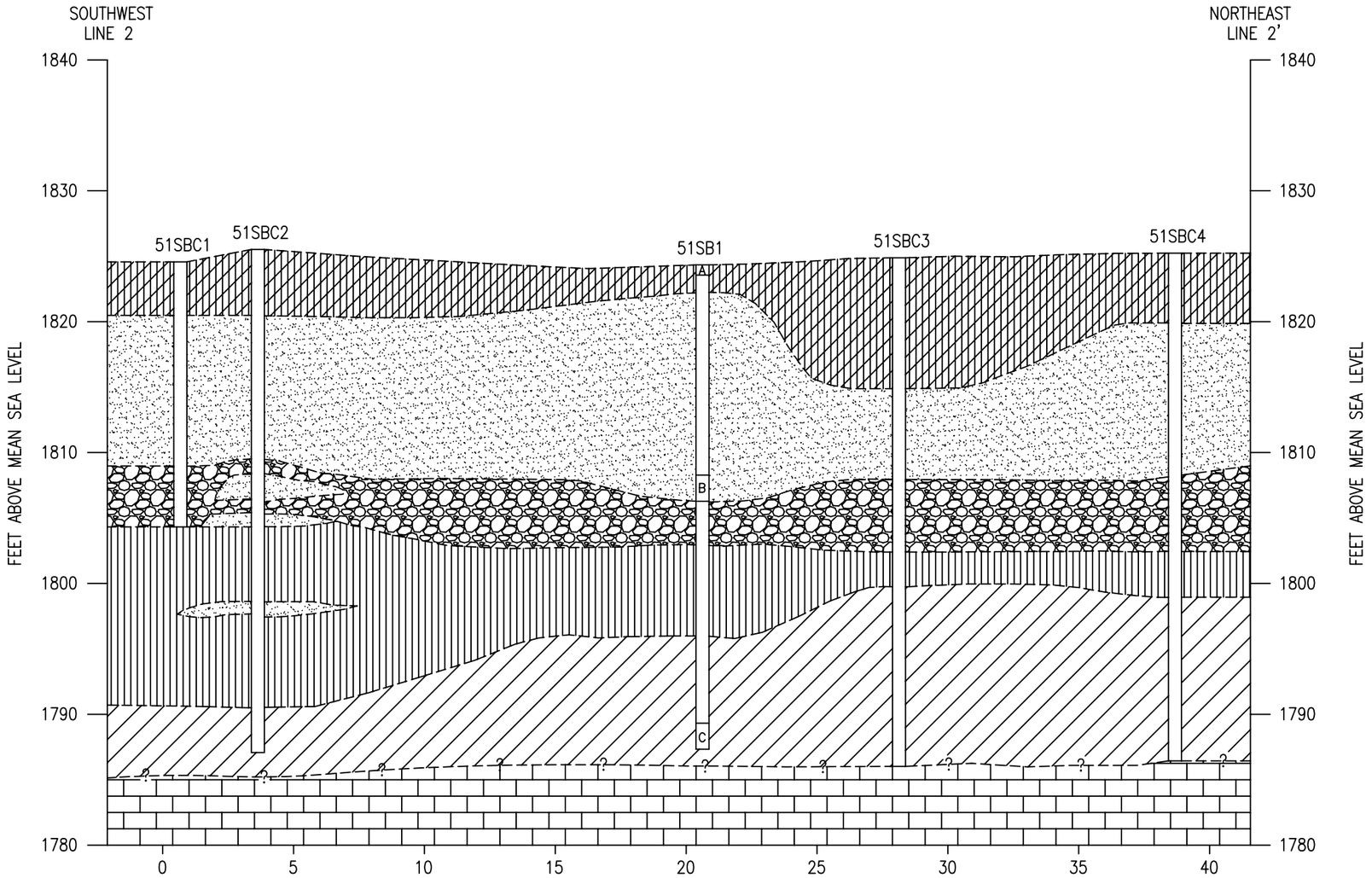
- FILL
- SILT/CLAY (ML/CL)
- CLAY (CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN–SITU WEATHERED BEDROCK (CL/ML)
- TRENCH SLUDGE MATERIAL
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- B — SAMPLE INTERVAL
- WATER LEVEL (MEASURED APRIL 2006)
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- SCREEN INTERVAL

NOTE: 51MW2 LITHOLOGY FROM DAMES AND MOORE (1992).

0 25 50 FEET
HORIZONTAL SCALE

0 10 20 FEET
VERTICAL SCALE

RADFORD AAP		FIGURE 2–4
PREPARED BY: SHAW	TASK NO: 83919705000000	SWMU 51 GEOLOGIC CROSS SECTION (LINE 1– LINE 1')
CHECKED BY: MT	SHAW DWG NO: Figure 2–4	
DATE: APRIL 2008		



LEGEND

- SILT/CLAY (ML/CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN–SITU WEATHERED BEDROCK (CL/ML)
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- B — SAMPLE INTERVAL

0 5 10 FEET
HORIZONTAL SCALE

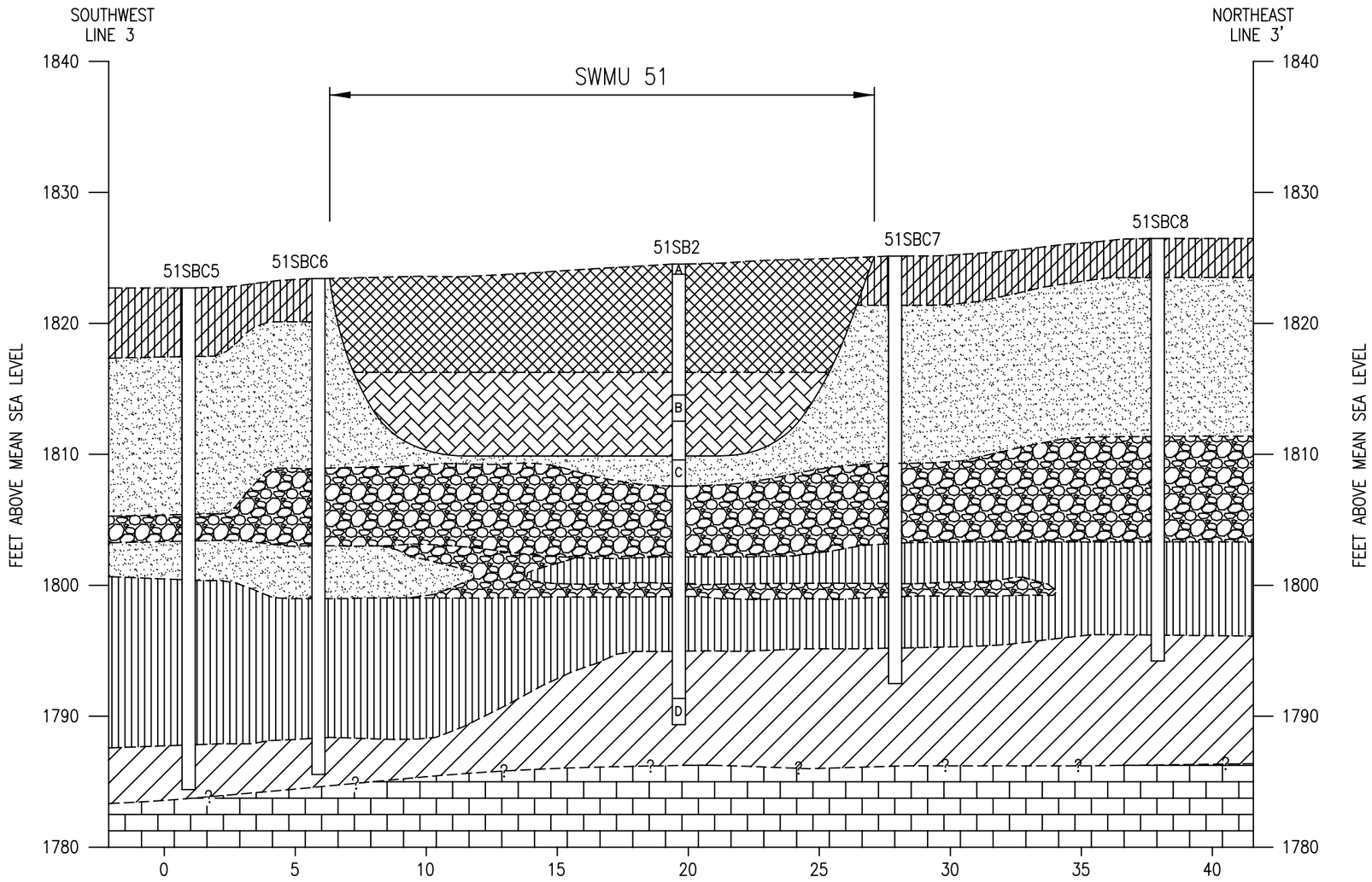
0 10 20 FEET
VERTICAL SCALE

RADFORD AAP

FIGURE 2–5

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2–5
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 2 – LINE 2')



LEGEND

- FILL
- SILT/CLAY (ML/CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN-SITU WEATHERED BEDROCK (CL/ML)
- TRENCH SLUDGE MATERIAL
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- [B] SAMPLE INTERVAL

0 5 10 FEET
HORIZONTAL SCALE

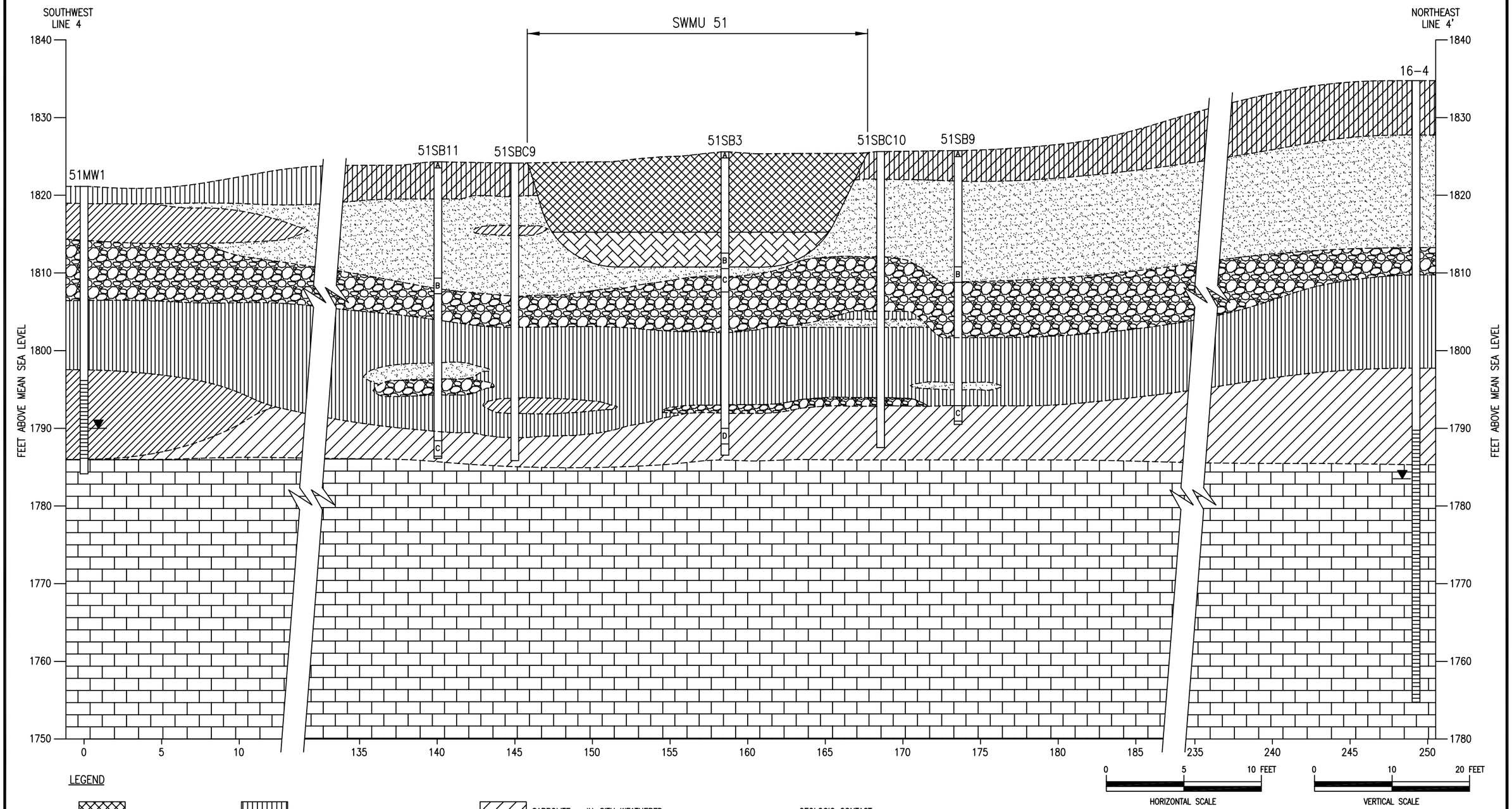
0 10 20 FEET
VERTICAL SCALE

RADFORD AAP

FIGURE 2-6

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2-6
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 3 – LINE 3')



LEGEND

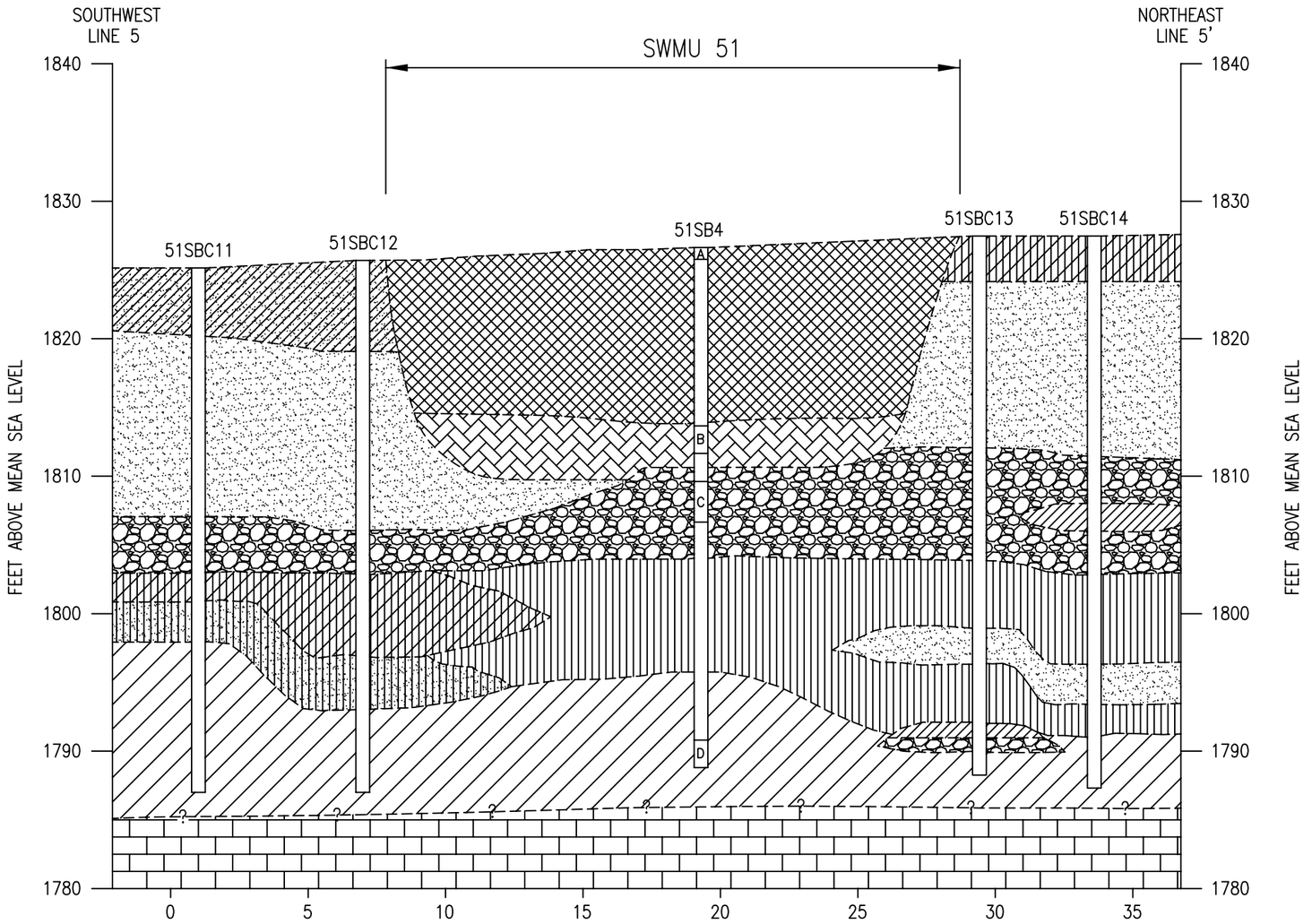
- FILL
- SILT/CLAY (ML/CL)
- CLAY (CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN-SITU WEATHERED BEDROCK (CL/ML)
- TRENCH SLUDGE MATERIAL
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- WATER LEVEL (MEASURED APRIL 2006)
- SCREEN INTERVAL
- B — SAMPLE INTERVAL

RADFORD AAP

FIGURE 2-7

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2-7
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 4 – LINE 4')



LEGEND

- FILL
- SILT/CLAY (ML/CL)
- CLAY (CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN-SITU WEATHERED BEDROCK (CL/ML)
- TRENCH SLUDGE MATERIAL
- SILT AND SANDY CLAY (ML/SC)
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- CLAY AND SANDY CLAY (CL/SC)
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- B — SAMPLE INTERVAL

0 5 10 FEET
HORIZONTAL SCALE

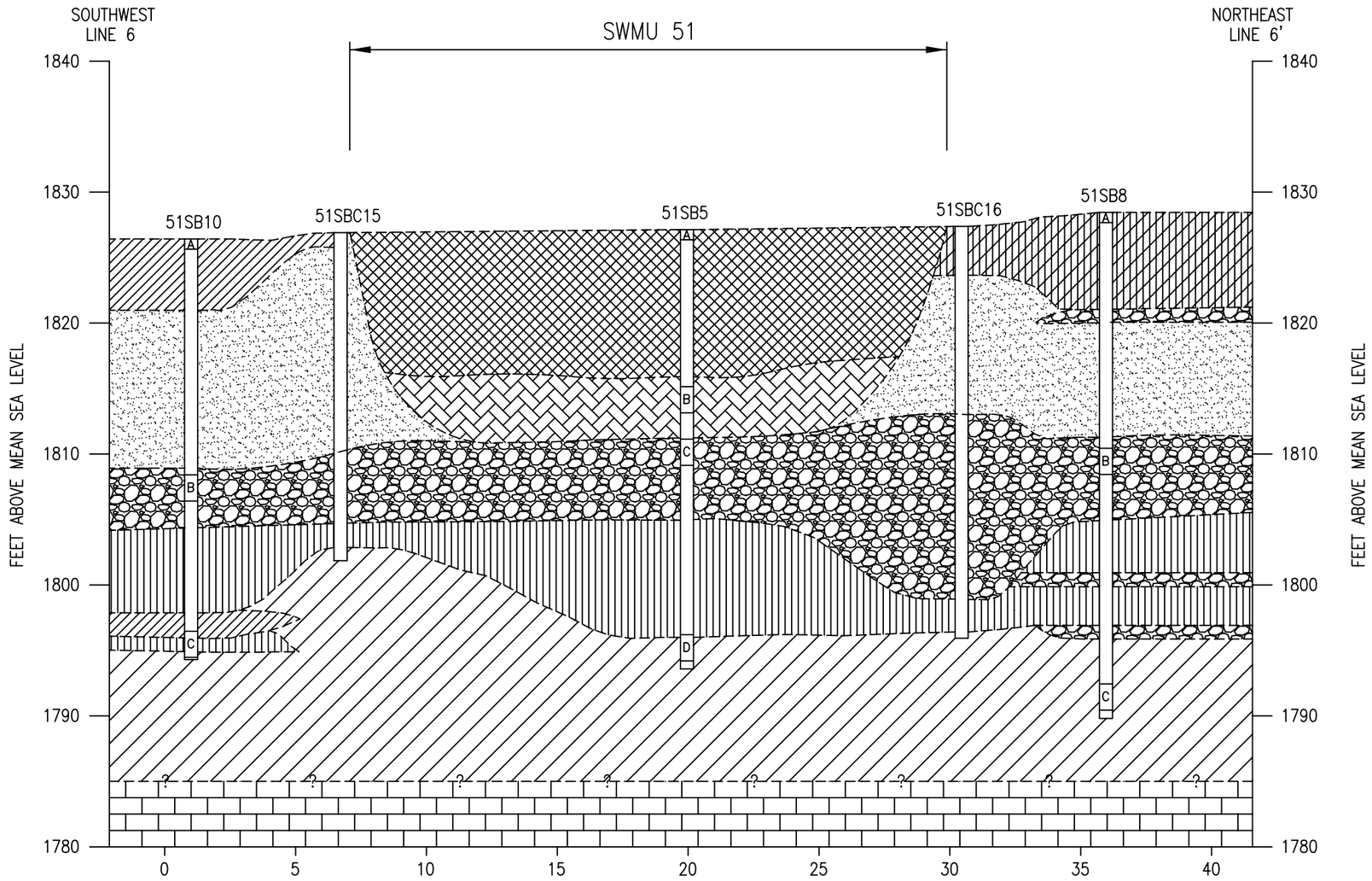
0 10 20 FEET
VERTICAL SCALE

RADFORD AAP

FIGURE 2-8

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2-8
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 5 – LINE 5')



LEGEND

- FILL
- SILT/CLAY (ML/CL)
- CLAY (CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN-SITU WEATHERED BEDROCK (CL/ML)
- TRENCH SLUDGE MATERIAL
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- B — SAMPLE INTERVAL

0 5 10 FEET
HORIZONTAL SCALE

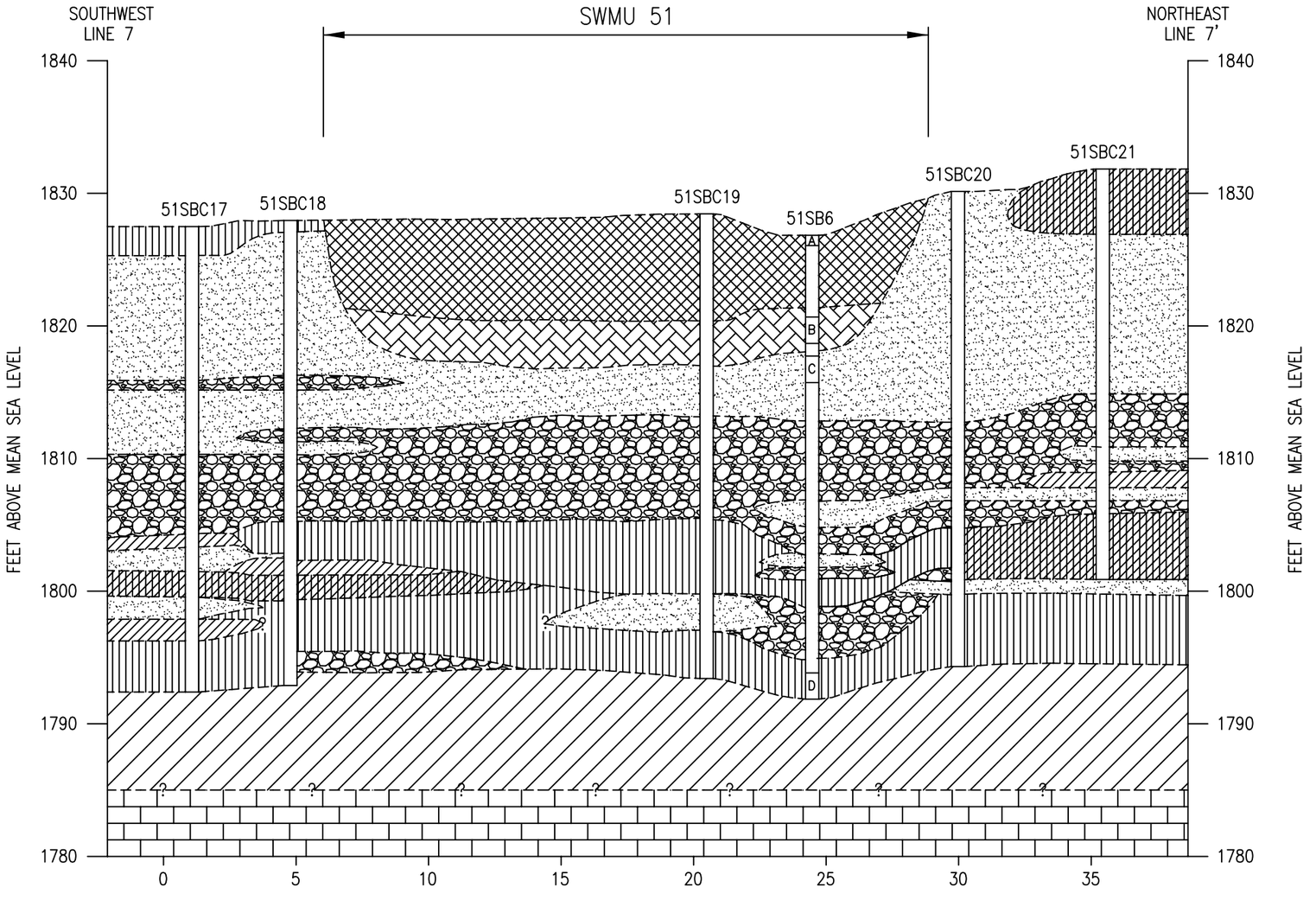
0 10 20 FEET
VERTICAL SCALE

RADFORD AAP

FIGURE 2-9

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2-9
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 6 – LINE 6')



LEGEND

- FILL
- SILT/CLAY (ML/CL)
- CLAY (CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN–SITU WEATHERED BEDROCK (CL/ML)
- TRENCH SLUDGE MATERIAL
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- B — SAMPLE INTERVAL

