RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SWMU 54
Monitored Natural Attenuation Sampling
Year Two Report

Prepared for:

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

Prepared by:

Shaw Environmental, Inc.
4696 Millennium Dr., Suite 320
Belcamp, MD 21017

Final Document **December 2013**

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

December 23, 2013

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

Jay Stewart
Environmental Manager
BAE Systems, Ordnance Systems, Inc.
Radford Army Ammunition Plant
114 Peppers Ferry Road, P.O. Box 1
Radford, VA 24143

VIA Electronic Mail

Re: Radford Army Ammunition Plant, Radford, Virginia
Solid Waste Management Unit 54
SWMU 54 Monitored Natural Attenuation Sampling Report and Response to Comment

Dear Mr. McKenna and Mr. Stewart:

The U.S. Environmental Protection Agency and Virginia Department of Environmental Quality have reviewed the U.S. Army's Solid Waste Management SWMU 54, Monitored Natural Attenuation Year Two Sampling Report (Report), located at the Radford Army Ammunition Plant (RFAAP) in Radford, Virginia. Based on the Response to Comments, submitted Friday, December 6, 2013, and our review of the Report, there are no additional comments. In accordance with Part II. (E)(5)(a) of RFAAP's Corrective Action Permit, the Report is considered final. If you have any questions, please call me at 215-814-3284.

Sincerely,

Erich Weissbart

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

c: James Cutler, VDEQ

BAE SYSTEMS

ORDNANCE SYSTEMS INC.
Radford Army Ammunition Plant
4050 Pepper's Ferry Road
Radford Virginia 24141

December 20, 2013

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

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

Subject: With Certifications, SWMU 54 Monitored Natural Attenuation Sampling Year Two Report, Final Document, December 2013 EPA ID# VA1210020730

Dear Mr. Weissbart and Mr. Cutler:

Enclosed is the certification for the subject documents that were sent to you on December 19, 2013. Also enclosed is the December 19, 2013 transmittal email.

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

Sincerely,

M.T. Boggs for

Jay Stewart, Environmental Manager
BAE Systems, Ordnance Systems Inc.

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

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

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

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

Coordination: J. McKenna J. McKenna

13-0900-178

Concerning the following:

Radford Army Ammunition Plant
SWMU 54
Monitored Natural Attenuation Sampling
Year Two Report
Final Document, December 2013

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

SIGNATURE: _____ 6 Jan 2014

PRINTED NAME: Luis A. Ortiz
TITLE: Lieutenant Colonel, US Army
Commanding

SIGNATURE: _____

PRINTED NAME: William M. Barnett
TITLE: General Manager
BAE Systems

Alberts, Matt (US SSA)

From: McKenna, James J CIV (US) <james.j.mckenna16.civ@mail.mil>
Sent: Thursday, December 19, 2013 2:07 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler,Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA); Alberts, Matt (US SSA); Bogucki, MaryAnn (US SSA); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Davie, Robert N.; Ortiz, Luis (RFAAP); Leahy, Timothy
Subject: FW: Final SWMU 54 MNA Year 2 Report (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Erich, Jim C., All:

Note the contractor will ship the subject document with a copy of this email to the POCs and tracking numbers below. Certification will follow by separate letter. The report has been revised per your email of December 12, 2013.

Jim McKenna	1Z66V7420195146038
Thomas Meyer	1Z66V7420199801447
Jim Bressette	1Z66V7420197296257
Susan M. Ryan	1Z66V7420197028073
Erich Weissbart	1Z66V7420196577080
JIM CUTLER	1Z66V7420197789493
E.A. LOHMAN	1Z66V7420196221301
Jay Stewart	1Z66V7420196468519
Rich Mendoza	1Z66V7420198026466

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

JJM

Classification: UNCLASSIFIED
Caveats: FOUO

Leahy, Timothy

From: McKenna, James J CIV (US) [james.j.mckenna16.civ@mail.mil]
Sent: Thursday, December 12, 2013 2:39 PM
To: Weissbart, Erich
Cc: Cutler,Jim; Alberts, Matt (US SSA); beth lohman (ealohman@deq.virginia.gov); Cutler,Jim; MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Mendoza, Richard R Jr CIV (US); Meyer, Tom NAB02; Stewart, Jay (US SSA); Leahy, Timothy; Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US)
Subject: RE: SWMU 54 (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Ok, we'll revise the report accordingly.

-----Original Message-----
From: Weissbart, Erich [mailto:Weissbart.Erich@epa.gov]
Sent: Thursday, December 12, 2013 2:27 PM
To: McKenna, James J CIV (US)
Cc: Cutler,Jim; Alberts, Matt (US SSA); beth lohman (ealohman@deq.virginia.gov); Cutler,Jim; MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Mendoza, Richard R Jr CIV (US); Meyer, Tom NAB02; Stewart, Jay (US SSA); Timothy.Leahy@shawgrp.com; Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US)
Subject: RE: SWMU 54 (UNCLASSIFIED)

The response adequately addresses the comment. Thank you.

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

-----Original Message-----
From: McKenna, James J CIV (US) [mailto:james.j.mckenna16.civ@mail.mil]
Sent: Friday, December 06, 2013 10:37 AM
To: Weissbart, Erich
Cc: Cutler,Jim; Alberts, Matt (US SSA); beth lohman (ealohman@deq.virginia.gov); Cutler,Jim; MaryAnn Bogucki - Radford (maryann.bogucki@baesystems.com); Mendoza, Richard R Jr CIV (US); Meyer, Tom NAB02; Stewart, Jay (US SSA); Timothy.Leahy@shawgrp.com; Davie, Robert N III CIV (US); Ortiz, Luis A LTC USARMY JMC (US)
Subject: RE: SWMU 54 (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

Erich, Jim C. all,

Attached is our response. Note during our recently completed groundwater sampling round (i.e. 9th round) we sampled 54MW2. If you approve our attached response, we'll revise the year 2 report accordingly and start sampling 54MW1 during the next round.

Thanks,
JJM

-----Original Message-----
From: Weissbart, Erich [mailto:Weissbart.Erich@epa.gov]
Sent: Monday, December 02, 2013 12:30 PM
To: McKenna, James J CIV (US)
Cc: Cutler,Jim
Subject: SWMU 54

Jim,

EPA and DEQ have reviewed the second year monitoring report for groundwater at SWMU 54. I have a single comment otherwise the report addresses all the comments from the first year report. In the second year report a smaller monitoring network was proposed. As part of the network a background well was proposed that in my opinion is not a background well since it is in the middle of a former SWMU. Pardon me for not having well numbers in front of me but I recall there were two true upgradient wells; upgradient of any potential contamination from the former SWMUs. I believe the purpose of a background well at this site is to compare geochemical parameters. There is no other purpose since we already have established risk-based cleanup standards for groundwater and further, the constituents of interest should not be in upgradient groundwater. Therefore, please propose an upgradient well as background that is closest to the monitoring network but not in a formerly contaminated area. Thank you.

Erich Weissbart, P.G.

Remedial Project Manager

Land and Chemicals Division

US EPA Region III

1650 Arch Street, Philadelphia PA

215 814-3284

weissbart.erich@epa.gov

Classification: UNCLASSIFIED
Caveats: FOUO

Classification: UNCLASSIFIED
Caveats: FOUO

Responses to EPA Review Comment on the SWMU 54 MNA Year 2 Report
Radford Army Ammunition Plant, Radford, VA

Comment received from Erich Weissbart

Comment 1: EPA and DEQ have reviewed the second year monitoring report for groundwater at SWMU 54. I have a single comment otherwise the report addresses all the comments from the first year report. In the second year report a smaller monitoring network was proposed. As part of the network a background well was proposed that in my opinion is not a background well since it is in the middle of a former SWMU. Pardon me for not having well numbers in front of me but I recall there were two true upgradient wells; upgradient of any potential contamination from the former SWMUs. I believe the purpose of a background well at this site is to compare geochemical parameters. There is no other purpose since we already have established risk-based cleanup standards for groundwater and further, the constituents of interest should not be in upgradient groundwater. Therefore, please propose an upgradient well as background that is closest to the monitoring network but not in a formerly contaminated area. Thank you.

Response 1: The proposed background well (54MW2) was the closest, upgradient well to the three remaining wells in the network. As pointed out in the comment, however, it is within the original area of contamination. Based on this comment, 54MW1 will be used as the upgradient well for the reduced monitoring network, as it was the original upgradient well for SWMU 54, Area A (see Table 2-2 in the *Final SWMU 54 MNA Interim Measures Workplan* (April 2011).

Leahy, Timothy

From: Weissbart, Erich [Weissbart.Erich@epa.gov]
Sent: Monday, December 02, 2013 12:30 PM
To: McKenna, James J CIV (US)
Cc: Cutler,Jim
Subject: SWMU 54

Jim,
EPA and DEQ have reviewed the second year monitoring report for groundwater at SWMU 54. I have a single comment otherwise the report addresses all the comments from the first year report. In the second year report a smaller monitoring network was proposed. As part of the network a background well was proposed that in my opinion is not a background well since it is in the middle of a former SWMU. Pardon me for not having well numbers in front of me but I recall there were two true upgradient wells; upgradient of any potential contamination from the former SWMUs. I believe the purpose of a background well at this site is to compare geochemical parameters. There is no other purpose since we already have established risk-based cleanup standards for groundwater and further, the constituents of interest should not be in upgradient groundwater. Therefore, please propose an upgradient well as background that is closest to the monitoring network but not in a formerly contaminated area. Thank you.
Erich Weissbart, P.G.
Remedial Project Manager
Land and Chemicals Division
US EPA Region III
1650 Arch Street, Philadelphia PA
215 814-3284
weissbart.erich@epa.gov

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

BAE SYSTEMS

November 15, 2013

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

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

Subject: With Certification, SWMU 54 Monitored Natural Attenuation Sampling Year Two Report, Draft Document, October 2013
EPA ID# VA1210020730

Dear Mr. Weissbart and Mr. Cutler:

Enclosed is the certification for the subject documents that were sent to you on November 6, 2013. Also enclosed is the November 6, 2013 transmittal email.

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

Sincerely,

Jay Stewart, Environmental Manager
BAE Systems, Ordnance Systems Inc

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

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

13-0900-154

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

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

Coordination: J. McKenna

Concerning the following:

Radford Army Ammunition Plant
SWMU 54
Monitored Natural Attenuation Sampling
Year Two Report
Draft Document, October 2013

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

SIGNATURE: _____
PRINTED NAME: Luis A. Ortiz
TITLE: Lieutenant Colonel, US Army
Commanding

SIGNATURE: _____ 18 Nov 2013
PRINTED NAME: Todd D. Hayes
TITLE: Director, Facility Support Services
BAE Systems

Alberts, Matt (US SSA)

From: McKenna, James J CIV (US) <james.j.mckenna16.civ@mail.mil>
Sent: Wednesday, November 06, 2013 2:50 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler,Jim
Cc: beth lohman (ealohman@deq.virginia.gov); Stewart, Jay (US SSA); Alberts, Matt (US SSA); Bogucki, MaryAnn (US SSA); Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); Davie, Robert N.; Ortiz, Luis (RFAAP); Leahy, Timothy
Subject: Draft SWMU 54 Year 2 Monitoring Report (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: FOUO

All:

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

Tom Meyer - 1Z66V7420192037063

Rich Mendoza - 1Z66V7420192693087

Erich Weissbart - 1Z66V7420191645096

Jim Cutler - 1Z66V7420193813105

Beth Lohman - 1Z66V7420194797113

Jay Stewart - 1Z66V7420190197126

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

Jim McKenna

Classification: UNCLASSIFIED
Caveats: FOUO

TABLE OF CONTENTS

LIST OF TABLES

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LIST OF APPENDICES

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

LIST OF ACRONYMS AND ABBREVIATIONS

°C .....degrees Celsius
µg/L.....micrograms per liter
2,4,6-TNT 2,4,6-trinitrotoluene
2ADNT 2-amino-4,6-dinitrotoluene
4ADNT 4-amino-2,6-dinitrotoluene
CMO .....Corrective Measures Objective
CMS .....Corrective Measures Study
COC .....Chain-of-Custody
COI.....Contaminant of Interest
COPC .....Chemical of Potential Concern
DIC.....Dissolved Inorganic Carbon
DIUF .....De-ionized Ultra-filtered
DNT .....Dinitrotoluene
DO.....Dissolved Oxygen
ft .....foot or feet
ft/day .....feet per day
ft/year .....feet per year
HHRA .....Human Health Risk Assessment
HI .....Hazard Index
IM.....Interim Measure
IMWP.....Interim Measures Work Plan
MCL.....Maximum Contaminant Level
mg/kg .....milligrams per kilogram
mg/L.....milligrams per liter
mL/min.....milliliters per minute
MNA .....Monitored Natural Attenuation
MS.....Matrix Spike
mS/cm .....millisiemens per centimeter
MSD.....Matrix Spike Duplicate
msl.....mean sea level
mV.....millivolts
MWP .....Master Work Plan
NG.....Nitroglycerin
NTU .....Nephelometric Turbidity Unit
ORP.....Oxidation-Reduction Potential
PID .....Photoionization Detector
QA/QC .....Quality Assurance/Quality Control
QC .....Quality Control
RCRA.....Resource Conservation and Recovery Act
RDX .....cyclotrimethylenetrinitramine
RFAAP.....Radford Army Ammunition Plant
RFI .....RCRA Facility Investigation
RG .....Remedial Goal
Shaw.....Shaw Environmental, Inc.
SL.....Screening Level
SOP .....Standard Operating Procedure
SWMU .....Solid Waste Management Unit
TOC.....Total Organic Carbon
URS.....URS Corporation
USEPA.....U.S. Environmental Protection Agency
VI .....Verification Investigation

1.0 INTRODUCTION

Shaw Environmental, Inc. (Shaw) was contracted by the U.S. Army Corps of Engineers to perform a Monitored Natural Attenuation (MNA) at Solid Waste Management Unit (SWMU) 54 (RAAP-014), the Propellant Burning Ash Disposal Area, at Radford Army Ammunition Plant (RFAAP), Radford, VA. This report contains a description of the activities involved in the fifth through eighth quarterly rounds of groundwater sampling conducted in 2012 through 2013. This report includes an analysis of the results of the fifth through eighth quarter's data and a summary of the second year of sampling.

1.1 Purpose and Scope

Based on the *Final SWMU 54 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) / Corrective Measures Study (CMS) Report* (URS, 2008), soil interim measures (IMs) were performed at SWMU 54. The IMs were conducted to mitigate the threat of a contaminant release, migration, and/or exposure to the public and the environment in accordance with Part II(D)(11-21) IM of the *RFAAP Corrective Action Permit* (USEPA, 2000). The IMs included:

1. Site Preparation.
2. Excavation.
3. Waste Characterization & Off-site Disposal.
4. Confirmation Sampling.
5. Site Restoration.

The soil IMs have been completed, and this report details the implementation of the groundwater MNA IMs approved in the *Final SWMU 54 MNA Interim Measures Work Plan (IMWP)* (Shaw, 2011a) including:

1. Installation and development of four groundwater monitoring wells, in accordance with the *RFAAP Master Work Plan (MWP)* (URS, 2003) Standard Operating Procedures (SOPs) 20.1 and 20.2.
2. Periodic sampling from existing and new groundwater monitoring wells and sediment pore water sample points.

The Corrective Measures Objectives (CMOs) and Remedial Goals (RGs) were developed in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). The site-specific CMOs for SWMU 54 Area A are to mitigate further leaching of explosives constituents from soil-to-groundwater at levels that would potentially increase observed concentrations and adversely impact future beneficial use of groundwater; and to the extent practicable, a goal of restoring site groundwater to the most beneficial use. The site-specific CMOs for SWMU 54 Area B are to mitigate the potential hypothetical future risks that have been identified for exposure to soil under a future construction worker scenario; and to prevent leaching of contaminants of concern from soil-to-groundwater at levels that would potentially adversely impact future beneficial use of groundwater. The site-specific CMOs for Area A and Area B have been met through the soil excavation and off-site disposal completed in 2010.

The objectives of the MNA program are to:

- Measure and track the reduction of:
  - 2,4,6-trinitrotoluene (2,4,6-TNT), dinitrotoluene (DNT)-mixture, cyclotrimethylenetrinitramine (RDX), and perchlorate to levels below the RGs as defined in **Table 1-1**.

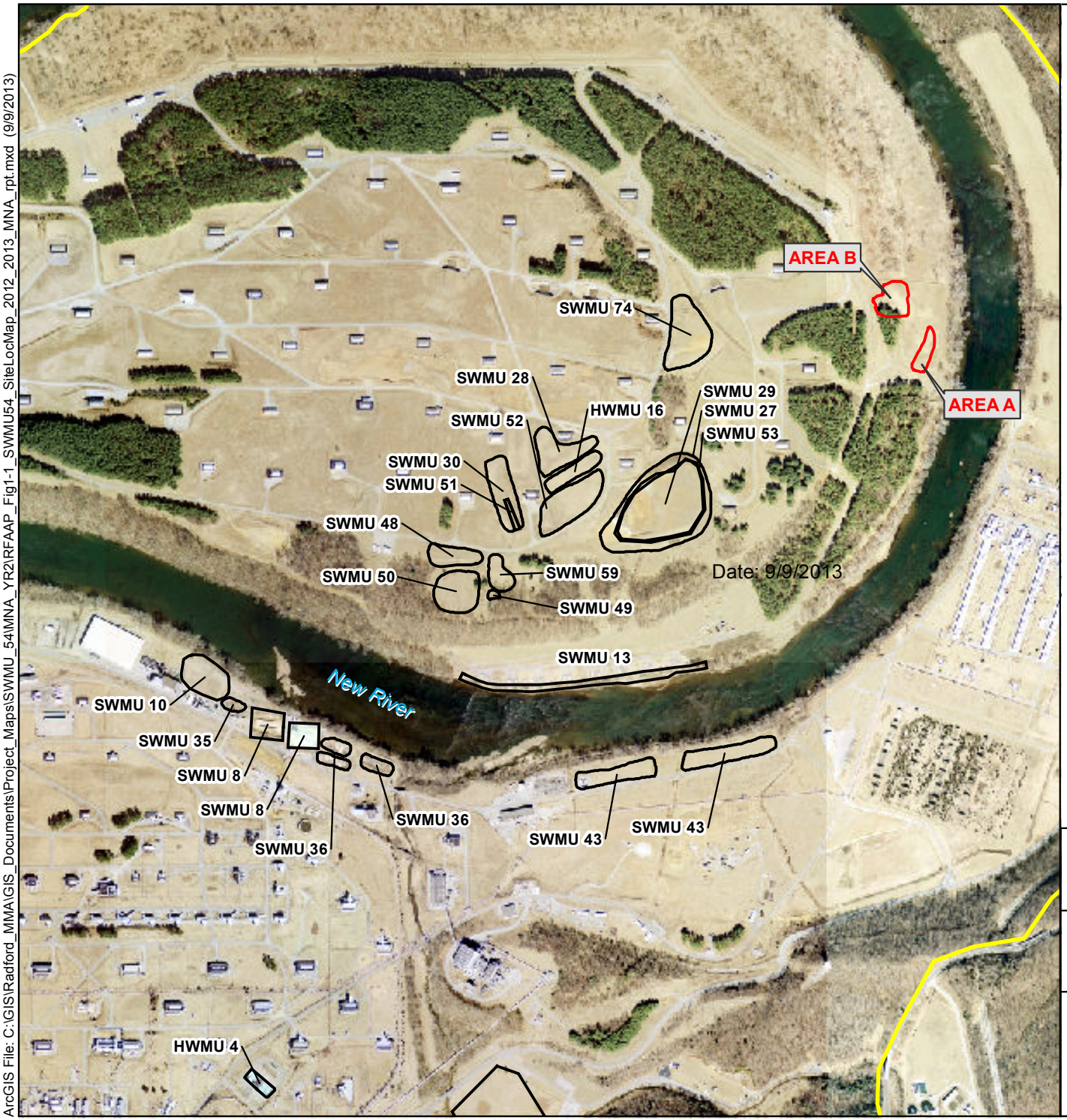
Table 1-1
SWMU 54 Groundwater Remedial Goals

Chemical of Interest	Groundwater RG (mg/L)	Groundwater RG Source(*)
2,4,6-TNT	0.00782	RG
DNT Mixture	0.000932	RG
RDX	0.0061	RG
Perchlorate	0.0109	RG

*RGs were calculated using target risk 1E-5 for the lifetime resident and a target hazard of 1 for the adult and child resident (see URS, 2008).

1.2 Site Description and Background

SWMU 54 is located within the easternmost portion of the Horseshoe Area at RFAAP. SWMU 54 consists of two contiguous disposal areas: Area A is an approximately 0.58-acre triangular shaped area in the southern portion of SWMU 54, and Area B is an approximately 1.09-acre area in the northern portion of SWMU 54 (**Figure 1-1**). SWMU 54 was reportedly used as a disposal area in the late 1970s for ash from propellant burning activities located at the Waste Propellant Burning Grounds. The site is currently undeveloped. The RFAAP Installation security fence is located along the northern and eastern boundaries of SWMU 54.



LEGEND

- SWMU 54 Boundary
- Other SWMU Boundary
- Installation Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

0 500 1,000 2,000 Feet

U.S. Army Corps of Engineers

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

FIGURE 1-1
SWMU 54
Site Location Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig1-1_SWMU54_SiteLocMap_2012_2013_MNA_rpt.mxd (9/9/2013)

2.0 PHYSICAL CHARACTERISTICS

2.1 Topography

As illustrated on **Figure 1-1**, SWMU 54 is situated on a gently sloping terrace ranging from approximately 1,716 to 1,696 feet (ft) mean sea level (msl) from east to west, respectively. The SWMU is positioned within the 100-year floodplain on a terrace feature of the New River. East of the site, the ground surface slopes steeply towards the New River (approximately 1,676 ft msl).

2.2 Surface Water

SWMU 54 is located within the easternmost portion of the Horseshoe Area at RFAAP. The SWMU is located within the floodplain of the New River. Any runoff from the SWMU will flow overland east, into the New River.

2.3 Geology

2.3.1 Regional Geology

SWMU 54 is located in the New River Valley, which crosses the Valley and Ridge Province approximately perpendicular to the regional strike of bedrock, and cross cuts Cambrian and Ordovician limestone or dolostone. Deep clay-rich residuum is prevalent in areas underlain by carbonate rocks. The valley is covered by river floodplain and terrace deposits; karst topography is dominant throughout the area. A more detailed description of the regional geology is presented in the *RFAAP MWP* (URS, 2003).

2.3.2 Site-Specific Geology

Lithologic characterization of the subsurface at SWMU 54 was performed during the advancement of soil borings and monitoring well borings at the site. Two geologic cross-sections were developed based on the logging descriptions recorded during the advancement of the soil borings. A plan view of the cross-sectional lines (Line A-A' and Line B-B') is presented on **Figure 2-1**. The geologic cross-sections are presented on **Figures 2-2 and 2-3**.

Borings advanced at the site ranged from 10 to 60 ft in depth. Depths to bedrock were directly measured at the monitoring well borings. Bedrock elevations ranged from approximately 1,716 to 1,670 ft msl, with the bedrock surface sloping to the east.

Depth to competent bedrock at the site ranges from 17 to 24 ft. A saprolitic layer, formed from *in situ* weathering of the carbonate bedrock, immediately overlies the competent bedrock. The saprolite is up to 2.5 ft in thickness.

The bedrock under the site is the Cambrian-aged Elbrook Formation, which is a thickly-bedded, blue-gray dolostone interspersed with blue-gray to white limestone. It is locally described in nearby well borings as interbedded green and maroon shale and yellowish-brown dolostone and greenish- to grayish-brown limestone and dolostone.

The unconsolidated sediment immediately overlying the saprolite consists of alluvial deposits. Alluvial deposits, consisting primarily of silty sand overly channel deposits of fine- to coarse-grained sand and gravel (river jack). These Paleo-channel deposits rest directly on the saprolite. Portions of the disposal areas contain fill material to depths of 9 to 10 ft below ground surface. A more detailed discussion of the geology and soil at RFAAP is presented in Sections 3.4 through 3.7 of the *RFAAP MWP* (URS, 2003) and in the *Facility-Wide Background Study Report* (IT, 2001).