0 5 10 FEET
HORIZONTAL SCALE

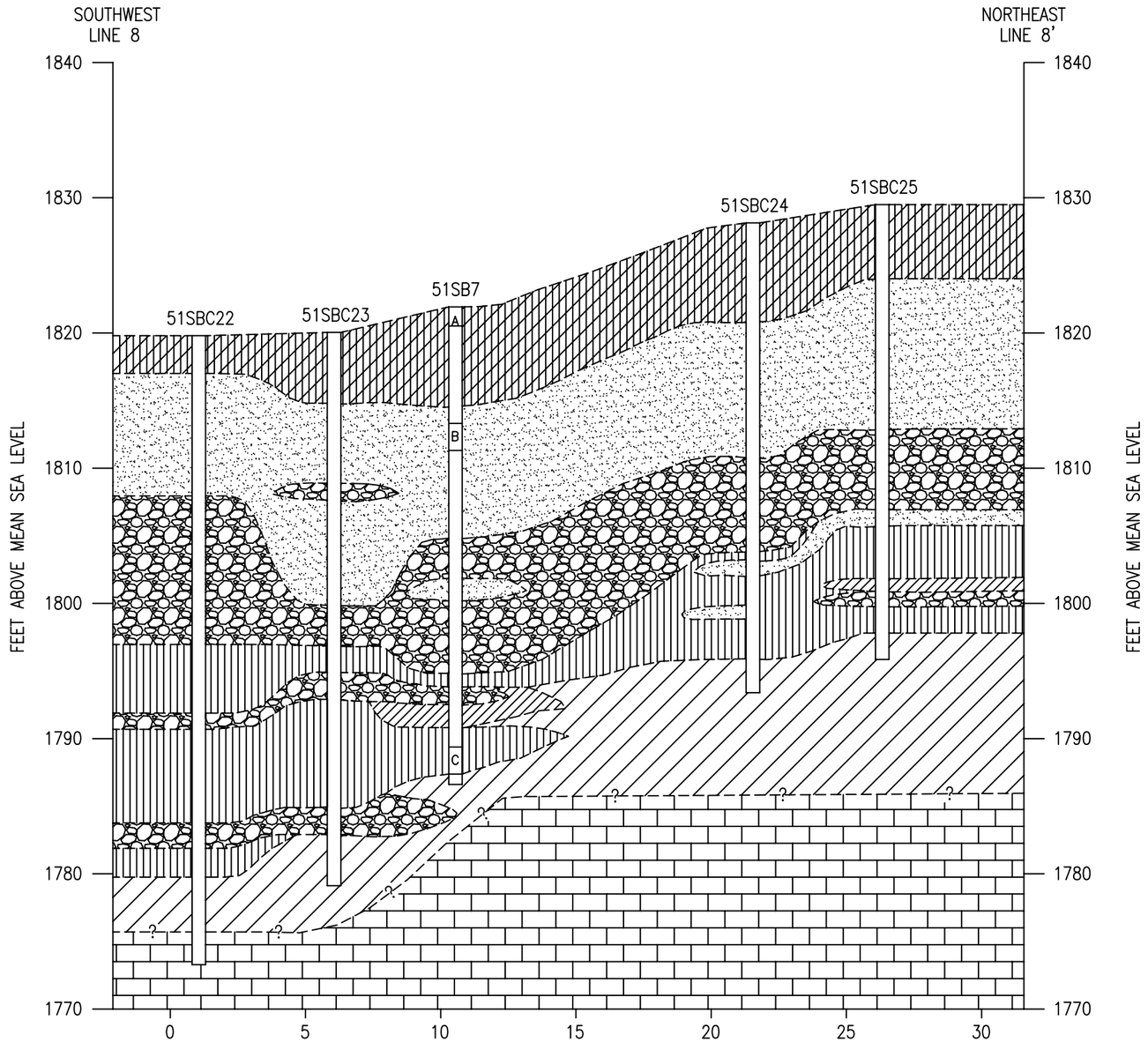
0 10 20 FEET
VERTICAL SCALE

RADFORD AAP

FIGURE 2–10

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2–10
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 7 – LINE 7')



LEGEND

- FILL
- SILT/CLAY (ML/CL)
- CLAY (CL)
- SILT (ML)
- SAND – SANDY CLAY, POORLY GRADED AND WELL GRADED SAND
- GRAVEL – GRAVEL AND GRAVELLY SAND (RIVER JACK)
- SAPROLITE – IN–SITU WEATHERED BEDROCK (CL/ML)
- BEDROCK – SHALE, LIMESTONE, AND DOLOMITE
- GEOLOGIC CONTACT
- GEOLOGIC CONTACT (INFERRED)
- B — SAMPLE INTERVAL

0 5 10 FEET
HORIZONTAL SCALE

0 10 20 FEET
VERTICAL SCALE

RADFORD AAP

FIGURE 2–11

PREPARED BY: SHAW	TASK NO: 83919705000000
CHECKED BY: MT	SHAW DWG NO: Figure 2–11
DATE: APRIL 2008	

SWMU 51 GEOLOGIC CROSS SECTION (LINE 8 – LINE 8')

B.1 INTRODUCTION

SWMU 51 is located in the southeast section of the Horseshoe Area and adjacent to SWMU 30. Background information indicates that the site consists of a 20x200-ft trench that has been filled to grade, and is weed and grass covered. An unknown quantity of TNT neutralization sludge from the treatment of red water was disposed in this unlined trench in the 1970s, and an estimated 10 tons of red water ash was reportedly disposed in the trench from 1968 to 1972 (Dames & Moore, 1992). The trench is reported to be centrally located between two-adjacent trenches that are part of SWMU 30.

Surface geophysical surveys using two-dimensional resistivity profiling, seismic refraction tomography, and EM-31/34 terrain-conductivity mapping were performed at SWMU 51 during the time period of August through September 2002. Additional downhole seismic velocity measurements were collected in four monitoring wells adjacent SWMU 51 to help guide the seismic interpretations, and downhole electrical logging was collected by USACE New England District personnel to help constrain the resistivity models.

B.2 OBJECTIVE

The primary objective of the SWMU 51 surveys was to provide both the lateral and vertical extent of the former trench used for the TNT neutralization sludge disposal. Information obtained by the geophysical surveys will be used to develop the CSM and focus the proposed sampling activities to assess the nature and extent of TNT neutralized sludge disposed at SWMU 51.

B.3 TECHNICAL APPROACH

Site conditions are critical in assessing what geophysical techniques are appropriate for an investigation. SWMU 51 is underlain by carbonate rock (limestone and dolomite) that in places is structurally complex (folded and faulted) and contains clastic interbeds and tectonic breccias. Overburden sediments range from 0 to 60+ feet in thickness, and in landfill areas, the overburden may contain a considerable thickness (>10-ft) of red water ash, as well as other debris associated with dump activities.

Two-dimensional electrical resistivity imaging (2D-ERI), seismic refraction profiling/tomography, electromagnetic (EM) terrain-conductivity mapping are applicable techniques that can map changes in the electrical (2D-ERI and EM) and acoustic (seismic) characteristics of the underlying soil and rock. **Appendix B-2** describes in more detail the theory and operation of these methods.

In general, the underlying rock should have a higher seismic-velocity than the overburden sediment, and should be readily distinguishable on the resulting tomographic sections. A decrease in seismic velocity will occur where the rock is fractured (weak zones), less competent, or dominated by void and cavity development.

The electrical response of the rock is more complex and depends on the type of strata present and the electrical properties of the pore fluid. Higher electrical-resistivity should occur if carbonate rock is present, though the presence of an electrically conductive pore-fluid, or a significant clay fraction, could alternately yield lower-resistivities than expected. Air-filled fractures and voids would likely increase the electrical resistivity.

The trench work within the overburden sediment is expected to produce a zone of slightly lower seismic-velocity and lower electrical resistivity. In addition, the presence of waste material and degradation products may also lower the electrical response in the vicinity of the trench. Metallic debris deposited within the trench will also have a significant electromagnetic response during the EM surveys.

B.4 GEOPHYSICAL SURVEYS

Geophysical surveys for SWMU 51 consisted of 3 seismic-refraction profiles, 4 two-dimensional resistivity (2D-ERI) profiles, and one EM grid **(Figure B-1)**. Also shown on Figure 1 are the locations of the main boundary fence for SWMU 30, the interior fence outlining the TNT sludge disposal trench, and the areal coverage provided by the EM grid (~33 ft major survey lines are shown). Two of the profiles (L-2 and L-3) were collected parallel to the long axis of the trench, and the other two profiles (L-1 and L-4) were collected perpendicular to the long axis.

B.4.1 Geophysical Profiling (Seismic and Resistivity)

Both seismic and two-dimensional resistivity data (2D-ERI) were collected along profiles L-1, L-2, and L-4, and only a resistivity survey was conducted along Profile L-3. Each profile was extended beyond the fence boundaries in order to verify whether or not the fenced area truly marks the limits of the TNT sludge disposal trench. Profile L-4 was also extended further to the west and outside the limits SWMU 30 fence to allow contrasting presumed natural conditions with the geophysical response within SWMUs 30 and 51.

Resistivity data were collected using both Schlumberger and dipole-dipole array surveys (see **Appendix B-3** for further explanation). Use of both array types allows discerning whether observed anomalies are modeling or data collection artifacts, and more credence is given to the results where models constructed from both array types show similar features.

The seismic data were processed using both refractor-layer (earth-layer) and tomographic models. Earth-layer models provide discreet boundaries between horizontal zones (layers) of different seismic velocity, and are limited to a single velocity per model layer. Tomographic models do not have this restriction, and attempt to show both horizontal and vertical changes in velocity. The tomographic cross-section was developed using several different velocity models including the earth-layer solution. Modeling generally resolved into similar solutions, of which one is shown for each profile.

The resistivity and seismic results are presented as color-contoured cross-sectional models with magenta-to-blue colors representing lower values, and red-to-white colors higher values. The same color-contour scheme is used throughout for all four profiles to allow a direct comparison of anomaly magnitudes. For each profile, three model panels are shown, with the upper two panels representing the dipole-dipole and Schlumberger array results, and the bottom panel the seismic refraction results. The seismic model for Profile L-2 is used as comparison with the resistivity data collected on Profile L-3. Also shown on each panel, are the intersecting points of cross-lines, the refractor-layer seismic model (orange trace lines), and the relative position of the SWMU 51 fence (magenta rectangle near ground surface labeled as the “SWMU 51 fenced area”).

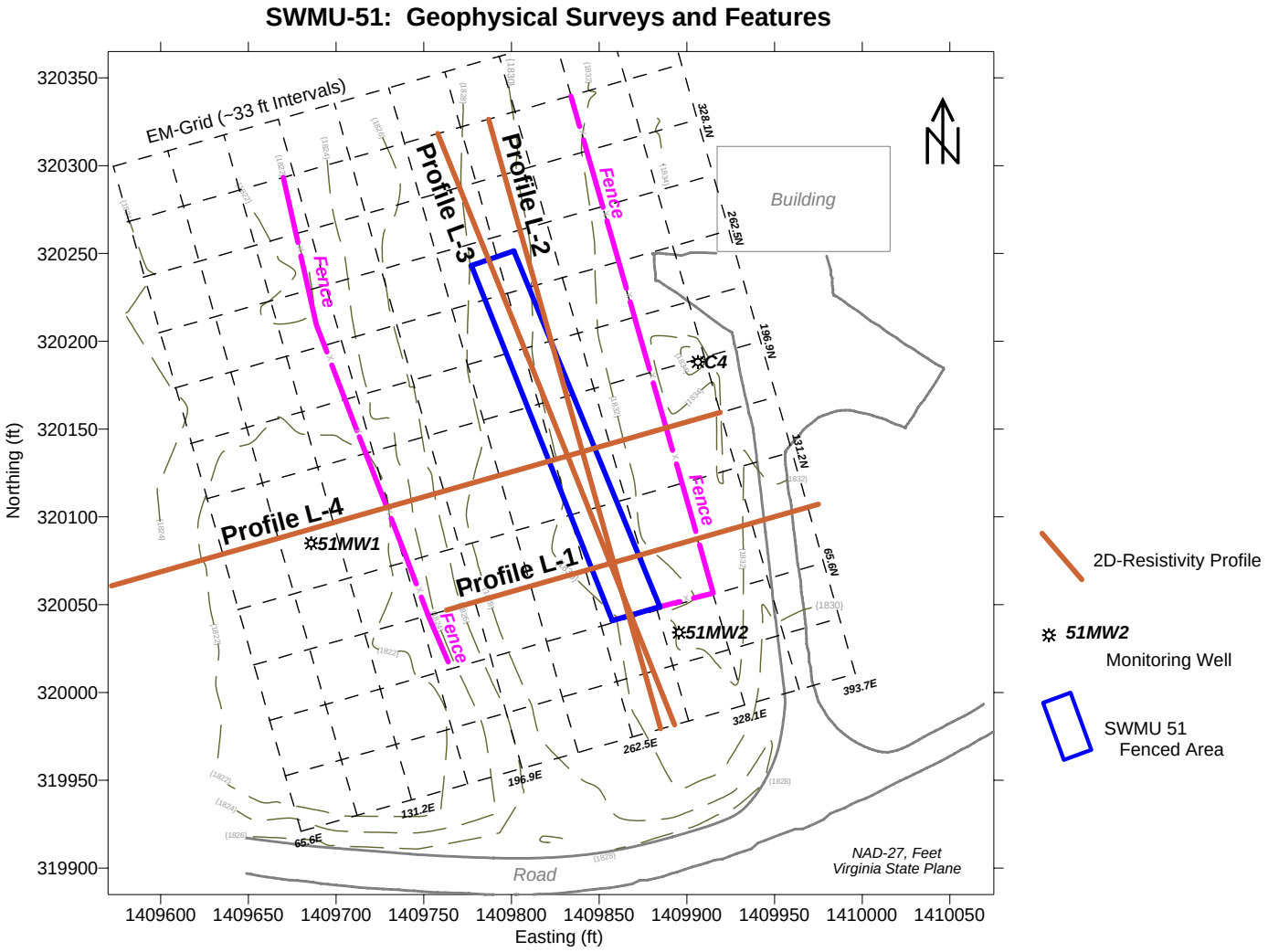


Figure B-1. Base Map for SWMU 51.

Profile L-1

Profile L-1 was acquired along a WSW-ENE transect near the southern end of the SWMU 51 area, along a line perpendicular to the long axis of the TNT trench (**Figure B-1**). Both 2D-ERI and seismic surveys were collect on this profile. The resistivity survey used an electrode spacing of 6.56 ft (2 m) and a total of 28 electrodes, and the seismic profile used a single array of 48 geophones spaced at a 3.28ft (1 m) interval. The resulting geophysical models are shown in **Figure B-2**.

A distinct zone of low-resistivity (<80 ohm-m) is present on the 2D-ERI models (upper 2 panels) of **Figure B-2**. The lateral extent of this low-resistivity zone coincides roughly with the area bounded by the SWMU 51 fence (264X to 292X on the profile). Low-resistivities within this zone are tentatively interpreted as waste and/or waste byproduct resulting from activities at SWMU 51. Depth to top of this low-resistivity zone ranges from 5 to 7 ft below ground surface (bgs), with the shallower depth-to-top near the western and eastern edges of this feature. The base of the low-resistivity occurs at approximately 16 ft bgs, giving 9-11 ft in total thickness.

Material of higher resistivity caps the low-resistivity zone, and is interpreted to correlate with the blocky (cobbles) rubble observed on the ground surface during data collection. Note also that a zone of low-to-moderate resistivity (100-300 ohm-m) occurs in the upper 10 ft of the subsurface in the approximate position of one of the SWMU 30 trenches (profile coordinates 212-250X).

The short length of the resistivity profile was not able to resolve the overburden-bedrock interface. The bedrock surface is approximately 1,780 ft in elevation near well 51MW2, and ~1,782 ft beneath well 51MW1.

A three-layer solution was used to construct the earth-layer model for Profile L-1 using seismic velocities of 400, 700, and 2,000 m/s. The tomographic solution yielded a slightly different set of average velocities (550, 970, 1,550 m/s) for the same range of depths on the earth layer model.

The uppermost refractor surface indicates a broader area of lower velocity material than that indicated by the SWMU 51 fenced area (and corresponding resistivity anomaly). This surface deepens to approximately 15 ft bgs immediately west of the SWMU 51 fence. The tomography model also depicts a zone of low seismic velocity (stippled pattern of velocity less than 450 m/s). The low-velocity zone, however, is much broader than the resistivity anomaly (and location marked by the fence), and extends in depth to approximately the top of the low-resistivity anomaly (base of cap material). The most likely interpretation is that this low-velocity zone is a result of backfilling and capping, and not representative of the waste material within the trench.

The lowermost refractor surface likely corresponds to an interface above the bedrock surface. Note that well 51MW2 (50 ft to the south) places the bedrock approximately 8-to-10 ft deeper than this refractor. The highest velocities observed on tomographic model for Profile L-1 are significantly lower (1,800 m/s versus 2,400-2,700 m/s) than seismic velocities observed for the bedrock on the other three profiles.

Profile L-2

Profile L-2 was collected along a transect sub-parallel to the long axis of the SWMU 51 fenced area, along the 278E axis line of the EM grid **(Figure B-1)**. Both 2D-ERI and seismic

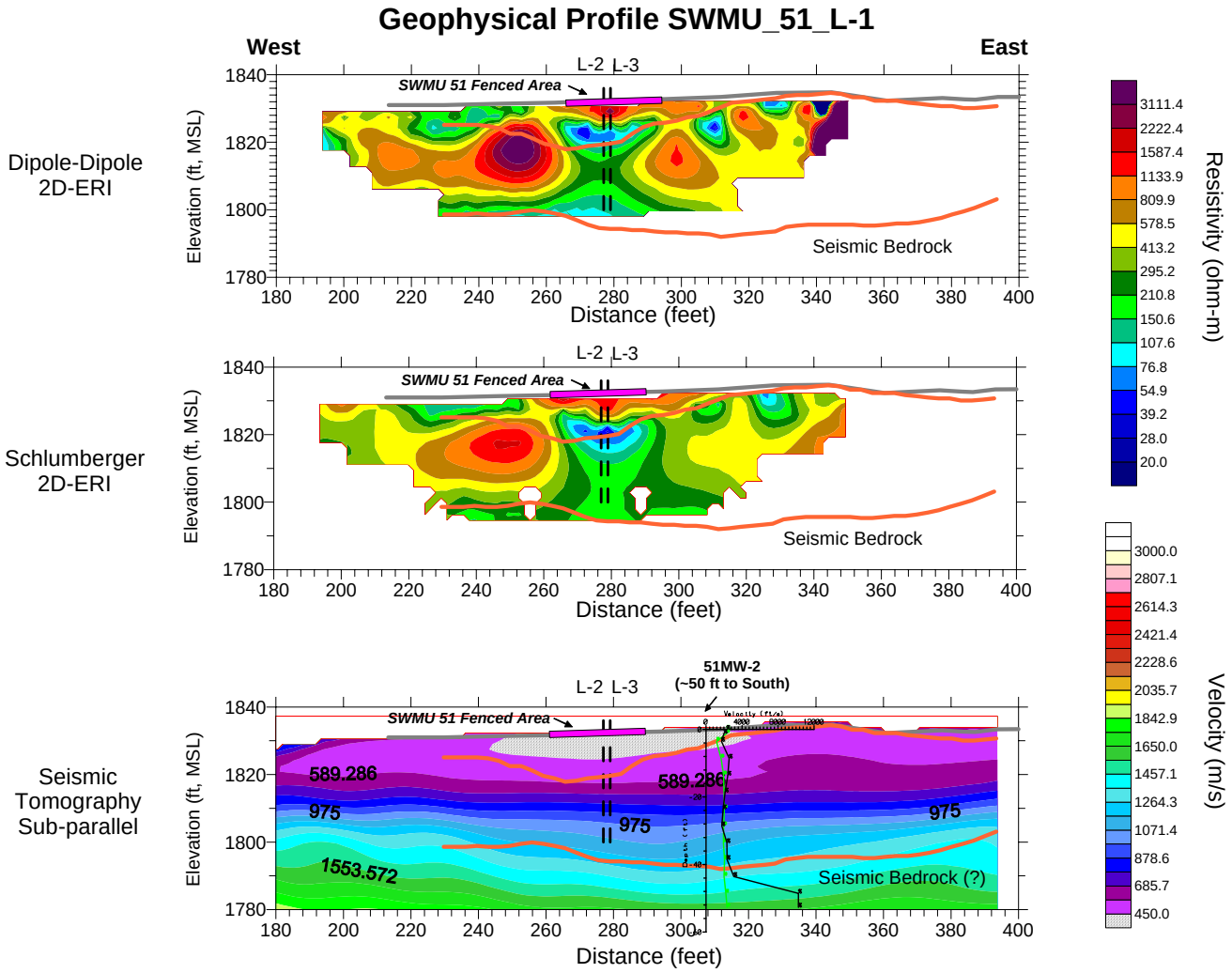


Figure B-2. Geophysical Results for Profile L-1

data were collected. The resistivity survey used an electrode spacing of 13.12 ft (4 m) and a total of 28 electrodes. The seismic profile used two adjacent spreads of 48 geophones spaced at a 3.28 ft (1 m) interval. The resulting geophysical models are shown in **Figure B-3**.

Both resistivity models (upper two panels, **Figure B-3**) show a zone of low-resistivity (<80 ohm-m) extending from 100X to 205X. The electrical response of this zone is interpreted to be caused by the waste and/or waste byproduct based on its position relative to the SWMU 51 fence area (note that Profile L-2 exits the fence enclosure approximately three-quarters the length of the N-S fence length) and similarity to responses observed on the other three profiles. The top of this feature ranges from 6-9 ft bgs and the base from 16 to 21 ft bgs, with a general deepening towards the north. The Schlumberger model (middle panel) does not provide a sharp boundary for the base of this anomaly, but instead models a zone of intermediate resistivity (100-300 ohm-m) immediately beneath the suspected location of the trench.

A three-layer model was used to construct the earth-layer solution for Profile L-2. Layer velocities are higher than that indicated for L-1, and are (top to bottom) 521, 1,046, and 3,035 m/s. The resulting tomographic solution yielded overburden velocities consistent with the earth-layer model, but with a lower bedrock velocity (2,421 m/s).

The uppermost refractor surface exhibits a slight depression in the vicinity of the trench, but the tomographic solution models this interface as a horizontal surface. A distinct zone of low velocity (<450 m/s, stippled area), with a thickness of 5-6 ft, is modeled over the southern two-thirds of the resistivity defined trench location. The upper refractor surface appears to approximate the base of the low-resistivity anomaly within the central part of the profile (150X), but is more likely corresponding to natural changes in subsurface conditions. As with the L-1 Profile, the L-2 seismic data cannot be used to resolve the waste thickness within the SWMU 51 trench.

The top of bedrock, as defined by the earth-layer model, is interpreted as a relatively flat surface ranging approximately 55-60 ft in depth, and with a slight rise to 50 ft bgs near profile coordinate 80X. The corresponding tomographic model images the bedrock as a horizontal surface at approximately 60 ft in depth. A slight decrease in velocity is observed in the bedrock between profile coordinates 50X and 90X.

Profile L-3

Profile L-3 was collected along the long axis of the SWMU 51 fenced area, extending approximately 66 ft to the south of the fenced area and 70 ft to the north. Only resistivity data were collected using 56 electrodes at a spacing of 6.56 ft (2m), which provided a line length of 360.9 ft (110 m). It was hoped that the finer electrode spacing and co-linearity with the trench's long axis would yield a better definition of the trench boundaries. The resulting dipole-dipole and Schlumberger array models are shown in **Figure B-4** (upper two panels), and the seismic model results for Profile L-2 (lower panel) are shown for comparison.