2.4 Hydrogeology

2.4.1 Regional Hydrogeology

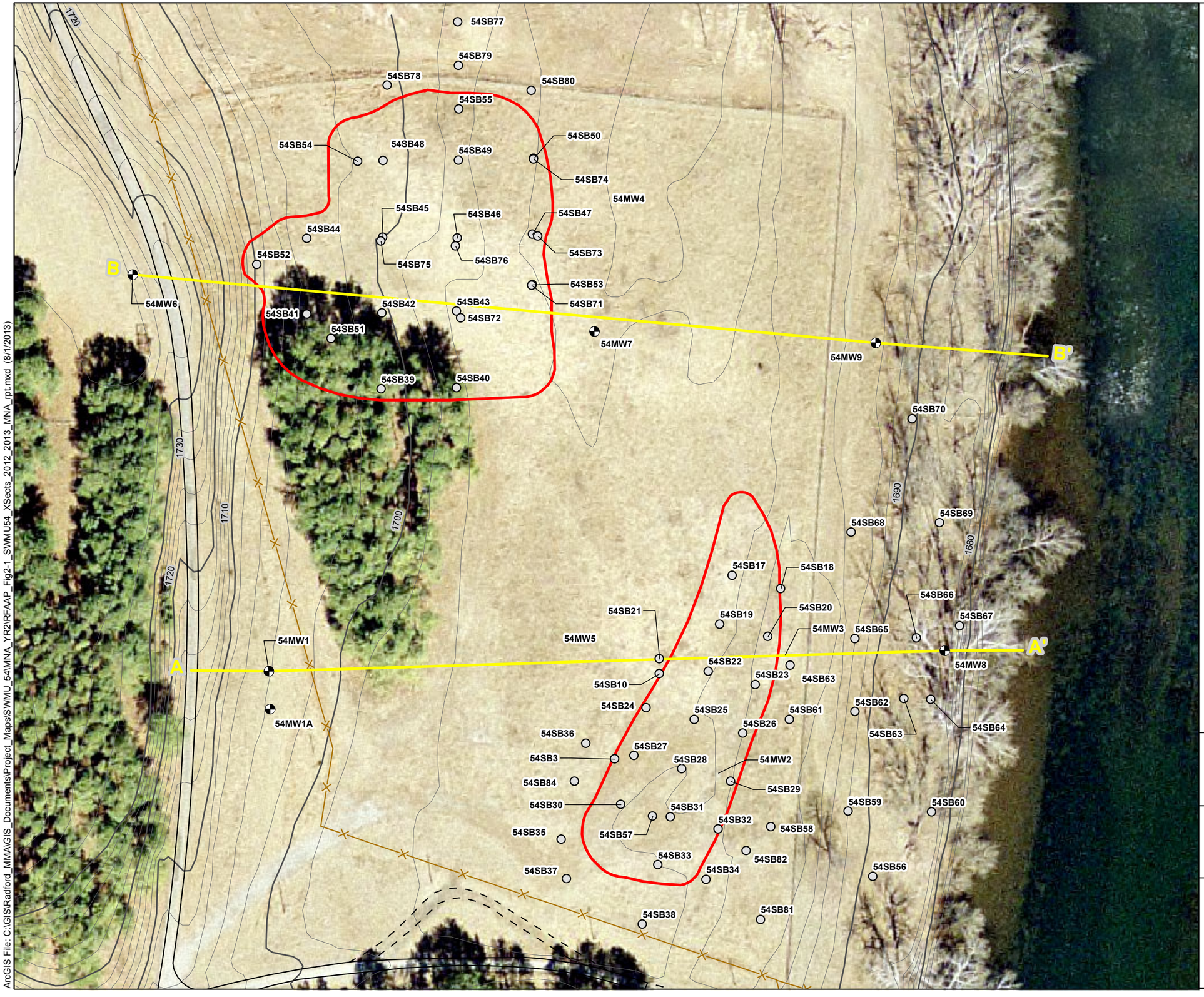
Geologically, the Appalachian Plateaus and Valley and Ridge Province encompass two major tectonic domains: the southern Appalachian Basin and the southeastern part of the Eastern Interior Basin. The hydrogeologic framework is based on generalized stratigraphic succession, with indurated sedimentary rocks of the Paleozoic age forming predominant units.

Groundwater flow paths are typically short, commonly extending no more than several miles in their longest dimension. The largest groundwater supplies are produced from the carbonate rocks, especially where they are associated with thick regolith, an important storage reservoir throughout the entire area. The regolith stores recharge that would be otherwise rapidly diverted to overland flow. It also slowly releases water to underlying carbonate aquifers. Because of the widespread distribution of carbonate rocks and associated regolith, abundant precipitation in a humid climate, and relatively steep hydraulic gradients, this region (and locally) is one of the major karstlands in the eastern United States.

Groundwater supplies in the Valley and Ridge Province are generally good quality compared to surface water supplies (Parsons, 1996). However, due to extended contact with minerals, many groundwater supplies contain higher levels of dissolved solids than the streams into which they discharge. Because of sinkholes and underground caverns in karst aquifers, there is a high potential for groundwater to be impacted by direct infiltration of contaminated surface water.

2.4.2 Site-Specific Hydrogeology

Monitoring wells installed at SWMU 54 were screened in both the shallow, surficial aquifer, and shallow bedrock. Water levels were measured in the wells to calculate the groundwater flow direction at the site. Groundwater contour maps have been prepared using water level data collected prior to each round of groundwater sampling. The maps for the first year of monitoring are presented on **Figures 4-1**, **4-2**, **4-3, and 4-4**. Contour lines shown on the figures represent lines of equal elevation of the water table; consequently, groundwater flow direction is always perpendicular to the contour lines. Groundwater at the site tends to flow east and appears to discharge to the New River along the eastern side of the site.



ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig2-1_SWMU54_XSects_2012_2013_MNA_rpt.mxd (8/1/2013)

LEGEND

- Soil Sample Location
- Monitoring Well
- Cross Section Line
- Dirt Road
- Paved Road
- Railroad
- Fence
- 10 ft Contour Line
- SWMU 54 Boundary
- Other SWMU Boundary

N

Scale:

0 37.5 75 150 Feet

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

U.S. Army Corps of Engineers

Shaw Environmental, Inc.
(A CB&I Company)
4696 Millennium Drive, Suite 320
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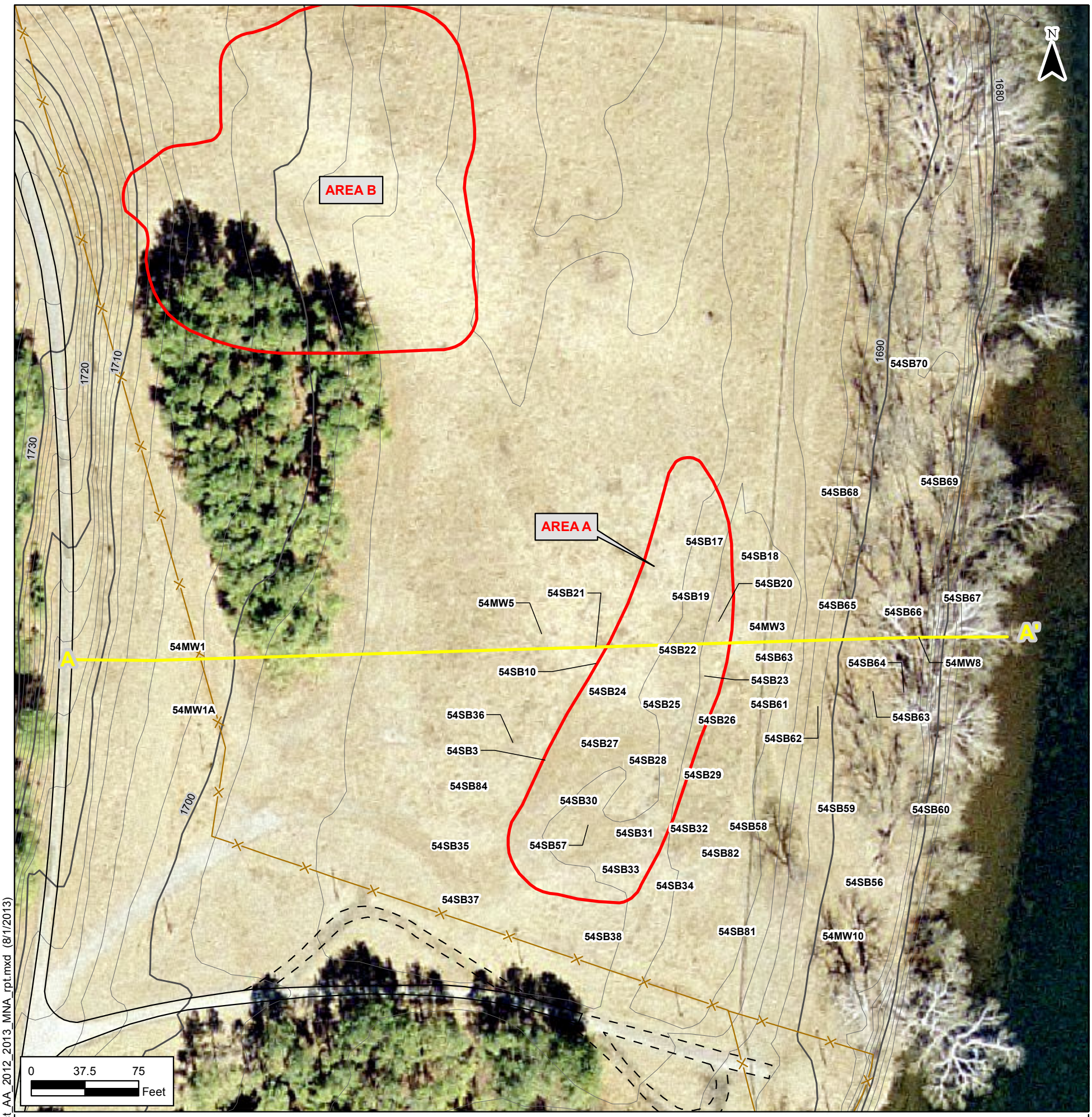
FIGURE 2-1
SWMU 54
Cross Sections
Radford Army Ammunition Plant,
Radford, VA



ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig2-2_SWMU54_XSect_AA_2012_2013_MNA_rpt.mxd (8/1/2013)

LEGEND

- Soil Sample Location
- Monitoring Well
- Dirt Road
- Paved Road
- Railroad
- Fence
- Cross Section Line
- 10 ft Contour Line
- SWMU 54 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Cross section A-A' profile and soil sample locations were obtained from SWMU 54 Final RCRA Facility Investigation/Corrective Measures Study Report, Volume I (September 2008, URS). Distance and elevation units are in feet. Vertical exaggeration = 5.

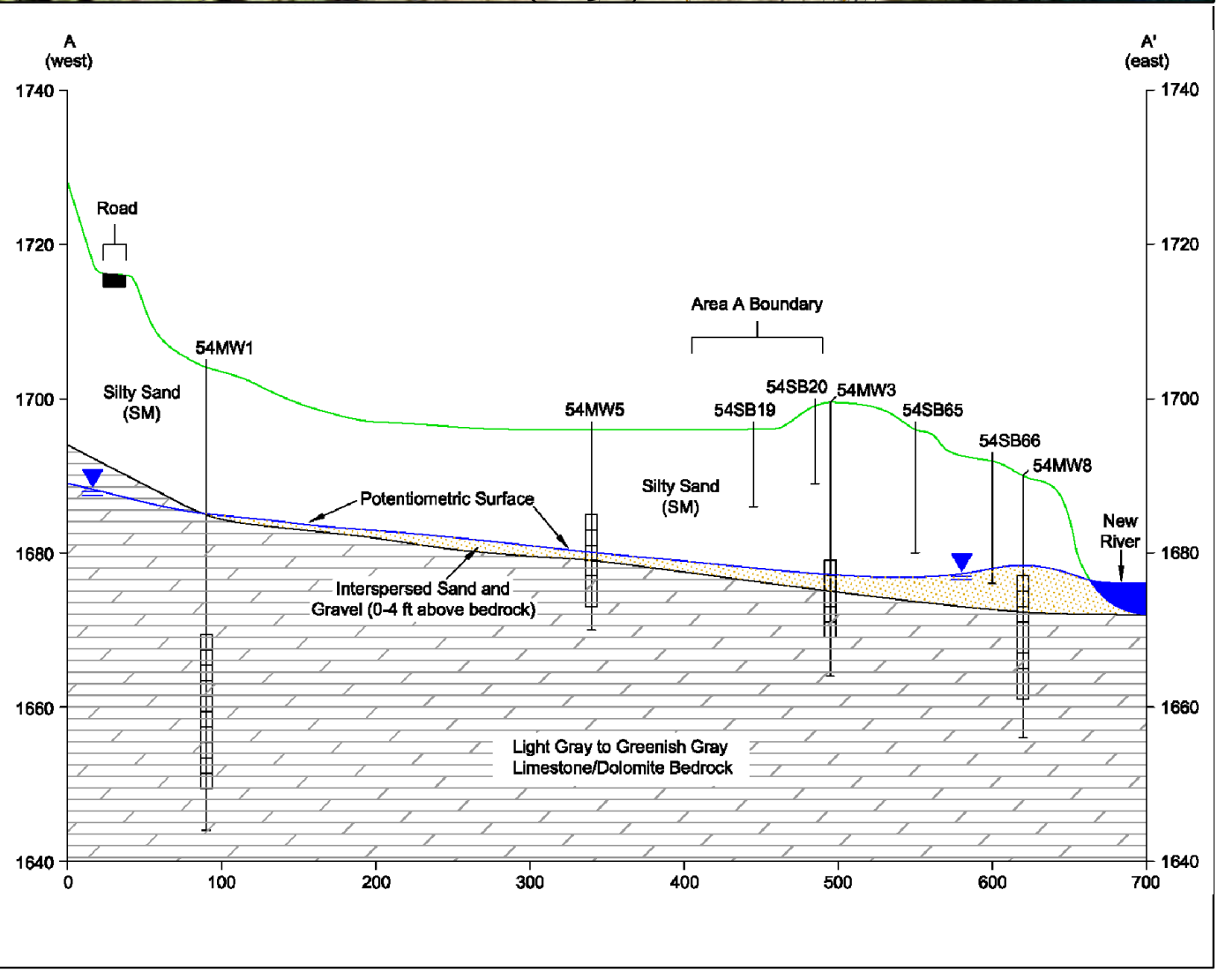


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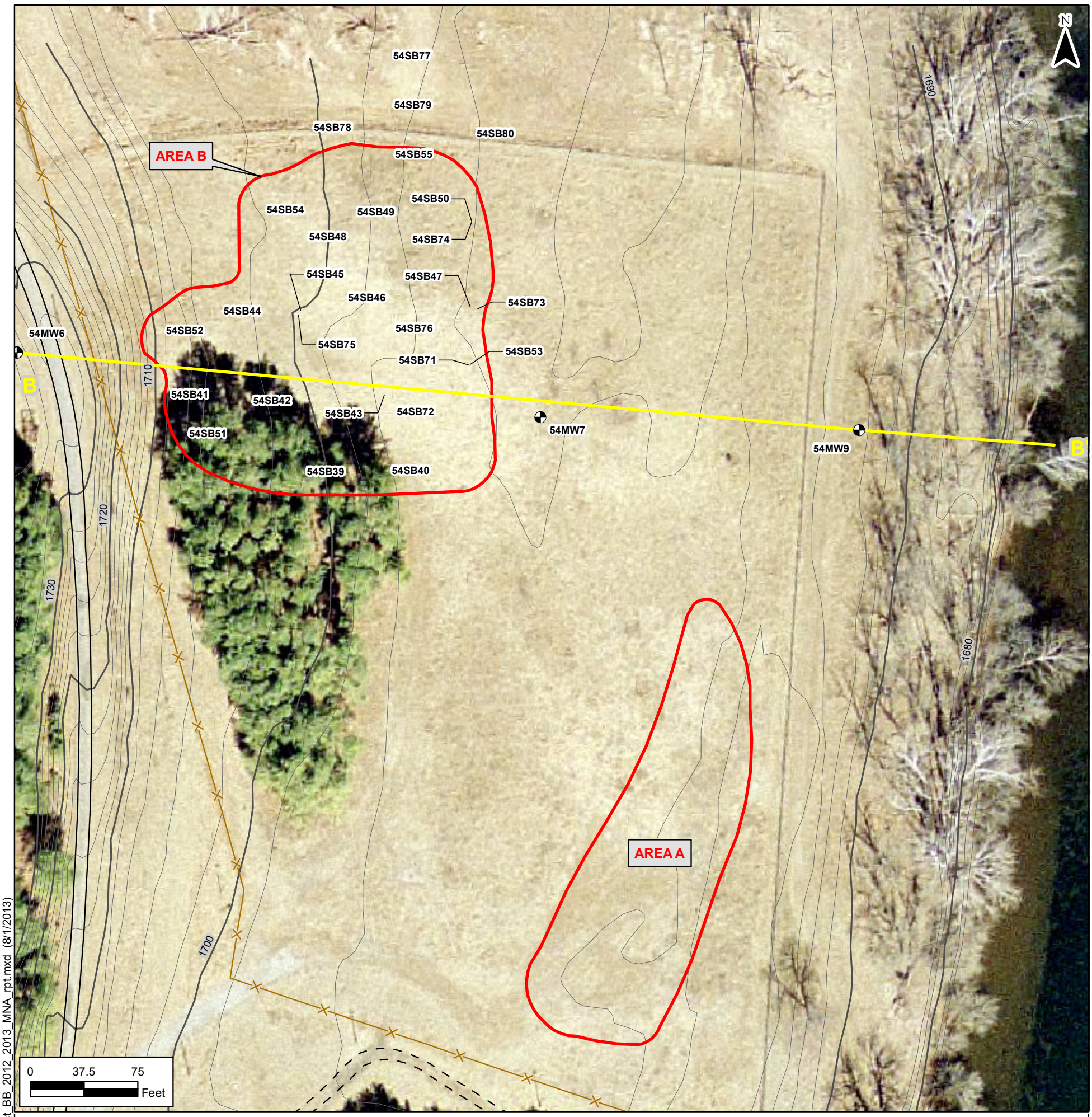
FIGURE 2-2
SWMU 54
Cross Section A-A'
Radford Army Ammunition Plant,
Radford, VA



LEGEND

- Soil Sample Location
- Monitoring Well
- Cross Section Line
- Dirt Road
- Paved Road
- Railroad
- 10 ft Contour Line
- Fence
- SWMU 54 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Cross section B-B' profile and soil sample locations were obtained from SWMU 54 Final RCRA Facility Investigation/Corrective Measures Study Report, Volume I (September 2008, URS). Distance and elevation units are in feet. Vertical exageration = 5.

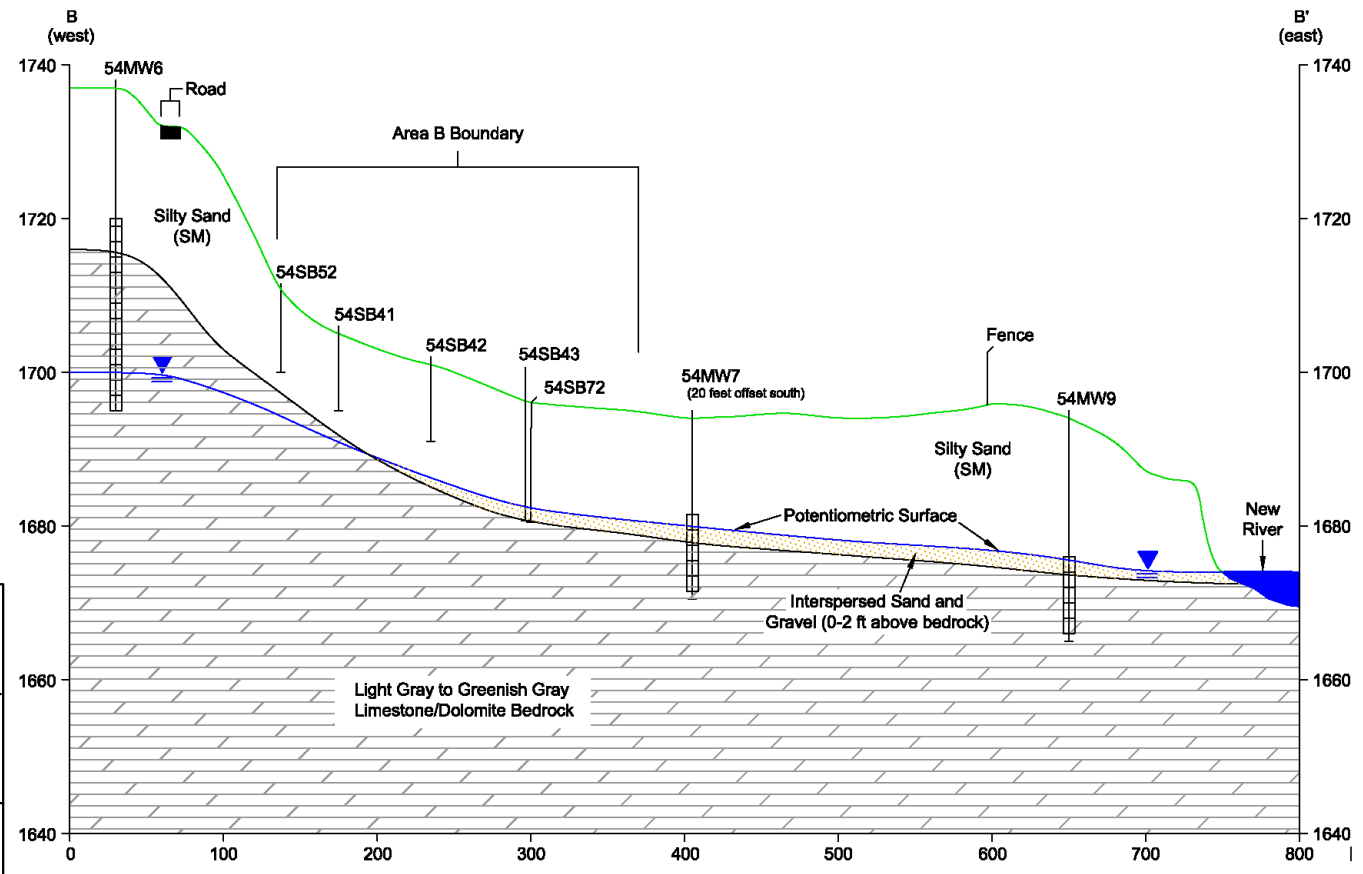


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FIGURE 2-3
SWMU 54
Cross Section B-B'
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig2-3_SWMU54_XSect_BB_2012_2013_MNA_rpt.mxd (8/1/2013)

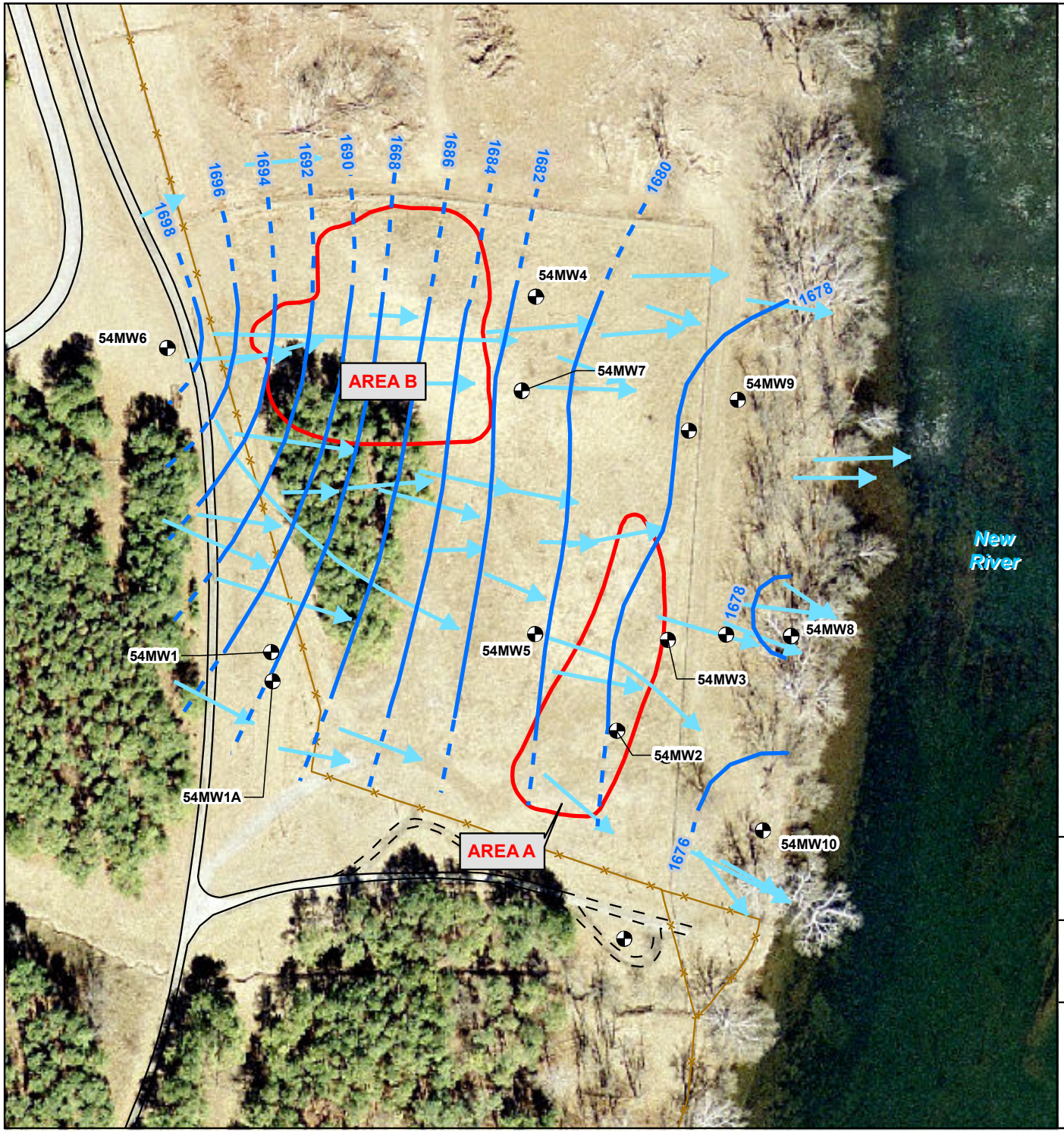
3.0 PREVIOUS INVESTIGATIONS

Four previous investigations have been conducted at this site prior to completion of an interim removal measure in 1999 by Parallax, Inc. Data obtained from previous site investigations prior to the IM were used to identify site boundaries and characteristics, and identify chemicals of potential concern (COPCs). In 1992, the Environmental Photographic Interpretation Center provided aerial photographic analysis of SWMU 54, under the direction of the U.S. Environmental Protection Agency (USEPA). Also in 1992, under authority of the 1984 Hazardous and Solid Waste Amendments, Dames & Moore conducted a RCRA Verification Investigation (VI) at the site to identify the ash disposal at Area A. As a follow-up to the 1992 VI, Parsons completed an RFI in 1996, as part of a multiple site investigation to "define the extent of ash and the limits of soil contamination." In 1998, a Supplemental RFI/CMS was conducted to investigate a flat grassy area ringed by mature pine trees northwest of Area A. This area was defined as Area B within SWMU 54. The purpose of the supplemental RFI was to "characterize the nature and extent of contamination within SWMU 54." In 1999, Parallax, Inc. completed IMs at Area A and Area B of SWMU 54 consisting of excavation of selected "hot spot" areas of lead and explosives in soil.