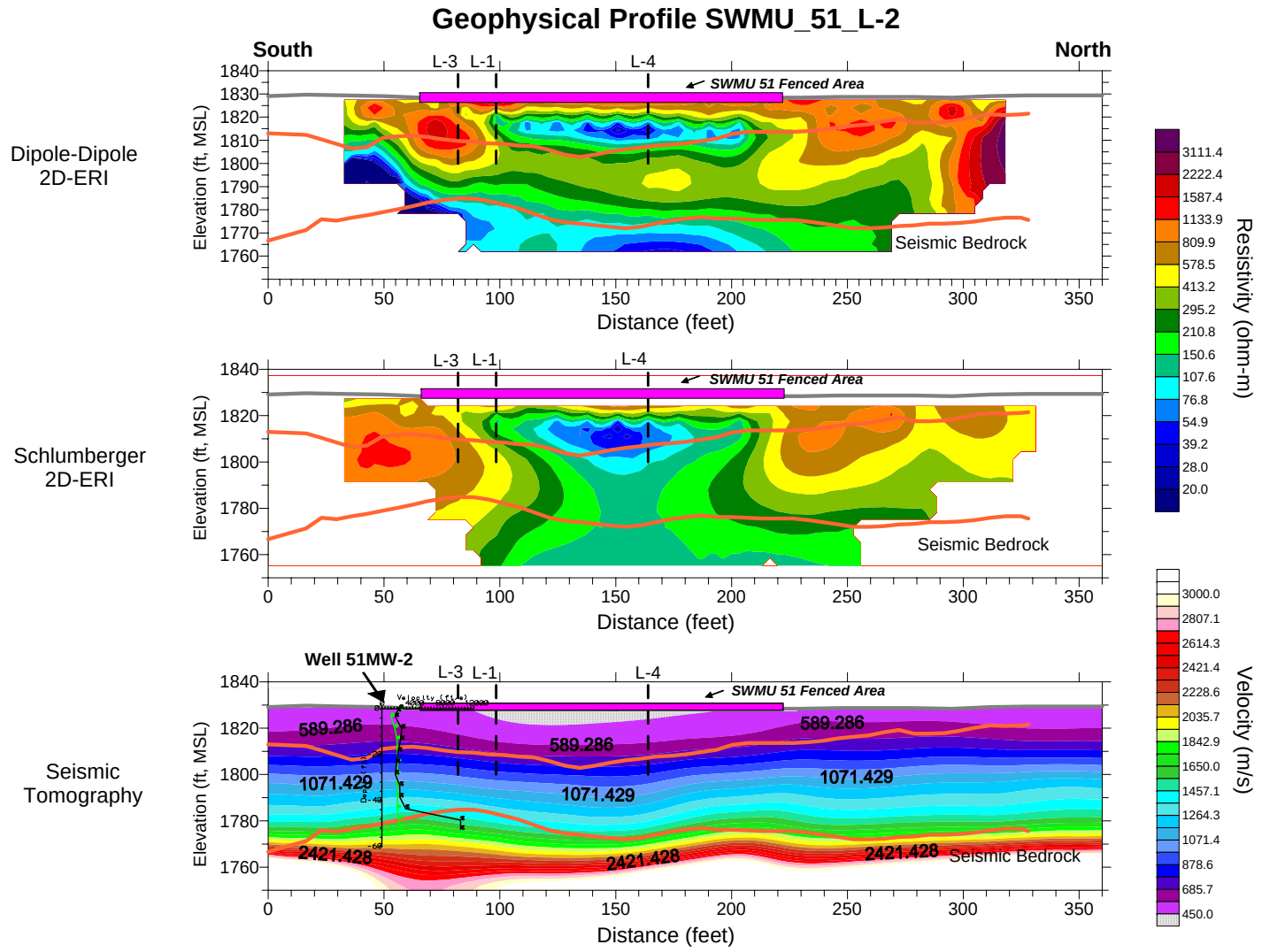


Figure B-3. Geophysical Results for Profile L-2

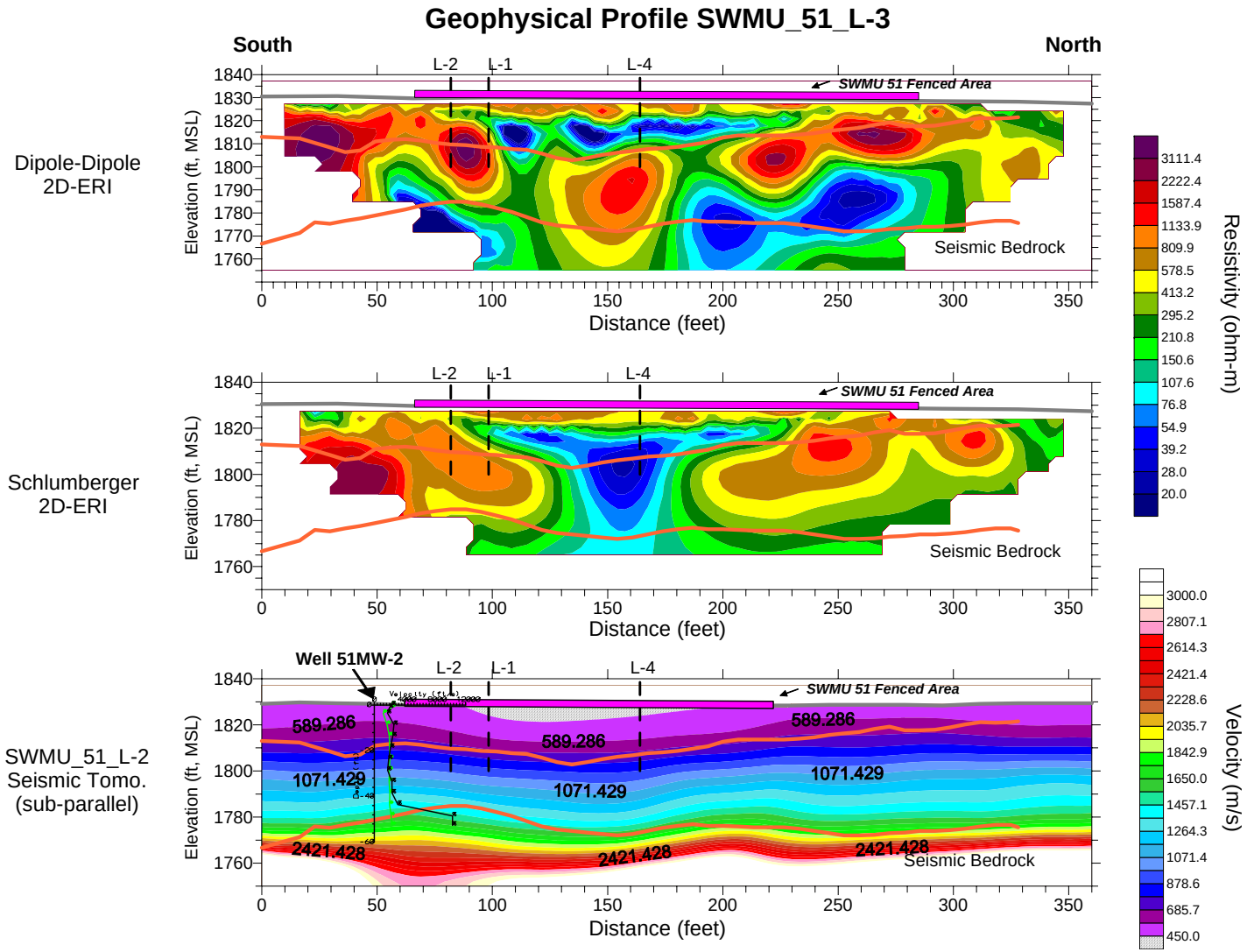


Figure B-4. Geophysical Results for Profile L-3

The resistivity models depict a zone of low-resistivity (<80 ohm-m) between profile coordinates 90X to 225X, with a depth to top ranging from 7-to-9 ft bgs and depth-to-base from 15-to-25 ft (average is approximately 18 ft bgs). Following interpretations for Profiles L-1 and L-2, this low-resistivity zone is probably the electrical response of the waste and/or waste byproduct. The dipole-dipole model indicates less lateral continuity in the trench, exhibiting a break in the low-resistivity near profile coordinate 120X. This low-resistivity zone extends to its greatest depth immediately adjacent to this break. The Schlumberger model does not resolve the base of this anomaly in the central part of the profile, although the upper refractor of the L-2 seismic model appears to mimic the base of the low-resistivity zone.

Other zones of low-resistivity are modeled by the dipole-dipole data near the southern end and northern third of the SWMU 51 fenced area. The Schlumberger model does not image these same features suggesting that they are most likely modeling artifacts.

Profile L-4

Profile L-4 was collected on a line perpendicular to the long axis of the trench along EM grid axis 164N. The profile was extended to the west so that well 51MW1 could be used to help guide the interpretation, and so the electrical and seismic character of the "undisturbed" area west of SWMU 30 could be used as a contrast. The resistivity data were collected with 56 electrodes at a spacing of 6.56 ft (2 m), providing a profile length of approximately 360 ft. Two adjacent spreads of 48 geophones, spaced at 3.28 ft (1m) intervals, were used for seismic data collection. The resulting geophysical models are shown in **Figure B-5**.

A distinct, low-resistivity anomaly (<80 ohm-m) is centered beneath the SWMU 51 fenced area, located between profile coordinates 265X and 280X. The depth-to-top of this anomaly is approximately 7 ft, and the depth-to-bottom, though not fully resolved, is estimated at approximately 20 ft. This depth estimate is based on the Schlumberger model at the point where the upper seismic refractor crosses the base of the low-resistivity anomaly. Note that unlike the results for the other three profiles, the dipole-dipole array did not resolve the base of the low-resistivity zone.

Two other zones of low-resistivity are present at depth to the west of the SWMU 51 fenced area. The zone of low-resistivity occurring between coordinates 170X and 200X is interpreted to correlate with the SWMU 30 trenches. The source for the furthest west zone of low-resistivity is not known, but may be due to the general decrease in resistivity observed near the overburden-bedrock interface.

The seismic model for Profile L-4 (bottom panel **Figure B-5**) shows a relatively flat bedrock surface, and a broad area of lower velocity underlying SWMU 30 and SWMU 51. A three-layer solution was required for the earth-layer model, using velocities of 500, 800, and 2,550 m/s. The tomographic model yielded similar velocities (550, 878, and 2,421 m/s) for equivalent depth ranges. A zone of low-velocity (<450 m/s) is modeled by the tomographic solution as a broad swale underlying the SWMU 51 fenced area. The base of this low-velocity zone corresponds with the top of the low-resistivity anomaly, suggesting that this is related to the cap and/or backfill material.

B.4.2 EM-31 and EM-34 Conductivity Surveys

Electromagnetic (EM) surveys were performed in the grid area shown on **Figure B-1** with the objective of mapping the lateral extent of the SWMU 51 trench, and to determine

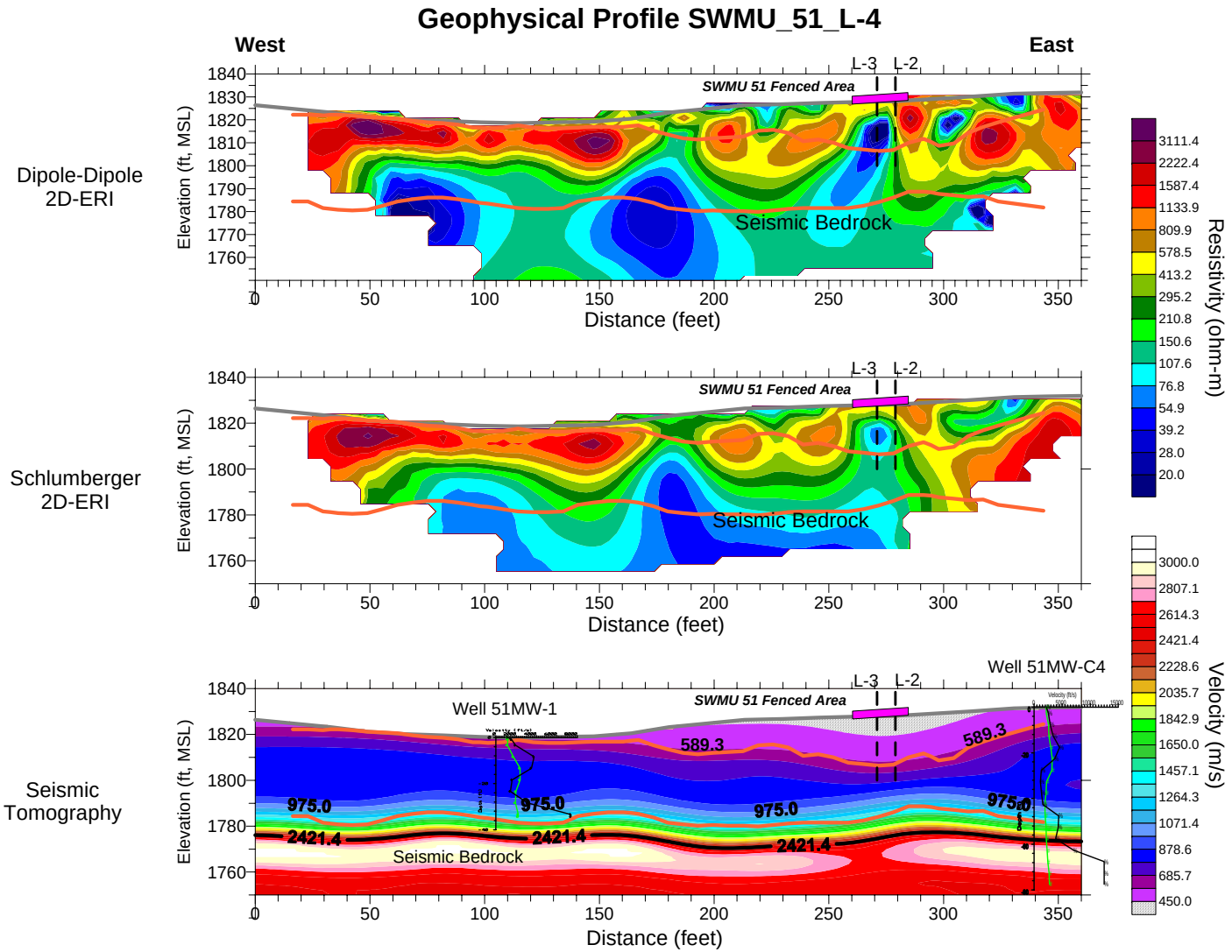


Figure B-5. Geophysical Results for Profile L-4

whether a significant quantity of metallic debris has been buried. It was expected that the activities involved in the construction of and disposal within the trench would alter the subsurface electrical properties, yielding a distinguishable anomalous area associated with the trench. Prior to performing the surveys, the barbed wire fence enclosure surrounding SWMU 51 was removed to the extent practicable, with only the corner fence posts and possibly some rusted fencing material within the vegetation at the site remaining in place.

Both the EM-31 and EM-34 terrain-conductivity meters were used to collect EM measurements at SWMU 51 (see **Appendix B-3** for a further description). EM-31 measurements were collected along profiles spaced at 8 ft (2.5 m) in the approximate north-south direction and along profiles spaced at 33 ft (10 m) in the approximate east-west direction. Both quad-phase (electrical-conductivity) and inphase (percent metals) data were collected with the EM-31. EM-34 surveys were collected along profiles spaced at 33 ft (10 m) in the approximate north-south direction, and along 66 ft (20 m) spaced profiles in the approximate east-west direction (except for profiles along 164E and 328.1E, which were excluded to reduce interference from the SWMU 30 fence lines). The EM-34 collects only quad-phase (electrical conductivity) data.

EM measurements reflect a weighted average with greater weight given to shallower depths. The EM-31 was operated in the vertical dipole mode, and 80% of the measured response correlates with the upper 10 ft (3 m) of subsurface material, with the peak response occurring in the 1.6 to 8.2 ft (0.5-2.5 m) depth range. The EM-34 meter was operated in the horizontal dipole mode using a coil spacing of 66 ft (20 m), which resulted in 80% of the response (also peak response) coming from the upper 33 ft (10 m) of subsurface material.

Figure B-6 shows the conductivity anomaly map constructed from the EM-31 survey. Red-to-white colors indicate areas of relatively higher electrical conductivity, whereas blue-to-magenta colors areas of lower conductivity. The locations of the 4 geophysical profiles are shown as heavy brown lines, and the interpreted area of the trench (from 2D ERI profiles) as a crosshatched region. Site features including roads, fences, wells, and ground-surface topography are also shown. Some of the EM-31 data were not included in construction of the map due to their proximity to the fence lines. Natural or background conditions are inferred on **Figure B-6** for the western side of the grid (west of the fence line) where conductivity values range from 5-to-7 mS/m.

The high conductivity anomalies (>12 mS/m) located to the west of Profile L-3, and north of Profile L-1 (grid area: 99N-to-396N; 164E-to-260E), are most likely related to one or more of the SWMU 30 disposal trenches. Another zone of high conductivity parallels the easternmost fence line, and may be related to another SWMU 30 trench. Profile data collected within 10 ft of this easternmost fence were excluded from the plot, and thus the observed anomalous character cannot fully be due to the fence. Note that the original description of SWMU 51 cites that the neutralization sludge trench lies between two adjacent SWMU 30 trenches, supporting this interpretation of the EM-31 plot.

Inspection of the EM-31 anomaly map reveals a slight increase in conductivity within the southern two-thirds of the SWMU 51 fenced area. This increase, related to changes in electrical properties within the upper 10 ft (3 m) at the site, is approximately 1-2 mS/m higher than background levels, and is roughly coincident with the trench area defined by the resistivity profiles. All four resistivity profiles indicate an electrically conductive zone from 5-9 ft bgs, which is near the practicable depth limits of the EM-31 instrument.

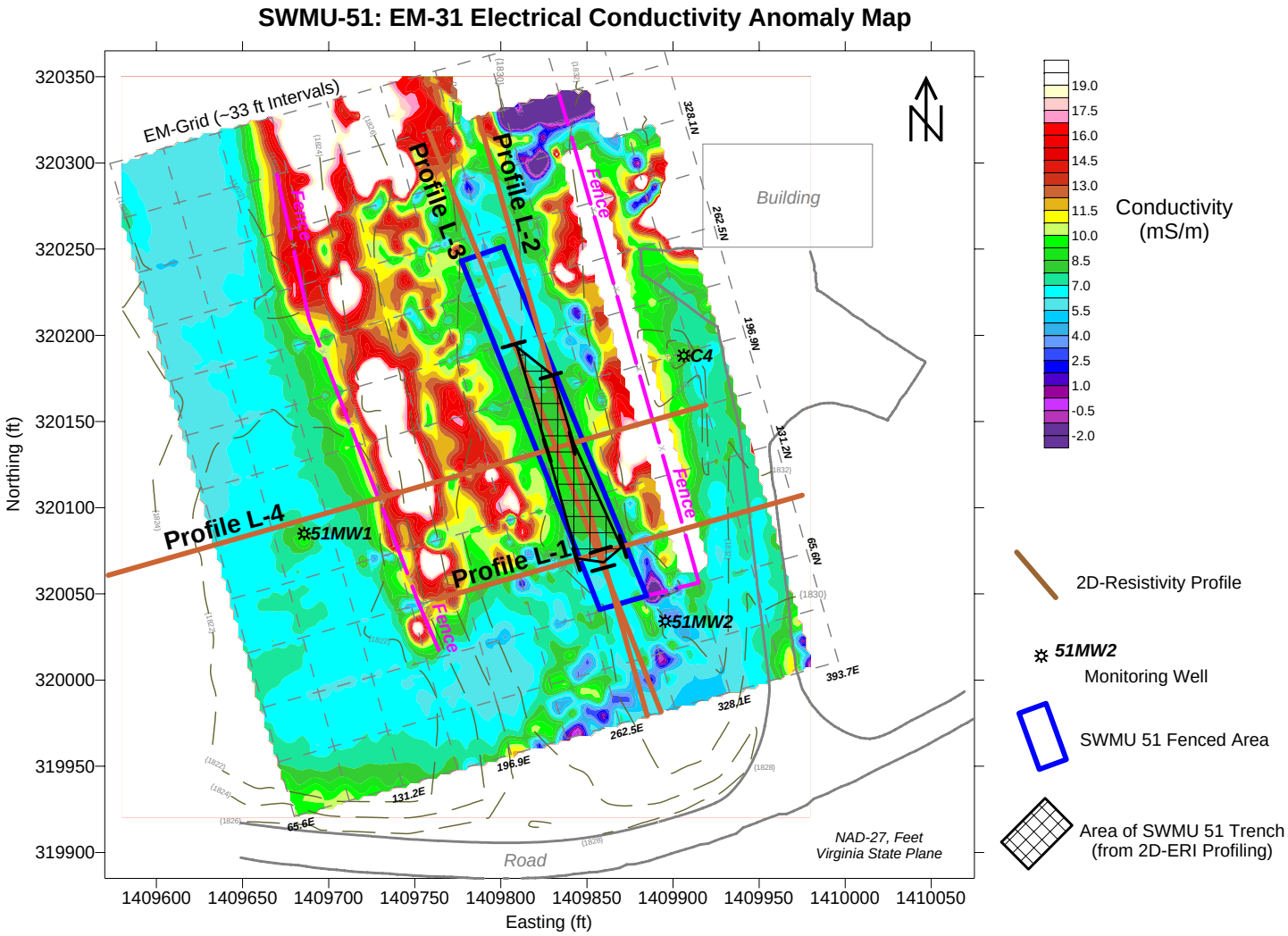


Figure B-6. EM-31 Conductivity Anomaly Map

In-phase (metals) data were collected concurrently with the EM-31 conductivity data, and the resulting anomaly map is shown in **Figure B-7**. No metal response is indicated in the areas west, south, and east of the SWMU 30 fence (outer fence lines). No metal (other than a couple fence posts at the inner fence corners) was detected within the fenced boundary of SWMU 51 (blue outlined rectangle). Metal related anomalies associated with other site activities were detected to the west, north, and east of SWMU 51 corresponding with anomalous areas shown on the conductivity plot **(Figure B-6)**.

The EM-34 conductivity anomaly map is shown in **Figure B-8** using the same color scale as that used in **Figure B-6** (EM-31 conductivity). The relatively higher "background" conductivity (8-10 mS/m vs. 5-7 mS/m) is interpreted to result from the EM-34 sampling to a greater depth, and thus including presumably wetter soils in the measurement (depth to bedrock is great enough to have little impact on the EM measurements).

An area of increase in conductivity (~4 mS/m) is observed within the southern two-thirds of the SWMU 51 fenced area. This relative high area is in the approximate location as a conductivity increase observed in the EM-31 data, though of greater relative magnitude. Therefore, it is likely that the conductive material (possibly the waste itself or leached material) delineated by the EM surveys extend to depths greater than 10 ft (~3 m). The north-south extent of this anomaly is less than the areal coverage indicated by the 2D-ERI profiles (crosshatched polygon). Other areas of high-conductivity, the grid area between 164E-260E, 99N-230N, and those north of grid 250N are most likely related to the trenches of SWMU 30.

B.5 SUMMARY

Seismic refraction profiling, two-dimensional electrical-resistivity imaging (2D-ERI), and electromagnetic terrain-conductivity surveying were conducted at SWMU 51 in order to delineate the boundaries of the disposal trench. The geophysical data suggest that the SWMU 51 related trenching and disposal is contained within the current SWMU 51 fence, and restricted to the southern two-thirds of the fenced area.

Seismic refraction tomography mapped a low-velocity zone interpreted to be due to the capping or backfilled material, but did not map the base of the trench. Earth-layer models constructed for the profiles indicate an intra-overburden increase in velocity, which occurs near the base of the trenching, and may indicate a maximum boundary for trenching. No significant structural features were indicated for the bedrock, and top-of-bedrock was mapped as a relatively horizontal surface.

2D-ERI profiling modeled a zone of low-resistivity (<80 ohm-m) underlying the SWMU 51 fenced area. The source for the low-resistivity is interpreted to be either the waste or waste byproducts (leachate or leached material). Depth-to-top of this low-resistivity zone ranged from 5-9 ft bgs, and averaged 6-7 ft bgs. Therefore it is argued that the waste material deposited in the SWMU 51 trench is at least 5 ft bgs.

Depth to the true base of waste is the issue. The resistivity data indicate a range of 15-to-25 ft bgs for the base, though it is possible that a downward migration of leachate (or leached material) has increased thickness of the low-resistivity zone, thus overstating the thickness of the waste. At best, the base of the low-resistivity zone can serve as an upper boundary for estimating the thickness of the waste material.

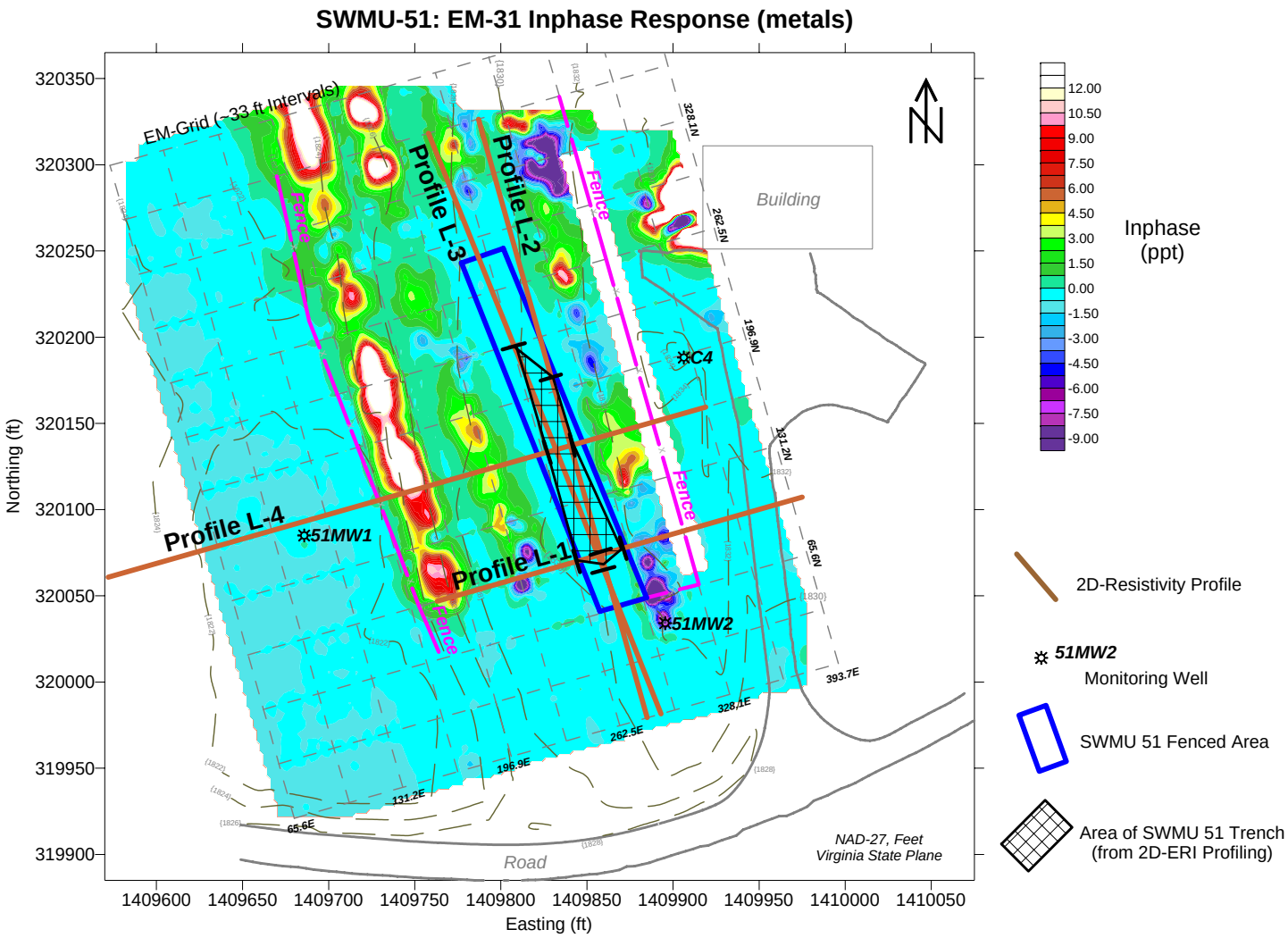


Figure B-7. EM-31 Inphase Response (Metals) Anomaly Map

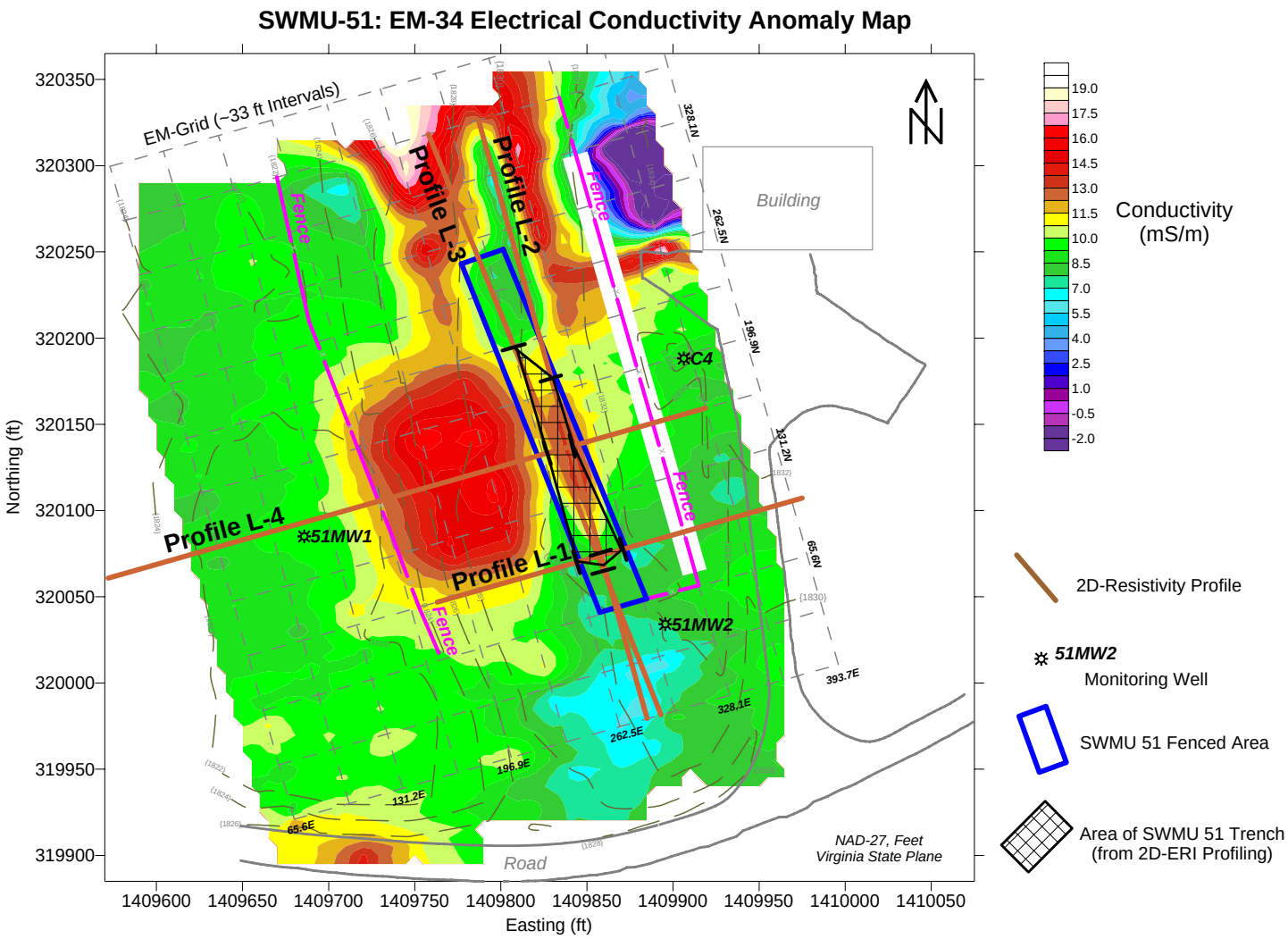


Figure B-8. EM-34 Conductivity Anomaly Map

Electromagnetic surveys using the EM-31 and EM-34 instruments mapped a zone of increased electrical-conductivity (decreased resistivity) within the southern two-thirds of the SWMU 51 fenced area. A 1-2 mS/m increase was measured by the EM-31, and suggests that the top of the anomalous region must be within the upper 10 ft (3 m) of the subsurface. The EM-34 instrument yielded a greater electromagnetic response than the EM-31, indicating that the source of this electrically conductivity zone (low-resistivity) extends below 10 ft (~3 m in depth). The anomalous area mapped by the EM-34 is approximately two-thirds that indicated by the 2D-ERI profiles.

The volume of waste is estimated as follows:

- The maximum areal extent of the trench defined by the 2D-ERI data is approximately 2,300 square feet (115 ft x 20 ft). The minimum areal extent can be estimated from the EM-34 conductivity anomaly map, and is 1,800 square feet (90 ft x 20 ft).
- Depth to top of the low-resistivity (electrically conductive) zone ranges from 5-9 ft, and averages 6-7 ft. Depth to bottom ranges from 15-25 ft, with an average of approximately 18 ft. The range in thickness is 6-20 ft, and averages approximately 11 ft.
- Using the average thickness (indicated on the 2D-ERI sections) and the areal extent, a volume range of 19,800 (11 ft x 90 ft x 20 ft) to 25,300 (11 ft x 115 ft x 20 ft) cubic ft or 733 to 937 cubic yards is calculated.

GEOPHYSICAL METHODS

2D Electrical Resistivity Imaging

Two-dimensional electrical resistivity imaging (2D-ERI) measures horizontal and vertical variations in the electrical-resistance of the subsurface. For RFAAP, the underlying carbonate rock was expected to be of higher-electrical resistivity than the overburden sediment. The electrical response of the rock is probably more complex, depending on the type of strata present and the electrical properties of the pore fluid. Higher electrical-resistivity should occur if carbonate rock is present, though the presence of an electrically conductive pore-fluid, or a significant clay fraction, could alternately yield lower-resistivities than expected. In addition, weak or fractured zones within the carbonate rock should display changes in electrical character, from either an increase in resistivity for air-filled regions, to a decrease in resistivity for clayey intervals. The trench work within the overburden sediment is expected to produce a zone of lower electrical resistivity. In addition, the presence of waste material and degradation products may also lower the electrical response in the vicinity of the trench.

The Advanced Geosciences, Inc. (AGI) Sting/Swift™ system is an automatic multi-electrode system and earth resistivity meter that acquires data by passing an electric current between two electrodes and measuring the potential difference (voltage) between two separate electrodes. The measured voltage is a factor of the resistance of the earth material and the geometry of the electrode array. Resistivity, an intrinsic property of the earth, is then calculated using the measured voltage, the electric current strength, and a geometric factor for the electrode array. The calculated resistivity value is actually an "apparent-resistivity" because it includes the resistances of all the material that the electrical current passes through. A modeling procedure is then used to convert the measured apparent-resistivity data into earth-layer resistivity sections.

The electrodes used to measure the voltage difference are arranged in various geometries called arrays, and the calculated apparent-resistivity value is interpreted to represent a depth point at the center of an individual array. Depth of measurement is related to width of electrode separation, with greater electrode separation resulting in greater depths of penetration. Classically, two different techniques are used to determine the electrical resistivity of earth materials. In vertical electrical sounding (VES), electrodes are expanded about the center of an array to generate a layered electrical section at a single point (vertical profile). The lateral profiling technique uses an array with a fixed electrode separation, which is marched along a line to image lateral variations at a constant depth.

Two-dimensional electrical-resistivity imaging (2D-ERI) combines VES and lateral profiling into a single survey without the time-consuming process of constantly moving electrodes and reconnecting cables. In 2D-ERI a single cable connects a linear array of electrodes, which are turned on and off using a preprogrammed sequence via a controller box. The raw apparent-resistivity data are typically displayed as a pseudosection where the lateral position of the measurement point is placed at the center of the corresponding electrode array, and the depth of the measurement increases with increasing electrode spacing. Apparent-resistivity pseudosections are useful for performing quality-control checks and for examining whether manmade objects have impacted the data set.

Apparent-resistivity pseudosections are converted, through a process termed inversion, into an electrical-resistivity cross-section showing true earth-layer resistivities. RES2DINV (Loke,

1996), a commercially available program, was used to perform the two-dimensional inversion modeling. During the inversion, the subsurface is divided into a number of blocks equal to or less than the number of measurement points. A smoothness-constrained, least-squares inversion routine is used to estimate the resistivity value of each block, and finite-element or finite-difference forward modeling is used to calculate the resulting pseudosection. The model is iteratively corrected until an apparent-resistivity pseudosection calculated from the model converges with the measured apparent-resistivity pseudosection. A root-mean-square (RMS) error calculation of the difference between the two apparent-resistivity pseudosections is used as a measure of the degree of fit for the model. Maximum convergence often occurs within 3 to 5 iterations, after which RMS values do not change significantly and the model may start to become unstable.

Electromagnetic Terrain-Conductivity Surveying

Electromagnetic-induction instruments (EM-31 and EM-34) are used to measure the electrical conductivity of the near surface, and can also be used to locate buried metallic objects. A transmitter coil is used to induce an electrical current into the ground, and the receiver coil measures the strength of the secondary magnetic field generated by these currents. Two components of the secondary magnetic field are recorded: 1) the quadrature-phase component which is used to measure the ground conductivity, and 2) the inphase component which is used for metallic detection due to its extreme sensitivity to large metallic objects (Geonics Ltd., 1991). The electrical conductivity of the ground is nearly linearly proportional to strength of the quadrature-phase component and is given in units of milli-siemens per meter (mS/m). The inphase measurement is the ratio of the secondary magnetic field to the primary field, and is expressed in parts per thousands (ppt).

The coils can be oriented in either a vertical dipole or horizontal dipole configuration. For the vertical dipole case, the axes of the coils are oriented perpendicular to the ground surface, and for the horizontal dipole, the axes are parallel to the ground surface. For both cases, the coils are maintained in a coplanar state. The vertical dipole orientation is generally preferred over the horizontal dipole because it provides for a greater investigative depth and is less sensitive to near surface variations.

The separation between the transmitter and receiver coils is the primary component that determines the depth of penetration. **Table B-1** lists the depth of investigation for different coil orientations and separations for the Geonics EM-31 and EM-34 meters. The “Practical Depth” is roughly the depth at which 80% of the instrument response has occurred, and the “Effective Depth Range” is the where the instrument’s overall response is the greatest. Thus, layers within the “Effective Depth Range” contribute most to the measured conductivity. The bolded numbers are for configurations used in this study.

Table B-1
Effective Penetration Depth of the EM-31 and EM-34 Instruments

Instrument	Coil Orientation	Practical Depth	Effective Depth Range
EM-31 (3.3 m)	Horizontal Dipole	5.5 ft (1.7 m)	0-5.5 ft (0-1.7 m)
	Vertical Dipole	10 ft (3 m)	1.6-8.2 ft (0.5-2.5 m)
EM-34 (20 m)	Horizontal Dipole	33 ft (10 m)	0-33 ft (0-10 m)
	Vertical Dipole	59 ft (18 m)	10-49 ft (3-15 m)

Conductivity values obtained in EM surveying represent weighted mean values of all the layer conductivities from the ground surface to the maximum depth that is sensed by the EM instrument (McNeill, 1980). If the underlying rock or sediment is uniform, the measured conductivity value will be the true conductivity. The amount of contribution to the measured conductivity from a single layer depends on its conductivity, depth, and thickness. In general, deeper layers contribute less to the final value than do near-surface layers, as do layers outside the effective depth range.

Geonics EM-31. The EM-31 transmitter and receiver coils are housed in a 3.5m long sensor boom, and a single person can operate the instrument (Geonics, 1991). A nominal depth of investigation of 18-ft (5.5-m) is realized when measurements are made using the vertical-dipole mode. Measurements are collected at ½ second intervals, and the quadrature and inphase components are collected simultaneously. This allows discrimination between anomalies sourced by buried metallic objects from those that are either lithologically or hydrologically controlled. Additional information consisting of the profile position, starting, and ending points, as well as fiducial mark locations along the profile, were recorded with an OMNI 720 data logger (Polycorder). This information is then downloaded to a personal computer for processing and display.

Geonics EM-34. The EM-34 is a two-person operable instrument that can measure terrain conductivities to depths of 150-ft (Geonics, 1991). Data were collected at approximately 1 sample per two-feet, and fiducial marker points are recorded at 20-to-50-ft intervals to help mitigate measurement point location errors due to uneven walking speeds. A Polycorder data logger is used to record the line geometry and profile data, which are downloaded to a personal computer for processing and display.

Seismic Refraction Tomography

Seismic refraction provides acoustic velocity and layer depth information (Redpath, 1973). The refraction method generally depends on an increase in seismic-wave velocity (speed of sound through earth material) with depth, though the newer tomographic codes presently available have the capability of handling a velocity inversion (zones of lower seismic velocity underlying zones of higher velocity). Both a tomographic model and an earth-layer (refractor) cross-section are planned as processing outputs from the refraction profiling. The commercially available SeisOpt2D code will be used to construct the tomographic model, and the SIPT software package was used to generate the earth-layer cross-section.

In the refraction method, the seismic energy (or wave) bends (refracts) at interfaces between layers of different velocities. In the special case where the seismic wave has been refracted parallel to the interface, the seismic energy travels along this interface, generating a head wave

that returns to the surface. A linear array of acoustic receivers (geophones) is used to record the travel-time of the first returning seismic signal. This information is plotted on a time-distance graph; for the case of plane layer geometry, the time-distance plot will show distinct linear segments for each layer where the inverse of the slope of a segment is equivalent to the apparent seismic velocity for a particular layer.

A multi-channel, engineering seismograph was used to record the seismic refraction information, and either a 500-lb weight drop (EWG) or a 16-lb. sledgehammer were used as the energy source. Geophones (seismic-receivers) were spaced at a 3.28-ft (1-m) interval during surveying. Shot points were acquired at every fifth geophone position, which allows input to the tomographic modeling software.

The processing sequence for the refraction data consists of:

- Picking first arrival times of return energy for each shot;
- Assigning the array-geometric to the first arrival data;
- Inverting the first-arrival information for velocity and depth using the SIPT algorithm (delay-time method); and
- Constructing a tomographic model of the first-arrival information using the either the SeisOpt2D code available from Optim Software, or the GeoCT-II code from GeoTomo.

The SIPT method takes advantage of the reverse-spread geometry and far offset shot points of the survey to compute depths to interfaces below each geophone. The algorithm employs the delay-time method of Pakiser and Black (1957) to calculate depth and position of refraction horizons. The generated refraction model is further refined using a ray-tracing algorithm which overcomes difficulties associated with dipping or undulating horizons.

The SeisOpt2D software achieves a globally optimized, velocity model using only first arrival travel time data and array geometry as input. SeisOpt2D requires no prior assumptions of subsurface structure, or any other subjective data, as input. A controlled Monte-Carlo inversion method is employed where the derived models are conditionally accepted or rejected based on a probability criterion. The criterion allows the algorithm to escape from non-unique, local, travel time minima to achieve a unique, globally optimized model of subsurface velocity structure. The algorithm makes no assumptions on the orientation of the subsurface velocity gradient, and can therefore reveal vertical structures and strong lateral gradients, if present.

The GeoCT-II inversion code also uses the geometry and first-arrival information as a starting point to apply a nonlinear continuum inversion in order to achieve a velocity-depth model. This package also allows providing a priori constraints such as known velocities from downhole surveys, and using earth-layer models as starting points.

Vertical Seismic Profiling

Vertical seismic profiles (check shots) are used to measure the in-situ velocity of the underlying sediment and rock, and these data provide confirmatory velocity information for the refraction models. The general configuration for recording the downhole seismic data consists of a three-component geophone, implementing 40Hz receiver elements. The downhole geophone is moved in 5-ft increments within the borehole (5-ft receiver spacing). A sledgehammer is used as the energy source, and is placed at offsets up to 15-ft from the borehole. Three additional geophones are placed on the surface at offsets up to 20-ft from the borehole, and are required to resolve any shot-timing variations that occur when using impact sources. Data are recorded at a 0.1 ms

interval (10,000 samples per second), which is required so that very small changes in arrival time (up to 0.2 milli-seconds) can be detected. The small arrival time changes are due to the presence of fast-velocity limestones and dolomites and correspond to a seismic wave traveling from 10,000 to 25,000-ft/s (yields arrival-time changes of 0.2 to 0.5milliseconds over a 5 foot interval).

Data processing consisted of the following:

- Pick first arrival energy for the downhole and reference geophones;
- Sort the arrival-time data by depth point;
- Compute and apply shot-timing corrections using the arrival time picks obtained from the reference geophones;
- Compute the average velocity to a receiver station using the straight-line distance from the shot to the receiver and the corrected arrival time;
- Convert to vertical travel-time using the depth point for the receiver and the computed average velocities; and
- Compute interval velocities using least squares line-fitting algorithm to estimate the slope (inverse of velocity) between measurement points. The least-squares operator has the advantage of smoothing over small time-picking errors.
- Where available, the data are correlated with the lithologic information and other available borehole geophysical data.

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APPENDIX D.3

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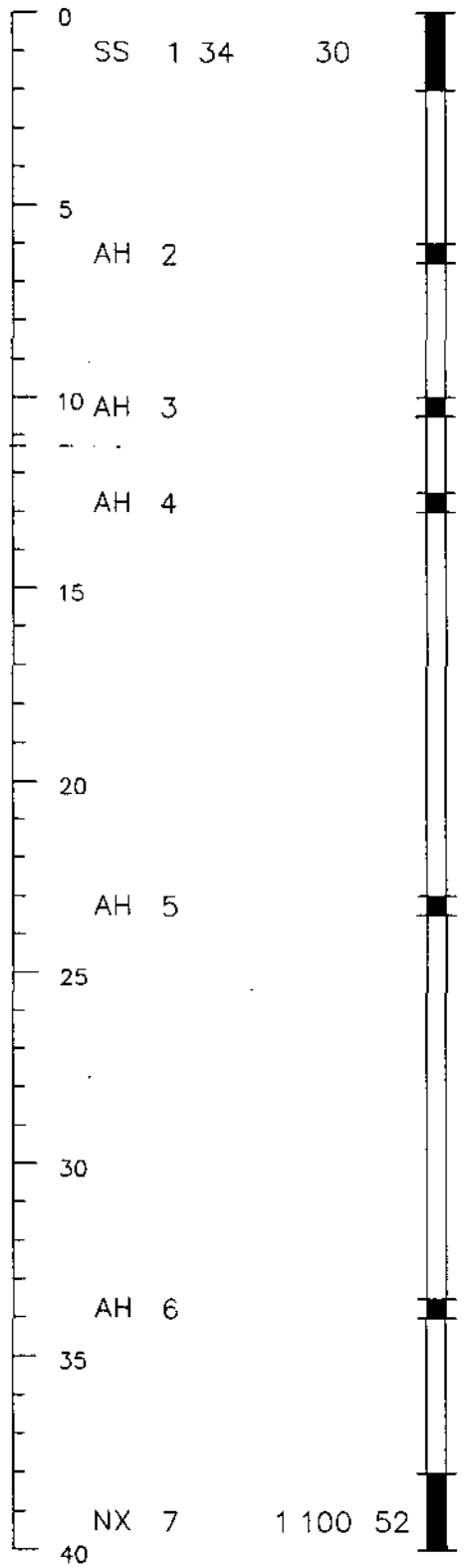
BORING 17PZ1

Surface Elevation: 1904.7 Feet, MSL
Location: Radford AAP, Virginia
Start: 2:11 on 10-30-91
Finish: 1:20 on 11-1-91

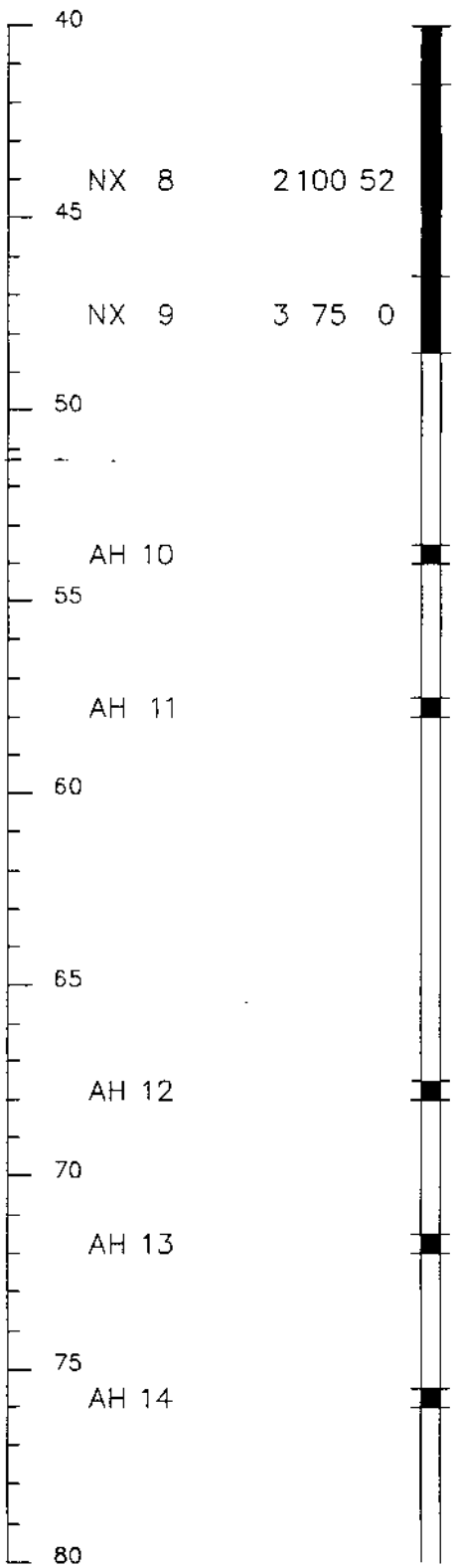


Symbols	Description
ML	VERY PALE BROWN (10YR 7/4) FINE SANDY SILT, DRY, VERY STIFF
	ENCOUNTER ROCK AT 3 FEET CONTINUE DRILLING USING 8-INCH AIR HAMMER LOG BOREHOLE FROM CUTTINGS
	GRAY (5Y 5/1) DOLOSTONE, FINE GRAINED, DRY, HARD, DUSTY CONDITIONS
DS/LS Shale	INTERBEDDED WITH LIGHT YELLOWISH BROWN LIMESTONE
	WITH PALE RED (2.5YR 6/2) AND BROWNISH YELLOW (10YR 6/6) SILTSTONE
	SOFT HIGHLY WEATHERED ZONE FROM 17.5 TO 20.0 FEET, WITH MUCH CLAY AND SILT, SLIGHTLY MOIST
	ALTERNATING BEDS OF HARD GRAY DOLOSTONE AND SOFT BROWNISH YELLOW SILTSTONE AND LIMESTONE
	SOFT INTERBEDDED DOLOMITE LIMESTONE AND SILTSTONE
	HARDER
	VERY DARK GRAY (2.5Y N/3) DOLOSTONE, HARD, WITH SOME CALCITE AND LIMESTONE SEAMS
	BEGIN NX CORING VERY DARK GRAY DOLOSTONE, HARD, SLIGHT WEATHERING AT FRACTURES
DS/LS Shale	FREQUENT THIN LIMESTONE SEAMS EVERY 0.1 FEET

PLATE
LOG OF BORING

Dames & Moore

BORING 17PZ1 (Cont'd)



Symbols	Description
DS / LS / Shale	WITH LAYERS OF GRAY (5Y 5/1) HIGHLY WEATHERED LIMESTONE AND PALE YELLOW (2.5Y 7/3) SANDSTONE, POORLY TO MODERATELY CEMENTED
	MAINLY PALE YELLOW HIGHLY WEATHERED LIMESTONE AND DOLOSTONE, ABUNDANT FRACTURES
	STOP CORING, LOG OF BOREHOLE FROM CUTTINGS
	VERY SOFT FROM 51–54 FEET, WITH VOIDS, NO RETURN CUTTINGS
	HIGHLY WEATHERED, INTERBEDDED DOLOSTONE AND LIMESTONE
	WITH MORE DARK GRAY DOLOSTONE
	CONTINUED INTERBEDDED DARK GRAY DOLOSTONE AND HIGHLY WEATHERED LIGHT GRAY AND PALE YELLOW LIMESTONE
	VERY SOFT HIGHLY WEATHERED FROM 77 TO 79 FEET

PLATE
LOG OF BORING

Dames & Moore

BORING 17PZ1 (Cont'd)

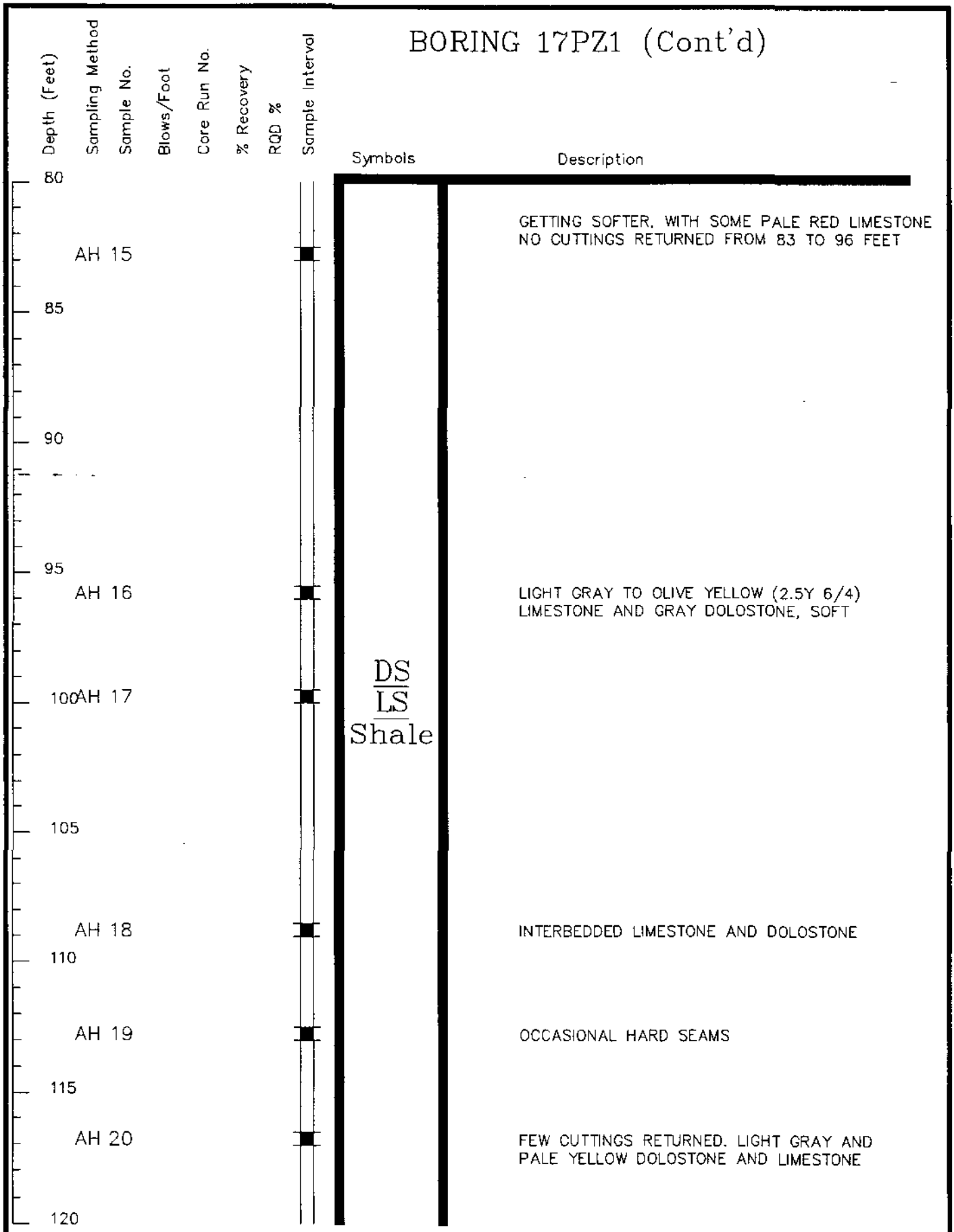


PLATE
LOG OF BORING

Dames & Moore

BORING 17PZ1 (Cont'd)

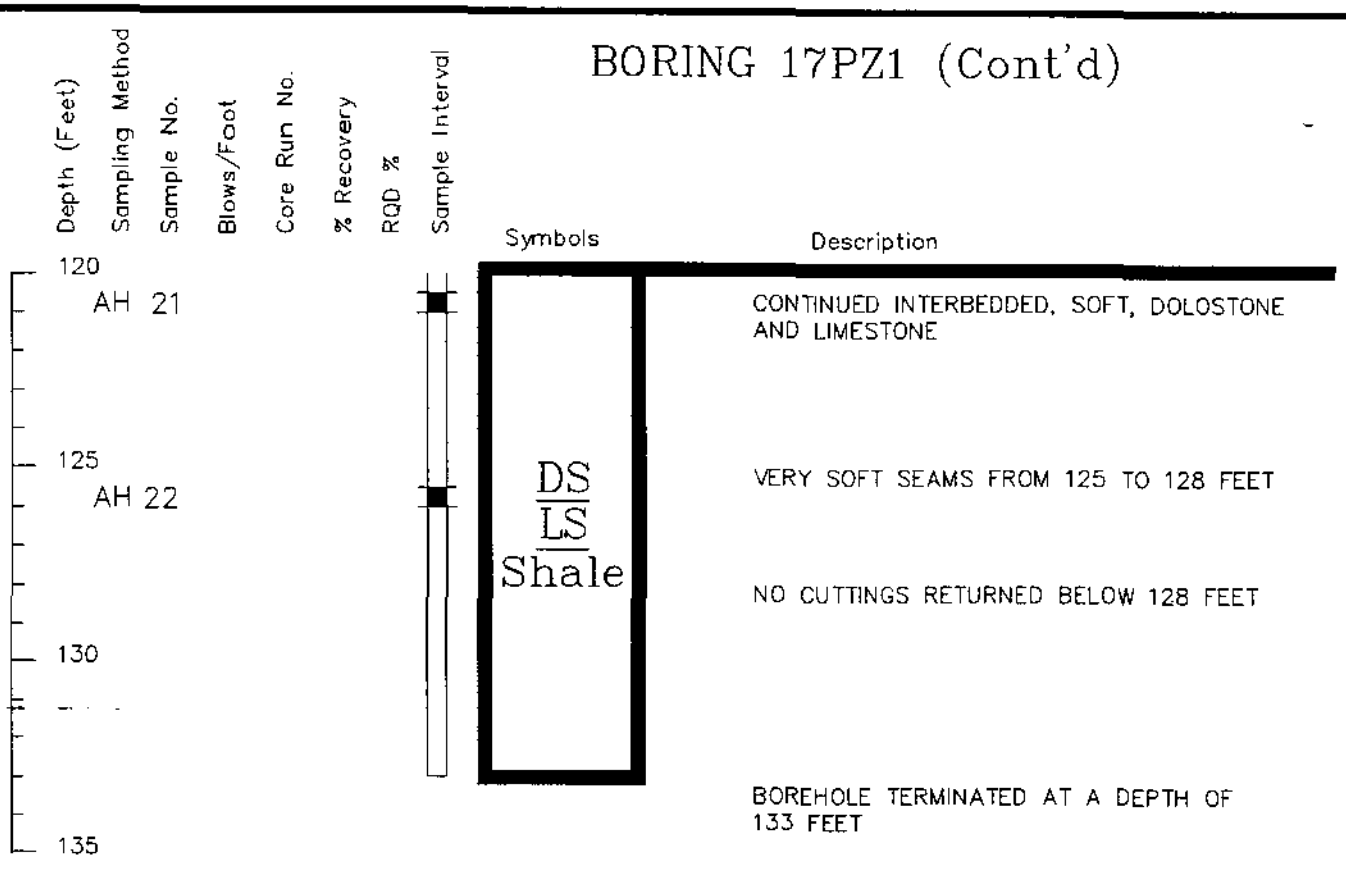


PLATE
LOG OF BORING

Dames & Moore

RILL. CONTR.: EDI
DRILLER: T. Lynch
EOLOGIST: J. Titus
G TYPE: Mobile B-80
ING METHOD: Air Hammer

WATER LEVEL MEASUREMENT
EASUREMENT POINT: TOC
DATE/TIME: 10-Jun-93; 0956
EPTH TO WATER: 79.83 ft.