In 2008, URS Corporation (URS) conducted an RFI/CMS investigating both Area A and Area B to confirm the effectiveness of the IM as well as evaluate and assess current conditions at the sites and provide recommendations regarding potential corrective measure requirements at the sites. Direct push soil borings with chemical sampling were used to: characterize the nature and extent of constituents in soil at SWMU 54, identify the lateral and vertical extent of any waste material present, and characterize soil lithology and depth to groundwater and bedrock. Additionally, monitoring wells were installed at the site and groundwater samples were collected and analyzed. Details of these investigations are described in Section 3.0 (Field Investigation Program) of the *Final SWMU 54 RFI/CMS Report* (URS, 2008). A potentiometric map, portraying the most recent groundwater levels is provided as **Figure 3-1**. Historical data listing constituent concentrations in the existing wells on site can be found in **Tables 3-1 through 3-6**.

The nature and extent assessment indicated that the main concern at the site is the fill material and grossly-contaminated soil directly below the material. Areas A and B were evaluated separately for the soil and groundwater nature and extent assessments given the 200-ft separation between the areas, their topographic cross-gradient position, the lack of mobility of the chemicals in soil, and observed distributions of chemicals.

The main parameters of concern in Area A soil are lead, 2,4,6-TNT, DNT, RDX, amino DNTs, nitroglycerin (NG), heptachlor epoxide, and dioxins/furans. The main parameters of concern in groundwater at Area A are explosives and perchlorate. Concentrations of 2,4,6-TNT, DNT, amino DNT, RDX, and perchlorate in groundwater have decreased since RFI monitoring began in 2003 and 2004. The lateral extent of explosives and perchlorate in groundwater extends from Area A eastward to the New River. Sampling of the groundwater/surface water interface (sediment pore water) and surface water of the New River did not indicate detectable impacts to sediment pore water or surface water from COPCs in groundwater.



LEGEND

- Monitoring Well Location
- Groundwater Contour
- Inferred Groundwater Contour
- Groundwater Flow Direction
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

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FIGURE 3-1
SWMU 54
June 5, 2007 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig3-1_SWMU54_2007_GW_Contours_2012_2013_MNA_rpt.mxd (8/1/2013)

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
Page 1 of 5

Sample ID / Sample Date	CAS	C/N	RG	Units	54DPW1 12/11/2002		MDL	RL	54DPW2 12/11/2002		MDL	RL	54DPW3 12/11/2002		MDL	RL	54GP77 10/13/2004		MDL	RL	54GP78 10/11/2004		MDL	RL	54GP78-DUP(DUP-1) 10/11/2004		MDL	RL	54GP79 10/11/2004		MDL	RL
					Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	<7.2	U,R,I	0.73	7.2	1.5	JB,B,z	0.33	3.3	<2.1	U,R,I	0.21	2.1	NT				NT				NT				NT			
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	<7.2	U,R,I	1	7.2	<3.3	U,R,I	0.48	3.3	<2.1	U,R,I	0.31	2.1	NT				NT				NT				NT			
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	5.5		0.54	1	27.7		0.54	1	2		0.54	1	3.5		0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
Page 2 of 5

Sample ID / Sample Date	CAS	C/N	RG	Units	54GP80 10/13/2004		MDL	RL	54GP81 10/11/2004		MDL	RL	54GP82 10/11/2004		MDL	RL	54GP83 10/11/2004		MDL	RL	54GP84 10/13/2004		MDL	RL	54GP85 10/14/2004		MDL	RL	54GP86 10/13/2004		MDL	RL
					Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	NT				NT				NT				NT				NT				NT				NT			
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	NT				NT				NT				NT				NT				NT				NT			
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	<1	U	0.1	1	1		0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
Page 3 of 5

Sample ID / Sample Date	CAS	C/N	RG	Units	54GP87 10/14/2004		MDL	RL	54GW56 8/18/2004		MDL	RL	54GW57 8/17/2004		MDL	RL	54GW58 8/24/2004		MDL	RL	54GW59 8/18/2004		MDL	RL	54GW59-DUP(DUP-3) 8/18/2004		MDL	RL	54GW60 8/24/2004		MDL	RL
					Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	NT				160		0.15	1.3	1.7	,J,g	0.0749	0.65	15		0.0749	0.65	4.2	,L,f	0.0749	0.65	11	,J,g	0.0749	0.65	9.3		0.0749	0.65
DNT mixture*			**0.932**		ND				ND				ND	U			ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	NT				35	,J,g	0.164	0.65	0.69		0.164	0.65	3.7		0.164	0.65	1		0.164	0.65	1.7		0.164	0.65	0.8		0.164	0.65
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	<1	U	0.1	1	13.5		0.1	1	2		0.1	1	25.8		0.1	1	4		0.1	1	3.6		0.1	1	1.7		0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
Page 4 of 5

Sample ID / Sample Date	CAS	C/N	RG	Units	54GW61 8/24/2004		MDL	RL	54GW62 8/23/2004		MDL	RL	54GW63 8/23/2004		MDL	RL	54GW64 8/23/2004		MDL	RL	54GW64-DUP(DUP-9) 8/23/2004		MDL	RL	54GW65 8/20/2004		MDL	RL	54GW66 8/20/2004		MDL	RL
					Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	74		0.0749	0.65	9		0.0749	0.65	<0.65	U	0.0749	0.65	0.82	,J,g	0.0749	0.65	0.76	,J,g	0.0749	0.65	3		0.0749	0.65	NT			
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	<0.65	U	0.164	0.65	1.6		0.164	0.65	<0.65	U	0.164	0.65	0.75	,J,g	0.164	0.65	0.73	,J,g	0.164	0.65	0.7		0.164	0.65	NT			
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	3		0.1	1	5.3		0.1	1	<1	U	0.1	1	1.1		0.1	1	0.97	B	0.1	1	1.7		0.1	1	0.94	B,J,m	0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
Page 5 of 5

Sample ID / Sample Date	CAS	C/N	RG	Units	54GW66 8/23/2004		MDL	RL	54GW67 8/20/2004		MDL	RL	54GW67 8/23/2004		MDL	RL	54GW68 8/20/2004		MDL	RL	54GW69 8/20/2004		MDL	RL	54GW69 8/23/2004		MDL	RL	54GW70 8/20/2004		MDL	RL
					Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	<0.65	U	0.0749	0.65	NT				<0.65	U	0.0749	0.65	2.6	,J,g	0.0749	0.65	NT				1.4		0.0749	0.65	<0.65	U	0.0749	0.65
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	<0.65	U	0.164	0.65	NT				<0.65	U	0.164	0.65	<0.65	U	0.164	0.65	NT				0.51	J	0.164	0.65	<0.65	U	0.164	0.65
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	NT				0.59	B,J,m	0.1	1	NT				<1	U	0.1	1	0.65	B,J,m	0.1	1	NT				0.76	B	0.1	1

Notes:
µg/L = Microgram Per Liter
TAL = Target Analyte List
TCL = Target Compound List
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
NI = Not Identified
NT = Not Tested
ND = Not Detected
*The results of 2,4-DNT and 2,6-DNT were added together to get the DNT mixture result.

C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)

=Exceeds RG

Data Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blanks.
E = Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis. For TICs, compound not present in calibration standard, calculated using total peak areas ion chromatographs and response factor of 1.
J = Analyte present. Reported value may not be accurate or precise.
L = Analyte present. Reported value may be biased low. Actual value is expected to be higher.
N = Sample spike recovery is outside of control limits.
P = Greater than 40% difference for detected concentrations between the two GC or HPLC columns.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
UL = Not detected, quantitation limit is probably higher.
g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.
o = Calibration blank contamination.
p = Preparation blank contamination.
s = Serial dilution failure.
w = Field and/or equipment blank contamination.
x = Trip blank contamination.
z = Method blank and/or storage blank contamination.

Table 3-2
2003-2004 Area A Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Sample ID / Sample Date	CAS	C/N	RG	Units	54MW2 3/4/2003		MDL	RL	54MW3 3/4/2003		MDL	RL	54MW5 3/4/2003		MDL	RL	54MW-8 12/21/2004		MDL	RL	54MW-9 12/21/2004		MDL	RL	54MW-10 12/21/2004		MDL	RL	54MW10-DUP(DUP-1) 12/21/2004		MDL	RL
					Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	<3.6	U	0.365	3.6	38		0.365	3.6	<4.2	U	0.43	4.2	<0.65	U	0.0749	0.65	<0.65	U	0.0749	0.65	62		0.15	1.3	65		0.15	1.3
DNT mix*			**0.932**	ug/L	ND				ND				ND				ND				ND				ND				ND			
RDX (Hexahydro-1,3,5-trinitro-1,3,5-tria	121-82-4	C	**6.1**	ug/L	<3.6	U	0.526	3.6	32		0.526	3.6	<4.2	U	0.61	4.2	0.2	J,J,g	0.164	0.65	1.1	,J,g	0.164	0.65	28		0.164	0.65	29		0.164	0.65
Perchlorate																																
Perchlorate	14797-73-0	N	**10.90**	ug/L	12		0.54	1	59.2		0.54	1	1.6		0.54	1	0.22	B	0.1	1	0.21	B	0.1	1	9.8		0.1	1	9.1		0.1	1
Field Parameters																																
Dissolved Oxygen	--	--	--	mg/L	6.97				5.18				2.88				0.25				2.56				1.25				1.25			
Oxidation Reduction Potential	--	--	--	mV	159.5				119.0				95.1				215				234				208				208			
pH	--	--	--	SU	6.37				6.65				7.00				7.20				7.53				7.06				7.06			
Conductivity	--	--	--	mS	0.191				0.341				0.310				0.627				0.706				0.760				0.760			
Temperature	--	--	--	°C	16.24				15.97				12.91				13.6				13.2				13.8				13.8			
Turbidity	--	--	--	NTU	0.80				1.93				12.0				4.17				4.13				3.52				3.52			

*DNT mixture result is the result of the adding together of 2,4-DNT and 2,6-DNT.

Notes:

CAS = Chemical Abstracts Service
µg/L = Microgram Per Liter
TAL = Target Analyte List
TCL = Target Compound List
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
ND = Not Detected
NT = Not Tested
mV = millivolt

SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
MCL = Maximum Contaminant Level

= detected above Remedial Goal (RG)

Data Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blanks.
E = Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis. For TICs, compound not present in calibration standard, calculated using total peak areas ion chromatographs and response factor of 1.
J = Analyte present. Reported value may not be accurate or precise.
L = Analyte present. Reported value may be biased low. Actual value is expected to be higher.
N = Sample spike recovery is outside of control limits.
P = Greater than 40% difference for detected concentrations between the two GC or HPLC columns.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
UL = Not detected, quantitation limit is probably higher.

g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.
o = Calibration blank contamination.
p = Preparation blank contamination.
s = Serial dilution failure.
w = Field and/or equipment blank contamination.
x = Trip blank contamination.
z = Method blank and/or storage blank contamination.

Table 3-3
2006-2007 Area A Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

First Quarter - November/December 2006

Sample ID / Sample Date	CAS	C/N	RG	54MW1 11/29/2006		MDL	RL	54MW2 11/29/2006		MDL	RL	54MW3 12/5/2006		MDL	RL	54MW5 11/29/2006		MDL	RL	54MW8 12/1/2006		MDL	RL	54MW9 12/1/2006		MDL	RL	54MW10 12/1/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.075	5	5.6		0.075	5	0.85	J	0.075	5	0.29	J	0.075	5	<5	U	0.075	5	<5	U	0.075	5	2.1	J	0.075	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	3.3	J	0.16	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	11.95				10.29				11.94				10.1				8.94				8.51				8.13			
Oxidation Reduction Potential (mV)	--	--	--	153				159				171				231				32				53				36			
pH (SU)	--	--	--	7.86				7.15				7.26				7.2				7.53				7.65				7.39			
Conductivity (mS)	--	--	--	0.44				0.533				0.580				0.557				0.605				0.790				0.733			
Temperature (°C)	--	--	--	18.6				17.7				18.3				18.5				17.1				19.1				16.3			
Turbidity (NTU)	--	--	--	4.47				1.16				0.07				16.6				11.83				23.5				10.31			

Second Quarter - March 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-1 3/28/2007		MDL	RL	54MW-2 3/28/2007		MDL	RL	54MW-3 3/28/2007		MDL	RL	54MW-5 3/28/2007		MDL	RL	54MW-8 3/27/2007		MDL	RL	54MW-9 3/27/2007		MDL	RL	54MW10 DUP AVG 3/27/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	0.25	J,J,d	0.1	5	<5	U	0.1	5	0.84	J,J,g	0.1	5	14		0.1	5	<5	U	0.1	5	6.018		0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				1.146				<5				<5				<5				<5				0.898			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	8.1		0.092	5	<5	U	0.092	5	3.87		0.092	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.036	0.2	3.6		0.036	0.2	<0.2	U	0.036	0.2	0.52		0.036	0.2	0.26		0.036	0.2	0.24		0.036	0.2	2.9		0.036	0.2
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	8.06				7.75				6.12				8.38				6.68				6.51				8			
Oxidation Reduction Potential (mV)	--	--	--	-5				44				-11				53				-17				-10				11			
pH (SU)	--	--	--	7.63				6.45				6.94				6.51				7.05				7.18				6.88			
Conductivity (mS)	--	--	--	0.199				0.183				0.311				0.167				0.267				0.960				0.334			
Temperature (°C)	--	--	--	13.44				15.8				15.22				12.73				13.92				14.43				15.95			
Turbidity (NTU)	--	--	--	1.82				0.37				2.13				1.22				13.96				7.71				3.64			

Table 3-3
2006-2007 Area A Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Third Quarter - June 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-1 6/5/2007		MDL	RL	54MW-2 6/5/2007		MDL	RL	54MW-3 6/5/2007		MDL	RL	54MW-5 6/5/2007		MDL	RL	54MW-8 6/5/2007		MDL	RL	54MW-9 6/5/2007		MDL	RL	54MW-10 6/5/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	3.9	J	0.1	5	1	J	0.1	5	0.49	J	0.1	5	<5	U	0.1	5	<5	U	0.1	5	2.4	J	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	ND				ND				ND				ND				ND				0.466				ND			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	6.3		0.092	5	<5	U	0.092	5	1.6	J	0.092	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	2		0.08	0.2	0.88		0.08	0.2	0.58		0.08	0.2	0.7		0.08	0.2	0.23		0.08	0.2	0.37		0.08	0.2
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	7.57				8.46				5.06				8.44				8.82				5.21				7.35			
Oxidation Reduction Potential (mV)	--	--	--	297				268				109				236				285				94				187			
pH (SU)	--	--	--	7.33				6.78				6.2				6.24				6.9				6.25				6.87			
Conductivity (mS)	--	--	--	0.192				0.225				0.003				0.163				0.245				0.003				0.353			
Temperature (°C)	--	--	--	13.58				13.48				15.66				21.68				13.4				15.44				14.51			
Turbidity (NTU)	--	--	--	0.48				0.29				0.36				0.67				0.06				1.67				9.37			

Fourth Quarter - September 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-1 9/19/2007		MDL	RL	54MW-2 9/19/2007		MDL	RL	54MW-3 9/19/2007		MDL	RL	54MW-5 9/19/2007		MDL	RL	54MW-8 9/18/2007		MDL	RL	54MW-9 9/18/2007		MDL	RL	54MW-10 9/18/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	0.78	J	0.1	5	1.2	J	0.1	5	0.38	J,J,g	0.1	5	<5	U	0.1	5	<5	U	0.1	5	17		0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	ND				ND				ND				ND				ND				ND				0.696			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	8		0.092	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	0.57		0.08	0.2	0.31		0.08	0.2	0.34		0.08	0.2	0.37		0.08	0.2	<0.2	U	0.08	0.2	2.9		0.08	0.2
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	4.03				2.37				6.34				5.53				4.06				3.78				3.89			
Oxidation Reduction Potential (mV)	--	--	--	233				172				205				228				288				237				239			
pH (SU)	--	--	--	8.2				7.01				5.67				6.89				6.82				7.11				6.76			
Conductivity (mS)	--	--	--	0.487				0.637				0.57				0.647				0.711				0.833				0.844			
Temperature (°C)	--	--	--	19.79				15.91				15.6				17.36				14.41				18.05				17.27			
Turbidity (NTU)	--	--	--	0.79				2.19				2.02				1.62				0.43				2.19				7.19			

Notes:

CAS = Chemical Abstracts Service
ug/L = Microgram Per Liter
ng/L = Nanograms Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

ND = Not Detected
NT = Not Tested
mV = millivolt
SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
MCL = Maximum Contaminant Level

=Exceeds RG

Data Qualifiers:
J = Analyte present. Reported value may not be accurate or precise.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
c = Calibration failure.
d = MS/MSD or LCS/LCSD RPD imprecision.
g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.

Table 3-4
2003 Area B Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Sample ID			54MW4				54MW6				54MW7				54MW7-DUP(GW-DUP-1)			
Sample Date			3/4/2003		MDL	RL	3/3/2003		MDL	RL	3/4/2003		MDL	RL	3/4/2003		MDL	RL
	RG	Units	Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Perchlorate																		
Perchlorate[1]	**10.9**	µg/L	<1	U	0.54	1	<1	U	0.54	1	<1	U	0.54	1	<1	U	0.54	1
Explosives																		
2,4,6-Trinitrotoluene	**7.82**	µg/L	<5.4	U	0.55	5.4	<4.2	U	0.43	4.2	<3.6	U	0.365	3.6	<4.8	U	0.487	4.8
DNT Mixture	**0.932**	ug/L	ND				ND				ND				ND			
RDX (Hexahydro-1,3,5-trinitro-1,3,5-tria	**6.1**	µg/L	<5.4	U	0.79	5.4	<4.2	U	0.61	4.2	<3.6	U	0.526	3.6	<4.8	U	0.701	4.8

Notes:
CAS = Chemical Abstracts Service
µg/L = Microgram Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
ND = Not Detected

mV = millivolt
SU = Standard Units
mS = miliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

=Exceeds RG

Data Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blanks.
E = Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis. For TICs, compound not present in calibration standard, calculated using total peak areas ion chromatographs and response factor of 1.
J = Analyte present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
L = Analyte present. Reported value may be biased low. Actual value is expected to be higher.
N = Sample spike recovery is outside of control limits.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
UL = Not detected, quantitation limit is probably higher.
g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.
o = Calibration blank contamination.
p = Preparation blank contamination.
s = Serial dilution failure.
w = Field and/or equipment blank contamination.
x = Trip blank contamination.
z = Method blank and/or storage blank contamination.

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

First Quarter - November/December 2006

Sample ID / Sample Date	CAS	C/N	Adjusted Tap Water RBC	54MW4 11/30/2006		MDL	RL	54MW6 11/29/2006		MDL	RL	54MW7 12/5/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	9.9				11.63				10.46			
Oxidation Reduction Potential (mV)	--	--	--	-92				181				170			
pH (SU)	--	--	--	7.77				8				7.56			
Conductivity (mS)	--	--	--	1.13				0.297				0.729			
Temperature (°C)	--	--	--	15				16.6				15.9			
Turbidity (NTU)	--	--	--	2.66				4.87				5.91			

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Second Quarter - March 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-4 3/27/2007		MDL	RL	54MW-6 3/27/2007		MDL	RL	54MW-7 3/27/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	<5	U	0.1	5	<5	U	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.036	0.2	<0.2	U	0.036	0.2	<0.2	U	0.036	0.2
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	5.97				8.8				6			
Oxidation Reduction Potential (mV)	--	--	--	-95				135				-44			
pH (SU)	--	--	--	7.16				8.21				7			
Conductivity (mS)	--	--	--	1.11				0.314				0.323			
Temperature (°C)	--	--	--	15.68				17.77				14.25			
Turbidity (NTU)	--	--	--	1.54				31.1				6.59			

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Third Quarter - June 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW4 DUP AVG 6/5/2007		MDL	RL	54MW-6 6/5/2007		MDL	RL	54MW-7 6/5/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	<5	U	0.1	5	<5	U	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	<0.2	U	0.08	0.2	<0.2	U	0.08	0.2
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	5.15				4.5				7.72			
Oxidation Reduction Potential (mV)	--	--	--	91				76				225			
pH (SU)	--	--	--	6.39				6.03				6.97			
Conductivity (mS)	--	--	--	0.003				0.003				0.302			
Temperature (°C)	--	--	--	14.54				19.28				3.03			
Turbidity (NTU)	--	--	--	0.67				9.96				0.71			

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Fourth Quarter - September 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW4 9/19/2007		MDL	RL	54MW6 9/19/2007		MDL	RL	54MW7 DUP AVG 9/19/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	<5	U	0.1	5	<5	U	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	ND				ND				ND			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	0.1	J	0.08	0.2	<0.2	U	0.08	0.2
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	4.03				7.47				4.56			
Oxidation Reduction Potential (mV)	--	--	--	-1				236				266			
pH (SU)	--	--	--	7.91				8.13				6.97			
Conductivity (mS)	--	--	--	1.1				0.267				0.766			
Temperature (°C)	--	--	--	16.08				16.69				16.83			
Turbidity (NTU)	--	--	--	0.43				4.37				0.39			

Notes:

CAS = Chemical Abstracts Service
ug/L = Microgram Per Liter
ng/L = Nanogram Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
ND = Not Detected

mV = millivolt
SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

=Exceeds RG

C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)

Data Qualifiers:
J = Analyte present. Reported value may not be accurate or precise.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.

See Table 6-3D (December 2006) and Table 6-3E (June 2007) for Total 2,3,7,8-TCDD TEQ Calculations

Table 3-6
2006 New River Surface Water and Sediment Pore Water Sample Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Surface Water

Sample ID / Sample Date	CAS	C/N	RG	NR-SW-1 11/30/2006		MDL	RL	NR-SW-2 11/30/2006		MDL	RL	NR-SW-3 11/30/2006		MDL	RL	NR-SW-4 11/30/2006		MDL	RL	NR-SW-5 11/30/2006		MDL	RL	NR-SW-6 11/30/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																											
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																											
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																											
Dissolved Oxygen (mg/L)	--	--	--	17.05				15.83				14.64				12.93				14.83				15.11			
Oxidation Reduction Potential (mV)	--	--	--	219				118				47				53				32				35			
pH (SU)	--	--	--	8.9				8.1				7.96				7.81				7.67				8.3			
Conductivity (mS)	--	--	--	0.116				0.113				0.118				0.174				0.117				0.155			
Temperature (°C)	--	--	--	10.1				9.9				10.1				10.3				10.2				10.4			
Turbidity (NTU)	--	--	--	71.3				13.7				17.48				9.94				7.66				6.21			

Pore Water

Sample ID / Sample Date	CAS	C/N	RG	NR-PW-1 11/30/2006		MDL	RL	NR-PW-2 11/30/2006		MDL	RL	NR-PW-3 11/30/2006		MDL	RL	NR-PW-4 11/30/2006		MDL	RL	NR-PW-5 11/30/2006		MDL	RL	NR-PW-6 11/30/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																											
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																											
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																											
Dissolved Oxygen (mg/L)	--	--	--	10.38				10.46				12.2				9.35				10.82				11.34			
Oxidation Reduction Potential (mV)	--	--	--	-109				-174				20				-182				-44				-58			
pH (SU)	--	--	--	7.33				7.21				7.47				7.57				7.44				7.2			
Conductivity (mS)	--	--	--	0.307				0.344				0.248				0.38				0.553				0.353			
Temperature (°C)	--	--	--	12.8				10.7				10.8				10.6				13.2				11.9			
Turbidity (NTU)	--	--	--	16.35				37.9				22.7				4.86				3.63				11.85			

Table 3-6
2006 New River Surface Water and Sediment Pore Water Sample Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Surface Water

Sample ID / Sample Date	CAS	C/N	RG	NR-SW-7 12/1/2006		MDL	RL	NR-SW-8 12/1/2006		MDL	RL	NR-SW-8-DUP(DUP-4) 12/1/2006		MDL	RL	NR-SW-9 12/1/2006		MDL	RL	NR-SW-10 12/1/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																							
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																							
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																							
Dissolved Oxygen (mg/L)	--	--	--	13.13				13.27				13.27				13.76				14.69			
Oxidation Reduction Potential (mV)	--	--	--	10				41				41				51				52			
pH (SU)	--	--	--	8.11				7.8				7.8				7.62				7.83			
Conductivity (mS)	--	--	--	0.140				0.124				0.124				0.131				0.114			
Temperature (°C)	--	--	--	11.7				12.5				12.5				11.8				11			
Turbidity (NTU)	--	--	--	148				13.8				13.8				20.5				11.46			

Pore Water

Sample ID / Sample Date	CAS	C/N	RG	NR-PW-6-DUP(DUP-3) 11/30/2006		MDL	RL	NR-PW-7 12/1/2006		MDL	RL	NR-PW-8 12/1/2006		MDL	RL	NR-PW-9 12/1/2006		MDL	RL	NR-PW-10 12/1/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)																							
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																							
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																							
Dissolved Oxygen (mg/L)	--	--	--	11.34				9.25				9.74				10.55				10.18			
Oxidation Reduction Potential (mV)	--	--	--	-58				-194				-173				-173				-157			
pH (SU)	--	--	--	7.2				7.54				7.36				7.23				7.47			
Conductivity (mS)	--	--	--	0.353				0.517				0.660				0.533				0.479			
Temperature (°C)	--	--	--	11.9				13				12.9				13.2				13.1			
Turbidity (NTU)	--	--	--	11.85				3.72				5.6				15.87				1.66			

Notes:

CAS = Chemical Abstracts Service
mg/L = Milligram Per Liter
ug/L = Microgram Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

mV = millivolt
SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

*DNT mixture results are obtained by adding together the results of 2,4-DNT and 2,6-

RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
BTAG = Biological Technical Assistance Group Water - BTAG Freshwater Screening Values, 2006a

=Exceeds Remedial Goal (RG)

Data Qualifiers:
J = Analyte present. Reported value may not be accurate or precise
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.