ENGINEERING-SCIENCE, INC.
DRILLING RECORD

INSTALLATION: RAAP
SITE: SWMU 17
CLIENT: USAEC
PROJECT NO.: FB517
DATE/TIME START: 19-May-93; 0745
DATE/TIME END: 20-May-93; 1505

BORING/WELL ID: 17MW2

TOTAL DEPTH (feet): 173
BOREHOLE DIAM.: 8 in.
CASING DIAM.: 4 in.
TOC ELEV.: 1906.29 ft. msl
GS ELEV.: 1903.99 ft. msl

DEPTH (FEET)	DRILL RATE	HCl TEST	LITHOLOGY/REMARKS	LITHOLOGIC COLUMN	WELL COMPLETION	DEPTH (FEET)
			DRILLING WITH 10-INCH AIR ROTARY BIT SILT and CLAY; color: dark yellowish brown (10YR4/4)		10-inch borehole	
			BEDROCK SWITCH TO 8-INCH AIR HAMMER			
5	1ft/4min	+pwd	interbedded DOLOTONE and argillaceous DOLOSTONE			5
10	1ft/4min		DOLOSTONE: massive, hard color: gray (10YR5/1 to 2.5YR6/0)			10
			argillaceous DOLOSTONE: weathered, soft weathered color: light, yellowish brown (2.5Y7/6) unweathered color: gray (2.5Y6/0)			15
	1ft/5min				8-inch borehole	
20					grout	20
			VOID, filled with fine SAND and SILT color: reddish brown		4-inch ID PVC riser	
25	1ft/4.5min					25
30	1ft/7min					30
35						35
40						40

RILL. CONTR.: EDI
DRILLER: T. Lynch
GEOLOGIST: J. Titus
IG TYPE: Mobile B-80
NG METHOD: Air Hammer

WATER LEVEL MEASUREMENT
EASUREMENT POINT: TOC
DATE/TIME: 10-Jun-93; 0956
EPTH TO WATER: 79.83 ft.

ENGINEERING-SCIENCE, INC.
DRILLING RECORD

INSTALLATION: RAAP
SITE: SWMU 17
CLIENT: USAEC
PROJECT NO.: FB517
DATE/TIME START: 19-May-93; 0745
DATE/TIME END: 20-May-93; 1505

BORING/WELL ID: 17MW2

TOTAL DEPTH (feet): 173
BOREHOLE DIAM.: 8 in.
CASING DIAM.: 4 in.
TOC ELEV.: 1906.29 ft. msl
GS ELEV.: 1903.99 ft. msl

DEPTH (FEET)	DRILL RATE	HO TEST	LITHOLOGY/REMARKS	LITHOLOGIC COLUMN	WELL COMPLETION	DEPTH (FEET)
45						45
50						50
			interbedded DOLOSTONE and argillaceous DOLOSTONE			55
			DOLOSTONE massive, hard color: gray (10YR5/1 to 2.5YR6/0)		8-inch borehole	
60					grout	60
			argillaceous DOLOSTONE weathered, soft weathered color: light, yellowish brown (2.5Y7/6) unweathered color: gray (2.5Y6/0)		4-inch ID PVC riser	
65		+pwd				65
70						70
75						75
			VOID, some clayey SILT color: reddish brown (7.5YR6/8)		bentonite seal (78-80)	
80						80

DRILL CONTR.: EDI
DRILLER: T. Lynch
GEOLOGIST: J. Titus
RIG TYPE: Mobile B-80
DRILLING METHOD: Air Hammer

WATER LEVEL MEASUREMENT
MEASUREMENT POINT: TOC
DATE/TIME: 10-Jun-93; 0956
DEPTH TO WATER: 79.83 ft.

ENGINEERING-SCIENCE, INC.
DRILLING RECORD

INSTALLATION: RAAP
SITE: SWMU 17
CLIENT: USAEC
PROJECT NO.: FB517
DATE/TIME START: 19-May-93; 0745
DATE/TIME END: 20-May-93; 1505

BORING/WELL ID: 17MW2

TOTAL DEPTH (feet): 173
BOREHOLE DIAM.: 8 in.
CASING DIAM.: 4 in.
TOC ELEV.: 1906.29 ft. msl
GS ELEV.: 1903.88 ft. msl

DEPTH (FEET)	DRILL RATE	HCl TEST	LITHOLOGY/REMARKS	LITHOLOGIC COLUMN	WELL COMPLETION	DEPTH (FEET)
85	1ft/6min	+pwd	interbedded DOLOSTONE and argillaceous DOLOSTONE DOLOTONE massive, hard color: gray (10YR5/1 to 2.5YR6/0) argillaceous DOLOSTONE weathered, soft weathered color: light, yellowish brown (2.5Y7/6) unweathered color: gray (2.5Y6/0)		8-inch borehole no grout present (80-142) due to formation bridging 4-inch ID PVC riser	85
90						90
95						95
100						100
105	1ft/1min					105
110						110
115						115
120						120

RILL CONTR.: EDI
URILLER: T. Lynch
EOLOGIST: J. Titus
IG TYPE: Mobile B-80
L NG METHOD: Air Hammer

WATER LEVEL MEASUREMENT
EASUREMENT POINT: TOC
DATE/TIME: 10-Jun-93; 0956
EPTH TO WATER: 79.83 ft.

ENGINEERING-SCIENCE, INC.
DRILLING RECORD

INSTALLATION: RAAP
SITE: SWMU 17
CLIENT: USAEC
PROJECT NO.: FB517
DATE/TIME START: 19-May-93; 0745
DATE/TIME END: 20-May-93; 1505

BORING/WELL ID: 17MW2

TOTAL DEPTH (feet): 173
BOREHOLE DIAM: 8 in.
CASING DIAM.: 4 in.
TOC ELEV.: 1906.29 ft. msl
GS ELEV.: 1903.88 ft. msl

DEPTH (FEET)	DRILL RATE	HCl TEST	LITHOLOGY/REMARKS	LITHOLOGIC COLUMN	WELL COMPLETION	DEPTH (FEET)
125						125
130			VOID, some CLAY and v. fine SAND MAJOR WATER PRODUCING ZONE		8-inch borehole; no grout present (80-142) due to formation bridging	130
135	111/5.5min	+pwd	interbedded DOLOSTONE and argillaceous DOLOSTONE DOLOSTONE massive, hard color: gray (10YR5/1 to 2.5Y6/0) argillaceous DOLOSTONE weathered, soft weathered color: light, yellowish brown (2.5Y7/6) unweathered color: gray (2.5Y6/0)		4-inch ID PVC riser	135
140						140
145					sand; bentonite seal (144-147) Baroid, 3/8" pellets	145
150					sand filter pack Morie, #1	150
155	111/1.3min				screen (150-170) PVC, 0.010 inch slot	155
160						160

RILL CONTR.: EDI
DRILLER: T. Lynch
GEOLOGIST: J. Titus
G TYPE: Mobile B-80
G METHOD: Air Hammer

WATER LEVEL MEASUREMENT
EASUREMENT POINT: TOC
DATE/TIME: 10-Jun-93; 0956
PTH TO WATER: 79.83 ft.

ENGINEERING-SCIENCE, INC.
DRILLING RECORD

INSTALLATION: RAAP
SITE: SWMU 17
CLIENT: USAEC
PROJECT NO.: FB517
DATE/TIME START: 19-May-93; 0745
DATE/TIME END: 20-May-93; 1505

BORING/WELL ID: 17MW2

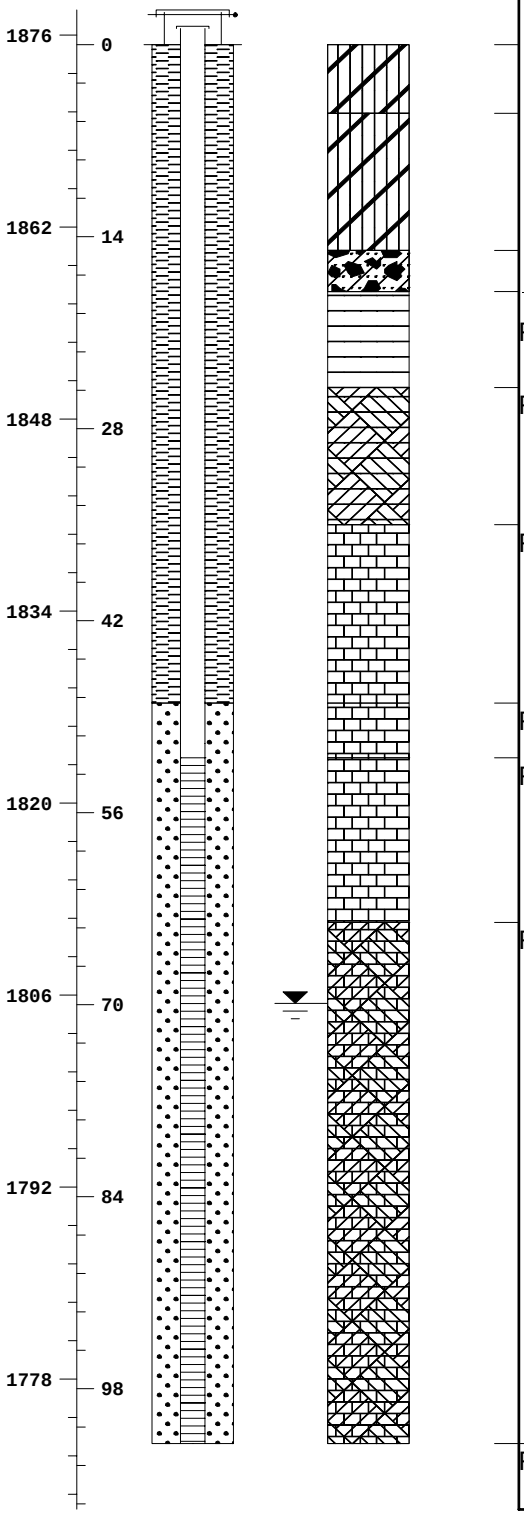
TOTAL DEPTH (feet): 173
BOREHOLE DIAM.: 8 in.
CASING DIAM.: 4 in.
TOC ELEV.: 1906.28 ft. msl
GS ELEV.: 1903.99 ft. msl

DEPTH (FEET)	DRILL RATE	HCl TEST	LITHOLOGY/REMARKS	LITHOLOGIC COLUMN	WELL COMPLETION	DEPTH (FEET)
	1ft/4min		interbedded DOLOSTONE and argillaceous DOLOSTONE			
165			DOLOSTONE massive, hard color: gray (10YR5/1 to 2.5YR6/0)		screen (150-170) PVC, 0.010 inch slot	165
170		+pwd	argillaceous DOLOSTONE weathered, soft weathered color: light, yellowish brown (2.5Y7/6) unweathered color: gray (2.5Y6/0)		sand filter pack Morie, #1	170
175						175
180						180
185						185
190						190
195						195
200						200

DRILL HOLE LOG
DRILL HOLE NO.: LFMW01

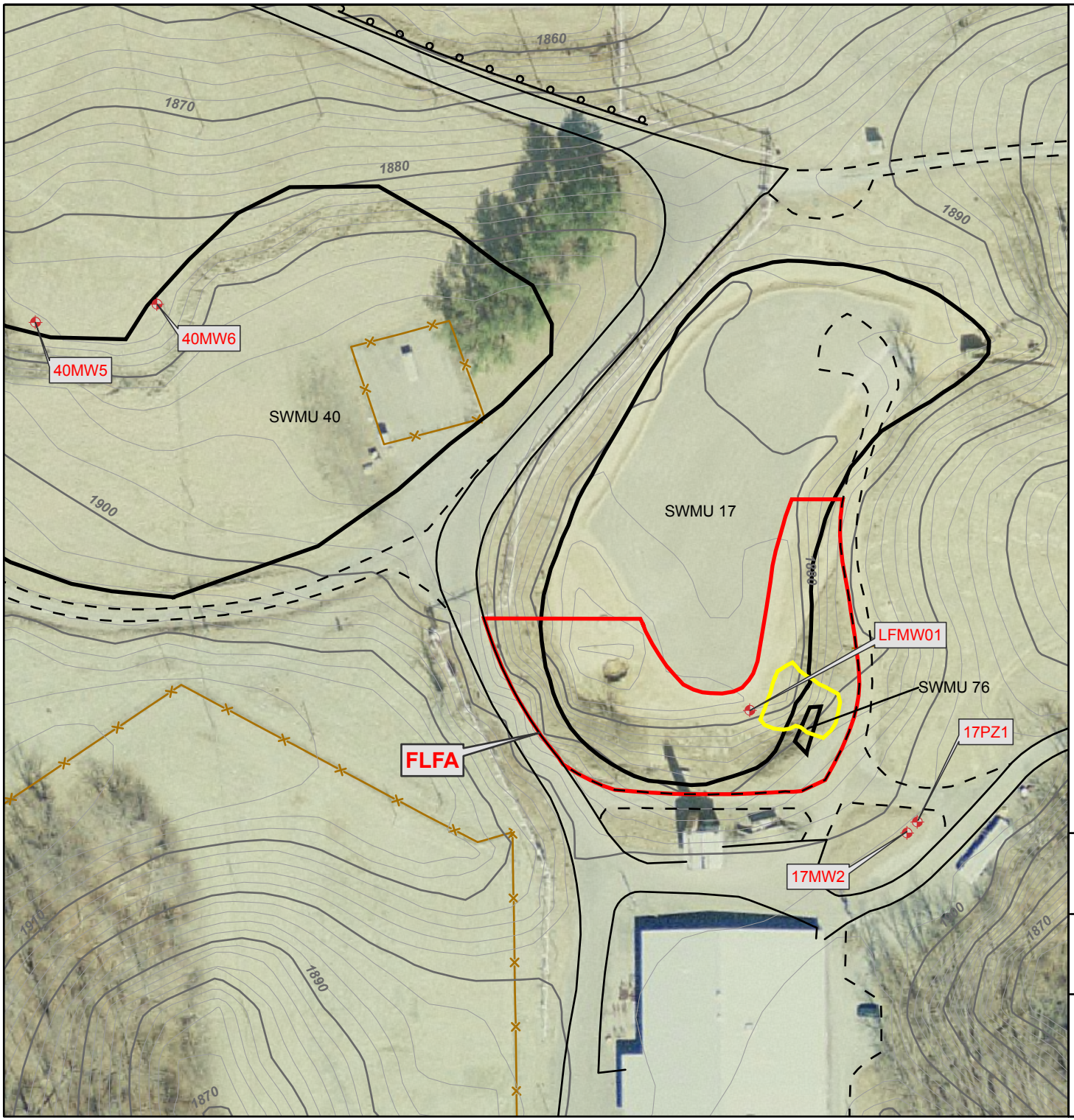
PROJECT: WPA 019 Groundwater Investigation
CLIENT/OWNER: RFAAP
HOLE LOCATION: RFAAP Radford, VA
DRILLER: Bedford Well Drilling
DRILL RIG: T3 Air Rotary
DEPTH TO WATER: 69.9
HOLE DIAMETER: 6 Inch

PROJECT NO.: 123461
DATE: 8/10/07
TOC ELEV.: 1877.9
GS ELEV.: 1875.3
LOGGED BY: J. Choynowski
HOLE NO.: LFMW01



ELEVATION / DEPTH	USCS	DESCRIPTION	Sample Number	Recovery	Water Content
		4" Protective case.			
0	CL-ML	Dark brown clay and silt, little(+) gravel. 2" PVC well pipe.			
5	CL-ML	Yellowish brown clay & silt.			
15	GC-SC	Yellowish brown clay w/ gravel, little(-) silt, some(+) coarse to medium sand.			
18	ROCK	Pale brown shale.			
25	ROCK	Pale brown shale & dolostone.			
35	ROCK	Pale brown limestone			
48	ROCK	Top of sand filter layer.			
52	ROCK	Top of well screen, 0.010" slot.			
64	ROCK	Alternating layers of Limestone and dolostone.			
102	ROCK	Bottom of screen and well.			

FIGURE NO.



LEGEND

- Monitoring Well
- Fence Line
- Dirt Road
- Paved Road
- 10 Ft Elevation Contour
- 1998 RFI Excavation Boundary
- Other SWMU Boundary
- Former Lead Furnace Area Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.

N

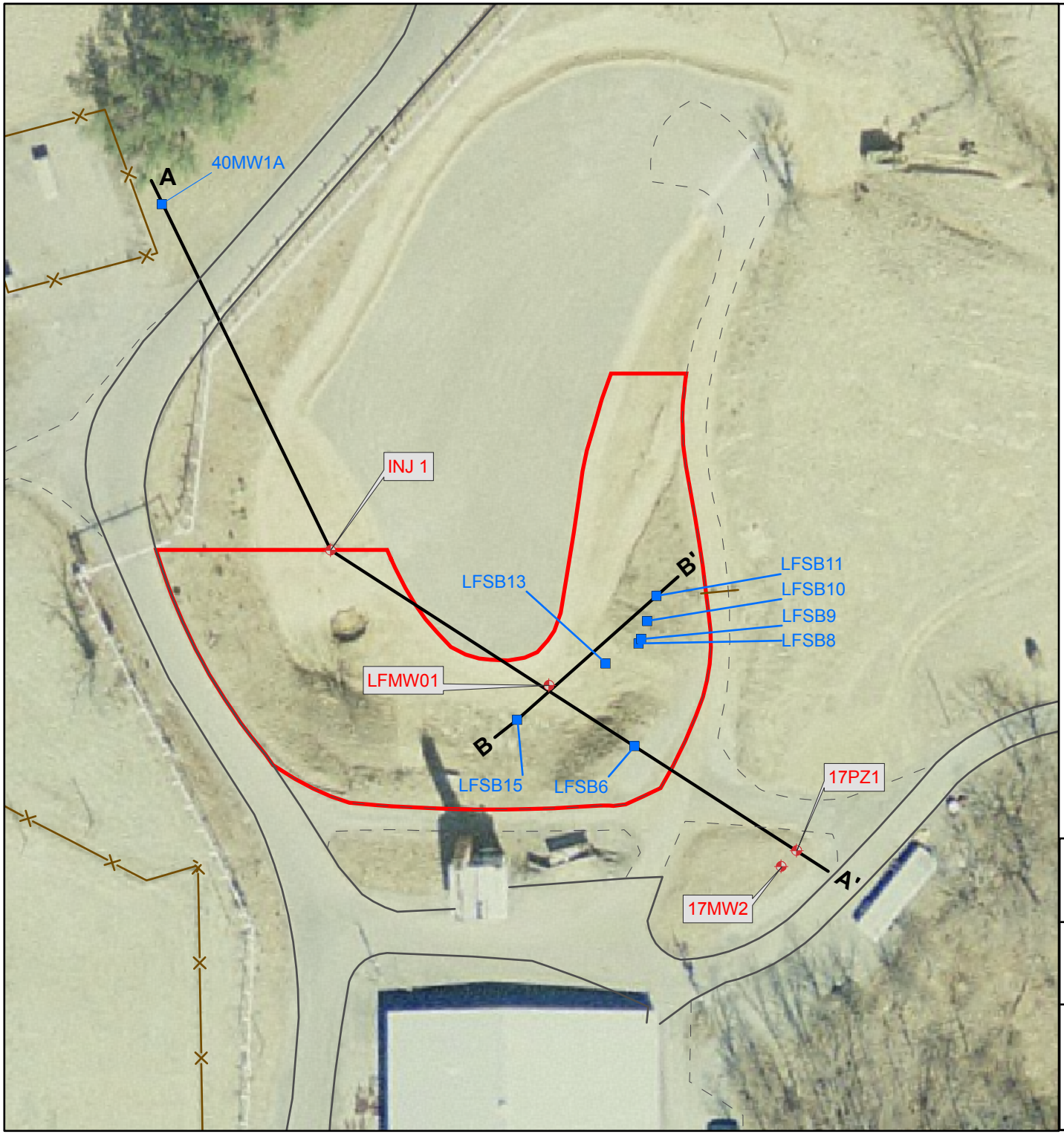
Scale:
0 55 110 220 Feet

U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 2-1
Former Lead Furnace Area
Site Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: RFAAP_Fig2-1_FLFA_Site_Map.mxd (1/31/2008 2:40:11 PM)



LEGEND

- Soil Sample Location
- Monitoring Well
- Dirt Road
- Paved Road
- Fence Line
- Geologic Cross Section Line
- Former Lead Furnace Area Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.