Parameters of concern in Area B soils include lead, DNT, amino DNT, NG, RDX, dieldrin, Aroclor 1254, heptachlor epoxide, and dioxins/furans. No contaminants of interest (COIs) were identified for Area B Groundwater.

The Human Health Risk Assessment (HHRA) identified eight COIs at Area A (2,4,6-TNT, DNT, RDX, perchlorate, amino DNTs, NG, heptachlor epoxide, and 2,3,7,8-TCDD) and ten COIs at Area B (2,4,6-TNT, DNT, RDX, amino DNTs, NG, lead, Aroclor 1254, heptachlor epoxide, dieldrin, and 2,3,7,8-TCDD) under both an industrial and residential future-use scenario for total soil at SWMU 54. The HHRA determined that unacceptable risks to potential future residential and industrial receptors were associated with the COIs. Based on the results from the HHRA, it was concluded that based on the levels detected in the soil hot spot areas, COIs could potentially leach from soil to groundwater at levels of concern, although groundwater impacts at levels of concern have not yet been identified at Area B. Because the RFI demonstrated that COI contamination is present at concentrations associated with unacceptable human health concerns, a CMS was performed to address the propellant ash material and grossly-contaminated soil under the ash material at SWMU 54. The alternatives evaluated were as follows:

- Alternative One: No Further Action.
- Alternative Two: Excavation of Soil at Area A and Area B, Off-site Disposal, and MNA of Groundwater.
- Alternative Three: Excavation of Soil at Area A and Area B, Off-site Disposal, and Enhanced *In Situ* Bioremediation of Groundwater.

These three alternatives were evaluated using the selection criteria: effectiveness, implementability, and cost. The site-specific CMO for SWMU 54 is to mitigate further leaching of explosives constituents from soil to groundwater at levels that would potentially increase observed concentrations and adversely impact future beneficial use of groundwater, and to eliminate the potential threats to human health and the environment that exist within materials found in SWMU 54. Observations from the SWMU 54 soil investigations indicate that the propellant ash material consisted of a black, ashy material that was very evident when encountered. Therefore, identification and removal of the propellant ash and grossly-contaminated soil was partially based on visual observations during excavation, with analytical confirmation samples collected to confirm the observations.

Alternative Two, which entails excavation and off-site disposal as the primary remediation process, was found to achieve the CMO. Therefore, Alternative Two was selected as the final alternative for SWMU 54 because it is implementable and provides a greater level of protection to human health and the environment not provided by other alternatives. In addition, Alternative Two is the sole alternative that facilitates RGs without potential adverse effects to groundwater (i.e., degradation of secondary water quality parameters) from remedial implementation activities, which would occur with implementation of Alternative Three. By achieving the CMOs, Alternative Two accomplishes the Army's goal for the Installation Restoration Program and its funding source the Environmental Restoration, Army account.

The CMOs and RGs were developed in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). The following is a summary of the findings from that process.

The site-specific CMO for SWMU 54 Area A is to mitigate further leaching of explosives constituents from soil-to-groundwater at levels that would potentially increase observed concentrations and adversely impact future beneficial use of groundwater; and to the extent practicable, a goal of restoring site groundwater to the most beneficial use. The soil CMOs for Area A have been met, and the purpose of this Report is to implement the groundwater IMs to meet the CMOs for groundwater.

The site-specific CMO for SWMU 54 Area B is to mitigate the potential hypothetical future risks that have been identified for exposure to soil under a future construction worker scenario; and to prevent leaching of contaminants of concern from soil-to-groundwater at levels that would potentially adversely impact future beneficial use of groundwater. The site-specific CMOs have been met through the soil excavation and off-site disposal completed in 2010.

RGs for SWMU 54 groundwater are shown in Table 1-7 in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). These RGs were used at SWMU 54 to confirm that all COIs were removed from soil to levels that are safe for human health and the environment. Results from the soil remedial action at SWMU 54 can be found in the approved *Final Interim Measures Completion Report for SWMU 54* (Shaw, 2011b). The groundwater RGs (displayed in **Table 1-1** of this Report) will be used to compare results from groundwater monitoring wells to assess the progress of the MNA.

4.0 FIELD ACTIVITIES

The following sections provide a discussion of field activities conducted by Shaw in the second year of monitoring at SWMU 54.

The second year of groundwater monitoring consisted of four sampling events conducted in August 2012 (fifth quarter), November 2012 (sixth quarter), February 2013 (seventh quarter), and May 2013 (eighth quarter). Field activities were conducted in accordance with the *Final SWMU 54 MNA IMWP* (Shaw, 2011a).

4.1 Groundwater Sampling – Fifth Quarter

Groundwater elevation measurements and groundwater samples were collected from 14 groundwater monitoring wells. The fifth quarter of groundwater sampling was conducted August 7-9, 2012. Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.1.1 Groundwater Elevation Measurements

A round of synoptic water levels was conducted at SWMU 54 prior to each sampling event in the second year of sampling. Water levels were recorded at each of the 14 monitoring wells. **Table 4-1** presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the fifth quarter and is presented on **Figure 4-2**.

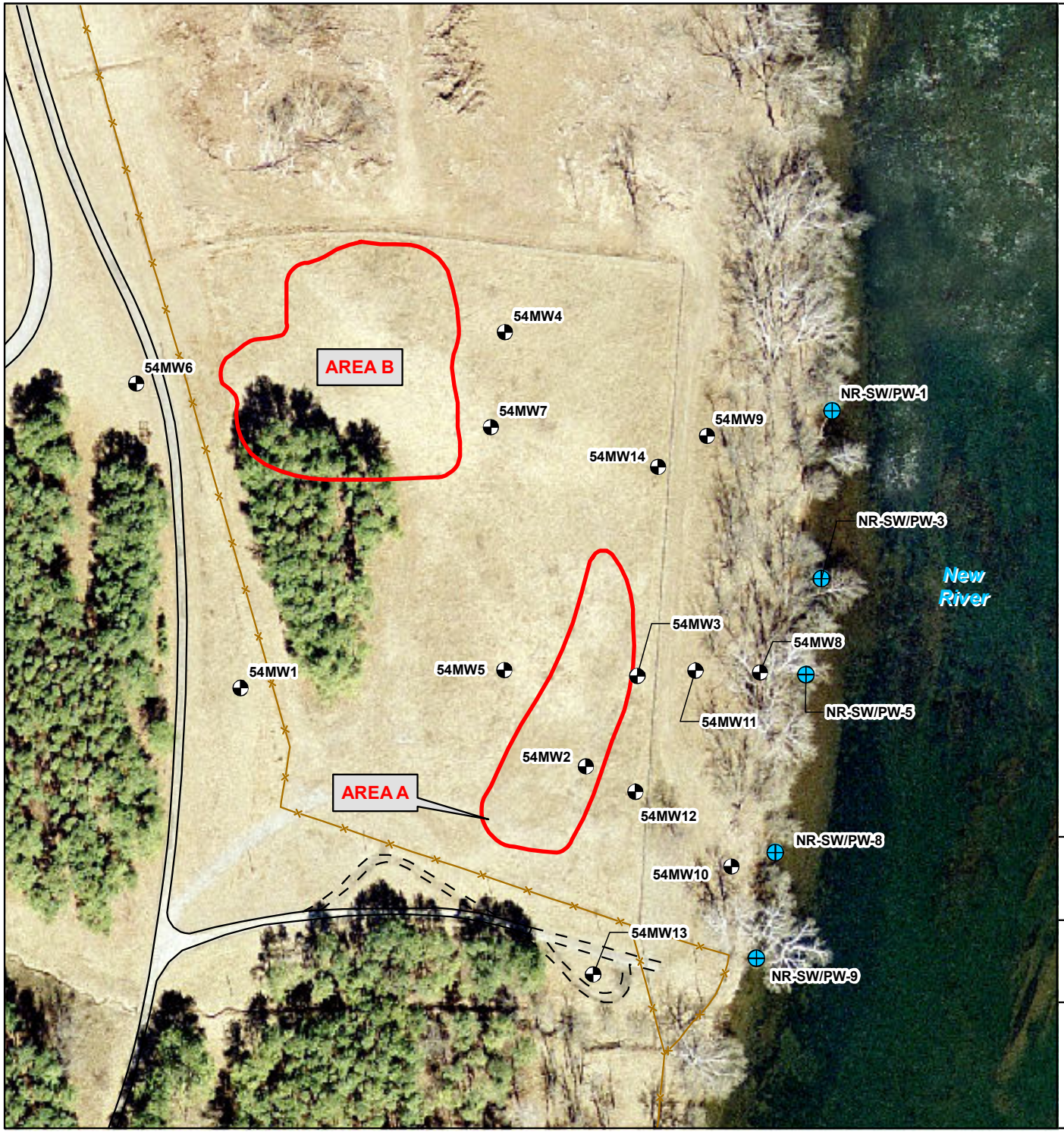
Estimated groundwater flow velocities were calculated for Area A and Area B based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 13.3 ft, resulting in a calculated hydraulic gradient of 0.025 ft/ft. Using an average K value for Area A of 4.86 feet per day (ft/day) and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.62 ft/day [225.2 feet per year (ft/year)].

The Area B flow path of approximately 600 ft had a groundwater elevation difference of 23.37 ft, resulting in a calculated hydraulic gradient of 0.039 ft/ft. Using an average K value for Area B of 4.55 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area B is approximately 0.89 ft/day (323.43 ft/year).

Table 4-1
Fifth Quarter Groundwater Elevations at SWMU 54

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	20.60	1687.18	62.0
54MW2	1701.41	24.13	1677.28	32.0
54MW3	1702.15	24.12	1678.03	36.0
54MW4	1696.14	16.65	1679.49	47.5
54MW5	1698.11	19.08	1679.03	25.0
54MW6	1739.19	39.25	1699.94	42.0
54MW7	1696.58	17.24	1679.34	23.0
54MW8	1692.64	14.94	1677.70	34.0
54MW9	1696.04	19.42	1676.62	28.5
54MW10	1691.10	17.25	1673.85	35.0
54MW11	1696.27	19.70	1676.57	31.0
54MW12	1702.42	25.68	1676.74	30.0
54MW13	1698.90	22.22	1676.68	22.0
54MW14	1700.66	23.44	1677.22	31.5

Notes:
TOC – Top of casing
DTW – Depth to water



LEGEND

- Monitoring Well
- Surface Water and Pore Water Sample Location
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

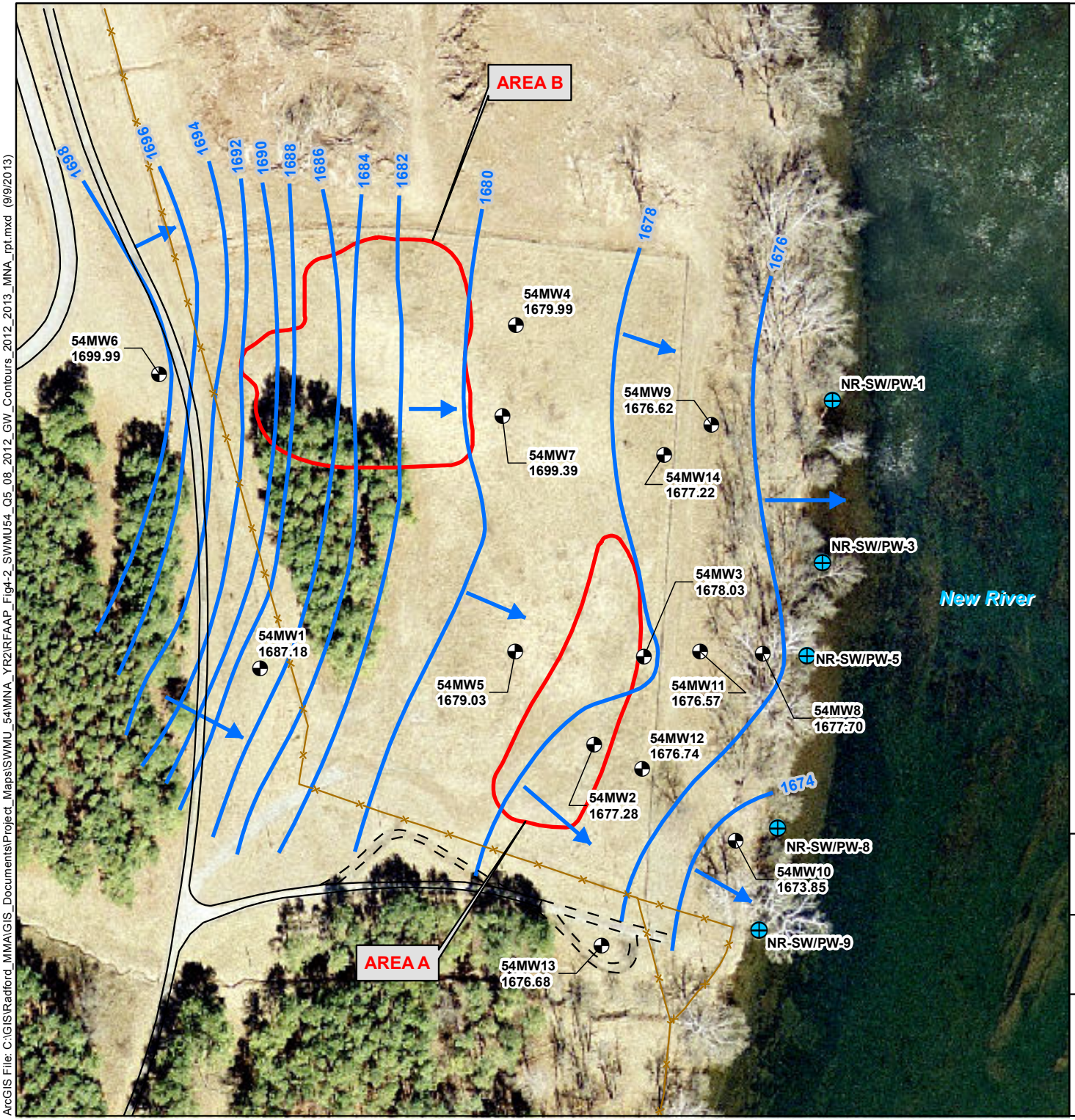
0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 4-1
SWMU 54
Sample Locations
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig4-1_SWMU54_Sample_Locations_2012_2013_MNA_rpt.mxd (8/1/2013)



LEGEND

- Monitoring Well
- Surface Water and Pore Water Sample Location
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 4-2
SWMU 54
August 2012 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig4-2_SWMU54_Q5_08_2012_GW_Contours_2012_2013_MNA_rpt.mxd (9/9/2013)

4.1.2 Groundwater Sampling

Groundwater samples were collected from each of the 14 monitoring wells on August 7-9, 2012. Groundwater samples from the fifth through eighth quarters of sampling were analyzed for the following analyte classes: Explosives and perchlorate. In addition, the following indicator parameters were also collected: Total Organic Carbon (TOC), Dissolved Inorganic Carbon (DIC), dissolved ferrous iron, dissolved manganese, nitrate, sulfate, pH, temperature, specific conductance, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity. The analysis list is presented in **Table 4-2**.

Table 4-2
Sample Analysis for SWMU 54 Groundwater Monitoring

Site ID	Sample ID	Frequency*	Explosives	Perchlorate	MNA Indicator Parameters
54MW01	54MW01	Quarterly	X	X	X
54MW02	54MW02	Quarterly	X	X	X
54MW03	54MW03	Quarterly	X	X	X
54MW04	54MW04	Quarterly	X	X	X
54MW05	54MW05	Quarterly	X	X	X
54MW06	54MW06	Quarterly	X	X	X
54MW07	54MW07	Quarterly	X	X	X
54MW08	54MW08	Quarterly	X	X	X
54MW09	54MW09	Quarterly	X	X	X
54MW10	54MW10	Quarterly	X	X	X
54MW11	54MW11	Quarterly	X	X	X
54MW12	54MW12	Quarterly	X	X	X
54MW13	54MW13	Quarterly	X	X	X
54MW14	54MW14	Quarterly	X	X	X
NRSW1/ PW1	NRSW1/ PW1	Annually	X	X	X
NRSW3/ PW3	NRSW3/ PW3	Annually	X	X	X
NRSW5/ PW5	NRSW5/ PW5	Annually	X	X	X
NRSW8/ PW8	NRSW8/ PW8	Annually	X	X	X
NRSW9/ PW9	NRSW9/ PW9	Annually	X	X	X

* Reduce from quarterly to an annual frequency if four consecutive quarters are below RGs.

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A photoionization detector (PID) reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screen. Monitoring wells were initially pumped at a rate of approximately 300-350 milliliters per minute (mL/min) on average. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-3** presents a summary of the final, stabilized reading for each well from the fifth quarter.

Table 4-3
SWMU 54 Fifth Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	7.08	0.395	4.1	5.34	212	13.89	<0.05	<0.2
54MW2	6.94	0.722	43	0	65	13.49	<0.05	<0.2
54MW3	6.71	0.644	19	0	209	12.93	0.05	<0.2
54MW4	7.05	0.968	14	0.23	-33	15.06	0.05	<0.2
54MW5	6.71	0.580	23	3.96	200	13.44	<0.05	<0.2
54MW6	7.47	0.363	0	4.84	134	16.52	0.05	<0.2
54MW7	7.03	0.817	7.4	0	128	13.66	0.05	<0.2
54MW8	6.87	0.599	19	2.78	125	13.70	0.05	<0.2
54MW9	6.84	0.752	5.2	0.56	-10	14.09	0.20	<0.2
54MW10	6.71	0.693	0.8	0.40	47	13.93	0.05	<0.2
54MW11	7.06	0.715	10.8	0	-22	13.64	0.05	<0.2
54MW12	6.61	0.665	48.0	0.33	226	13.71	<0.05	<0.2
54MW13*	6.97	0.697	95	1.75	135	16.12	0.30	<0.2
54MW14	7.05	0.625	9.2	0	-13	14.08	<0.05	<0.2

* Well experienced accelerated drawdown and pump rate was lowered to 150ml/min to stabilize water level and for sampling.

Measurements conducted for SWMU 54 generally showed aerobic conditions for groundwater. Due to the poor correlation between DO and ORP, the assessment of aerobic conditions is based on the ORP for this event. Levels of DO in the wells ranged from 0 to 4.84 milligrams per liter (mg/L). ORP measurements in the wells ranged from -33 to 226 millivolts (mV). Levels of pH were generally in the neutral range with measurements ranging from 6.61 to 7.47 standard units. Specific conductance measurements in the wells ranged from 0.363 to 0.968 millisiemens per centimeter (mS/cm).

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained at 300 mL/min during sample collection. Samples were collected, preserved, and packed in ice

until shipment to the laboratory. Chain-of-custody (COC) forms and temperature blanks accompanied the samples at all times. Copies of the COCs are provided in **Appendix B**.

4.1.3 Quality Control Samples

Quality control (QC) samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 10 percent, with two duplicate groundwater samples [54TM01 and 54TM12 taken at well locations 54MW01 and 54MW12, respectively (see **Table 4-2** for analytes)] obtained during the fifth quarter of groundwater sampling. Matrix spike/matrix spike duplicates (MS/MSDs) were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW4. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected per sampling quarter. Equipment rinse blanks were collected by pouring de-ionized ultra-filtered (DIUF) water over decontaminated sampling equipment and into laboratory supplied bottles. Rinse blanks are collected for the same suite of parameters as the samples. Results of the quality assurance/quality control (QA/QC) sample analysis are presented in **Appendix B**.

4.2 Groundwater Sampling – Sixth Quarter

Groundwater elevation measurements and groundwater samples were collected from 14 groundwater monitoring wells. The sixth quarter of groundwater sampling was conducted November 6-8, 2012. Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.2.1 Groundwater Elevation Measurements

Table 4-4 presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the sixth quarter and is presented on **Figure 4-3**.

Estimated groundwater flow velocities were calculated for Area A and Area B based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 10.9 ft, resulting in a calculated hydraulic gradient of 0.020 ft/ft. Using an average K value for Area A of 4.86 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.50 ft/day (183.6 ft/year).

The Area B flow path of approximately 600 ft had a groundwater elevation difference of 10.5 ft, resulting in a calculated hydraulic gradient of 0.017 ft/ft. Using an average K value for Area B of 4.55 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area B is approximately 0.39 ft/day (144.76 ft/year).

Table 4-4
SWMU 54 Sixth Quarter Groundwater Elevations

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	21.59	1686.19	62.0
54MW2	1701.41	23.45	1677.96	32.0
54MW3	1702.15	24.78	1677.37	36.0
54MW4	1696.14	17.6	1678.54	47.5
54MW5	1698.11	19.98	1678.13	25.0
54MW6*	1739.19	Dry	Dry	42.0
54MW7	1696.58	18.25	1678.33	23.0
54MW8	1692.64	15.08	1677.56	34.0
54MW9	1696.04	20.91	1675.13	28.5
54MW10	1691.10	15.58	1675.52	35.0
54MW11	1696.27	20.50	1675.77	31.0
54MW12	1702.42	26.37	1676.05	30.0
54MW13	1698.90	20.21	1678.69	22.0
54MW14	1700.66	23.95	1676.71	31.5

*****Boring was dry. Tip of water level probe was covered in mud upon retrieval.

Notes:
TOC – Top of casing
DTW – Depth to water

4.2.2 Groundwater Sampling

Groundwater samples were collected from each of the 14 monitoring wells on November 6-8, 2012. Samples from the sixth quarter were tested for the analyte list presented in **Table 4-2**.

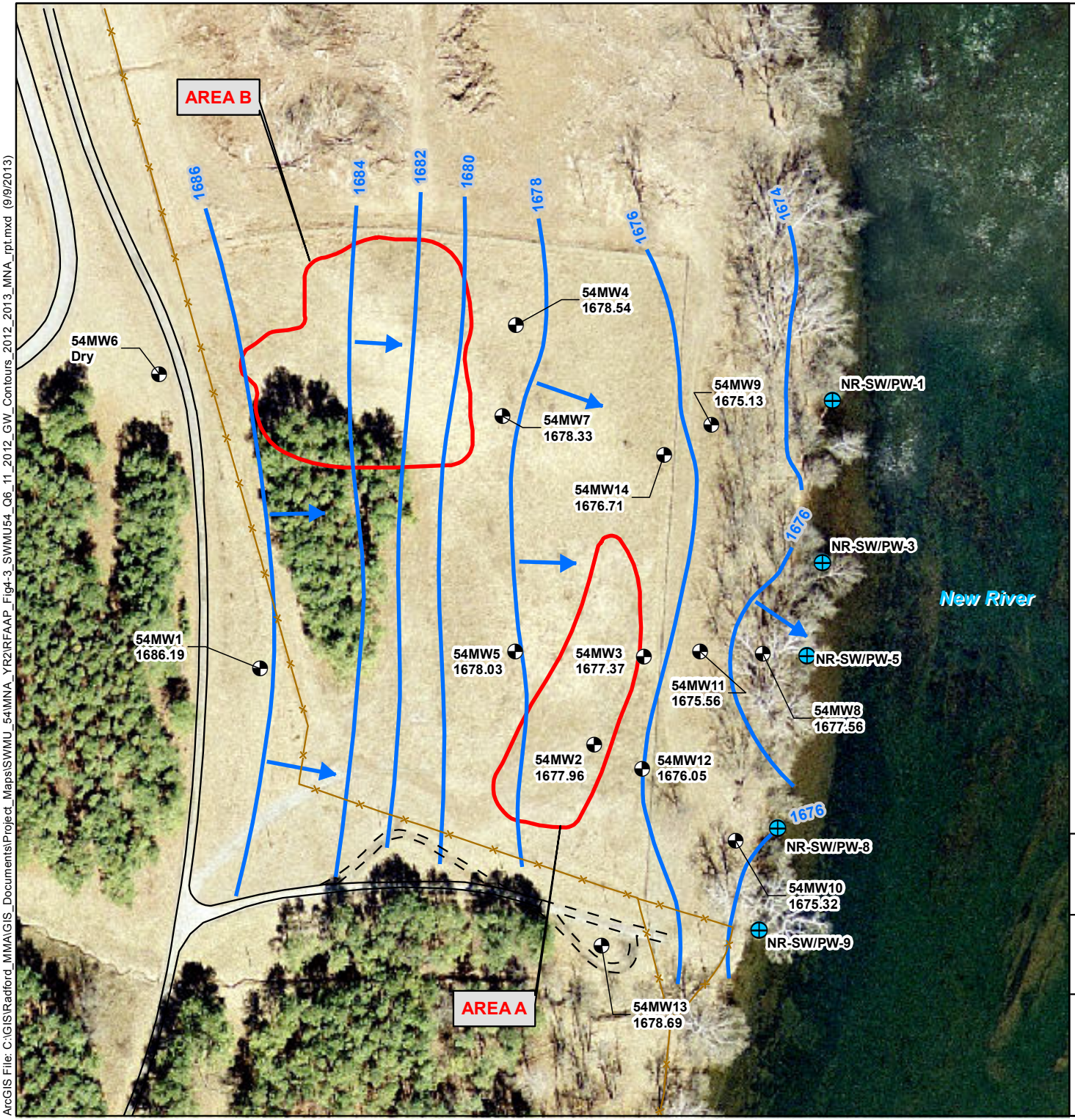
Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A PID reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screen. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-5** presents a summary of the final, stabilized reading for each well.