N

Scale:

0 37.5 75 150 Feet

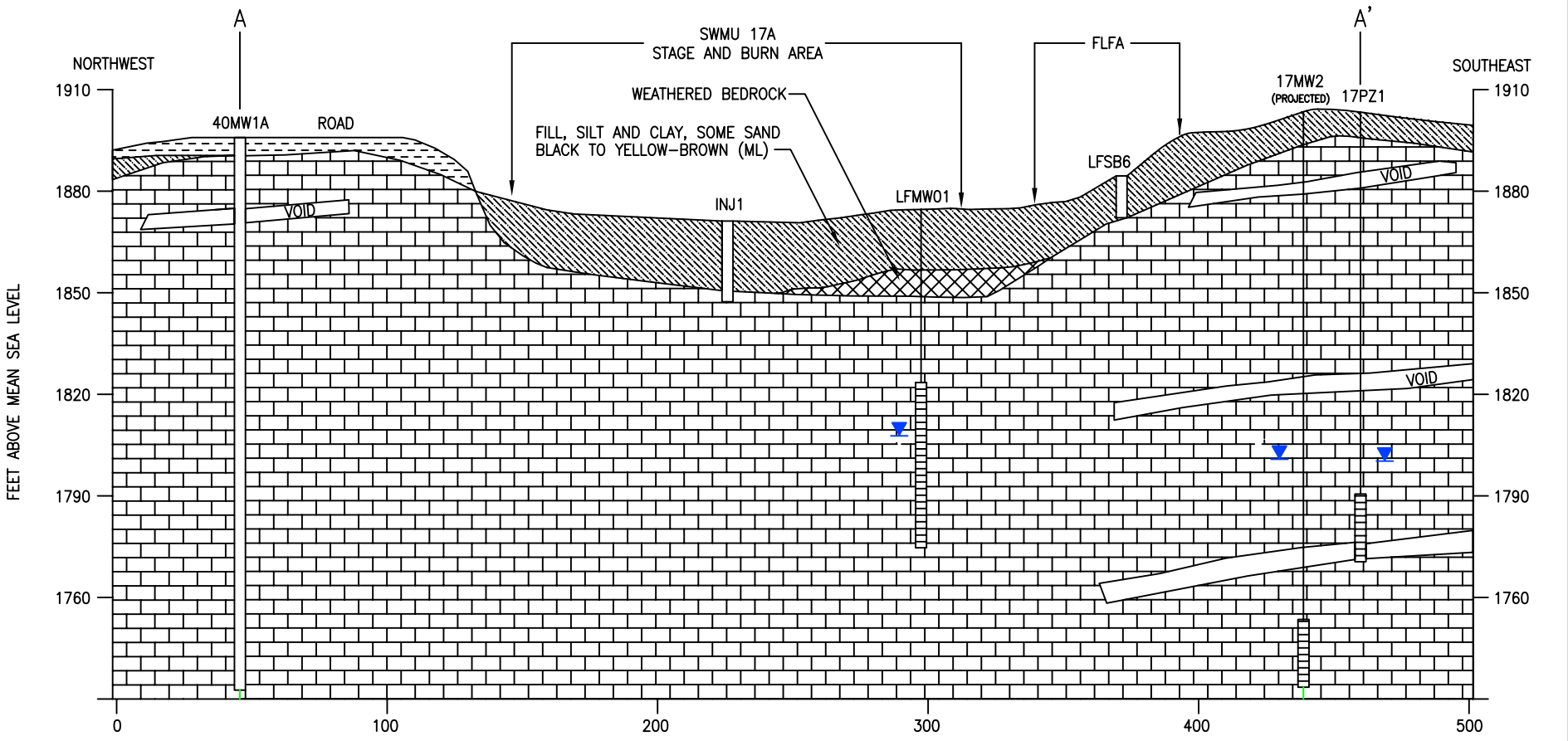
U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 2-3
Former Lead Furnace Area
Geologic Cross Section Lines A-A' and B-B'

Radford Army Ammunition Plant,
Radford, VA

GIS File: RFAAP_Fig2-3_FLFA_XSect.mxdjoy.pasquarelli (1/29/2008 11:28:55 AM)



HORIZ. SCALE: 0 50 100

VERT. SCALE: 0 15 30 45 60 75

LEGEND

- CLAY AND SILT, LITTLE SAND, RED-BROWN (CL)
- SILT AND CLAY (ML/CL)
- WEATHERED BEDROCK
- LIMESTONE, GRAY-BROWN, ARGILLACEOUS (LMSN)
- STATIC GROUNDWATER LEVEL

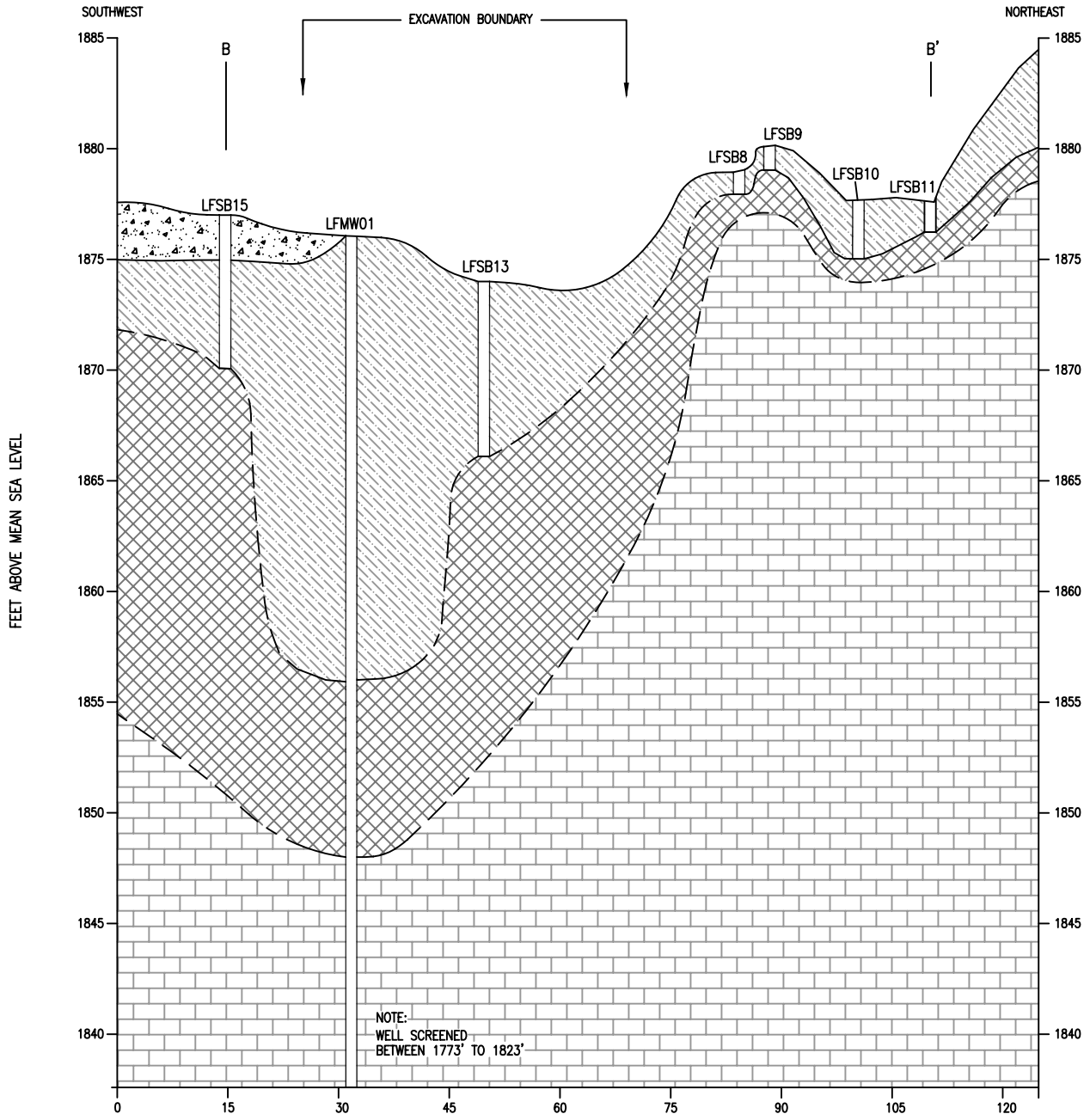
NOTES

1) WATER LEVELS MEASURED DECEMBER 2007 (17MW2 AND 17PZ1) AND AUGUST 2007 (LFMW01)
2) SOME DATA POINTS ARE PROJECTED ONTO PROFILE.
3) 40MW1A AND 17PZ1 LITHOLOGY FROM DAMES AND MOORE.
4) 40MW1A IS A BORING.
5) INJECTION WELL IS AN OPEN HOLE AT THE BEDROCK INTERFACE.

SOURCE: PARSONS ENGINEERING SCIENCE INC

RADFORD AAP		FIGURE 2-4
PREPARED BY: SHAW	TASK NO: 12346161030000	FORMER LEAD FURNACE AREA GEOLOGIC CROSS-SECTION A-A'
CHECKED BY: MT	SHAW DWG NO: FIG 2-4 (A-A').dwg	
DATE: REVISED DECEMBER 2007		

FILE: FIG2-3.dwg PLOT: 8-19-05



LEGEND

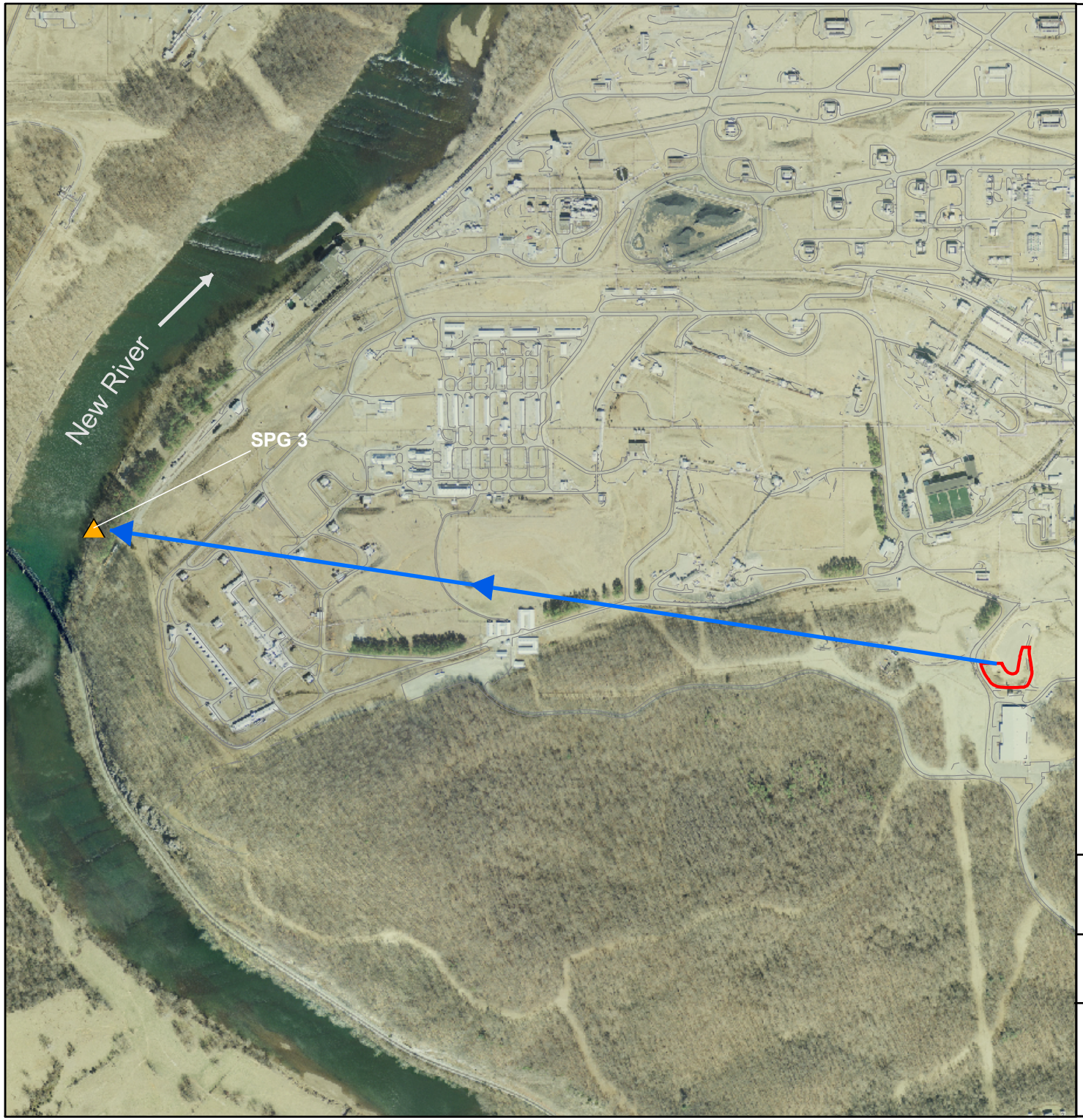
- FILL, SILT, SOME SAND, SOME CLAY, ORANGE–BROWN (ML)
- LIMESTONE, GRAY–BROWN, ARGILLACEOUS (LMSN)
- SILT, SAND, AND GRAVEL, ORANGE–BROWN (GM)
- SILT AND CLAY (ML/CL)
- WEATHERED BEDROCK

VERT. SCALE: 0 5 10

HORIZ. SCALE: 0 15 30

FILE: FIG2-5.dwg PLOT: 8-19-05

RADFORD AAP		FIGURE 2-5
PREPARED BY: SHAW	TASK NO: 82987002500000	FORMER LEAD FURNACE AREA GEOLOGIC CROSS-SECTION B-B'
CHECKED BY: MT	SHAW DWG NO: FIG2-5.dwg	
DATE: REVISED JAN. 2008		



LEGEND

- Surface Water/Sediment Sample Location
- Groundwater Flow Path Identified by Engineering Science, Inc. (May 1994)
- Former Lead Furnace Area Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.

N

Scale:

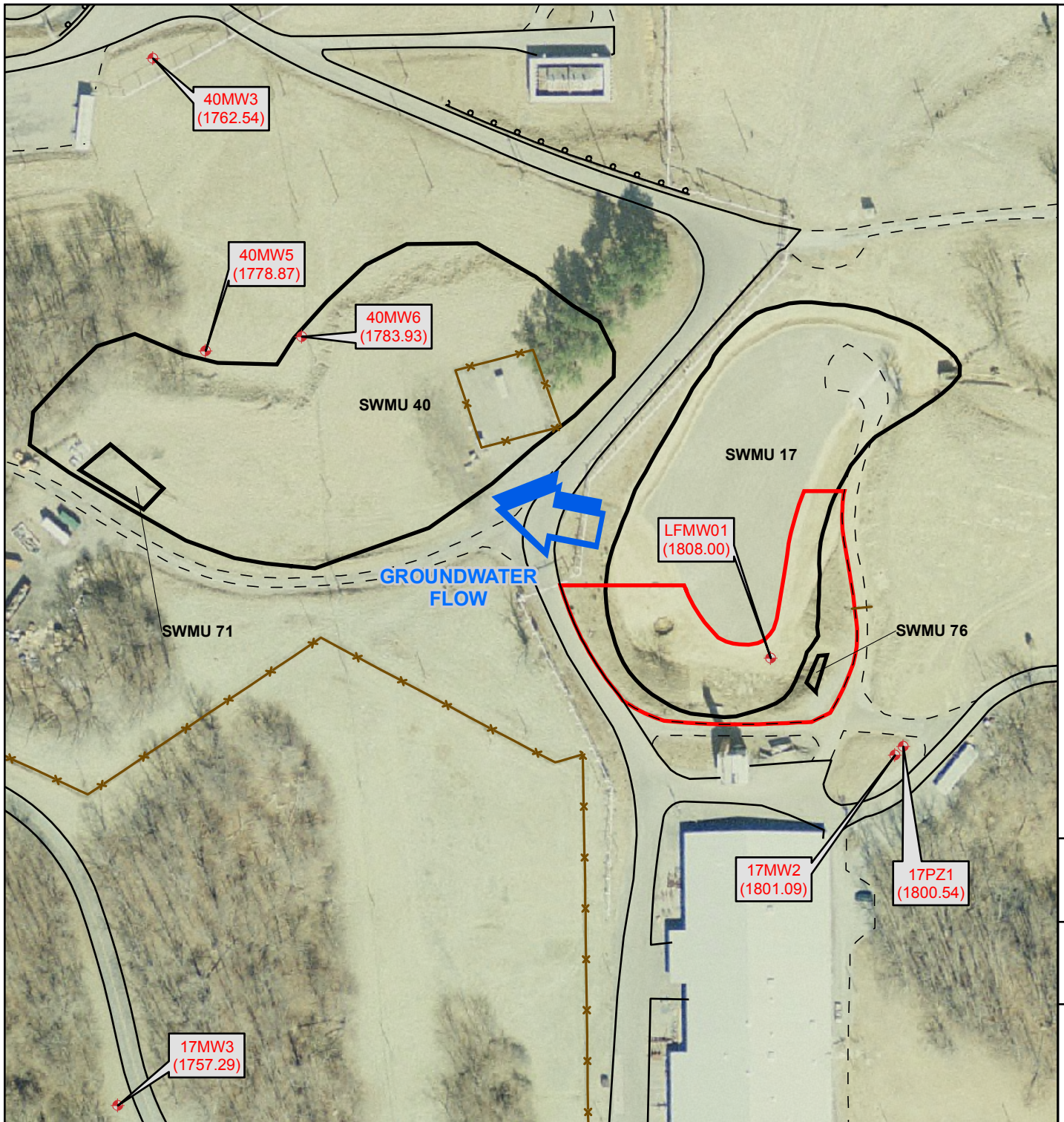
0 400 800 1,600 Feet

U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 2-6
Former Lead Furnace Area
Groundwater Flow Path From
FLFA Sinkhole to Spring Discharge
Radford Army Ammunition Plant
Radford, VA

ArcGIS File: RFAAP_Fig2-6_FLFA_GW_Flow.mxd (1/24/2008 4:05:20 PM)



LEGEND

- Monitoring Well Location
- Dirt Road
- Paved Road
- Fence Line
- Former Lead Furnace Area Boundary
- Other Site Boundary

Notes:

1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) All water levels measured in December 2007, except LFMW01, which was measured in August 2007.
3) Water levels are expressed in feet above mean sea level.
4) Groundwater flow direction is based on the 1994 dye trace study results (Engineering Science, 1994).

N

Scale:

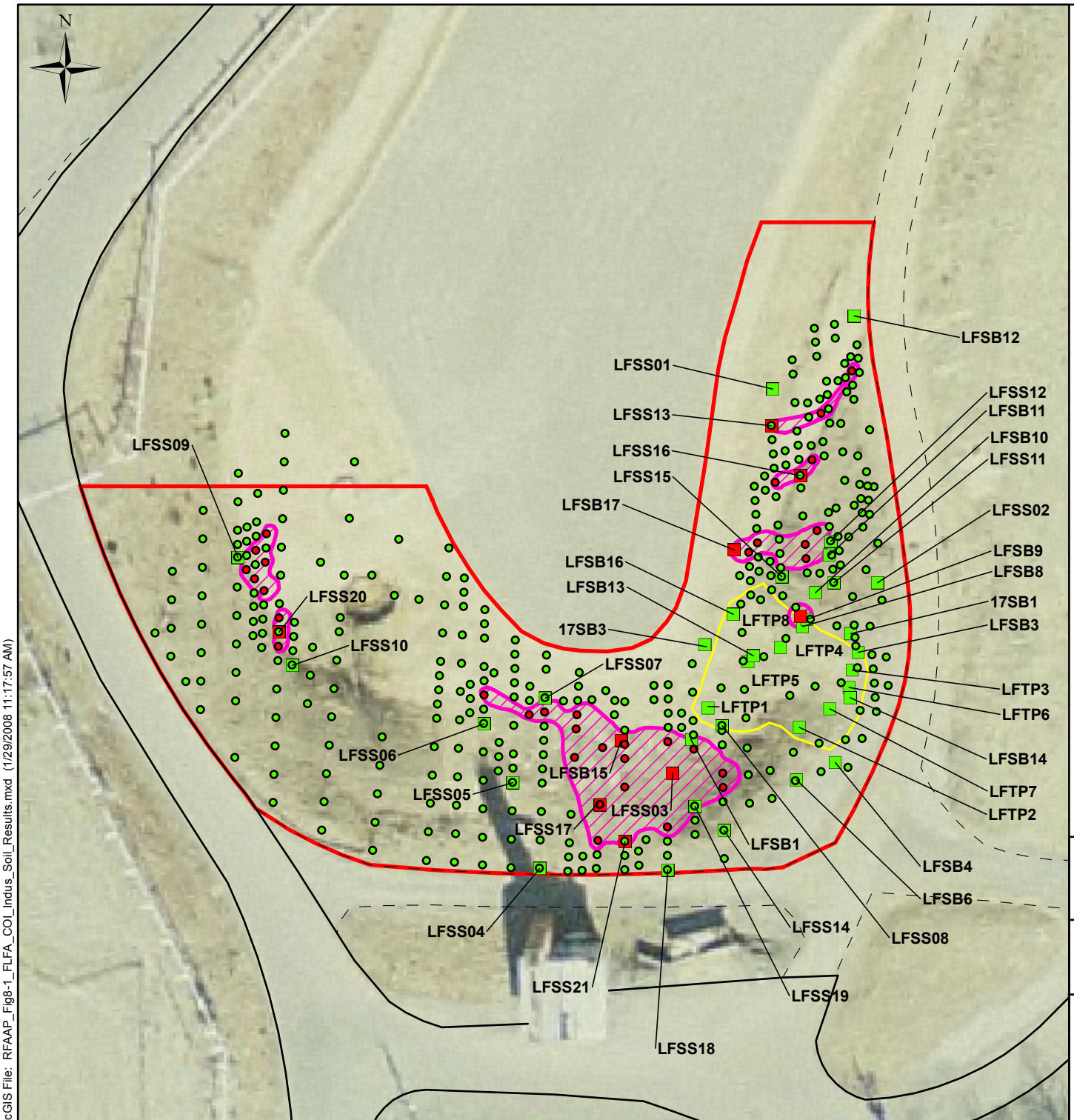
0 70 140 280 Feet

U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 2-7
Former Lead Furnace Area
Groundwater Flow Map
Radford Army Ammunition Plant,
Radford, VA

GIS File: RFAAP_Fig2-7_FLFA_GW_Flow.mxd (1/28/2008 10:14:12 AM)



LEGEND

- Sample Location (XRF Lead Result Below Industrial Remedial Goal)
- Sample Location (XRF Lead Result Above Industrial Remedial Goal)
- Sample Location (Contaminants of Interest Below Industrial Remedial Goal)
- Sample Location (Contaminants of Interest Above Industrial Remedial Goal)
- Dirt Road
- Paved Road
- Industrial Remedial Goal Excavation Area
- 1998 RFI Soil Excavation Area
- Former Lead Furnace Area Boundary

Notes:
1) Aerial photo, dated 25 May 2000, was obtained from the Army Topographic Engineering Center.

Scale:
0 25 50 100 Feet

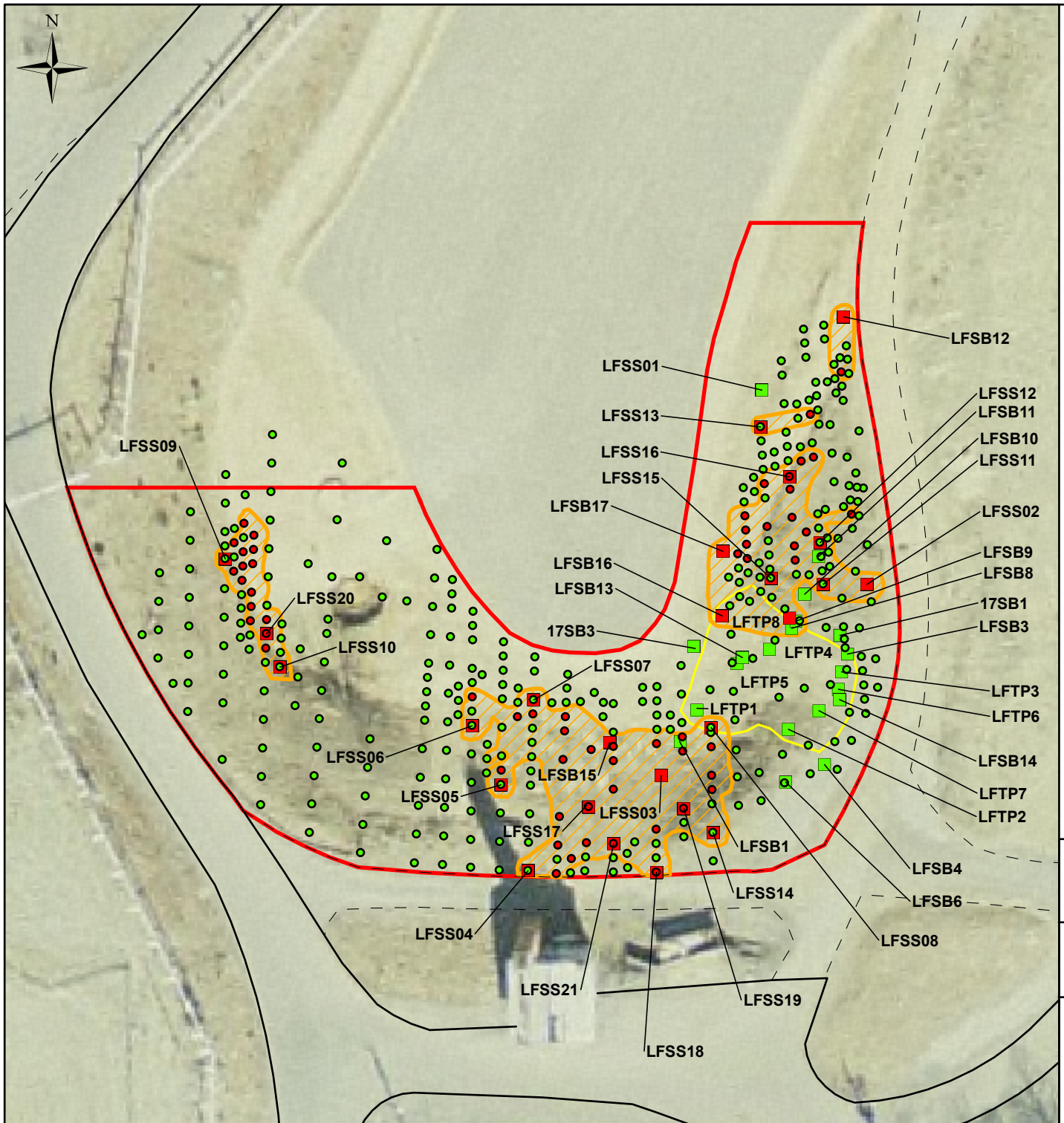
U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 8-1
Former Lead Furnace Area
Area of Soil Contamination
Above Industrial Remedial Goals

Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: RFAAP_Fig8-1_FLFA_COI_Indus_Soil_Results.mxd (1/29/2008 11:17:57 AM)



LEGEND

- Sample Location (XRF Lead Result Below Residential Remedial Goal)
- Sample Location (XRF Lead Result Above Residential Remedial Goal)
- Sample Location (Contaminants of Interest Below Residential Remedial Goal)
- Sample Location (Contaminants of Interest Above Residential Remedial Goal)
- Dirt Road
- Paved Road
- Residential Remedial Goal Excavation Area
- 1998 RFI Soil Excavation Area
- Former Lead Furnace Area Boundary

Notes:
1) Aerial photo, dated 25 May 2000, was obtained from the Army Topographic Engineering Center.

Scale:
0 25 50 100 Feet

U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

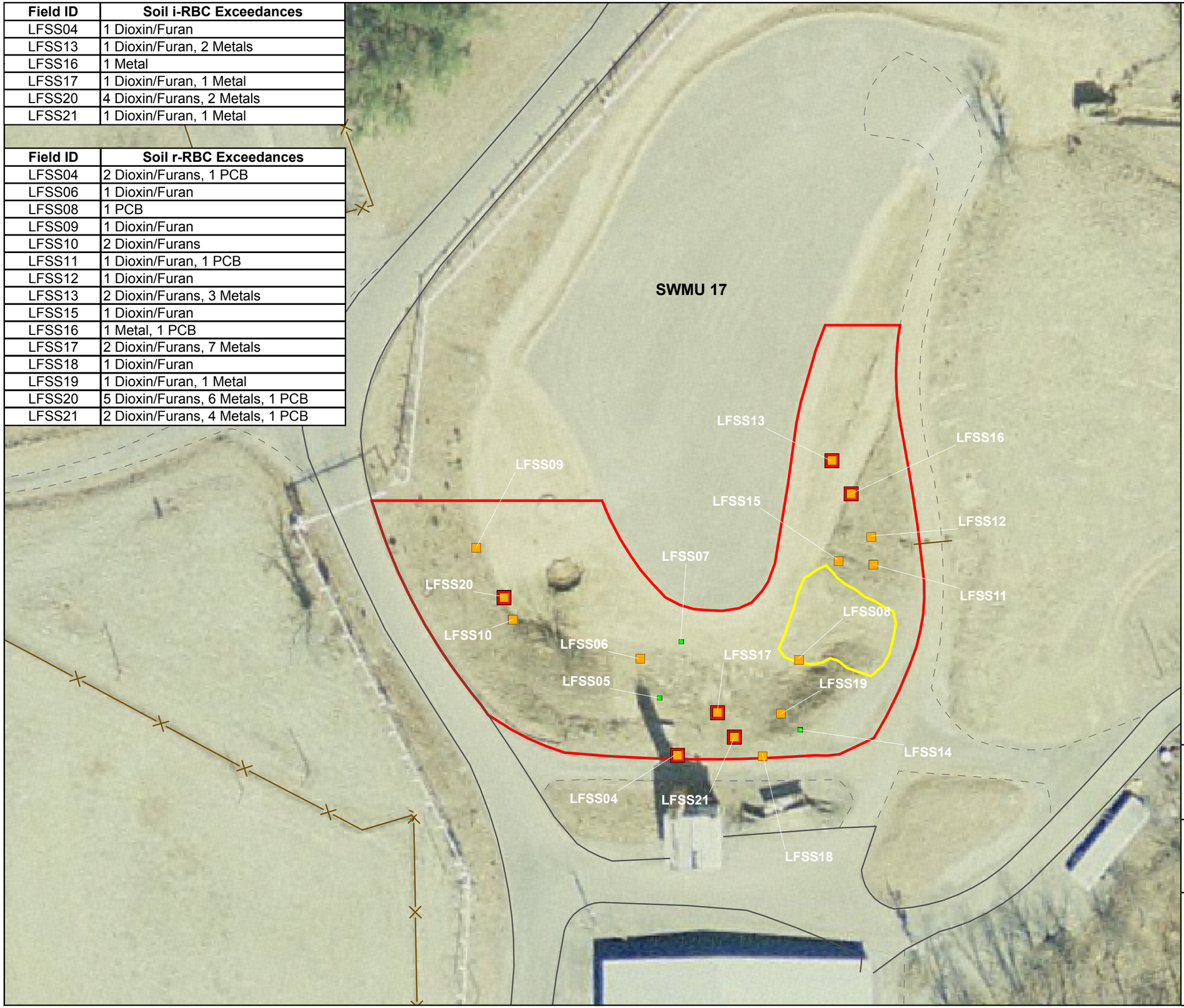
FIGURE 8-2
Former Lead Furnace Area
Area of Soil Contamination
Above Residential Remedial Goals

Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: RFAAP_Fig8-2_FLFA_COI_Res_Soil_Results.mxd (1/29/2008 11:01:18 AM)

Field ID	Soil i-RBC Exceedances
LFSS04	1 Dioxin/Furan
LFSS13	1 Dioxin/Furan, 2 Metals
LFSS16	1 Metal
LFSS17	1 Dioxin/Furan, 1 Metal
LFSS20	4 Dioxin/Furans, 2 Metals
LFSS21	1 Dioxin/Furan, 1 Metal

Field ID	Soil r-RBC Exceedances
LFSS04	2 Dioxin/Furans, 1 PCB
LFSS06	1 Dioxin/Furan
LFSS08	1 PCB
LFSS09	1 Dioxin/Furan
LFSS10	2 Dioxin/Furans
LFSS11	1 Dioxin/Furan, 1 PCB
LFSS12	1 Dioxin/Furan
LFSS13	2 Dioxin/Furans, 3 Metals
LFSS15	1 Dioxin/Furan
LFSS16	1 Metal, 1 PCB
LFSS17	2 Dioxin/Furans, 7 Metals
LFSS18	1 Dioxin/Furan
LFSS19	1 Dioxin/Furan, 1 Metal
LFSS20	5 Dioxin/Furans, 6 Metals, 1 PCB
LFSS21	2 Dioxin/Furans, 4 Metals, 1 PCB



LEGEND

- Soil Sample Location Result < r-RBC and < i-RBC
- Soil Sample Location Result >= r-RBC
- Soil Sample Location Result >= i-RBC
- Fence Line
- Dirt Road
- Paved Road
- Excavation Boundary
- Former Lead Furnace Area Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) i-RBC and r-RBC values as of October 2007.

N

Scale:

0 25 50 100 Feet

U.S. Army Corps of Engineers

Shaw® Shaw Environmental, Inc.

FIGURE 4-2
Former Lead Furnace Area
2007 Investigation Soil Results
Radford Army Ammunition Plant
Radford, VA

ArcGIS File: RFAAP_Fig4-2_FLFA_2007_Soil_Results.mxd (1/9/2008 11:31:16 AM)

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Table 4-2
Analytes Detected in FLFA Soil - 2007 Investigation

Analyte				Sample ID	LFSS04					LFSS05					LFSS06				
				Sample Date	8/2/07					8/2/07					8/2/07				
				Sample Depth	0-0.5					0-0.5					0-0.5				
	i-RBC	r-RBC	Background		Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
PCBs (mg/kg)																			
PCB-1254	1.4	0.16	na		0.161	J	J	*0.021*	*0.042*	0.0285		J	*0.01*	*0.021*	0.0243		J	*0.0096*	*0.019*
PCB-1260	1.4	0.32	na		0.0568	J	J	*0.021*	*0.042*	0.021	U		*0.01*	*0.021*	0.019	U		*0.0096*	*0.019*
Metals (mg/kg)																			
Aluminum	100000	7800	40041		16300		J	*3*	*12*	17800		J	*2.8*	*12*	10200		J	*2.7*	*11*
Antimony	41	3.1	na		1	J	B	*0.24*	*3.7*	0.94	J	B	*0.22*	*3.5*	0.89	J	B	*0.21*	*3.4*
Arsenic	1.9	0.43	15.8		12.2		J	*0.24*	*0.5*	3.7		J	*0.23*	*0.47*	5.9		J	*0.22*	*0.45*
Barium	20000	1600	209		90		J	*0.31*	*12*	90.3		J	*0.29*	*12*	**253**	**C**	**J**	*0.28*	*11*
Beryllium	200	16	1.02		**1.5**		**B**	*0.12*	*0.62*	**1.6**		**B**	*0.12*	*0.58*	0.98		B	*0.11*	*0.56*
Cadmium	51	3.9	0.69		0.062	U	UL	*0.062*	*0.25*	0.59	U	UL	*0.59*	*1.2*	0.28	U	UL	*0.28*	*0.44*
Calcium	na	na	na		5420		J	*6.2*	*310*	4140		J	*5.9*	*290*	1520		J	*5.6*	*280*
Chromium	310	23	65.3		30.2		J	*0.087*	*0.62*	32.7		J	*0.082*	*0.59*	20.6		J	*0.078*	*0.56*
Cobalt	na	na	72.3		11.9		J	*0.068*	*3.1*	9.4		J	*0.064*	*2.9*	22.5		J	*0.061*	*2.8*
Copper	4100	310	53.5		**160**		**J**	*0.12*	*1.6*	**54.3**		**J**	*0.11*	*1.5*	**64.2**		**J**	*0.11*	*1.4*
Iron	72000	5500	50962		22300		J	*0.87*	*6.2*	21100		J	*0.82*	*5.9*	19600		J	*0.78*	*5.6*
Lead	800	400	26.8		**118**		**J**	*0.15*	*6.2*	**94.5**		**J**	*0.14*	*5.9*	**135**		**J**	*0.13*	*5.6*
Magnesium	na	na	na		4450		J	*6.2*	*310*	11000		J	*5.9*	*290*	4490		J	*5.6*	*280*
Manganese	2000	160	2543		435	C	J	*0.062*	*0.93*	360	C	J	*0.059*	*0.88*	2060		J	*0.56*	*8.4*
Mercury	31	2.3	0.13		**0.21**		**J**	*0.012*	*0.1*	**0.16**		**J**	*0.012*	*0.094*	0.081	J	J	*0.011*	*0.088*
Nickel	2000	160	62.8		16.4		J	*0.16*	*2.5*	19.3		J	*0.15*	*2.3*	12.8		J	*0.14*	*2.2*
Potassium	na	na	na		1920		J	*6.2*	*620*	2550		J	*5.9*	*590*	1440		J	*5.6*	*560*
Selenium	510	39	na		0.61	J	L	*0.28*	*6.2*	0.53	J	L	*0.26*	*5.9*	1.1	J	L	*0.25*	*5.6*
Silver	510	39	na		0.91		L	*0.087*	*0.62*	0.62		L	*0.082*	*0.59*	0.6		L	*0.078*	*0.56*
Sodium	na	na	na		465	J	L	*31*	*620*	328	J	L	*29*	*590*	307	J	L	*28*	*560*
Thallium	7.2	0.55	2.11		0.7	U	UL	*0.7*	*1.2*	0.66	U	UL	*0.66*	*1.2*	0.62	U	UL	*0.62*	*1*
Vanadium	102	7.8	108		44.6		J	*0.062*	*3.1*	44.8		J	*0.059*	*2.9*	32.7		J	*0.056*	*2.8*
Zinc	31000	2300	202		**290**	**C**	**J**	*0.31*	*1.2*	165		J	*0.29*	*1.2*	**327**	**C**	**J**	*0.28*	*1.1*
Dioxins/Furans (ng/kg)																			
2,3,7,8-TCDF	na	na	na		29.9					6.95					7.6				
2,3,7,8-TCDD	19	4.3	na		11					2.88					2.67				
1,2,3,7,8-PECDD	na	na	na		38.8	EMPC	J	*0.584*	*0.584*	3.54	J	J			5.17	J	J		
1,2,3,4,7,8-HXCDD	460	100	na		43.8					3.75	J	J			6.11				
1,2,3,6,7,8-HXCDD	460	100	na		85.6					8.13					9.98				
1,2,3,7,8,9-HXCDD	460	100	na		80.7					7.67					10.2				
1,2,3,4,6,7,8-HPCDD	na	na	na		1730					158					155				
OCDD	na	na	na		11500	E	J			5280	E	J			2670				
1,2,3,7,8-PECDF	na	na	na		26.1					3.42	J	J			6.31				
2,3,4,7,8-PECDF	na	na	na		45.3					7.92					8.67				
1,2,3,4,7,8-HXCDF	na	na	na		59.3					12.1					10.8				
1,2,3,6,7,8-HXCDF	na	na	na		47.7					7.36					7.82				
2,3,4,6,7,8-HXCDF	na	na	na		58					9.75					10.6				
1,2,3,7,8,9-HXCDF	na	na	na		15					2.73	J	J			2.79	J	J		
1,2,3,4,6,7,8-HPCDF	na	na	na		467					52.3					47.3				
1,2,3,4,7,8,9-HPCDF	na	na	na		33.3					4.06	J	J			3.52	J	J		
OCDF	na	na	na		1000					60.1					52				
TOTAL TCDD	na	na	na		166	EMPC	J			27.6	EMPC	J			40.4	EMPC	J		
TOTAL PECDD	na	na	na		347	Q, EMPC	J			46.1					73.3				
TOTAL HXCDD	460	100	na		828					80.6					113				
TOTAL HPCDD	na	na	na		3880					373					370				
TOTAL TCDF	na	na	na		408	Q, EMPC	J			77.5	EMPC	J			81.4	EMPC	J		
TOTAL PECDF	na	na	na		362	Q, EMPC	J			66.9	EMPC	J			73.2	EMPC	J		
TOTAL HXCDF	na	na	na		542					76.3	EMPC	J			86				
TOTAL HPCDF	na	na	na		1330					100					95.7	EMPC	J		

**Refer to legend immediately following this table for a list of definitions and table notes

Table 4-2
Analytes Detected in FLFA Soil - 2007 Investigation

Analyte	Sample ID / Sample Date / Sample Depth			LFSS07 8/2/07 0-0.5					LFSS08 8/2/07 0-0.5					LFSS09 8/2/07 0-0.5				
	i-RBC	r-RBC	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
PCBs (mg/kg)																		
PCB-1254	1.4	0.16	na	0.0135	J	J	*0.009*	*0.018*	0.309			*0.043*	*0.087*	0.0453	J	J	*0.0098*	*0.02*
PCB-1260	1.4	0.32	na	0.018	U		*0.009*	*0.018*	0.087	U		*0.043*	*0.087*	0.0621	J	J	*0.0098*	*0.02*
Metals (mg/kg)																		
Aluminum	100000	7800	40041	14300		J	*2.7*	*11*	9770		J	*2.5*	*10*	16400		J	*2.9*	*12*
Antimony	41	3.1	na	0.34	J	B	*0.21*	*3.3*	0.42	J	B	*0.2*	*3.1*	1	J	B	*0.23*	*3.6*
Arsenic	1.9	0.43	15.8	1.9		J	*0.22*	*0.44*	2.6		J	*0.2*	*0.41*	5.1		J	*0.23*	*0.48*
Barium	20000	1600	209	79.9		J	*0.28*	*11*	65.1		J	*0.26*	*10*	70.6		J	*0.3*	*12*
Beryllium	200	16	1.02	0.8		B	*0.11*	*0.56*	0.9		B	*0.11*	*0.56*	**1.5**		**B**	*0.12*	*0.6*
Cadmium	51	3.9	0.69	0.55	U	UL	*0.55*	*0.88*	1	U	UL	*1*	*2.1*	1.2	U	UL	*1.2*	*2.4*
Calcium	na	na	na	5540		J	*5.5*	*280*	3740		J	*5.2*	*260*	1580		J	*6*	*300*
Chromium	310	23	65.3	18.5		J	*0.078*	*0.55*	13.1		J	*0.072*	*0.52*	35.7		J	*0.083*	*0.6*
Cobalt	na	na	72.3	8.7		J	*0.061*	*2.8*	6.4		J	*0.057*	*2.6*	12.1		J	*0.066*	*3*
Copper	4100	310	53.5	46.4		J	*0.11*	*1.4*	30.3		J	*0.098*	*1.3*	**62.1**		**J**	*0.11*	*1.5*
Iron	72000	5500	50962	17800		J	*0.78*	*5.5*	14100		J	*0.72*	*5.2*	25000		J	*0.83*	*6*
Lead	800	400	26.8	**51.1**		**J**	*0.13*	*5.5*	**37.1**		**J**	*0.12*	*5.2*	**126**		**J**	*0.14*	*6*
Magnesium	na	na	na	4910		J	*5.5*	*280*	2720		J	*5.2*	*260*	5160		J	*6*	*300*
Manganese	2000	160	2543	417	C	J	*0.055*	*0.83*	247	C	J	*0.052*	*0.77*	467	C	J	*0.06*	*0.89*
Mercury	31	2.3	0.13	0.049	J	J	*0.011*	*0.086*	0.03	J	J	*0.011*	*0.086*	0.12		J	*0.012*	*0.096*
Nickel	2000	160	62.8	12.3		J	*0.14*	*2.2*	7.7		J	*0.13*	*2.1*	16.3		J	*0.15*	*2.4*
Potassium	na	na	na	1520		J	*5.5*	*550*	1130		J	*5.2*	*520*	1530		J	*6*	*600*
Selenium	510	39	na	0.51	J	L	*0.25*	*5.5*	0.5	J	L	*0.23*	*5.2*	0.7	J	L	*0.27*	*6*
Silver	510	39	na	6.1		L	*0.078*	*0.55*	0.11	J	L	*0.072*	*0.52*	0.19	J	L	*0.083*	*0.6*
Sodium	na	na	na	264	J	B	*28*	*550*	214	J	B	*26*	*520*	341	J	L	*30*	*600*
Thallium	7.2	0.55	2.11	0.78	J	B	*0.62*	*1*	0.83	J	B	*0.6*	*1*	1.3		B	*0.66*	*1.2*
Vanadium	102	7.8	108	33.1		J	*0.055*	*2.8*	21.6		J	*0.052*	*2.6*	53		J	*0.06*	*3*
Zinc	31000	2300	202	123		J	*0.28*	*1.1*	44		J	*0.26*	*1*	145		J	*0.3*	*1.2*
Dioxins/Furans (ng/kg)																		
2,3,7,8-TCDF	na	na	na	3.6					1.62					6.94				
2,3,7,8-TCDD	19	4.3	na	1.25					0.682	J	B			3.03				
1,2,3,7,8-PECDD	na	na	na	4.6	J	J			0.932	J	J			4.8	J	J		
1,2,3,4,7,8-HXCDD	460	100	na	4.71	J	J			1.29	J	J			6.1				
1,2,3,6,7,8-HXCDD	460	100	na	8.42					2.32	J	J			9.94				
1,2,3,7,8,9-HXCDD	460	100	na	8.88					2.76	J	J			10.6				
1,2,3,4,6,7,8-HPCDD	na	na	na	167					57.2					250				
OCDD	na	na	na	4700	E	J			1440					7270	E	J		
1,2,3,7,8-PECDF	na	na	na	4.91	J	J			1.8	J	J			5.28	J	J		
2,3,4,7,8-PECDF	na	na	na	6.99					1.37	J, EMPC	J	*1.37*	*1.37*	5.6	J	J		
1,2,3,4,7,8-HXCDF	na	na	na	11.6					2.15	J	J			8.36				
1,2,3,6,7,8-HXCDF	na	na	na	8.51					1.4	J, EMPC	J	*1.4*	*1.4*	5.46	J	J		
2,3,4,6,7,8-HXCDF	na	na	na	10.1					1.76	J	J			6.04				
1,2,3,7,8,9-HXCDF	na	na	na	2.84	J	J			0.387	J, EMPC	J	*0.378*	*0.378*	1.51	J	J		
1,2,3,4,6,7,8-HPCDF	na	na	na	61.4					12.1					44.6				
1,2,3,4,7,8,9-HPCDF	na	na	na	5.15					0.845	J	J			3.15	J	J		
OCDF	na	na	na	101					23.1					84.9				
TOTAL TCDD	na	na	na	27.6					4.61	EMPC	J			34.1	EMPC	J		
TOTAL PECDD	na	na	na	56.6					12.8	EMPC	J			53	EMPC	J		
TOTAL HXCDD	460	100	na	94.4					25.5	EMPC	J			108				
TOTAL HPCDD	na	na	na	399					137					619				
TOTAL TCDF	na	na	na	63.8	EMPC	J			14.4	EMPC	J			63.3	EMPC	J		
TOTAL PECDF	na	na	na	62.4	EMPC	J			14.1	EMPC	J			53.8	EMPC	J		
TOTAL HXCDF	na	na	na	92.8	EMPC	J			18	EMPC	J			67.1				
TOTAL HPCDF	na	na	na	142					32					116	EMPC	J		

**Refer to legend immediately following this table for a list of definitions and table notes

Table 4-2
Analytes Detected in FLFA Soil - 2007 Investigation

Analyte	Sample ID			LFSS10					LFSS11					LFSS12				
	Sample Date			8/2/07					8/2/07					8/2/07				
	Sample Depth			0-0.5					0-0.5					0-0.5				
	i-RBC	r-RBC	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
PCBs (mg/kg)																		
PCB-1254	1.4	0.16	na	0.067	J	J	*0.011*	*0.022*	0.402			*0.047*	*0.095*	0.117			*0.01*	*0.02*
PCB-1260	1.4	0.32	na	0.0373	J	J	*0.011*	*0.022*	0.095	U		*0.047*	*0.095*	0.02	U		*0.01*	*0.02*
Metals (mg/kg)																		
Aluminum	100000	7800	40041	14400		J	*3.1*	*13*	17300		J	*2.6*	*11*	18700		J	*3*	*12*
Antimony	41	3.1	na	0.88	J	B	*0.25*	*3.9*	0.89	J	B	*0.2*	*3.2*	0.86	J	B	*0.23*	*3.7*
Arsenic	1.9	0.43	15.8	3.7		J	*0.25*	*0.52*	6.1		J	*0.21*	*0.43*	6.8		J	*0.24*	*0.49*
Barium	20000	1600	209	69.7		J	*0.33*	*13*	89.8		J	*0.27*	*11*	112		J	*0.31*	*12*
Beryllium	200	16	1.02	**1.7**		**B**	*0.13*	*0.66*	0.7		B	*0.11*	*0.54*	**1.2**		**B**	*0.12*	*0.62*
Cadmium	51	3.9	0.69	1.3	U	UL	*1.3*	*2.6*	1.1	U	UL	*1.1*	*2.2*	1.2	U	UL	*1.2*	*2.5*
Calcium	na	na	na	2070		J	*6.5*	*330*	8340		J	*5.4*	*270*	2930		J	*6.2*	*310*
Chromium	310	23	65.3	29.9		J	*0.091*	*0.65*	24.3		J	*0.075*	*0.54*	32.1		J	*0.086*	*0.62*
Cobalt	na	na	72.3	13.7		J	*0.072*	*3.3*	6.3		J	*0.059*	*2.7*	10.6		J	*0.068*	*3.1*
Copper	4100	310	53.5	**92.3**		**J**	*0.12*	*1.6*	**86.2**		**J**	*0.1*	*1.3*	**121**		**J**	*0.12*	*1.5*
Iron	72000	5500	50962	28700		J	*0.91*	*6.5*	21900		J	*0.75*	*5.4*	25200		J	*0.86*	*6.2*
Lead	800	400	26.8	**86.2**		**J**	*0.16*	*6.5*	**372**	**C**	**J**	*0.13*	*5.4*	**241**		**J**	*0.15*	*6.2*
Magnesium	na	na	na	4540		J	*6.5*	*330*	4460		J	*5.4*	*270*	15000		J	*6.2*	*310*
Manganese	2000	160	2543	500	C	J	*0.065*	*0.98*	823		J	*0.54*	*8.1*	607		J	*0.062*	*0.92*
Mercury	31	2.3	0.13	0.12		J	*0.013*	*0.1*	**0.16**		**J**	*0.011*	*0.09*	0.1		J	*0.012*	*0.098*
Nickel	2000	160	62.8	18.7		J	*0.16*	*2.6*	25.6		J	*0.13*	*2.2*	19.5		J	*0.15*	*2.5*
Potassium	na	na	na	1440		J	*6.5*	*650*	1400		K	*5.4*	*540*	3510		K	*6.2*	*620*
Selenium	510	39	na	0.78	J	L	*0.29*	*6.5*	0.37	J	L	*0.24*	*5.4*	0.34	J	L	*0.28*	*6.2*
Silver	510	39	na	0.5	J	L	*0.091*	*0.65*	0.18	J	K	*0.075*	*0.54*	0.39	J	K	*0.086*	*0.62*
Sodium	na	na	na	357	J	L	*33*	*650*	344	J	J	*27*	*540*	397	J	J	*31*	*620*
Thallium	7.2	0.55	2.11	2		B	*0.74*	*1.2*	0.6	U		*0.6*	*1*	0.64	U		*0.64*	*1.2*
Vanadium	102	7.8	108	45		J	*0.065*	*3.3*	45.3		J	*0.054*	*2.7*	40.2		J	*0.062*	*3.1*
Zinc	31000	2300	202	**223**		**J**	*0.33*	*1.3*	132		J	*0.27*	*1.1*	172		J	*0.31*	*1.2*
Dioxins/Furans (ng/kg)																		
2,3,7,8-TCDF	na	na	na	13.4					9.35					7.34				
2,3,7,8-TCDD	19	4.3	na	16.1					3.94					1.79				
1,2,3,7,8-PECDD	na	na	na	12.1					14.3					5.6	J	J		
1,2,3,4,7,8-HXCDD	460	100	na	12.9					14.1					5.98	J	J		
1,2,3,6,7,8-HXCDD	460	100	na	21					22.8					10.3				
1,2,3,7,8,9-HXCDD	460	100	na	23.3					25.3					11.1				
1,2,3,4,6,7,8-HPCDD	na	na	na	395					458					171				
OCDD	na	na	na	7690	E	J			7440	E	J			1300		K		
1,2,3,7,8-PECDF	na	na	na	10.5					10.6					6.02	J	J		
2,3,4,7,8-PECDF	na	na	na	14.1					14.6					7.4				
1,2,3,4,7,8-HXCDF	na	na	na	20.8					20					8.77				
1,2,3,6,7,8-HXCDF	na	na	na	13.6					13.8					6.47				
2,3,4,6,7,8-HXCDF	na	na	na	15.1					17.3					8.26				
1,2,3,7,8,9-HXCDF	na	na	na	3.64	J	J			4.41	J	J			2.25	J	J		
1,2,3,4,6,7,8-HPCDF	na	na	na	89.9					112					47.6				
1,2,3,4,7,8,9-HPCDF	na	na	na	5.89	J	J			7.39					3.58	J	J		
OCDF	na	na	na	133					191					74.5				
TOTAL TCDD	na	na	na	96	EMPC	J			85	EMPC	J			40.2				
TOTAL PECDD	na	na	na	147					163					68.7				
TOTAL HXCDD	460	100	na	245					255					109	EMPC	J		
TOTAL HPCDD	na	na	na	984					1080					384				
TOTAL TCDF	na	na	na	155	EMPC	J			187	EMPC	J			87.9	EMPC	J		
TOTAL PECDF	na	na	na	123	EMPC	J			127	EMPC	J			66.1	EMPC	J		
TOTAL HXCDF	na	na	na	148	EMPC	J			172	EMPC	J			77.4				
TOTAL HPCDF	na	na	na	187					282					115	EMPC	J		