Table 4-5
SWMU 54 Sixth Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	7.63	0.443	2.9	1.44	148	10.03	0.05	<0.2
54MW2	7.21	0.620	11.4	0.86	141	13.43	0.05	<0.2
54MW3	6.97	0.561	0.2	4.09	145	12.22	0.05	<0.2
54MW4	7.03	1.01	17.0	1.00	72	11.27	0.05	<0.2
54MW5	6.99	0.612	5.5	1.01	167	11.21	0.05	<0.2
54MW6	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
54MW7	7.31	0.826	46	0.56	59	10.83	0.05	<0.2
54MW8	7.23	0.628	3.9	2.71	101	11.98	0.05	<0.2
54MW9	7.23	0.784	27.7	1.14	-28	11.35	0.20	<0.2
54MW10	7.29	0.779	4.7	0.38	43	13.61	0.05	<0.2
54MW11	7.28	0.698	2.5	1.10	117	12.95	0.05	<0.2
54MW12	7.60	0.635	2.4	0.26	135	13.99	0.10	<0.2
54MW13	5.72	0.918	35	0.95	209	12.26	0.30	<0.2
54MW14	7.30	0.600	43	0.45	100	10.61	0.05	<0.2

Measurements conducted for the sixth quarter of SWMU 54 monitoring generally showed aerobic conditions for groundwater. Levels of DO in the wells ranged from 0.26 to 4.09 mg/L. ORP measurements in the wells ranged from -28 to 209 mV. Levels of pH were generally in the neutral range with measurements ranging from 5.72 to 7.63 standard units. Specific conductance measurements in the wells ranged from 0.443 to 1.01 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the second quarter are provided in **Appendix B**.



LEGEND

- Monitoring Well
- Surface Water and Pore Water Sample Location
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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FIGURE 4-3
SWMU 54
November 2012 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig4-3_SWMU54_Q6_11_2012_GW_Contours_2012_2013_MNA_rpt.mxd (9/9/2013)

4.2.3 Quality Control Samples

QC samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 10 percent, with two duplicate groundwater samples [54TM07 and 54TM10 (see **Table 4-2** for analytes)] obtained during the sixth quarter of groundwater sampling. MS/MSDs were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW1 during the sixth quarter. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected during the sampling event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, 54RB110812, was collected on November 8, 2012, by pouring DIUF water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

4.3 Groundwater Sampling – Seventh Quarter

Groundwater elevation measurements and groundwater samples were collected from 14 groundwater monitoring wells. The seventh quarter of groundwater sampling was conducted February 19-21, 2013. Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.3.1 Groundwater Elevation Measurements

Water levels were recorded at each of the 14 monitoring wells. **Table 4-6** presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the seventh quarter and is presented on **Figure 4-4**.

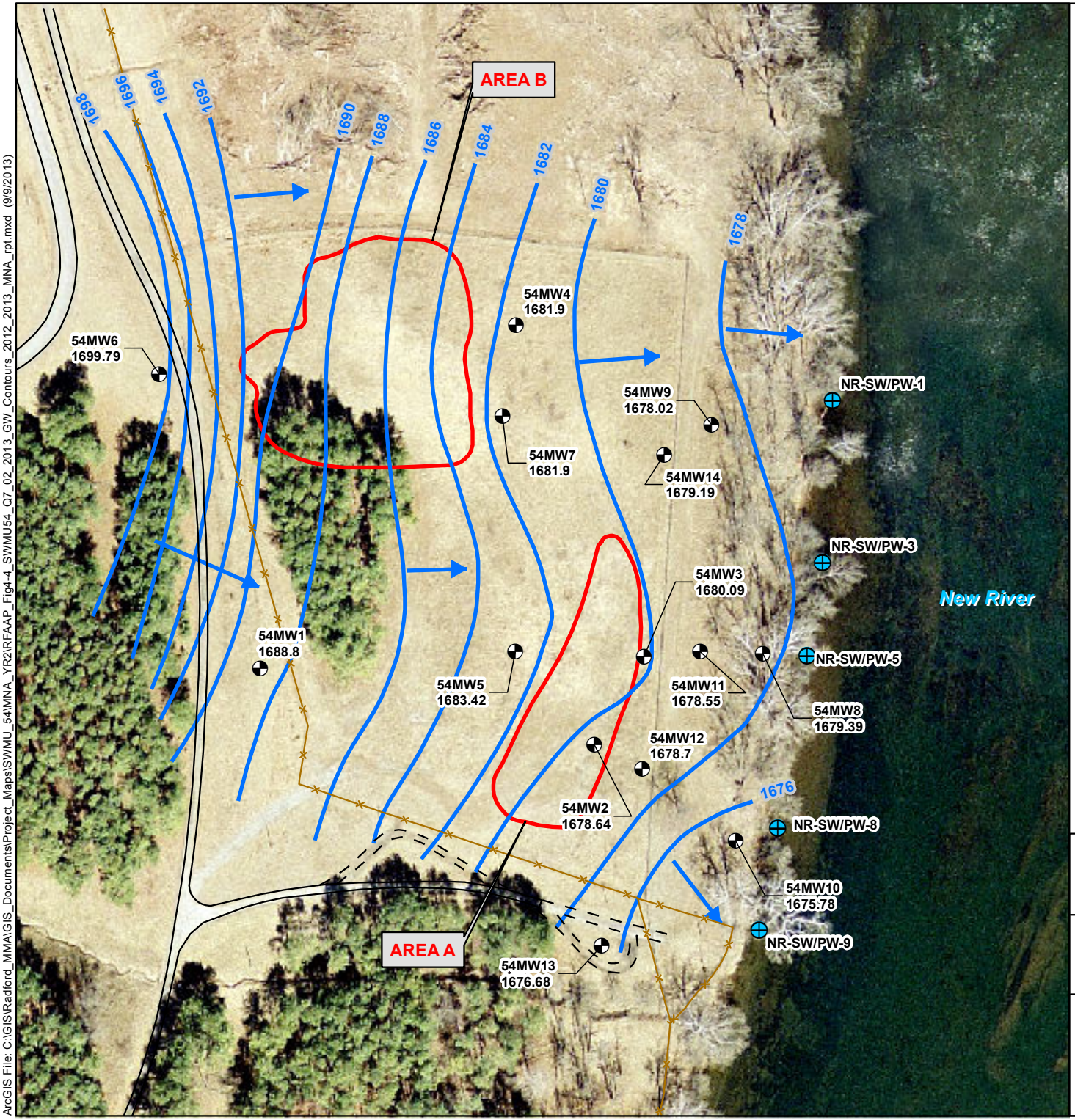
Estimated groundwater flow velocities were calculated for Area A and Area B based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 13.2 ft, resulting in a calculated hydraulic gradient of 0.025 ft/ft. Using an average K value for Area A of 4.86 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.61 ft/day (221.7 ft/year).

The Area B flow path of approximately 600 ft had a groundwater elevation difference of 21.8 ft, resulting in a calculated hydraulic gradient of 0.036 ft/ft. Using an average K value for Area B of 4.55 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area B is approximately 0.82 ft/day (301.28 ft/year).

Table 4-6
SWMU 54 Seventh Quarter Groundwater Elevations

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	18.98	1688.8	62.0
54MW2	1701.41	22.77	1678.64	32.0
54MW3	1702.15	22.06	1680.09	36.0
54MW4	1696.14	14.24	1681.9	47.5
54MW5	1698.11	14.69	1683.42	25.0
54MW6	1739.19	39.40	1699.79	42.0
54MW7	1696.58	14.68	1681.9	23.0
54MW8	1692.64	13.25	1679.39	34.0
54MW9	1696.04	17.42	1678.62	28.5
54MW10	1691.10	15.32	1675.78	35.0
54MW11	1696.27	17.72	1678.55	31.0
54MW12	1702.42	23.72	1678.7	30.0
54MW13	1698.90	22.22	1676.68	22.0
54MW14	1700.66	21.52	1679.14	31.5

Notes:
TOC – Top of casing
DTW – Depth to water



LEGEND

- Monitoring Well
- Surface Water and Pore Water Sample Location
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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FIGURE 4-4
SWMU 54
February 2013 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig4-4_SWMU54_Q7_02_2013_GW_Contours_2012_2013_MNA_rpt.mxd (9/9/2013)

4.3.2 Groundwater Sampling

Groundwater samples were collected from each of the 14 monitoring wells on February 19-20, 2013. Samples from the seventh quarter were analyzed for the analyte list presented in **Table 4-2**.

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A PID reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screened interval. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-7** presents a summary of the final, stabilized reading for each well.

Table 4-7
SWMU 54 Seventh Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	7.85	0.465	0	0.71	-5	12.17	0.05	<0.2
54MW2	6.89	0.682	20	1.43	156	8.28	<0.05	<0.2
54MW3	6.76	0.504	9.0	6.97	171	11.98	0.10	<0.2
54MW4	7.52	1.01	16	0.53	-56	12.09	0.05	<0.2
54MW5	6.56	0.417	0	9.19	168	11.18	<0.05	<0.2
54MW6	7.08	0.293	44.3	9.28	72	13.15	0.05	<0.2
54MW7	7.40	0.474	16	2.83	12	11.48	0.10	<0.2
54MW8	7.03	0.498	9.2	5.36	168	9.89	0.05	<0.2
54MW9	7.04	0.487	10.9	8.28	194	9.74	0.20	<0.2
54MW10	6.69	0.542	13.2	2.97	125	11.22	0.10	<0.2
54MW11	7.09	0.687	2	0.58	169	10.14	0.25	<0.2
54MW12	6.36	0.464	14.2	1.27	168	10.31	<0.05	<0.2
54MW13	6.96	0.370	6.8	8.39	158	7.98	0.20	<0.2
54MW14	7.45	0.619	1.2	0.47	56	12.26	<0.05	<0.2

*Readings exhibited very high, unchanging turbidity.

Measurements conducted for the seventh quarter of SWMU 54 monitoring generally showed aerobic conditions for groundwater. Levels of DO in the wells ranged from 0.47 to 9.28 mg/L. ORP measurements in the wells ranged from -56 to 194 mV. Levels of pH were generally in the neutral range with measurements ranging from 6.36 to 7.85 standard units. Specific conductance measurements in the wells ranged from 0.293 to 1.01 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to

the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the fourteenth quarter are provided in **Appendix B**.

4.3.3 Quality Control Samples

QC samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 10 percent, with two duplicate groundwater samples [54TM01 and 54TM09 collected from 54MW1 and 54MW9, respectively(see **Table 4-2** for analytes)] obtained during the seventh quarter of groundwater sampling. MS/MSDs were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW8 during the seventh quarter. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected during the sample event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, 54RB22113, was collected on February 21, 2013, by pouring DIUF water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

4.4 Groundwater Sampling – Eighth Quarter

Groundwater elevation measurements and groundwater samples were collected from 14 groundwater monitoring wells. Five pore water samples were collected along the New River. The eighth quarter of groundwater sampling was conducted May 14-16, 2013. Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.4.1 Groundwater Elevation Measurements

Water levels were recorded at each of the 14 monitoring wells. **Table 4-8** presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the eighth quarter and is presented on **Figure 4-5**.

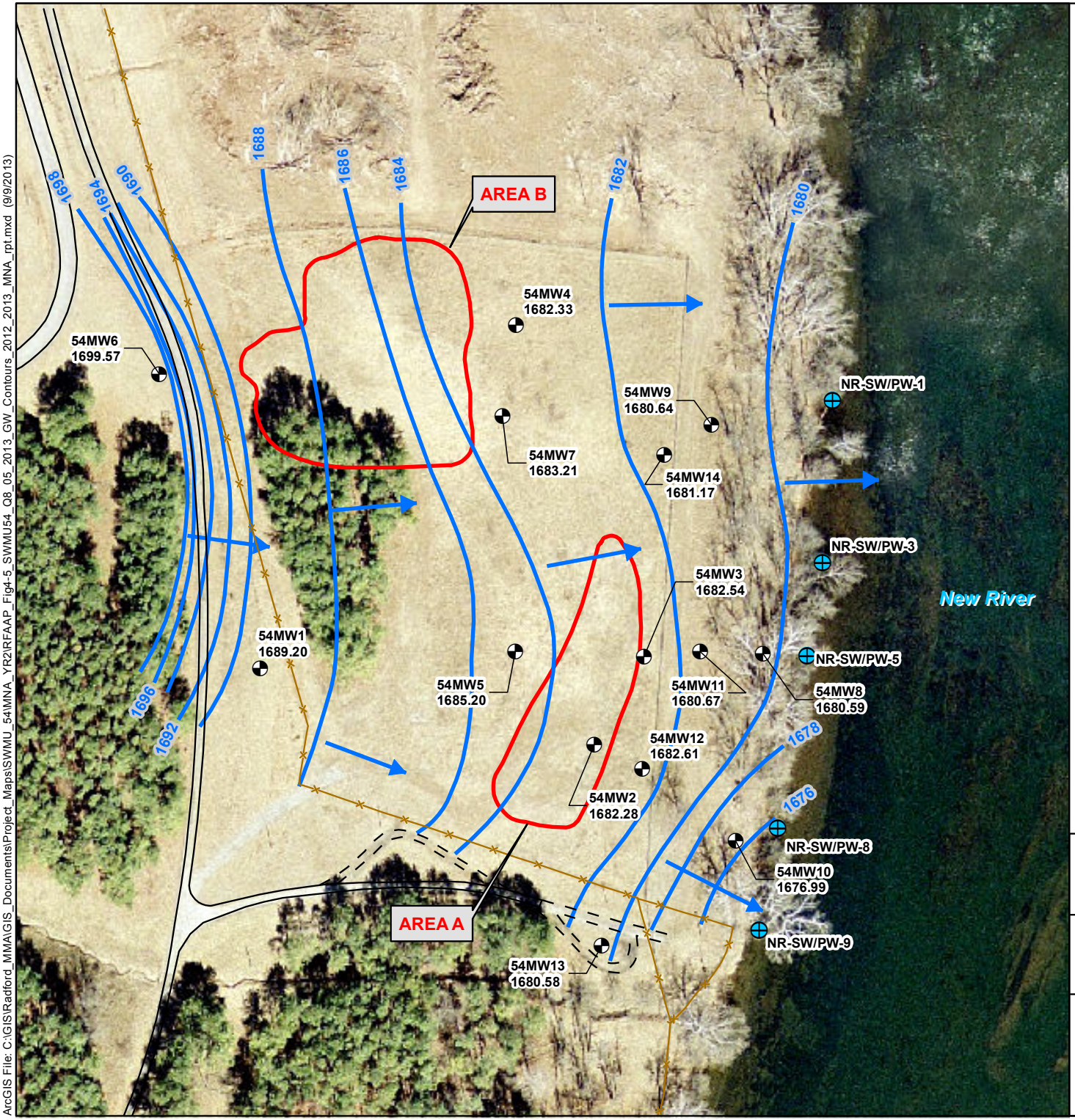
Estimated groundwater flow velocities were calculated for Area A and Area B based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 12.2 ft, resulting in a calculated hydraulic gradient of 0.023 ft/ft. Using an average K value for Area A of 4.86 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.57 ft/day (206.3 ft/year).

The Area B flow path of approximately 600 ft had a groundwater elevation difference of 18.9 ft, resulting in a calculated hydraulic gradient of 0.032 ft/ft. Using an average K value for Area B of 4.55 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area B is approximately 0.72 ft/day (261.9 ft/year).

Table 4-8
SWMU 54 Eighth Quarter Groundwater Elevations

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	18.58	1689.20	62.0
54MW2	1701.41	19.13	1682.28	32.0
54MW3	1702.15	19.81	1682.34	36.0
54MW4	1696.14	13.81	1682.33	47.5
54MW5	1698.11	12.49	1685.20	25.0
54MW6	1739.19	39.62	1699.57	42.0
54MW7	1696.58	13.37	1683.21	23.0
54MW8	1692.64	12.10	1680.54	34.0
54MW9	1696.04	15.40	1680.64	28.5
54MW10	1691.10	14.20	1676.90	35.0
54MW11	1696.27	15.60	1680.67	31.0
54MW12	1702.42	19.81	1682.61	30.0
54MW13	1698.90	18.32	1680.58	22.0
54MW14	1700.66	19.49	1681.17	31.5

Notes:
TOC – Top of casing
DTW – Depth to water



LEGEND

- Monitoring Well
- Surface Water and Pore Water Sample Location
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:
0 75 150 300
Feet

U.S. Army Corps of Engineers

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Belcamp, Maryland 21017

FIGURE 4-5
SWMU 54
May 2013 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig4-5_SWMU54_Q8_05_2013_GW_Contours_2012_2013_MNA_rpt.mxd (9/9/2013)

4.4.2 Groundwater Sampling

Groundwater samples were collected from each of the 14 monitoring wells on May 14-16, 2013. Samples from the eighth quarter were analyzed for the full analyte list presented in **Table 4-2**.

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A PID reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screened section of the well. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-9** presents a summary of the final, stabilized reading for each well.

Table 4-9
SWMU 54 Eighth Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	7.82	0.452	3.0	0.136	223.2	14.51	0.05	<0.2
54MW2	6.52	0.315	0.2	2.74	254.3	12.22	0.05	<0.2
54MW3	7.06	0.499	1.4	3.55	273.6	13.31	0.05	<0.2
54MW4	7.51	1.021	6.2	1.05	257.1	11.73	0.05	<0.2
54MW5	6.83	0.400	8.9	3.28	283.1	12.20	<0.05	<0.2
54MW6	7.33	0.494	7.1	1.29	128.4	13.48	<0.05	<0.2
54MW7	7.41	0.674	0.5	3.24	282.7	12.74	0.05	<0.2
54MW8	7.47	0.596	1.6	0.40	255.1	13.32	0.05	0.2
54MW9	7.95	0.521	5.2	7.58	244.2	11.12	0.10	<0.2
54MW10	6.94	0.537	1.4	2.43	287.8	12.89	0.05	<0.2
54MW11	7.59	0.592	0.3	1.17	255.8	12.42	0.05	<0.2
54MW12	6.78	0.665	3.8	2.54	292.4	13.28	<0.05	<0.2
54MW13	6.97	0.440	0.2	1.40	284.0	12.84	0.15	<0.2
54MW14	7.31	0.608	6.4	4.13	296.5	13.42	0.05	<0.2

Measurements conducted for the eighth quarter of SWMU 54 monitoring generally showed aerobic conditions for groundwater. Levels of DO in the wells ranged from 0.136 to 7.58 mg/L. ORP measurements in the wells ranged from 128 to 296.5 mV. Levels of pH were typically in the neutral range with measurements reading from 6.52 to 7.82 standard units. Specific conductance measurements in the wells ranged from 0.315 to 1.021 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to

the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the eighth quarter are provided in **Appendix B**.

4.4.3 Quality Control Samples

QC samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 10 percent, with two duplicate groundwater samples [54TM01 and 54TM02 were collected from sample locations 54MW4 and 54MW5, respectively (see **Table 4-2** for analytes)] obtained during the eighth quarter of groundwater sampling. MS/MSDs were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW01 during the eighth quarter. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected during the sample event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, 54RB051513, was collected on May 15, 2013, by pouring DIUF water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

4.4.4 Pore Water Sampling

Pore water samples were collected from five locations along the New River on May 15, 2013. Pore samples from the eighth quarter were analyzed for the full analyte list presented in **Table 4-2**.

Pore water samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the pore water sampling event. A PushPoint sampling device was inserted into the sediment approximately 6-8 inches below the sediment surface. A peristaltic pump was used to purge air in the tubing prior and draw pore water to the water level meter. A water level meter was used to monitor water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity. **Table 4-10** presents a summary of the final, stabilized reading for each pore water location.

Table 4-10
SWMU 54 Eighth Quarter Pore Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)
NR-SW/PW-1	7.23	0.160	111.1	0.74	214.4	19.60
NR-SW/PW-3	7.25	0.233	442.6	1.30	202.2	17.81
NR-SW/PW-5	7.08	0.687	26.2	0.4	266.4	19.74
NR-SW/PW-8	6.88	0.383	377.4	2.67	272.4	19.23
NR-SW/PW-9	6.36	0.346	28.6	1.45	254.2	18.42

Measurements conducted for the pore water locations in the eighth quarter of SWMU 54 generally showed aerobic conditions. Levels of DO in the pore water samples ranged from 0.4 to 2.67 mg/L. ORP measurements in the wells ranged from 202.2 to 272.4 mV. Levels of pH were in the slightly acidic range with measurements ranging from 6.36 to 7.25 standard units. Specific conductance measurements in the wells ranged from 0.160 to 0.687 mS/cm.

Prior to sampling, the flow cell was disconnected and the pore water flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the eighth quarter are provided in **Appendix B**.

5.0 CHEMICAL ANALYTICAL RESULTS

5.1 Selection of Comparison Criteria

The chemical data collected during this investigation were compared to RGs selected in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). Groundwater chemical data were compared to current USEPA Maximum Contaminant Levels (MCLs) (USEPA, 2011). Screening levels (SLs) are calculated values that are derived from theoretical risk scenarios. Compounds are grouped as carcinogens or noncarcinogens, and carcinogen SL values are calculated to represent an increase of 10^{-6} in cancer risk. Noncarcinogen SLs are calculated to a Hazard Index (HI) of 1. In order to account for potential cumulative effects of exposure to noncarcinogenic compounds, values for noncarcinogens have been recalculated to an HI of 0.1. **Tables 5-1 through 5-10** present the sample results and summaries of the fifth through eighth quarter data, including number of RG and MCL exceedances, frequency of detection, the minimum and maximum detected concentrations, and the location of the maximum concentration.

5.2 Fifth Quarter Groundwater Results

Fourteen (14) groundwater monitoring wells were sampled during the fifth quarterly sampling event. Sample locations are shown on **Figure 4-1**. A duplicate sample was collected from monitoring wells 54MW1 and 54MW12 and analyzed for explosives, perchlorate, and MNA indicator parameters. Groundwater samples were analyzed for explosives, perchlorate, and MNA indicator parameters. Detected constituents are summarized in **Table 5-1** and presented in **Table 5-2**.

Explosives

Four explosives were detected in the groundwater samples. 2,4,6-TNT was detected in three wells (54MW10, 54MW12, 54MW13) at concentrations of 9.17 micrograms per liter (µg/L), 10.1 µg/L, and 9.4 µg/L, respectively. All detections of 2,4,6-TNT exceeded the RG of 7.8 µg/L in the fifth quarter.

2-amino-4,6-dinitrotoluene (2ADNT) was detected in six wells on site (54MW3, 54MW5, 54MW8, 54MW10, 54MW12, and 54MW13). 4-amino-2,6-dinitrotoluene (4ADNT) was detected in seven wells (54MW3, 54MW5, 54MW8, 54MW10, 54MW12, 54MW13, and 54MW14).

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX was detected at levels below RGs in sample 54MW2. Detected concentrations in 54MW10 exceeded the RG for RDX (6.1 µg/L) with a concentration of 7.84 µg/L.

The locations of detected explosives were typically consistent with earlier sampling rounds. **Figure 5-1** depicts RG exceedances measured during the fifth quarter of groundwater sampling.

Perchlorate

Perchlorate was detected in eight samples (54MW3, 54MW5, 54MW6, 54MW8, 54MW10, and 54MW12 through 54MW14) collected in the fifth quarter MNA sampling. Perchlorate detections did not exceed the RGs.