**Refer to legend immediately following this table for a list of definitions and table notes

Table 4-2
Analytes Detected in FLFA Soil - 2007 Investigation

Analyte	Sample ID			LFSS13					LFSS14					LFSS15				
	Sample Date			8/2/07					8/2/07					8/2/07				
	Sample Depth			0-0.5					0-0.5					0-0.5				
	i-RBC	r-RBC	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
PCBs (mg/kg)																		
PCB-1254	1.4	0.16	na	0.111			*0.011*	*0.021*	0.0533			*0.01*	*0.02*	0.151			*0.018*	*0.037*
PCB-1260	1.4	0.32	na	0.021	U		*0.011*	*0.021*	0.02	U		*0.01*	*0.02*	0.037	U		*0.018*	*0.037*
Metals (mg/kg)																		
Aluminum	100000	7800	40041	20400		J	*2.9*	*12*	14400		J	*2.7*	*11*	17900		J	*2.6*	*11*
Antimony	41	3.1	na	1.4	J	B	*0.23*	*3.6*	0.65	J	B	*0.22*	*3.4*	0.74	J	B	*0.2*	*3.2*
Arsenic	1.9	0.43	15.8	**31.4**		**J**	*0.23*	*0.48*	4.3		J	*0.22*	*0.45*	4.9		J	*0.21*	*0.43*
Barium	20000	1600	209	84		J	*0.3*	*12*	52.9		J	*0.28*	*11*	75.5		J	*0.27*	*11*
Beryllium	200	16	1.02	**1.3**		**B**	*0.12*	*0.6*	0.64		B	*0.11*	*0.56*	0.7		B	*0.11*	*0.54*
Cadmium	51	3.9	0.69	0.14	J	L	*0.06*	*0.24*	1.1	U	UL	*1.1*	*2.3*	1.1	U	UL	*1.1*	*2.1*
Calcium	na	na	na	10600		J	*6*	*300*	1590		J	*5.7*	*280*	6850		J	*5.3*	*270*
Chromium	310	23	65.3	44		J	*0.083*	*0.6*	27.6		J	*0.079*	*0.57*	29.9		J	*0.075*	*0.53*
Cobalt	na	na	72.3	11.2		J	*0.066*	*3*	6.9		J	*0.062*	*2.8*	7.1		J	*0.059*	*2.7*
Copper	4100	310	53.5	**7560**		**J**	*5.7*	*75*	37.5		J	*0.11*	*1.4*	33.4		J	*0.1*	*1.3*
Iron	72000	5500	50962	24600		J	*0.83*	*6*	20400		J	*0.79*	*5.7*	23100		J	*0.75*	*5.3*
Lead	800	400	26.8	**161**		**J**	*0.14*	*6*	**35.9**		**J**	*0.14*	*5.7*	**186**		**J**	*0.13*	*5.3*
Magnesium	na	na	na	9290		J	*6*	*300*	1070		J	*5.7*	*280*	3500		J	*5.3*	*270*
Manganese	2000	160	2543	794		J	*1.2*	*18*	548		J	*0.057*	*0.85*	680		J	*0.53*	*8*
Mercury	31	2.3	0.13	0.087	J	J	*0.012*	*0.099*	0.1		J	*0.012*	*0.095*	**0.14**		**J**	*0.011*	*0.086*
Nickel	2000	160	62.8	34.9		J	*0.15*	*2.4*	7.5		J	*0.14*	*2.3*	10.4		J	*0.13*	*2.1*
Potassium	na	na	na	2250		J	*6*	*600*	712		J	*5.7*	*570*	957		J	*5.3*	*530*
Selenium	510	39	na	0.39	J	L	*0.27*	*6*	1.3	J	L	*0.26*	*5.7*	0.79	J	L	*0.24*	*5.3*
Silver	510	39	na	0.53	J	L	*0.083*	*0.6*	0.19	J	L	*0.079*	*0.57*	0.075	U	UL	*0.075*	*0.53*
Sodium	na	na	na	527	J	L	*30*	*600*	228	J	B	*28*	*570*	304	J	L	*27*	*530*
Thallium	7.2	0.55	2.11	0.66	U	UL	*0.66*	*1.2*	1.7		B	*0.64*	*1.1*	0.78	J	B	*0.6*	*1*
Vanadium	102	7.8	108	48.1		J	*0.06*	*3*	45.2		J	*0.057*	*2.8*	51.3		J	*0.053*	*2.7*
Zinc	31000	2300	202	**2820**		**J**	*6*	*24*	60.5		J	*0.28*	*1.1*	111		J	*0.27*	*1.1*
Dioxins/Furans (ng/kg)																		
2,3,7,8-TCDF	na	na	na	40.3					2.77					3.83				
2,3,7,8-TCDD	19	4.3	na	12.9					1.01	J, EMPC	J	*0.143*	*0.143*	1.84				
1,2,3,7,8-PECDD	na	na	na	35.9					2.76	J	J			5.6	J	J		
1,2,3,4,7,8-HXCDD	460	100	na	27					2.85	J	J			4.95	J	J		
1,2,3,6,7,8-HXCDD	460	100	na	53.8					5.01	J	J			9.97				
1,2,3,7,8,9-HXCDD	460	100	na	57.2					5.47	J	J			11.2				
1,2,3,4,6,7,8-HPCDD	na	na	na	798					123					203				
OCDD	na	na	na	6770	E	J			4270					3430				
1,2,3,7,8-PECDF	na	na	na	40					2.15	J	J			3.26	J	J		
2,3,4,7,8-PECDF	na	na	na	79.5					3.63	J	J			4.3	J	J		
1,2,3,4,7,8-HXCDF	na	na	na	82.9					4.53	J	J			5.97	J	J		
1,2,3,6,7,8-HXCDF	na	na	na	75.5					3.88	J	J			4.69	J	J		
2,3,4,6,7,8-HXCDF	na	na	na	92.9					4.44	J	J			5.07	J	J		
1,2,3,7,8,9-HXCDF	na	na	na	16.1					0.955	J	J			1.22	J	J		
1,2,3,4,6,7,8-HPCDF	na	na	na	457					25.9					38.9				
1,2,3,4,7,8,9-HPCDF	na	na	na	19.5					2.15	J	J			3.12	J	J		
OCDF	na	na	na	327					41.3					80.6				
TOTAL TCDD	na	na	na	257	Q, EMPC	J			15.3	EMPC	J			28.2	EMPC	J		
TOTAL PECDD	na	na	na	370	Q, EMPC	J			30.1	EMPC	J			53.5	EMPC	J		
TOTAL HXCDD	460	100	na	675					57.9					106				
TOTAL HPCDD	na	na	na	1660					314					463				
TOTAL TCDF	na	na	na	1220	Q, EMPC	J			41.4	EMPC	J			53.7	EMPC	J		
TOTAL PECDF	na	na	na	1040	Q, EMPC	J			29	EMPC	J			37.5	EMPC	J		
TOTAL HXCDF	na	na	na	858					37.3	EMPC	J			51.8	EMPC	J		
TOTAL HPCDF	na	na	na	667					57.8					106				

**Refer to legend immediately following this table for a list of definitions and table notes

Table 4-2
Analytes Detected in FLFA Soil - 2007 Investigation
Page 5 of 6

Analyte	Sample ID			LFSS16					LFSS17					LFSS18				
	Sample Date			8/2/07					8/2/07					8/2/07				
	Sample Depth			0-0.5					0-0.5					0-0.5				
	i-RBC	r-RBC	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
PCBs (mg/kg)																		
PCB-1254	1.4	0.16	na	0.18	U		*0.088*	*0.18*	0.0642	J	J	*0.0094*	*0.019*	0.11	J	J	*0.0099*	*0.02*
PCB-1260	1.4	0.32	na	1.09			*0.088*	*0.18*	0.133	J	J	*0.0094*	*0.019*	0.0677	J	J	*0.0099*	*0.02*
Metals (mg/kg)																		
Aluminum	100000	7800	40041	20000		J	*2.7*	*11*	19300		J	*2.8*	*12*	16100		J	*2.7*	*11*
Antimony	41	3.1	na	1.1	J	B	*0.21*	*3.3*	5.3		L	*0.22*	*3.5*	1.4	J	B	*0.22*	*3.4*
Arsenic	1.9	0.43	15.8	3		J	*0.22*	*0.44*	10.7		J	*0.23*	*0.47*	5.3		J	*0.22*	*0.46*
Barium	20000	1600	209	68.3		J	*0.28*	*11*	**2420**		**J**	*5.9*	*230*	**438**	**C**	**J**	*0.29*	*11*
Beryllium	200	16	1.02	**1.4**		**B**	*0.11*	*0.56*	**1.6**		**B**	*0.12*	*0.58*	**1.4**		**B**	*0.11*	*0.58*
Cadmium	51	3.9	0.69	0.056	U	UL	*0.056*	*0.22*	**5.1**		**L**	*0.059*	*0.23*	0.45		L	*0.057*	*0.23*
Calcium	na	na	na	14200		J	*5.6*	*280*	12400		J	*5.9*	*290*	11300		J	*5.7*	*290*
Chromium	310	23	65.3	30.5		J	*0.078*	*0.56*	59.1		J	*0.082*	*0.59*	33.2		J	*0.08*	*0.57*
Cobalt	na	na	72.3	8.3		J	*0.061*	*2.8*	10.2		J	*0.065*	*2.9*	26.9		J	*0.063*	*2.9*
Copper	4100	310	53.5	**97.3**		**J**	*0.11*	*1.4*	**3090**		**J**	*2.2*	*29*	**179**		**J**	*0.11*	*1.4*
Iron	72000	5500	50962	20600		J	*0.78*	*5.6*	25500		J	*0.82*	*5.9*	26200		J	*0.8*	*5.7*
Lead	800	400	26.8	**1550**		**J**	*1.3*	*56*	**1660**		**J**	*2.8*	*120*	**294**	**C**	**J**	*0.14*	*5.7*
Magnesium	na	na	na	24100		J	*5.6*	*280*	12100		J	*5.9*	*290*	8400		J	*5.7*	*290*
Manganese	2000	160	2543	355		J	*0.56*	*8.3*	907		J	*1.2*	*18*	1940		J	*0.57*	*8.6*
Mercury	31	2.3	0.13	0.048	J	J	*0.011*	*0.086*	**0.89**		**J**	*0.036*	*0.29*	**0.45**		**J**	*0.011*	*0.091*
Nickel	2000	160	62.8	19.8		J	*0.14*	*2.2*	48.3		J	*0.15*	*2.3*	20.3		J	*0.14*	*2.3*
Potassium	na	na	na	3590		J	*5.6*	*560*	2250		J	*5.9*	*590*	2030		J	*5.7*	*570*
Selenium	510	39	na	0.25	U	UL	*0.25*	*5.6*	0.68	J	L	*0.26*	*5.9*	0.49	J	L	*0.26*	*5.7*
Silver	510	39	na	0.36	J	L	*0.078*	*0.56*	65.2		L	*0.082*	*0.59*	6.2		L	*0.08*	*0.57*
Sodium	na	na	na	362	J	L	*28*	*560*	915		L	*29*	*590*	435	J	L	*29*	*570*
Thallium	7.2	0.55	2.11	0.62	U	UL	*0.62*	*1.1*	0.66	U	UL	*0.66*	*1.2*	0.64	U	UL	*0.64*	*1.2*
Vanadium	102	7.8	108	44.6		J	*0.056*	*2.8*	39		J	*0.059*	*2.9*	37.3		J	*0.057*	*2.9*
Zinc	31000	2300	202	135		J	*0.28*	*1.1*	**3150**		**J**	*5.9*	*23*	**369**	**C**	**J**	*0.29*	*1.1*
Dioxins/Furans (ng/kg)																		
2,3,7,8-TCDF	na	na	na	6.29					41.8					19.5				
2,3,7,8-TCDD	19	4.3	na	1.11	J	J			5.67					3.32				
1,2,3,7,8-PECDD	na	na	na	3.2	J	J			21.7					15.4				
1,2,3,4,7,8-HXCDD	460	100	na	2.91	J, EMPC	J	*0.57*	*0.57*	23					23.7				
1,2,3,6,7,8-HXCDD	460	100	na	6.89					46.5					37.1				
1,2,3,7,8,9-HXCDD	460	100	na	6.57					40.3					33.6				
1,2,3,4,6,7,8-HPCDD	na	na	na	144					509					507				
OCDD	na	na	na	1780					3760					4400				
1,2,3,7,8-PECDF	na	na	na	3.44	J	J			63.2					24.6				
2,3,4,7,8-PECDF	na	na	na	4.65	J	J			79.5					43.3				
1,2,3,4,7,8-HXCDF	na	na	na	24					107					61.9				
1,2,3,6,7,8-HXCDF	na	na	na	4.95	J	J			97					50.2				
2,3,4,6,7,8-HXCDF	na	na	na	5.98					116					59.5				
1,2,3,7,8,9-HXCDF	na	na	na	1.59	J	J			29.8					16.4				
1,2,3,4,6,7,8-HPCDF	na	na	na	49.2					567					300				
1,2,3,4,7,8,9-HPCDF	na	na	na	4.11	J	J			42.4					27.7				
OCDF	na	na	na	72.5					414					257				
TOTAL TCDD	na	na	na	21.5	EMPC	J			241	Q	J			135				
TOTAL PECDD	na	na	na	36.3	EMPC	J			355					218	Q, EMPC	J		
TOTAL HXCDD	460	100	na	64	EMPC	J			534					447				
TOTAL HPCDD	na	na	na	321					1290					1170				
TOTAL TCDF	na	na	na	73.3	EMPC	J			882	EMPC	J			353	Q, EMPC	J		
TOTAL PECDF	na	na	na	108	EMPC	J			715	Q, EMPC	J			314	Q, EMPC	J		
TOTAL HXCDF	na	na	na	84.3					820					459				
TOTAL HPCDF	na	na	na	110					903					525				

**Refer to legend immediately following this table for a list of definitions and table notes

Table 4-2
Analytes Detected in FLFA Soil - 2007 Investigation
Page 6 of 6

Analyte	Sample ID			LFSS19					LFSS20					LFSS21				
	Sample Date			8/2/07					8/2/07					8/2/07				
	Sample Depth			0-0.5					0-0.5					0-0.5				
	i-RBC	r-RBC	Background	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
PCBs (mg/kg)																		
PCB-1254	1.4	0.16	na	0.0343			*0.01*	*0.02*	0.331	J	J	*0.051*	*0.1*	0.206	J	J	*0.053*	*0.11*
PCB-1260	1.4	0.32	na	0.02	U		*0.01*	*0.02*	0.125	J	J	*0.051*	*0.1*	0.179	J	J	*0.053*	*0.11*
Metals (mg/kg)																		
Aluminum	100000	7800	40041	18500		J	*2.9*	*12*	35600		J	*29*	*120*	21800		J	*3*	*13*
Antimony	41	3.1	na	1.3	J	B	*0.23*	*3.6*	6.2		L	*0.23*	*3.6*	3.8		B	*0.24*	*3.8*
Arsenic	1.9	0.43	15.8	7.3		J	*0.23*	*0.48*	13.8		J	*0.23*	*0.48*	14.1		J	*0.24*	*0.5*
Barium	20000	1600	209	72.3		J	*0.3*	*12*	**824**		**J**	*3*	*120*	**776**		**J**	*3.1*	*130*
Beryllium	200	16	1.02	0.79		B	*0.12*	*0.6*	0.64		B	*0.12*	*0.6*	**1.6**		**B**	*0.12*	*0.62*
Cadmium	51	3.9	0.69	1.5	U	UL	*1.5*	*2.4*	**6.6**		**L**	*0.06*	*0.24*	**4.4**		**L**	*0.063*	*0.25*
Calcium	na	na	na	1740		J	*6*	*300*	8950		J	*6*	*300*	19200		J	*6.3*	*310*
Chromium	310	23	65.3	59.1		J	*0.084*	*0.6*	**162**		**J**	*0.084*	*0.6*	55.8		J	*0.088*	*0.63*
Cobalt	na	na	72.3	18		J	*0.066*	*3*	13.7		J	*0.066*	*3*	12.4		J	*0.069*	*3.1*
Copper	4100	310	53.5	**55.1**		**J**	*0.11*	*1.5*	**37200**		**J**	*23*	*300*	**1130**		**J**	*1.2*	*16*
Iron	72000	5500	50962	40900		J	*8.4*	*60*	40800		J	*8.4*	*60*	48900		J	*8.8*	*63*
Lead	800	400	26.8	**105**		**J**	*0.14*	*6*	**36500**		**J**	*29*	*1200*	**1230**		**J**	*1.5*	*63*
Magnesium	na	na	na	1280		J	*6*	*300*	4880		J	*6*	*300*	15600		J	*6.3*	*310*
Manganese	2000	160	2543	732		J	*0.6*	*9*	906		J	*0.6*	*9*	809		J	*0.63*	*9.4*
Mercury	31	2.3	0.13	**0.21**		**J**	*0.011*	*0.091*	**0.15**		**J**	*0.011*	*0.091*	**2.2**		**J**	*0.066*	*0.54*
Nickel	2000	160	62.8	10.2		J	*0.15*	*2.4*	**123**		**J**	*0.15*	*2.4*	49.4		J	*0.16*	*2.5*
Potassium	na	na	na	945		J	*6*	*600*	2320		J	*6*	*600*	1970		J	*6.3*	*630*
Selenium	510	39	na	1.3	J	L	*0.27*	*6*	0.27	U	UL	*0.27*	*6*	0.28	U	UL	*0.28*	*6.3*
Silver	510	39	na	2.5		L	*0.084*	*0.6*	7.5		L	*0.084*	*0.6*	24.2		L	*0.088*	*0.63*
Sodium	na	na	na	376	J	L	*30*	*600*	3230		L	*30*	*600*	850		L	*31*	*630*
Thallium	7.2	0.55	2.11	**2.9**		**B**	*0.64*	*1.2*	0.64	U	UL	*0.64*	*1.2*	0.7	U	UL	*0.7*	*1.2*
Vanadium	102	7.8	108	75.6		J	*0.06*	*3*	35.1		J	*0.06*	*3*	40.5		J	*0.063*	*3.1*
Zinc	31000	2300	202	133		J	*0.3*	*1.2*	**22100**		**J**	*60*	*240*	**2090**		**J**	*3.1*	*13*
Dioxins/Furans (ng/kg)																		
2,3,7,8-TCDF	na	na	na	12.6					245					43.5				
2,3,7,8-TCDD	19	4.3	na	2.78					166					8.08				
1,2,3,7,8-PECDD	na	na	na	7.19					481					39				
1,2,3,4,7,8-HXCDD	460	100	na	7.29					428					52.1				
1,2,3,6,7,8-HXCDD	460	100	na	13.7					821					75.4				
1,2,3,7,8,9-HXCDD	460	100	na	13.2					826					70.3				
1,2,3,4,6,7,8-HPCDD	na	na	na	215					18100					1010				
OCDD	na	na	na	7090	E	J			135000					6530	E	J		
1,2,3,7,8-PECDF	na	na	na	12.2					273					57.5				
2,3,4,7,8-PECDF	na	na	na	18.8					507					99.2				
1,2,3,4,7,8-HXCDF	na	na	na	25.1					437					137				
1,2,3,6,7,8-HXCDF	na	na	na	19.3					381					117				
2,3,4,6,7,8-HXCDF	na	na	na	24.7					484					157				
1,2,3,7,8,9-HXCDF	na	na	na	6.79					83.3					37.5				
1,2,3,4,6,7,8-HPCDF	na	na	na	108					2330					727				
1,2,3,4,7,8,9-HPCDF	na	na	na	9.47					159					60.2				
OCDF	na	na	na	86.3					4090					565				
TOTAL TCDD	na	na	na	53.9	EMPC	J			2770	Q	J			333				
TOTAL PECDD	na	na	na	92.3					4130	Q	J			545	Q, EMPC	J		
TOTAL HXCDD	460	100	na	149					8090					953				
TOTAL HPCDD	na	na	na	526					34500					2340				
TOTAL TCDF	na	na	na	160	EMPC	J			6890	Q, EMPC	J			972	EMPC	J		
TOTAL PECDF	na	na	na	145	EMPC	J			4380	Q, EMPC	J			873	Q, EMPC	J		
TOTAL HXCDF	na	na	na	175	EMPC	J			3900	Q	J			1110				
TOTAL HPCDF	na	na	na	186					6470					1220				

**Refer to legend immediately following this table for a list of definitions and table notes

Table 4-2
Legend

12	J	Shading and black font indicate an industrial RBC exceedance.
12	J	Bold outline indicates a residential RBC exceedance.
12	**J**	Bold, underlined font indicates a background exceedance.
12	*12*	Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

RBCs for non-Carcinogenic compounds have been recalculated to an HI of 0.1.
The pyrene RBCs were used for acenaphthylene, benzo(g,h,i)perylene and phenanthrene.
Inorganic results below background UTLs are not indicated as exceedances on the table.
RBC = Risk-Based Concentration (October 2007).
RBC values in table are for the more conservative chromium VI.
RBC values for chromium III are 150,000 (ind) and 12,000 (res), which were not exceeded.
Lead screening values from Technical Review Workgroup for Lead: Guidance Document (April 1999).
mg/kg = milligrams per kilogram (parts per million).
ng/kg = nanograms per kilogram (parts per trillion).
µg/kg = micrograms per kilogram (parts per billion).
NA = not applicable.
NT = analyte not tested.

LQ = Lab Data Qualifiers

B = (organics) Blank contamination. Value detected in sample and associated blank.
A (Dioxins) = B = (metals) Value <MRL and >MDL and is considered estimated.
E (metals) = Reported value is estimated because of the presence of interferences.
EMPC (Dioxins) = The ion-abundance ratio between the two characteristic PCDD/PCDF ions was outside accepted ranges. The detected PCDD/PCDF was reported as an estimated maximum possible concentration (EMPC).
J = (organics) Value <MRL and >MDL and is considered estimated.
U = Analyte not-detected at the method reporting limit.
X = (dioxins) Ion abundance ratio outside acceptable range. Value reported is EMPC.

VQ = Validation Data Qualifiers:

B = blank contamination. Value detected in sample and associated blank.
J = estimated concentration
K = estimated concentration bias high
L = estimated concentration bias low
N = presumptive evidence for tentatively identified compounds using a library search
U = analyte not detected
UJ = estimated concentration non-detect
UL = estimated concentration non-detect bias low

Table 4-3
Summary of Analytes Detected in FLFA Soil - 2007 Investigation

Analyte	i-RBC	r-RBC	Background	# of i-RBC Exceedances	# of r-RBC Exceedances	# of Background Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
PCBs (mg/kg)											
PCB-1254	1.4	0.16	na	0	5	na	17	18	0.0135	0.402	LFSS11
PCB-1260	1.4	0.32	na	0	1	na	8	18	0.0373	1.09	LFSS16
Metals (mg/kg)											
Aluminum	100000	7800	40041	0	0	0	18	18	9770	35600	LFSS20
Antimony	41	3.1	na	0	3	na	18	18	0.34	6.2	LFSS20
Arsenic	1.9	0.43	15.8	1	1	1	18	18	1.9	31.4	LFSS13
Barium	20000	1600	209	0	1	5	18	18	52.9	2420	LFSS17
Beryllium	200	16	1.02	0	0	10	18	18	0.64	1.7	LFSS10
Cadmium	51	3.9	0.69	0	3	3	5	18	0.14	6.6	LFSS20
Calcium	na	na	na	na	na	na	18	18	1520	19200	LFSS21
Chromium	310	23	65.3	0	1	1	18	18	13.1	162	LFSS20
Cobalt	na	na	72.3	na	na	0	18	18	6.3	26.9	LFSS18
Copper	4100	310	53.5	2	4	14	18	18	30.3	37200	LFSS20
Iron	72000	5500	50962	0	0	0	18	18	14100	48900	LFSS21
Lead	800	400	26.8	4	4	18	18	18	35.9	36500	LFSS20
Magnesium	na	na	na	na	na	na	18	18	1070	24100	LFSS16
Manganese	2000	160	2543	0	0	0	18	18	247	2060	LFSS06
Mercury	31	2.3	0.13	0	0	9	18	18	0.03	2.2	LFSS21
Nickel	2000	160	62.8	0	0	1	18	18	7.5	123	LFSS20
Potassium	na	na	na	na	na	na	18	18	712	3590	LFSS16
Selenium	510	39	na	0	0	na	15	18	0.34	1.3	LFSS14
Silver	510	39	na	0	1	na	17	18	0.11	65.2	LFSS17
Sodium	na	na	na	na	na	na	18	18	214	3230	LFSS20
Thallium	7.2	0.55	2.11	0	1	1	7	18	0.78	2.9	LFSS19
Vanadium	102	7.8	108	0	0	0	18	18	21.6	75.6	LFSS19
Zinc	31000	2300	202	0	3	8	18	18	44	22100	LFSS20
Dioxins/Furans (ng/kg)											
2,3,7,8-TCDF	na	na	na	na	na	na	18	18	1.62	245	LFSS20
2,3,7,8-TCDD	19	4.3	na	1	6	na	18	18	0.682	166	LFSS20
1,2,3,7,8-PECDD	na	na	na	na	na	na	18	18	0.932	481	LFSS20
1,2,3,4,7,8-HXCDD	460	100	na	0	1	na	18	18	1.29	428	LFSS20
1,2,3,6,7,8-HXCDD	460	100	na	1	1	na	18	18	2.32	821	LFSS20
1,2,3,7,8,9-HXCDD	460	100	na	1	1	na	18	18	2.76	826	LFSS20
1,2,3,4,6,7,8-HPCDD	na	na	na	na	na	na	18	18	57.2	18100	LFSS20
OCDD	na	na	na	na	na	na	18	18	1300	135000	LFSS20
1,2,3,7,8-PECDF	na	na	na	na	na	na	18	18	1.8	273	LFSS20
2,3,4,7,8-PECDF	na	na	na	na	na	na	18	18	1.37	507	LFSS20
1,2,3,4,7,8-HXCDF	na	na	na	na	na	na	18	18	2.15	437	LFSS20
1,2,3,6,7,8-HXCDF	na	na	na	na	na	na	18	18	1.4	381	LFSS20
2,3,4,6,7,8-HXCDF	na	na	na	na	na	na	18	18	1.76	484	LFSS20
1,2,3,7,8,9-HXCDF	na	na	na	na	na	na	18	18	0.387	83.3	LFSS20
1,2,3,4,6,7,8-HPCDF	na	na	na	na	na	na	18	18	12.1	2330	LFSS20
1,2,3,4,7,8,9-HPCDF	na	na	na	na	na	na	18	18	0.845	159	LFSS20
OCDF	na	na	na	na	na	na	18	18	23.1	4090	LFSS20
TOTAL TCDD	na	na	na	na	na	na	18	18	4.61	2770	LFSS20
TOTAL PECDD	na	na	na	na	na	na	18	18	12.8	4130	LFSS20
TOTAL HXCDD	460	100	na	5	13	na	18	18	25.5	8090	LFSS20
TOTAL HPCDD	na	na	na	na	na	na	18	18	137	34500	LFSS20
TOTAL TCDF	na	na	na	na	na	na	18	18	14.4	6890	LFSS20
TOTAL PECDF	na	na	na	na	na	na	18	18	14.1	4380	LFSS20
TOTAL HXCDF	na	na	na	na	na	na	18	18	18	3900	LFSS20
TOTAL HPCDF	na	na	na	na	na	na	18	18	32	6470	LFSS20

APPENDIX E

FORMS

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Form E-1
Work Plan Revision Form
Work Plan – Quality Assurance Plan – Health and Safety Plan – Addendum 028
SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

SITE DESIGNATION / LOCATION:

Radford Army Ammunition Plant

Radford, VA

Section: _____

Addendum: _____

Version: _____

Effective Date: _____

SUBJECT:

Approved by:

Field Operations Leader

_____

Date: _____

Concurrence:

Project Manager

_____

Date _____

Sheet _____ of _____

Form E-2
Worker Acknowledgement Form
SSP for SSAs 18, 72, 30, 79, 60, and 77
Radford Army Ammunition Plant, Radford, Virginia

Document: Master Work Plan/QAP/HSP and Work Plan Addendum 028

Version: Final

Project: Radford Army Ammunition Plant

Location: SSAs 18, 72, 30, 79, 60, and 77

Prior to the initiation of field activities, I have been given an opportunity to read and question the contents of this Master Work Plan/QAP/HSP, this Site-Specific Addendum, and approved revisions through the number listed above. With my signature, I certify that I have read, understood, and agree to comply with the information and directions set forth in these plans. I further certify that I am in full compliance with 20 Code of Federal Regulations (CFR) 1910.120 concerning training and medical monitoring requirements.

Site Personnel:

Name (please print)	**Signature**	**Date**