Table 5-1
SWMU 54 Summary of Fifth Quarter Groundwater Samples

Analyte	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
2,4,6-Trinitrotoluene	7.8	3	3	14	9.17	10.1	54MW12
2-amino-4,6-Dinitrotoluene	na	na	6	14	0.318	5.32	54MW12
4-amino-2,6-Dinitrotoluene	na	na	7	14	0.36	7.69	54MW12
RDX	6.1	1	3	14	1.95	7.84	54MW10
Misc. (ug/L)							
Perchlorate	10.9	0	8	14	0.175	3.74	54MW10
Total Organic Carbon	na	na	6	14	721	2040	54MW14
Chloride	na	na	14	14	1040	6240	54MW09
Nitrate (as N)	na	na	9	14	120	1060	54MW12
Sulfate	na	na	14	14	15700	378000	54MW04

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples
Page 1 of 4

Analyte	Sample ID	54MW01					54MW02					54MW03					54MW04				
	Sample Date	8/8/12					8/9/12					8/9/12					8/8/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.02	U		*0.255*	*1.02*	1.12	U		*0.281*	*1.12*	1.11	U		*0.278*	*1.11*	1.08	U		*0.269*	*1.08*
2-amino-4,6-Dinitrotoluene	na	1.02	U		*0.255*	*1.02*	1.12	U		*0.281*	*1.12*	0.425	J	J	*0.278*	*1.11*	1.08	U		*0.269*	*1.08*
4-amino-2,6-Dinitrotoluene	na	1.02	U		*0.255*	*1.02*	1.12	U		*0.281*	*1.12*	0.466	J	J	*0.278*	*1.11*	1.08	U		*0.269*	*1.08*
RDX	6.1	1.02	U		*0.255*	*1.02*	1.12	U		*0.281*	*1.12*	1.11	U		*0.278*	*1.11*	1.08	U		*0.269*	*1.08*
Misc. (ug/L)																					
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	0.2	U		*0.1*	*0.2*	0.405			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Dissolved Ferrous Iron	na	<50					<50					50					50				
Dissolved Manganese	na	<200					<200					<200					<200				
Dissolved Inorganic Carbon	na	38500	J	J	*500*	*1000*	72300	J	J	*1000*	*2000*	65300	J	J	*1000*	*2000*	44400	J	J	*500*	*1000*
Total Organic Carbon	na	721	J	J	*500*	*1000*	2000	U	UJ	*1000*	*2000*	2000	U	UJ	*1000*	*2000*	1100		J	*500*	*1000*
Chloride	na	1630			*100*	*200*	4430			*100*	*200*	5090			*100*	*200*	1360			*500*	*1000*
Nitrate (as N)	na	600	U		*100*	*600*	190	J	J	*100*	*600*	613			*100*	*600*	3000	U		*500*	*3000*
Sulfate	na	26200			*500*	*1000*	95500			*500*	*1000*	23800			*500*	*1000*	378000			*2500*	*5000*

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples
Page 2 of 4

Analyte	Sample ID	54MW05					54MW06					54MW07					54MW08				
	Sample Date	8/9/12					8/8/12					8/8/12					8/7/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.02	U		*0.255*	*1.02*	1.1	U		*0.275*	*1.1*	1.11	U		*0.278*	*1.11*	1.03	U		*0.258*	*1.03*
2-amino-4,6-Dinitrotoluene	na	0.318	J	J	*0.255*	*1.02*	1.1	U		*0.275*	*1.1*	1.11	U		*0.278*	*1.11*	0.401	J	J	*0.258*	*1.03*
4-amino-2,6-Dinitrotoluene	na	0.36	J	J	*0.255*	*1.02*	1.1	U		*0.275*	*1.1*	1.11	U		*0.278*	*1.11*	0.505	J	J	*0.258*	*1.03*
RDX	6.1	1.02	U		*0.255*	*1.02*	1.1	U		*0.275*	*1.1*	1.11	U		*0.278*	*1.11*	1.03	U		*0.258*	*1.03*
Misc. (ug/L)																					
Perchlorate	10.9	0.42			*0.1*	*0.2*	0.175	J	J	*0.1*	*0.2*	0.2	U		*0.1*	*0.2*	0.392			*0.1*	*0.2*
Dissolved Ferrous Iron	na	<50					50					50					50				
Dissolved Manganese	na	<200					<200					<200					<200				
Dissolved Inorganic Carbon	na	68100	J	J	*1000*	*2000*	34000			*500*	*1000*	45800	J	J	*1000*	*2000*	8700	J	J	*1000*	*2000*
Total Organic Carbon	na	2000	U	UJ	*1000*	*2000*	1000	U	UJ	*500*	*1000*	1020			*500*	*1000*	2000	U	UJ	*1000*	*2000*
Chloride	na	4870			*100*	*200*	1040			*100*	*200*	2380			*500*	*1000*	4400			*100*	*200*
Nitrate (as N)	na	728			*100*	*600*	120	J	J	*100*	*600*	3000	U		*500*	*3000*	581	J	J	*100*	*600*
Sulfate	na	18000			*500*	*1000*	15700			*500*	*1000*	186000			*2500*	*5000*	41800			*500*	*1000*

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples
Page 3 of 4

Analyte	Sample ID	54MW09					54MW10					54MW11					54MW12				
	Sample Date	8/7/12					8/7/12					8/7/12					8/9/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.03	U		*0.258*	*1.03*	9.17			*0.258*	*1.03*	1.04	U		*0.26*	*1.04*	10.1			*0.269*	*1.08*
2-amino-4,6-Dinitrotoluene	na	1.03	U		*0.258*	*1.03*	1.66			*0.258*	*1.03*	1.04	U		*0.26*	*1.04*	5.32			*0.269*	*1.08*
4-amino-2,6-Dinitrotoluene	na	1.03	U		*0.258*	*1.03*	2.69	P	J	*0.258*	*1.03*	1.04	U		*0.26*	*1.04*	7.69	P	J	*0.269*	*1.08*
RDX	6.1	1.03	U		*0.258*	*1.03*	7.84			*0.258*	*1.03*	1.04	U		*0.26*	*1.04*	1.95	P	J	*0.269*	*1.08*
Misc. (ug/L)																					
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	3.74			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*	2			*0.5*	*1*
Dissolved Ferrous Iron	na	200					50					50					<50				
Dissolved Manganese	na	<200					<200					<200					<200				
Dissolved Inorganic Carbon	na	67300	J	J	*1000*	*2000*	37700	J	J	*1000*	*2000*	29200	J	J	*1000*	*2000*	73500	J	J	*1000*	*2000*
Total Organic Carbon	na	2000	U	UJ	*1000*	*2000*	1370	J	J	*1000*	*2000*	2000	U	UJ	*1000*	*2000*	2000	U	UJ	*1000*	*2000*
Chloride	na	6240			*300*	*600*	3710			*300*	*600*	3400			*300*	*600*	5350			*100*	*200*
Nitrate (as N)	na	1800	U		*300*	*1800*	594	J	J	*300*	*1800*	1800	U		*300*	*1800*	1060			*100*	*600*
Sulfate	na	87200			*1500*	*3000*	102000			*1500*	*3000*	97600			*1500*	*3000*	27000			*500*	*1000*

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples

Analyte	Sample ID	54MW13					54MW14				
	Sample Date	8/7/12					8/8/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
2,4,6-Trinitrotoluene	7.8	9.4			*0.26*	*1.04*	1.04	U		*0.26*	*1.04*
2-amino-4,6-Dinitrotoluene	na	1.84			*0.26*	*1.04*	1.04	U		*0.26*	*1.04*
4-amino-2,6-Dinitrotoluene	na	3.77	P	J	*0.26*	*1.04*	0.394	J	J	*0.26*	*1.04*
RDX	6.1	4.77	P	J	*0.26*	*1.04*	1.04	U		*0.26*	*1.04*
Misc. (ug/L)											
Perchlorate	10.9	0.627			*0.1*	*0.2*	0.24			*0.1*	*0.2*
Dissolved Ferrous Iron	na	300					<50				
Dissolved Manganese	na	<200					<200				
Dissolved Inorganic Carbon	na	6600	J	J	*1000*	*2000*	57300	J	J	*1000*	*2000*
Total Organic Carbon	na	1050	J	J	*1000*	*2000*	2040			*500*	*1000*
Chloride	na	5070			*100*	*200*	5220			*100*	*200*
Nitrate (as N)	na	681			*100*	*600*	214	J	J	*100*	*600*
Sulfate	na	38200			*500*	*1000*	31800			*500*	*1000*

12	J	Shading and black font indicates an RG exceedance
12	*12*	Shading in the MDL/MRL columns indicates the MDL/MRL exceeds the RG.

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

Data Qualifiers:

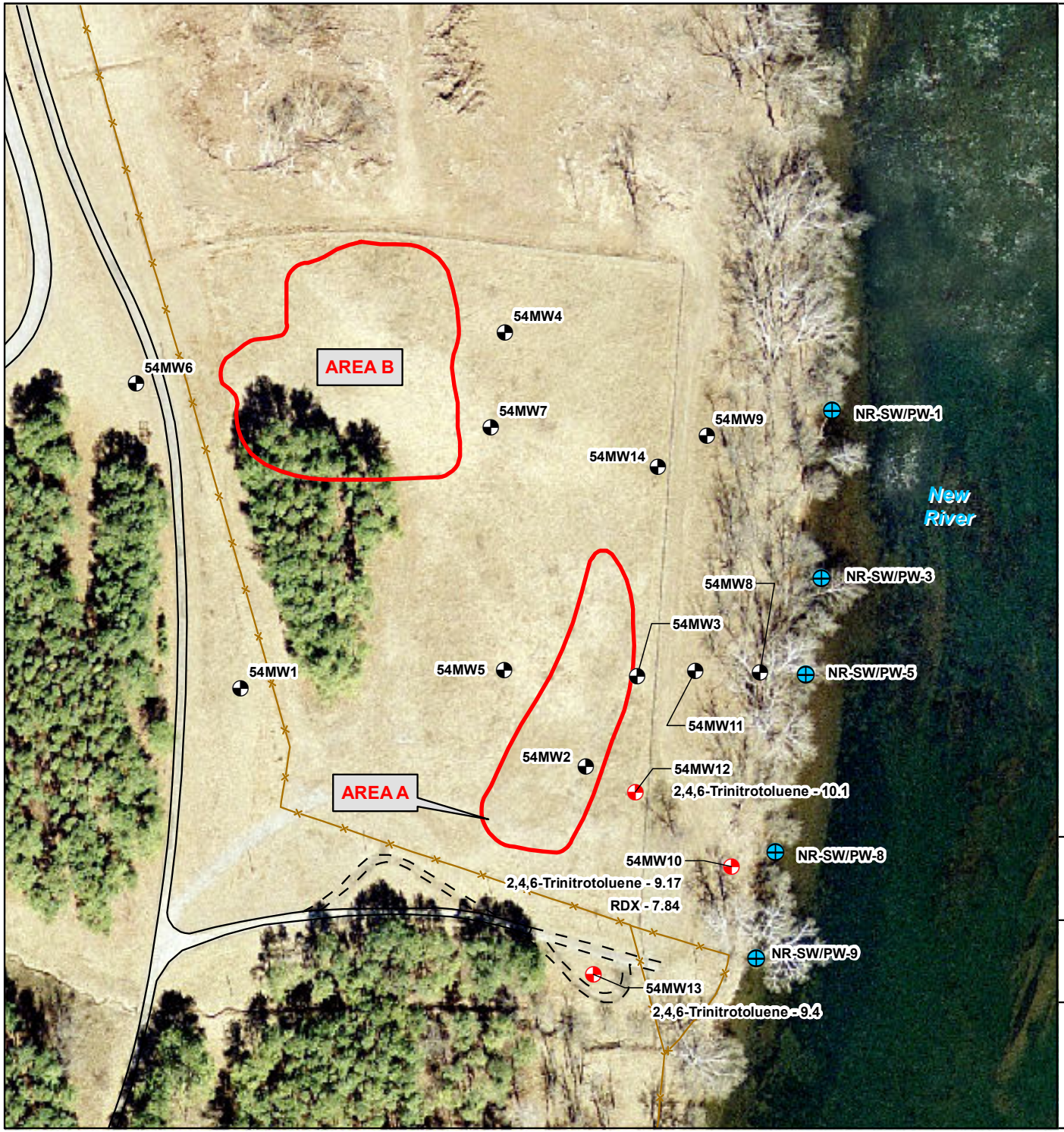
B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration bias high.

P = There is >40% RPD for detected concentrations between the two different columns. Lower of the two values is reported on the Form1

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Surface Water and Pore Water Sample Location
- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 5-1
SWMU 54
August 2012 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig5-1_SWMU54_Q5_08_2012_Results_2012_2013_MNA_rpt.mxd (9/9/2013)

Miscellaneous Analytes

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, nitrate, and sulfate) for the purposes of establishing a baseline concentration of the analytes.

Levels of TOC in the wells ranged from 7.14 to 204 mg/L. Levels of DIC ranged from 6.6 to 73.5 mg/L. Dissolved ferrous iron was measured at levels below 0.2 mg/L and dissolved manganese ranged from <0.05 to 0.3 mg/L. Nitrate was detected between 0.120 and 1.06 mg/L. Finally, sulfate detections ranged from 15.7 to 378 mg/L.

MNA indicators are displayed in **Table 4-3** and **Table 5-2**.

5.3 Sixth Quarter Groundwater Results

Thirteen (13) groundwater monitoring wells were sampled during the sixth quarterly sampling event, with well location 54MW6 being dry at the time of sampling. Sample locations are shown on **Figure 4-1**. Duplicate samples were collected from monitoring wells 54MW7 and 54MW10 (54TM07 and 54TM10, respectively). Groundwater samples were analyzed for explosives, perchlorate, and MNA indicator parameters. Detected constituents are summarized in **Table 5-3** and presented in **Table 5-4**.

Explosives

Four explosives were detected in the groundwater samples. 2,4,6-TNT was detected in three wells (54MW10, 54MW12, and 54MW13) at levels below its RG.

2ADNT was detected in three wells (54MW3, 54MW10, and 54MW12). 4ADNT was detected in four wells (54MW3, 54MW5, 54MW10, and 54MW12).

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX concentrations exceeded RGs in 54MW12, with a concentration of 6.59 µg/L.

Figure 5-2 depicts explosives concentrations for the wells where explosives have exceeded RGs.

Perchlorate

Perchlorate was detected in nine samples (54MW2, 54MW3, 54MW4, 54MW5 through 54MW8, 54MW10, 54MW12, and 54MW13) collected in the sixth quarter MNA sampling. Perchlorate concentrations did not exceed RGs in the sixth quarter of MNA sampling.

Miscellaneous Analyses

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, nitrate, and sulfate) for the purposes of establishing a baseline concentration of the analytes.

Levels of TOC in the wells ranged from 1.97 to 6.73 mg/L. Levels of DIC ranged from 55.0 to 91.8 mg/L. Dissolved ferrous iron was measured at levels below 0.2 mg/L and dissolved manganese ranged from <0.05 to 0.30 mg/L. Nitrate was detected between 0.327 and 3.00 mg/L. Finally, sulfate detections ranged from 22.9 to 403 mg/L.

MNA indicators are displayed in **Table 4-5** and **Table 5-4**.

Table 5-3
SWMU 54 Summary of Sixth Quarter Groundwater Samples

Analyte	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
2,4,6-Trinitrotoluene	7.8	0	3	13	0.843	7.62	54MW12
2-amino-4,6-Dinitrotoluene	na	na	3	13	0.339	3.35	54MW12
4-amino-2,6-Dinitrotoluene	na	na	4	13	0.553	3.45	54MW12
RDX	6.1	1	3	13	0.855	6.59	54MW12
Misc. (ug/L)							
Perchlorate	10.9	0	9	13	0.103	5.31	54MW12
Total Organic Carbon	na	na	12	13	1960	6730	54MW09
Chloride	na	na	13	13	825	5690	54MW05
Nitrate (as N)	na	na	7	13	327	2860	54MW12
Sulfate	na	na	13	13	21500	403000	54MW04

Table 5-4
SWMU 54 Detected Analytes in Sixth Quarter Groundwater Samples
Page 1 of 4

Analyte	Sample ID	54MW01					54MW02					54MW03					54MW04				
	Sample Date	11/8/12					11/8/12					11/8/12					11/6/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.05	U		*0.263*	*1.05*	1.04	U		*0.26*	*1.04*	1.05	U		*0.263*	*1.05*	1.09	U		*0.272*	*1.09*
2-amino-4,6-Dinitrotoluene	na	1.05	U		*0.263*	*1.05*	1.04	U		*0.26*	*1.04*	0.339	J	J	*0.263*	*1.05*	1.09	U		*0.272*	*1.09*
4-amino-2,6-Dinitrotoluene	na	1.05	U		*0.263*	*1.05*	1.04	U		*0.26*	*1.04*	0.553	J	J	*0.263*	*1.05*	1.09	U		*0.272*	*1.09*
RDX	6.1	1.05	U		*0.263*	*1.05*	1.04	U		*0.26*	*1.04*	1.05	U		*0.263*	*1.05*	1.09	U		*0.272*	*1.09*
Misc. (ug/L)																					
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	0.842			*0.1*	*0.2*	0.303			*0.1*	*0.2*	0.141	J	J	*0.1*	*0.2*
Dissolved Ferrous Iron	na	50					50					50					50				
Dissolved Manganese	na	>200					>200					>200					>200				
Dissolved Inorganic Carbon	na	55000			*1000*	*2000*	82100		J	*1000*	*2000*	71800		J	*1000*	*2000*	55300		J	*1000*	*2000*
Total Organic Carbon	na	1960		B	*500*	*1000*	2680		B	*500*	*1000*	3290		B	*500*	*1000*	2930		B	*500*	*1000*
Chloride	na	1580			*100*	*200*	5520			*100*	*200*	5010			*100*	*200*	825	J	J	*500*	*1000*
Nitrate (as N)	na	600	U		*100*	*600*	327	J	J	*100*	*600*	656			*100*	*600*	3000	U		*500*	*3000*
Sulfate	na	31300		K	*500*	*1000*	35400		K	*500*	*1000*	22900		K	*500*	*1000*	403000			*2500*	*5000*

Table 5-4
SWMU 54 Detected Analytes in Sixth Quarter Groundwater Samples
Page 2 of 4

Analyte	Sample ID	54MW05					54MW07					54MW08				
	Sample Date	11/8/12					11/6/12					11/7/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																
2,4,6-Trinitrotoluene	7.8	1.06	U		*0.266*	*1.06*	1.11	U		*0.278*	*1.11*	1.14	U		*0.284*	*1.14*
2-amino-4,6-Dinitrotoluene	na	1.06	U		*0.266*	*1.06*	1.11	U		*0.278*	*1.11*	1.14	U		*0.284*	*1.14*
4-amino-2,6-Dinitrotoluene	na	1.06	U		*0.266*	*1.06*	1.11	U		*0.278*	*1.11*	0.555	J	J	*0.284*	*1.14*
RDX	6.1	1.06	U		*0.266*	*1.06*	1.11	U		*0.278*	*1.11*	1.14	U		*0.284*	*1.14*
Misc. (ug/L)																
Perchlorate	10.9	0.28			*0.1*	*0.2*	0.103	J	J	*0.1*	*0.2*	0.286			*0.1*	*0.2*
Dissolved Ferrous Iron	na	50					50					50				
Dissolved Manganese	na	>200					>200					>200				
Dissolved Inorganic Carbon	na	81200			*1000*	*2000*	61800		J	*1000*	*2000*	79400		J	*1000*	*2000*
Total Organic Carbon	na	4310		J	*500*	*1000*	3720		B	*500*	*1000*	4900			*500*	*1000*
Chloride	na	5690			*100*	*200*	3060			*300*	*600*	4340			*100*	*200*
Nitrate (as N)	na	944			*100*	*600*	1800	U		*300*	*1800*	403	J	J	*100*	*600*
Sulfate	na	21500		K	*500*	*1000*	179000			*1500*	*3000*	60300			*500*	*1000*

Table 5-4
SWMU 54 Detected Analytes in Sixth Quarter Groundwater Samples
Page 3 of 4

Analyte	Sample ID	54MW09					54MW10					54MW11				
	Sample Date	11/7/12					11/7/12					11/7/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																
2,4,6-Trinitrotoluene	7.8	1.16	U		*0.291*	*1.16*	1.59		J	*0.275*	*1.1*	1.11	U		*0.278*	*1.11*
2-amino-4,6-Dinitrotoluene	na	1.16	U		*0.291*	*1.16*	0.648	J	J	*0.275*	*1.1*	1.11	U		*0.278*	*1.11*
4-amino-2,6-Dinitrotoluene	na	1.16	U		*0.291*	*1.16*	1.12	P	J	*0.275*	*1.1*	1.11	U		*0.278*	*1.11*
RDX	6.1	1.16	U		*0.291*	*1.16*	1.35			*0.275*	*1.1*	1.11	U		*0.278*	*1.11*
Misc. (ug/L)																
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	0.344			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Dissolved Ferrous Iron	na	200					50					50				
Dissolved Manganese	na	>200					>200					>200				
Dissolved Inorganic Carbon	na	64700		J	*1000*	*2000*	72000		J	*1000*	*2000*	78200		J	*1000*	*2000*
Total Organic Carbon	na	6730			*500*	*1000*	5550		J	*500*	*1000*	5880			*500*	*1000*
Chloride	na	2510			*300*	*600*	3710			*300*	*600*	4430			*100*	*200*
Nitrate (as N)	na	1800	U		*300*	*1800*	381	J	J	*300*	*1800*	600	U		*100*	*600*
Sulfate	na	199000			*1500*	*3000*	151000			*1500*	*3000*	99100			*500*	*1000*

Table 5-4
SWMU 54 Detected Analytes in Sixth Quarter Groundwater Samples
Page 4 of 4

Analyte	Sample ID	54MW12					54MW13					54MW14				
	Sample Date	11/8/12					11/7/12					11/8/12				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																
2,4,6-Trinitrotoluene	7.8	7.62			*0.26*	*1.04*	0.843	J	J	*0.275*	*1.1*	1.05	U		*0.263*	*1.05*
2-amino-4,6-Dinitrotoluene	na	3.35			*0.26*	*1.04*	1.1	U		*0.275*	*1.1*	1.05	U		*0.263*	*1.05*
4-amino-2,6-Dinitrotoluene	na	3.45	P	J	*0.26*	*1.04*	1.1	U		*0.275*	*1.1*	1.05	U		*0.263*	*1.05*
RDX	6.1	6.59			*0.26*	*1.04*	0.855	J	J	*0.275*	*1.1*	1.05	U		*0.263*	*1.05*
Misc. (ug/L)																
Perchlorate	10.9	5.31			*0.1*	*0.2*	0.308			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Dissolved Ferrous Iron	na	100					300					50				
Dissolved Manganese	na	>200					>200					>200				
Dissolved Inorganic Carbon	na	66100		J	*1000*	*2000*	91800		J	*1000*	*2000*	75700		J	*1000*	*2000*
Total Organic Carbon	na	3410		B	*500*	*1000*	2000	U	UJ	*1000*	*2000*	2120		B	*500*	*1000*
Chloride	na	3400			*100*	*200*	4720			*100*	*200*	5530			*100*	*200*
Nitrate (as N)	na	2860			*100*	*600*	369	J	J	*100*	*600*	600	U		*100*	*600*
Sulfate	na	49800		K	*500*	*1000*	76700			*500*	*1000*	39000		K	*500*	*1000*

12	J	Shading and black font indicates an RG exceedance
12	*12*	Shading in the MDL/MRL columns indicates the MDL/MRL exceeds the RG.

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

Data Qualifiers:

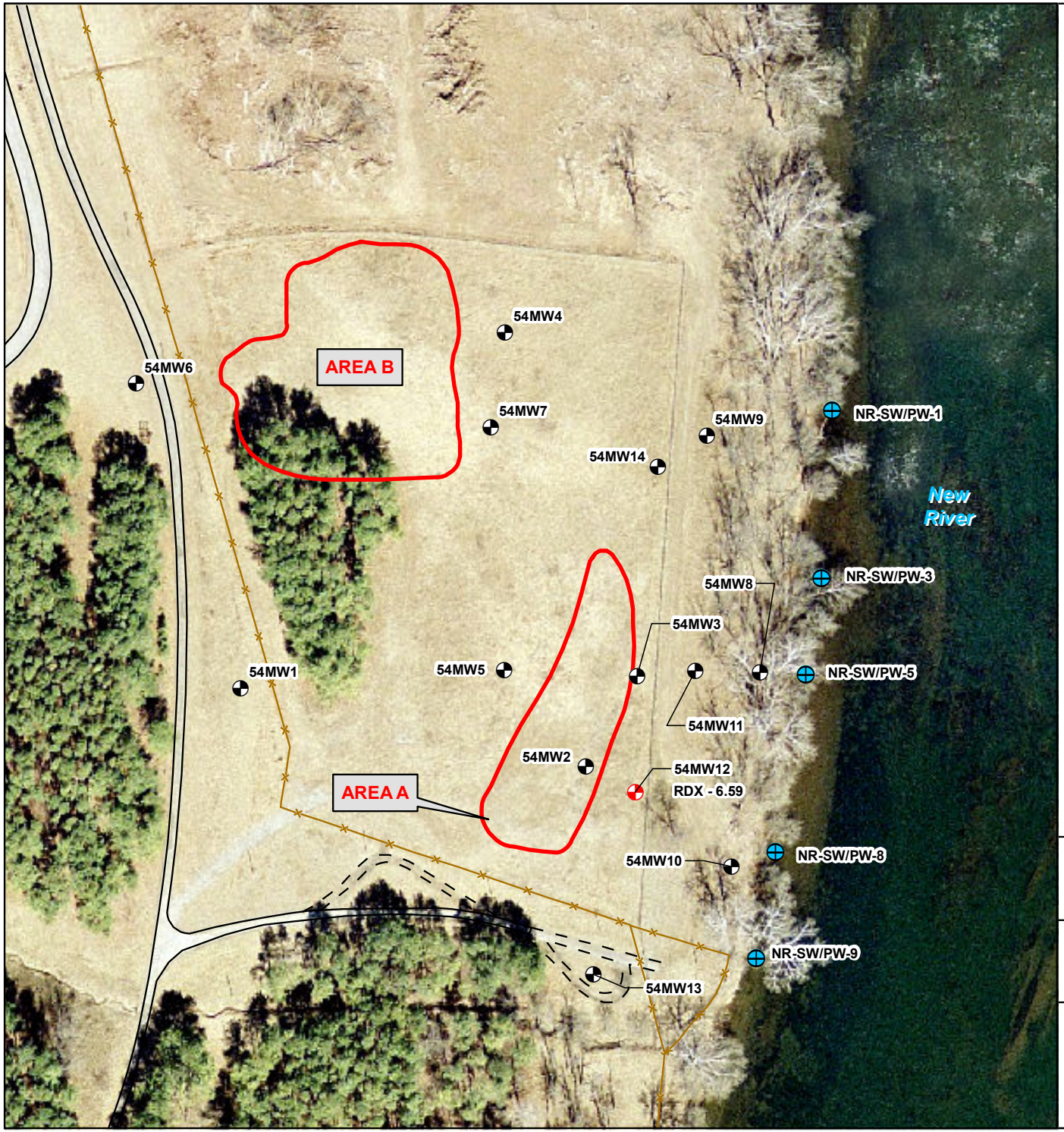
B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration bias high.

P = There is >40% RPD for detected concentrations between the two different columns. Lower of the two values is reported on the Form1

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Surface Water and Pore Water Sample Location
- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 5-2

SWMU 54
November 2012 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig5-2_SWMU54_Q6_11_2012_Results_2012_2013_MNA_rpt.mxd (9/9/2013)

5.4 Seventh Quarter Groundwater Results

Fourteen (14) groundwater monitoring wells were sampled during the seventh quarterly sampling event. Sample locations are shown on **Figure 4-1**. Duplicate samples were collected from monitoring wells 54MW4 and 54MW9 (54TM1 and 54TM5, respectively) for explosives, perchlorate, and MNA indicator parameters. Groundwater samples were analyzed for explosives, perchlorate, and MNA indicator parameters. Detected constituents are summarized in **Table 5-5** and presented in **Table 5-6**.

Explosives

Four explosives were detected in the groundwater samples. 2,4,6-TNT was detected in three wells (54MW10, 54MW12, and 54MW13). 2,4,6-TNT did not exceed its RG in any wells sampled in the seventh quarter of groundwater sampling.

2ADNT was detected in four wells (54MW2, 54MW3, 54MW10, and 54MW12). 4ADNT was detected in four wells (54MW2, 54MW3, 54MW10, and 54MW12).

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX concentrations did not exceed its RG in the seventh quarter of groundwater sampling.

Figure 5-3 depicts explosives concentrations for the wells where explosives have been detected, as compared to RGs.

Perchlorate

Perchlorate was detected in 11 samples (54MW2, 54MW3, and 54MW5 through 54MW13) collected in the third quarter MNA sampling. Perchlorate concentrations did not exceed RGs in the third quarter MNA sampling.

Miscellaneous Analyses

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, nitrate, and sulfate) for the purposes of establishing a baseline concentration of the analyses.

Levels of TOC in the wells ranged from non-detect to 2.09 mg/L. Levels of DIC ranged from 22.2 to 80.4 mg/L. Dissolved ferrous iron was measured at levels below 0.2 mg/L and dissolved manganese ranged from <0.05 to 0.25 mg/L. Nitrate was detected between non-detect and 1.95 mg/L. Finally, sulfate detections ranged from 15.5 to 340 mg/L.

MNA indicators are displayed in **Table 4-7** and **Table 5-6**.

Table 5-5
SWMU 54 Summary of Seventh Quarter Groundwater Samples

Analyte	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
2,4,6-Trinitrotoluene	7.8	0	3	14	0.318	6.29	54MW12
2-amino-4,6-Dinitrotoluene	na	na	4	14	0.367	2.95	54MW12
4-amino-2,6-Dinitrotoluene	na	na	4	14	0.378	1.82	54MW12
RDX	6.1	0	3	14	0.642	3.79	54MW12
Misc. (ug/L)							
Perchlorate	10.9	0	11	14	0.16	2.98	54MW12
Total Organic Carbon	na	na	12	14	683	2090	54MW09
Chloride	na	na	14	14	680	5540	54MW09
Nitrate (as N)	na	na	11	14	205	1950	54MW12
Sulfate	na	na	14	14	4290	340000	54MW04

Table 5-6
SWMU 54 Detected Analytes in Seventh Quarter Groundwater Samples

Analyte	Sample ID	54MW01					54MW02					54MW03					54MW04				
	Sample Date	2/19/13					2/21/13					2/20/13					2/19/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.05	U		*0.263*	*1.05*	1.09	U		*0.272*	*1.09*	1.08	U		*0.269*	*1.08*	1.14	U		*0.284*	*1.14*
2-amino-4,6-Dinitrotoluene	na	1.05	U		*0.263*	*1.05*	1.09	J	J	*0.272*	*1.09*	0.367	J	J	*0.269*	*1.08*	1.14	U		*0.284*	*1.14*
4-amino-2,6-Dinitrotoluene	na	1.05	U		*0.263*	*1.05*	1.01	J	J	*0.272*	*1.09*	0.378	J	J	*0.269*	*1.08*	1.14	U		*0.284*	*1.14*
RDX	6.1	1.05	U		*0.263*	*1.05*	1.09	U		*0.272*	*1.09*	1.08	U		*0.269*	*1.08*	1.14	U		*0.284*	*1.14*
Misc. (ug/L)																					
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	1.41			*0.1*	*0.2*	0.309			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Dissolved Ferrous Iron	na	<200					<200					<200					<200				
Dissolved Manganese	na	50					<50					100					50				
Dissolved Inorganic Carbon	na	56700		J	*1000*	*2000*	80400		J	*1000*	*2000*	64500		J	*1000*	*2000*	57400		J	*1000*	*2000*
Total Organic Carbon	na	1190		B	*500*	*1000*	916	J	B	*500*	*1000*	1070		B	*500*	*1000*	1350		B	*500*	*1000*
Chloride	na	1250			*100*	*200*	4300			*100*	*200*	3410			*100*	*200*	1960			*500*	*1000*
Nitrate (as N)	na	600	U		*100*	*600*	315	J	J	*100*	*600*	423	J	J	*100*	*600*	3000	U		*500*	*3000*
Sulfate	na	27100			*500*	*1000*	36800			*500*	*1000*	25300			*500*	*1000*	340000			*2500*	*5000*

Table 5-6
SWMU 54 Detected Analytes in Seventh Quarter Groundwater Samples

Analyte	Sample ID	54MW05					54MW06					54MW07					54MW08				
	Sample Date	2/20/13					2/19/13					2/19/13					2/20/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.1	U		*0.275*	*1.1*	1.08	U		*0.269*	*1.08*	2.38	U		*0.595*	*2.38*	1.14	U		*0.284*	*1.14*
2-amino-4,6-Dinitrotoluene	na	1.1	U		*0.275*	*1.1*	1.08	U		*0.269*	*1.08*	2.38	U		*0.595*	*2.38*	1.14	U		*0.284*	*1.14*
4-amino-2,6-Dinitrotoluene	na	1.1	U		*0.275*	*1.1*	1.08	U		*0.269*	*1.08*	2.38	U		*0.595*	*2.38*	1.14	U		*0.284*	*1.14*
RDX	6.1	1.1	U		*0.275*	*1.1*	1.08	U		*0.269*	*1.08*	2.38	U		*0.595*	*2.38*	1.14	U		*0.284*	*1.14*
Misc. (ug/L)																					
Perchlorate	10.9	0.255		J	*0.1*	*0.2*	0.16	J	J	*0.1*	*0.2*	0.162	J	J	*0.1*	*0.2*	0.484			*0.1*	*0.2*
Dissolved Ferrous Iron	na	<200					<200					<200					<200				
Dissolved Manganese	na	<50					50					100					50				
Dissolved Inorganic Carbon	na	54200		J	*1000*	*2000*	36500		J	*1000*	*2000*	22200		J	*1000*	*2000*	55800		J	*1000*	*2000*
Total Organic Carbon	na	1000	U		*500*	*1000*	1500		B	*500*	*1000*	791	J	B	*500*	*1000*	1000	U		*500*	*1000*
Chloride	na	4160			*100*	*200*	680			*100*	*200*	1750			*100*	*200*	5040			*100*	*200*
Nitrate (as N)	na	636			*100*	*600*	209	J	J	*100*	*600*	205	J	J	*100*	*600*	336	J	J	*100*	*600*
Sulfate	na	15500			*500*	*1000*	4290			*500*	*1000*	34200			*500*	*1000*	44600			*500*	*1000*

Table 5-6
SWMU 54 Detected Analytes in Seventh Quarter Groundwater Samples

Analyte	Sample ID	54MW09					54MW10					54MW11					54MW12				
	Sample Date	2/20/13					2/20/13					2/20/13					2/21/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.11	U		*0.278*	*1.11*	1.88		B	*0.275*	*1.1*	1.14	U		*0.284*	*1.14*	6.29			*0.275*	*1.1*
2-amino-4,6-Dinitrotoluene	na	1.11	U		*0.278*	*1.11*	0.8	J	J	*0.275*	*1.1*	1.14	U		*0.284*	*1.14*	2.95			*0.275*	*1.1*
4-amino-2,6-Dinitrotoluene	na	1.11	U		*0.278*	*1.11*	1	J	J	*0.275*	*1.1*	1.14	U		*0.284*	*1.14*	1.82			*0.275*	*1.1*
RDX	6.1	1.11	U		*0.278*	*1.11*	2.36			*0.275*	*1.1*	1.14	U		*0.284*	*1.14*	3.79			*0.275*	*1.1*
Misc. (ug/L)																					
Perchlorate	10.9	1.07			*0.1*	*0.2*	0.832			*0.1*	*0.2*	0.263		J	*0.1*	*0.2*	2.98			*0.1*	*0.2*
Dissolved Ferrous Iron	na	<200					<200					<200					<200				
Dissolved Manganese	na	200					100					250					>50				
Dissolved Inorganic Carbon	na	35300		J	*1000*	*2000*	56900		J	*1000*	*2000*	58400		J	*1000*	*2000*	55300		J	*1000*	*2000*
Total Organic Carbon	na	2090		B	*500*	*1000*	1140		B	*500*	*1000*	1880		B	*500*	*1000*	1210		B	*500*	*1000*
Chloride	na	5540			*100*	*200*	5530			*100*	*200*	4610			*100*	*200*	3850			*100*	*200*
Nitrate (as N)	na	510	J	J	*100*	*600*	477	J	J	*100*	*600*	346	J	J	*100*	*600*	1950			*100*	*600*
Sulfate	na	117000			*500*	*1000*	70100			*500*	*1000*	120000			*2500*	*5000*	35800			*500*	*1000*

Table 5-6
SWMU 54 Detected Analytes in Seventh Quarter Groundwater Samples
Page 4 of 4

Analyte	Sample ID	54MW13					54MW14				
	Sample Date	2/21/13					2/19/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
2,4,6-Trinitrotoluene	7.8	0.318	J	B	*0.266*	*1.06*	1.09	U		*0.272*	*1.09*
2-amino-4,6-Dinitrotoluene	na	1.06	U		*0.266*	*1.06*	1.09	U		*0.272*	*1.09*
4-amino-2,6-Dinitrotoluene	na	1.06	U		*0.266*	*1.06*	1.09	U		*0.272*	*1.09*
RDX	6.1	0.642	J	J	*0.266*	*1.06*	1.09	U		*0.272*	*1.09*
Misc. (ug/L)											
Perchlorate	10.9	0.313			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Dissolved Ferrous Iron	na	<200					<200				
Dissolved Manganese	na	200					>50				
Dissolved Inorganic Carbon	na	44200		J	*1000*	*2000*	76100		J	*1000*	*2000*
Total Organic Carbon	na	683	J	B	*500*	*1000*	1460		B	*500*	*1000*
Chloride	na	1920			*100*	*200*	4370			*100*	*200*
Nitrate (as N)	na	501	J	J	*100*	*600*	600	U		*100*	*600*
Sulfate	na	23100			*500*	*1000*	41100			*500*	*1000*

12	J	Shading and black font indicates an RG exceedance
12	*12*	Shading in the MDL/MRL columns indicates the MDL/MRL exceeds the RG.

SLs for non-carcinogenic compounds have been recalculated to an HI of 0.1.
SLs for carcinogenic compounds are shown in red font.
SL source: ORNL Regional Screening Table. November 2011.
MCL source: 2011 Edition of the Drinking Water Standards and Health Advisories. USEPA, January 2011

Data Qualifiers:

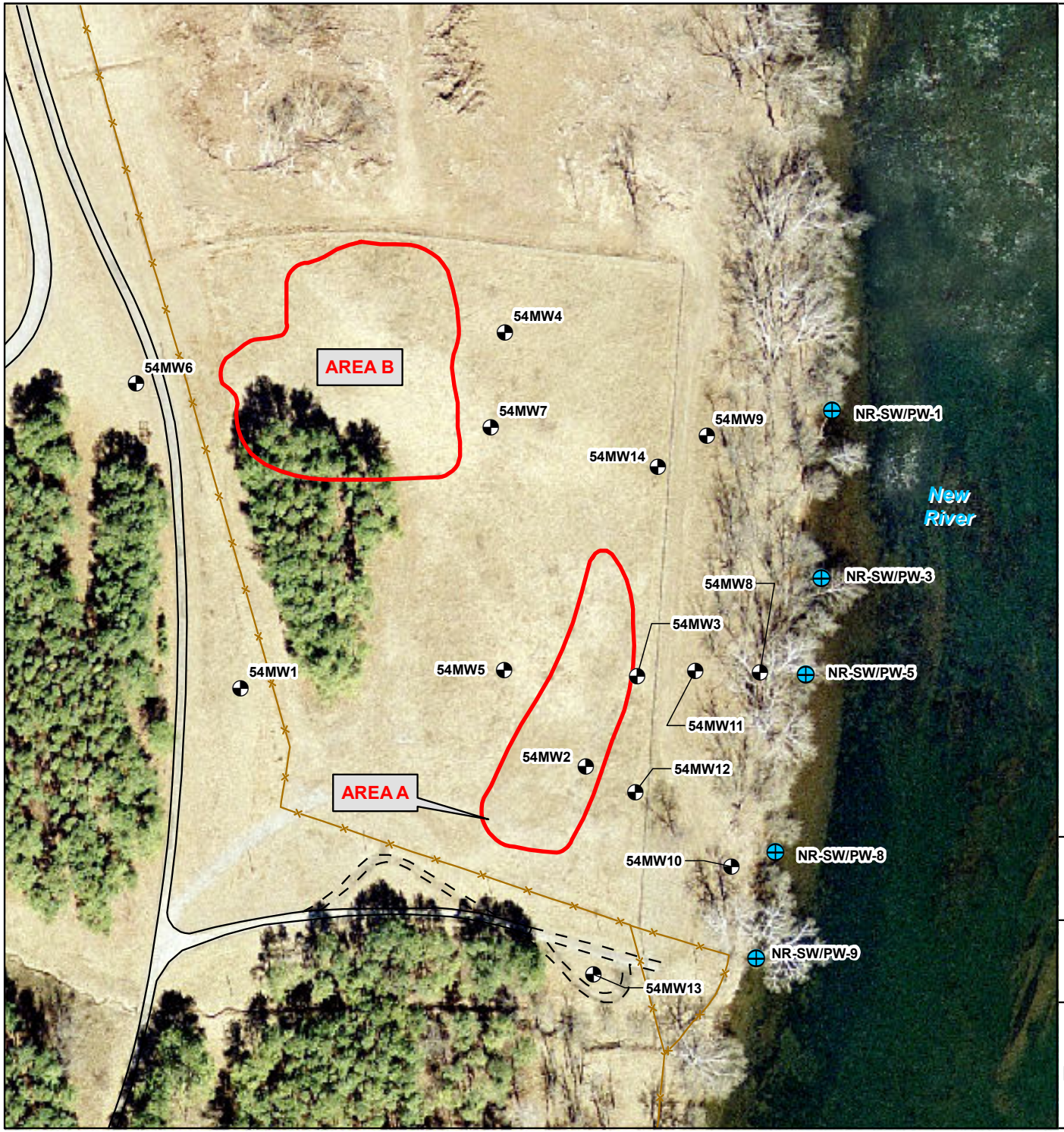
B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration bias high.

P = There is >40% RPD for detected concentrations between the two different columns. Lower of the two values is reported on the Form1

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Surface Water and Pore Water Sample Location
- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported (no samples collected in February 2013 exceed).

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 5-3
SWMU 54
February 2013 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig5-3_SWMU54_Q7_02_2013_Results_2012_2013_MNA_rpt.mxd (9/9/2013)

5.5 Eighth Quarter Groundwater Results

Fourteen (14) groundwater monitoring wells were sampled during the eighth quarterly sampling event. Sample locations are shown on **Figure 4-1**. Duplicate samples were collected from monitoring wells 54MW4 and 54MW5 (54TM01 and 54TM02, respectively) for explosives, perchlorate, and MNA indicator parameters. Groundwater samples were analyzed for explosives, perchlorate, and MNA indicator parameters. Detected constituents are summarized in **Table 5-7** and presented in **Table 5-8**.

Explosives

Four explosives were detected in the groundwater samples. 2,4,6-TNT was detected in four wells (54MW2, 54MW10, 54MW12, and 54MW13). 2,4,6-TNT exceeded its RG in one well (54MW12), with a concentration of 108 µg/L.

2ADNT was detected in four wells (54MW2, 54MW10, 54MW12, and 54MW13). 4ADNT was detected in five wells (54MW2, 54MW3, 54MW10, 54MW12, and 54MW13).

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX concentrations exceeded RGs in 54MW12, with a concentration of 25 µg/L.

Figure 5-4 depicts explosives exceedances for the eighth quarter of groundwater sampling.

Perchlorate

Perchlorate was detected in samples collected from 12 wells (54MW2 and 54MW4 through 54MW14, and 54MW12 through 54MW14) in the eighth quarter MNA sampling. Perchlorate concentrations exceeded RGs at 54MW12 with a concentration of 22.7 µg/L. **Figure 5-4** depicts perchlorate exceedances for the eighth quarter of groundwater sampling.

Miscellaneous Analyses

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, nitrate, and sulfate) for the purposes of establishing a baseline concentration of the analyses.

Levels of TOC in the wells ranged from non-detect to 2.41 mg/L. Levels of DIC ranged from 37.7 to 67.5 mg/L. Dissolved ferrous iron was measured at levels below 0.2 mg/L and dissolved manganese ranged from <0.05 to 0.15 mg/L. Nitrate levels were ranged from non-detect to 4.03 mg/L. Finally, sulfate detections ranged from 14.0 to 329 mg/L.

MNA indicators are displayed in **Table 4-9** and **Table 5-8**.

Table 5-7
SWMU 54 Summary of Eighth Quarter Groundwater Samples

Analyte	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
2,4,6-Trinitrotoluene	7.8	1	4	14	0.637	108	54MW12
2-amino-4,6-Dinitrotoluene	na	na	4	14	0.652	8.43	54MW12
4-amino-2,6-Dinitrotoluene	na	na	5	14	0.455	5.78	54MW12
RDX	6.1	1	3	14	1.29	25	54MW12
Misc. (ug/L)							
Perchlorate	10.9	1	12	14	0.103	22.7	54MW12
Total Organic Carbon	na	na	12	14	583	2410	54MW06
Chloride	na	na	14	14	1240	5800	54MW09
Nitrate (as N)	na	na	11	14	368	4030	54MW12
Sulfate	na	na	14	14	14000	329000	54MW04

Table 5-8
SWMU 54 Detected Analytes in Eighth Quarter Groundwater Samples
Page 1 of 4

Analyte	Sample ID	54MW01					54MW02					54MW03					54MW04				
	Sample Date	5/14/13					5/16/13					5/14/13					5/14/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.14	U		*0.284*	*1.14*	0.749	J	J	*0.298*	*1.19*	1.14	U		*0.284*	*1.14*	1.14	U		*0.284*	*1.14*
2-amino-4,6-Dinitrotoluene	na	1.14	U		*0.284*	*1.14*	1.98		L	*0.298*	*1.19*	1.14	U		*0.284*	*1.14*	1.14	U		*0.284*	*1.14*
4-amino-2,6-Dinitrotoluene	na	1.14	U		*0.284*	*1.14*	1.45		L	*0.298*	*1.19*	0.455	J	J	*0.284*	*1.14*	1.14	U		*0.284*	*1.14*
RDX	6.1	1.14	U		*0.284*	*1.14*	1.19	U	UL	*0.298*	*1.19*	1.14	U		*0.284*	*1.14*	1.14	U		*0.284*	*1.14*
Misc. (ug/L)																					
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	1.82		L	*0.1*	*0.2*	0.59			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Dissolved Ferrous Iron	na	>200					>200					>200					>200				
Dissolved Manganese	na	50					50					50					50				
Dissolved Inorganic Carbon	na	42600		J	*1000*	*2000*	57500		J	*1000*	*2000*	55700		J	*1000*	*2000*	52500		J	*1000*	*2000*
Total Organic Carbon	na	949	J	B	*500*	*1000*	1680		B	*500*	*1000*	1360		B	*500*	*1000*	619	J	B	*500*	*1000*
Chloride	na	2110		B	*100*	*200*	4460		L	*100*	*200*	4450			*100*	*200*	3240			*500*	*1000*
Nitrate (as N)	na	368	J	J	*100*	*600*	988		L	*100*	*600*	911			*100*	*600*	3000	U		*500*	*3000*
Sulfate	na	26100			*500*	*1000*	24100		L	*500*	*1000*	29000			*500*	*1000*	329000			*2500*	*5000*

Table 5-8
SWMU 54 Detected Analytes in Eighth Quarter Groundwater Samples

Analyte	Sample ID	54MW05					54MW06					54MW07					54MW08				
	Sample Date	5/14/13					5/14/13					5/14/13					5/15/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.11	U		*0.278*	*1.11*	1.09	U		*0.272*	*1.09*	8.33	UJ	UJ	*2.08*	*8.33*	1.11	U		*0.278*	*1.11*
2-amino-4,6-Dinitrotoluene	na	1.11	U		*0.278*	*1.11*	1.09	U		*0.272*	*1.09*	8.33	UJ	UJ	*2.08*	*8.33*	1.11	U		*0.278*	*1.11*
4-amino-2,6-Dinitrotoluene	na	1.11	U		*0.278*	*1.11*	1.09	U		*0.272*	*1.09*	8.33	UJ	UJ	*2.08*	*8.33*	1.11	U		*0.278*	*1.11*
RDX	6.1	1.11	U		*0.278*	*1.11*	1.09	U		*0.272*	*1.09*	8.33	UJ	UJ	*2.08*	*8.33*	1.11	U		*0.278*	*1.11*
Misc. (ug/L)																					
Perchlorate	10.9	0.309			*0.1*	*0.2*	0.171	J	J	*0.1*	*0.2*	0.103	J	J	*0.1*	*0.2*	0.118	J	J	*0.1*	*0.2*
Dissolved Ferrous Iron	na	>200					>200					>200					200				
Dissolved Manganese	na	>50					>50					50					50				
Dissolved Inorganic Carbon	na	45800		J	*1000*	*2000*	40700		J	*1000*	*2000*	57000		J	*1000*	*2000*	62300		J	*1000*	*2000*
Total Organic Carbon	na	1060		B	*500*	*1000*	2410		B	*500*	*1000*	793	J	B	*500*	*1000*	1000	U		*500*	*1000*
Chloride	na	5510			*100*	*200*	1240		B	*100*	*200*	3640			*300*	*600*	4730			*100*	*200*
Nitrate (as N)	na	1600			*100*	*600*	600	U		*100*	*600*	1100	J	J	*300*	*1800*	600	U		*100*	*600*
Sulfate	na	15700			*500*	*1000*	14000			*500*	*1000*	137000			*1500*	*3000*	41100			*500*	*1000*

Table 5-8
SWMU 54 Detected Analytes in Eighth Quarter Groundwater Samples
Page 3 of 4

Analyte	Sample ID	54MW09					54MW10					54MW11					54MW12				
	Sample Date	5/15/13					5/15/13					5/15/13					5/16/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.8	1.16	U		*0.291*	*1.16*	0.637	J	J	*0.284*	*1.14*	1.16	U		*0.291*	*1.16*	108		L	*2.91*	*11.6*
2-amino-4,6-Dinitrotoluene	na	1.16	U		*0.291*	*1.16*	0.652	J	J	*0.284*	*1.14*	1.16	U		*0.291*	*1.16*	8.43		L	*0.291*	*1.16*
4-amino-2,6-Dinitrotoluene	na	1.16	U		*0.291*	*1.16*	0.877	J	J	*0.284*	*1.14*	1.16	U		*0.291*	*1.16*	5.78		L	*0.291*	*1.16*
RDX	6.1	1.16	U		*0.291*	*1.16*	1.29			*0.284*	*1.14*	1.16	U		*0.291*	*1.16*	25		J	*0.291*	*1.16*
Misc. (ug/L)																					
Perchlorate	10.9	0.923			*0.1*	*0.2*	0.835			*0.1*	*0.2*	0.43			*0.1*	*0.2*	22.7		L	*1*	*2*
Dissolved Ferrous Iron	na	>200					>200					>200					>200				
Dissolved Manganese	na	100					50					50					>50				
Dissolved Inorganic Carbon	na	37700		J	*1000*	*2000*	58700		J	*1000*	*2000*	53800		J	*1000*	*2000*	67400		J	*1000*	*2000*
Total Organic Carbon	na	1380		B	*500*	*1000*	1000	U	UJ	*500*	*1000*	635	J	B	*500*	*1000*	1360		B	*500*	*1000*
Chloride	na	5800			*100*	*200*	5040			*100*	*200*	3990			*100*	*200*	5010		L	*100*	*200*
Nitrate (as N)	na	637			*100*	*600*	740			*100*	*600*	647			*100*	*600*	4030		L	*100*	*600*
Sulfate	na	96700			*500*	*1000*	48800			*500*	*1000*	89400			*500*	*1000*	47600		L	*500*	*1000*

Table 5-8
SWMU 54 Detected Analytes in Eighth Quarter Groundwater Samples
Page 4 of 4

Analyte	Sample ID	54MW13					54MW14				
	Sample Date	5/16/13					5/14/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
2,4,6-Trinitrotoluene	7.8	4.91		L	*0.333*	*1.33*	1.16	U		*0.291*	*1.16*
2-amino-4,6-Dinitrotoluene	na	0.869	J	J	*0.333*	*1.33*	1.16	U		*0.291*	*1.16*
4-amino-2,6-Dinitrotoluene	na	0.752	J	J	*0.333*	*1.33*	1.16	U		*0.291*	*1.16*
RDX	6.1	3.2		L	*0.333*	*1.33*	1.16	U		*0.291*	*1.16*
Misc. (ug/L)											
Perchlorate	10.9	0.64		L	*0.1*	*0.2*	0.195	J	J	*0.1*	*0.2*
Dissolved Ferrous Iron	na	>200					>200				
Dissolved Manganese	na	150					50				
Dissolved Inorganic Carbon	na	49000		J	*1000*	*2000*	67500		J	*1000*	*2000*
Total Organic Carbon	na	817	J	B	*500*	*1000*	583	J	B	*500*	*1000*
Chloride	na	3900		L	*100*	*200*	4890			*100*	*200*
Nitrate (as N)	na	1050		L	*100*	*600*	543	J	J	*100*	*600*
Sulfate	na	29200		L	*500*	*1000*	37000			*500*	*1000*

12 J Shading and black font indicates an RG exceedance

12 *12* Shading in the MDL/MRL columns indicates the MDL/MRL exceeds the RG.

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

Data Qualifiers:

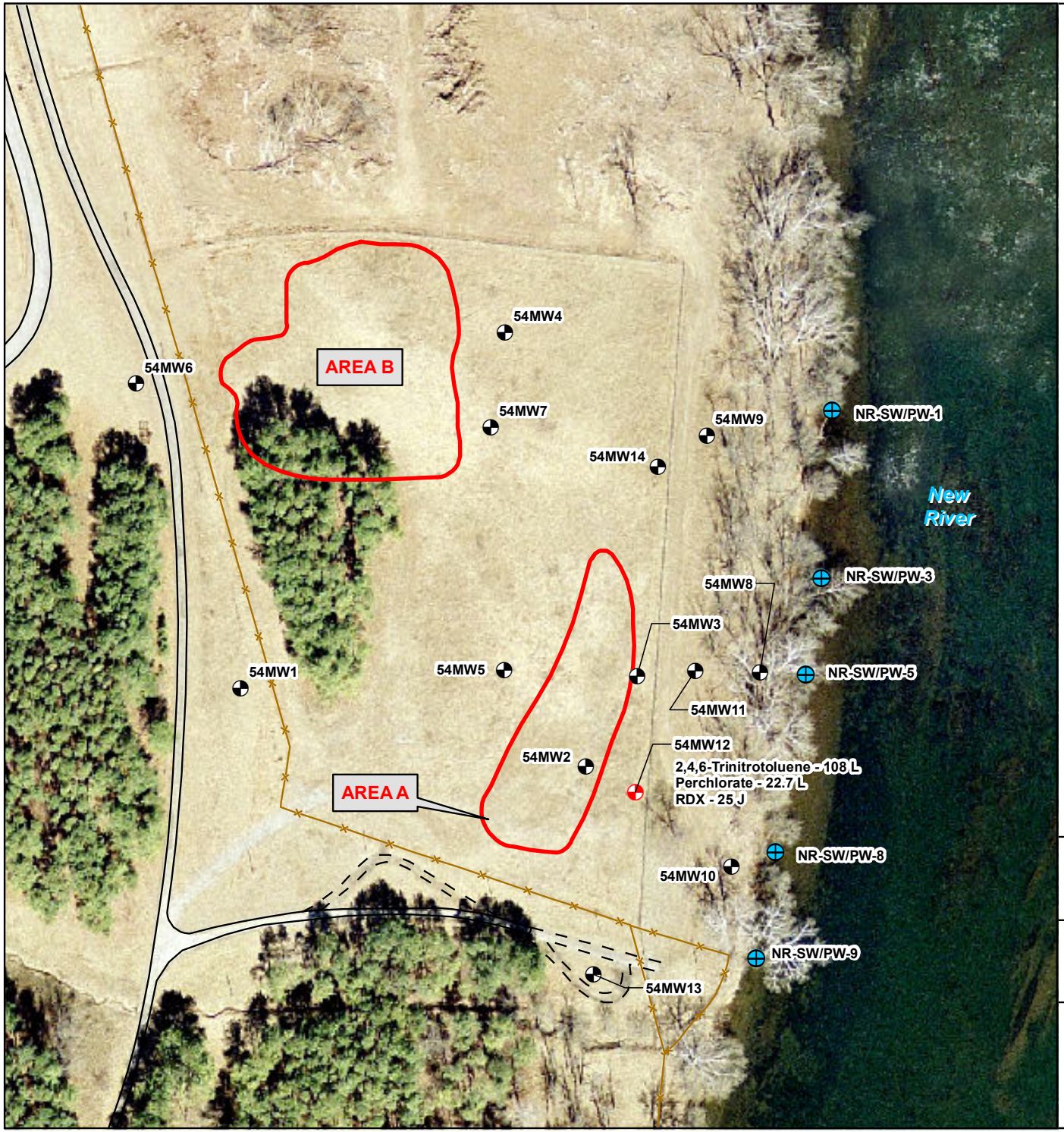
B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration bias high.

L = Analyte present. Reported value may be biased low. Actual value is expected to be higher.

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Surface Water and Pore Water Sample Location
- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 5-4
SWMU 54
May 2013 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig5-4_SWMU54_Q8_05_2013_Results_2012_2013_MNA_rpt.mxd (9/9/2013)

5.6 Pore Water Sampling

Five pore water samples were collected in the eighth quarter of MNA monitoring at SWMU 54. Sample locations are shown on **Figure 4-1**. Samples were collected for explosives, perchlorate, and MNA indicator parameters. Detected constituents are summarized in **Table 5-9** and presented in **Table 5-10**.

Explosives

Explosives were not detected in pore water samples.

Perchlorate

Perchlorate was not detected in pore water samples.

Miscellaneous Analyses

Pore water samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, nitrate, and sulfate) for the purposes of establishing a baseline concentration of the analyses.

Levels of TOC in the wells ranged from 0.810 to 4.15 mg/L. Levels of DIC ranged from 12.7 to 86.6 mg/L. Dissolved ferrous iron was measured at levels below 0.2 mg/L and dissolved manganese ranged from <0.05 to <0.05 mg/L. Nitrate was detected in four of the five locations ranging from 0.393 to 0.723 mg/L. Finally, sulfate detections ranged from 7.15 to 18.1 mg/L.

MNA indicators are displayed in **Table 4-10** and **Table 5-10**.

Table 5-9
SWMU 54 Summary of Second Year Pore Water Samples

Analyte	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)	***None detected***						
Misc. (ug/L)							
Total Organic Carbon	na	na	5	5	810	4150	NRSW5/PW5
Chloride	na	0	5	5	6380	10400	NRSW5/PW5
Nitrate (as N)	na	0	4	5	393	723	NRSW3/PW3
Sulfate	na	0	5	5	7150	18100	NRSW9/PW9

Table 5-10
Detected Analytes in Second Year Pore Water Samples

Analyte	Sample ID	NRSW1/PW1					NRSW3/PW3					NRSW5/PW5					NRSW8/PW8					NRSW9/PW9				
	Sample Date	5/15/13					5/15/13					5/15/13					5/15/13					5/15/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)	None detected																									
Misc. (ug/L)																										
Total Organic Carbon	na	2850		J	*500*	*1000*	3610		J	*500*	*1000*	4150			*1000*	*2000*	3030			*500*	*1000*	810	J	B	*500*	*1000*
Chloride	na	6380			*100*	*200*	6860			*100*	*200*	10400			*100*	*200*	7470			*100*	*200*	7700			*100*	*200*
Nitrate (as N)	na	642			*100*	*600*	723			*100*	*600*	600	U		*100*	*600*	393	J	J	*100*	*600*	461	J	J	*100*	*600*
Sulfate	na	7150			*500*	*1000*	7200			*500*	*1000*	9500			*500*	*1000*	7620			*500*	*1000*	18100			*500*	*1000*

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

Data Qualifiers:

B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.

5.7 Year One Through Year Two Sample Results

This section discusses the results from the first 2 years of MNA sampling. Samples collected during the first and second years were analyzed for the full suite of analytical parameters described in **Table 4-2** (explosives, perchlorate, and MNA indicators).

5.7.1 Groundwater

Explosives

Samples from the wells within SWMU 54 were analyzed for explosives for eight quarters of sampling. Five explosives (2,4,6-TNT, 2,4-DNT, 4ADNT, 2-amino-2,4-DNT, and RDX) were detected in the samples.

Explosives concentrations were below selected RGs in all monitoring well locations except 54MW10, 54MW12, and 54MW13. **Figures 5-5 through 5-7** depict the concentrations at these sampling locations throughout the eight quarters of sampling.

2,4,6-TNT was not detected in monitoring wells 54MW1, 54MW3 through 54MW7, 54MW9, 54MW11, and 54MW14 through eight quarters of sampling. 2,4,6-TNT concentrations have remained below RGs in 54MW2 and 54MW8 throughout the duration of the monitoring. 2,4,6-TNT concentrations were detected at levels above RGs in the fifth quarter of sampling at 54MW10. 2,4,6-TNT concentrations at 54MW10 have since remained below the RG in Quarters 6 through 8. 2,4,6-TNT concentrations have consistently been above the RG for all sampling events except Quarters 6 and 7. Quarter 8 recorded the highest concentration of 2,4,6-TNT to date at 108 µg/L. 2,4,6-TNT concentrations at 54MW13 have typically been below the RG with the exception of the fifth quarter of sampling where it exceeded the RG.

2ADNT and 4ADNT, degradation intermediaries of 2,4,6-TNT, were detected at monitoring wells 54MW2, 54MW3, 54MW5, 54MW8, 54MW10, 54MW12, 54MW13, and 54MW14. An analysis of monitoring locations 54MW10, 54MW12, and 54MW13 shows a correlation in 2,4,6-TNT concentration spikes with increasing concentrations of both 2ADNT and 4ADNT, indicating a limited transformation process from 2,4,6-TNT (**Figures 5-8 through 5-10**, respectively). 2,4,6-TNT degradation leading to amino-DNTs is likely occurring at localized zones within the soil matrix where the conditions are more favorable.

One detection of 2,4-DNT was encountered in the fourth quarter sample of 54MW12 at levels below RGs. 2,4-DNT has not been detected at any other sample location at SWMU 54.

RDX was not encountered in monitoring wells 54MW1, 54MW3 through 54MW7, 54MW9, 54MW11, and 54MW14. Concentrations of RDX were found to be below the RG for eight quarters in monitoring wells 54MW2, 54MW8, and 54MW13. RDX concentrations exceeded the RDX RG in the fifth quarter in sample location 54MW10. RDX concentrations measured in 54MW12 exceeded the RG in five of eight quarters sampled. It is currently unclear if MNA is the cause of a general downward trend in RDX concentrations site wide, with the exception of Quarters 5 and 8 at monitoring locations 54MW10 and 54MW12 (**Figures 5-5 and 5-7**). Additional testing of RDX degradation intermediaries would be useful in determining the degree, if any, MNA is playing in the remediation of RDX at SWMU 54.

Many of the intermediate and end-products of RDX degradation are relatively short-lived in the environment, and accumulation of these would not be expected. Studies on the fate and transport of explosives in the environment state that the nitroso intermediates of RDX (DNX, MNX, and

TNX) have rarely been observed in the field at the few sites where analyses have been conducted for them (Branning and Pennington, 2002). Many of these intermediates are observed only transiently due to their susceptibility to rapidly mineralization, typically persisting only on the scale of several hours to several days. Significant observations of the final end-products are also not expected. Hydrazines, dimethylhydrazines, and methanol are not likely to accumulate in the environment, particularly at the low concentrations they would be produced as end-products, because these compound very rapidly biodegrade. Therefore, the observation of intermediate and end-products of RDX biodegradation (DNX, MNX, and TNX), even at low concentrations, would be considered strong presumptive evidence of active and ongoing degradation processes.

In conclusion, concentrations of explosives at SWMU 54 have typically remained below the RGs throughout the site with the exception of 54MW10, 54MW12, and 54MW13.

Perchlorate

Samples from the wells within SWMU 54 were analyzed for perchlorate during all eight quarters of sampling. Perchlorate was detected in 13 of the 14 monitoring wells. Perchlorate concentrations were below the RGs in each monitoring well except for 54MW12, where the concentration exceeded the RG of 10.9 µg/L in the fourth and eighth quarters (**Figure 5-6**). These two exceedances corresponded with spikes in 2,4,6-TNT concentrations at 54MW12.

Perchlorate was not detected in 54MW1.

Site-wide perchlorate levels have typically been steady and below the site specific RG with the exception of the concentrations detected at 54MW12, which appear to mirror 2,4,6-TNT concentration peaks.

5.7.2 Pore Water Sampling

Pore water samples were collected from five areas along the New River in the fourth and eighth quarters of monitoring.

Explosives

Explosives were not detected in any of the pore water sampling locations.

Perchlorate

Perchlorate was not detected in any of the pore water sampling locations.

Figure 5-5. SWMU 54 54MW10 Explosives Concentrations Q1 through Q8

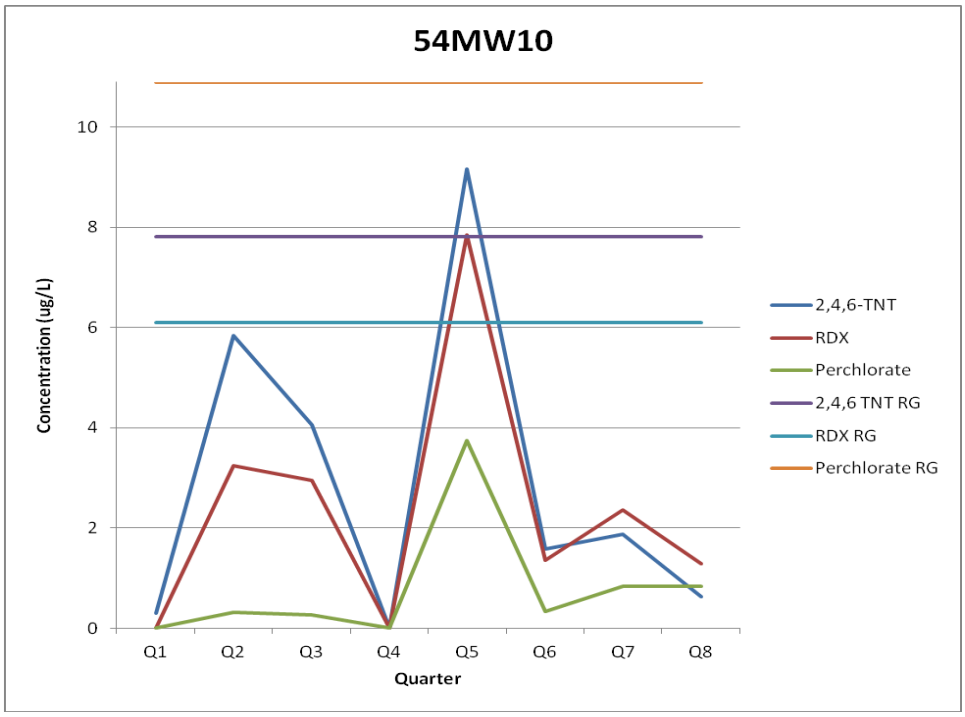


Figure 5-6. SWMU 54 54MW12 Explosives Concentrations Q1 through Q8

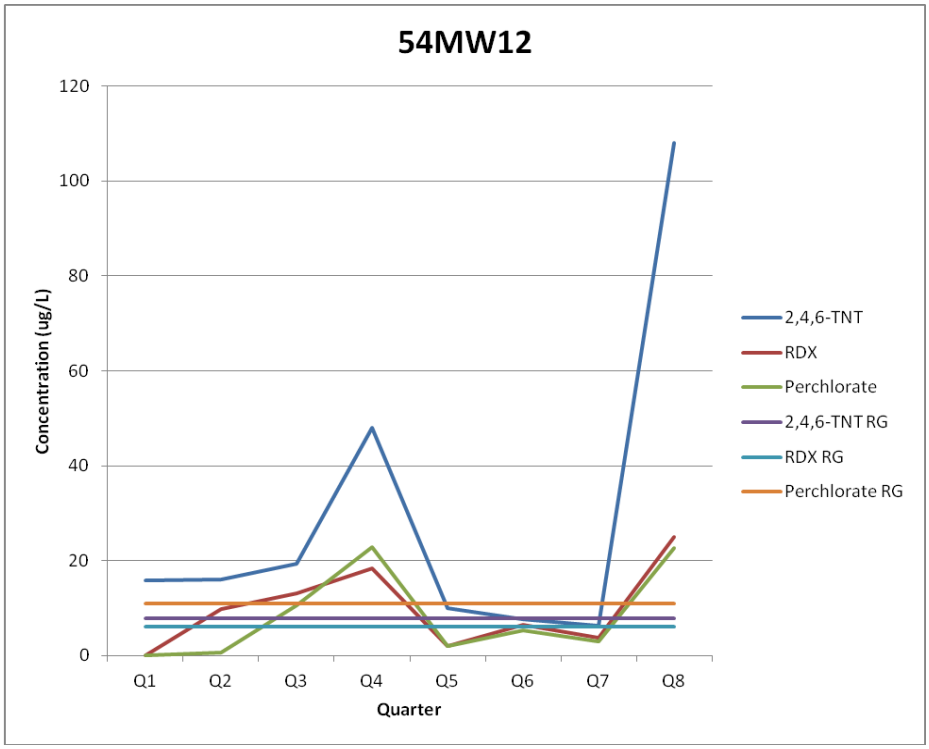


Figure 5-7. SWMU 54 54MW13 Explosives Concentrations Q1 through Q8

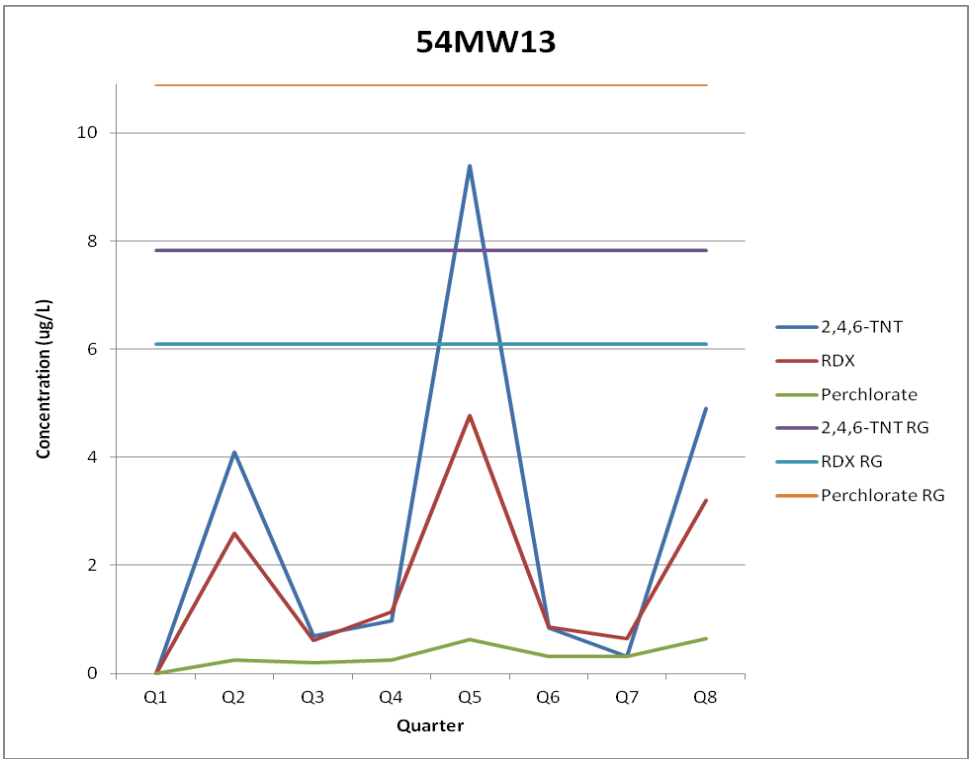


Figure 5-8. SWMU 54 54MW10 2,4,6-TNT to Amino-DNT Correlation

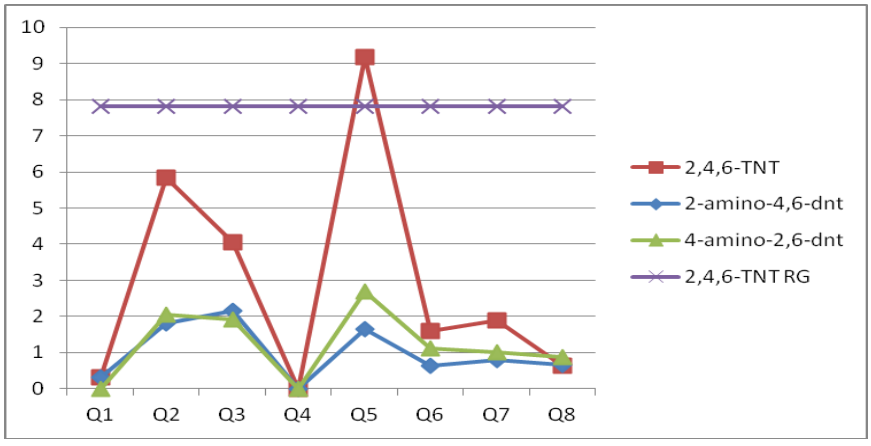


Figure 5-9. SWMU 54 54MW12 2,4,6-TNT to Amino-DNT Correlation

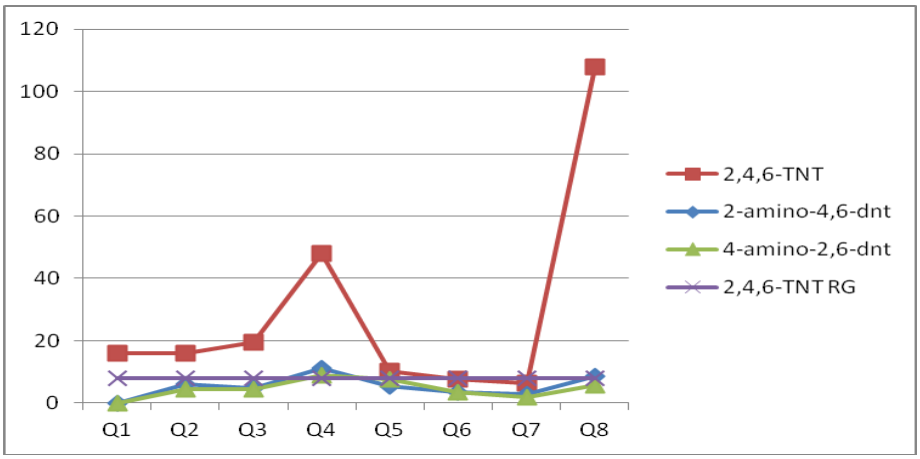
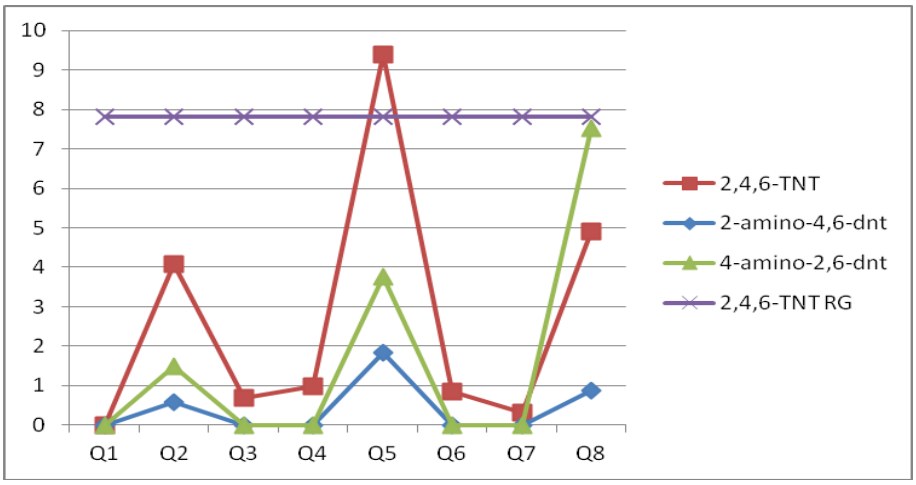


Figure 5-10. SWMU 54 54MW13 2,4,6-TNT to Amino-DNT Correlation



6.0 MNA EVALUATION OF SWMU 54

Monitoring natural attenuation (MNA) is a remedial approach in which physical, chemical, and biological processes occur under favorable conditions, without human interferences to reduce the mass, toxicity, volume, concentration, and mobility of contaminants in soil and groundwater. The physical, chemical, and biological processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization (USEPA, 1998). Analytical results from multiple groundwater sampling events at RFAAP SWMU 54 were evaluated for qualitative indications of natural attenuation processes that may reduce the levels of nitroaromatics (specifically 2,4,6-TNT and RDX) and perchlorate (ClO_4). The following sections present the results as they pertain to the lines of evidence used to demonstrate the potential for MNA.

6.1 First Line of Evidence: Occurrence of Contaminants

The first line of evidence consists of evaluating contaminant and daughter product concentrations in monitoring wells over time. SWMU 54 contains 14 wells (54MW1, 54MW2, 54MW3, 54MW4, 54MW5, 54MW6, 54MW7, 54MW8, 54MW9, 54MW10, 54MW11, 54MW12, 54MW13, and 54MW14), which targeted areas of potential nitroaromatic and perchlorate contamination. Historical trends and the results of quarterly groundwater sampling are discussed below, and the data is provided in **Table 6-1**.

2,4,6-TNT. Elevated concentrations of 2,4,6-TNT above the RG of 7.82 µg/L were observed in three wells, 54MW10, 54MW12, and 54MW13. 2,4,6-TNT concentrations have fluctuated in these three wells during the eight quarterly sampling events. At monitoring well 54MW10, an increase in 2,4,6-TNT concentration was observed from 0.0 µg/L in May 2012 (Q5) to 9.17 µg/L in August 2012 (Q6); however, a concentration below the RG in November 2012 (Q7) was observed. A similar pattern was detected at monitoring well 54MW13, with concentrations detected at 9.4 µg/L in May 2012 (Q5) and concentrations below the RG by the next quarterly sampling event in August 2012 (Q6). Monitoring well 54MW12 has generally maintained concentrations of 2,4,6-TNT above the RG; although, a slight reduction in 2,4,6-TNT was observed between November 2012 (Q7) and February 2013 before concentrations were detected at 108 µg/L in May 2013 (Q8).

DNT Mixture. DNT was detected in the fourth quarter of sampling at monitoring well 54MW12. There were no further detections of DNT.

RDX. Elevated concentrations of RDX above the RG of 6.1 µg/L were observed in two wells, 54MW10 and 54MW12. RDX concentrations have fluctuated in these two wells during the eight quarterly sampling events. At monitoring well 54MW10, an increase in RDX concentrations from 0.0 µg/L from May 2012 (Q5) to 7.84 µg/L in August 2012 (Q6) was observed; however, concentrations were then observed to be below the RG in November 2012 (Q7). Monitoring well 54MW12 has generally maintained concentrations of RDX above the RG. At this well, slight reductions in RDX were observed in May 2012 (Q5) and November 2012 (Q7); however, RDX concentrations were detected at 25 µg/L in May 2013 (Q8). Breakdown products for RDX were not included in the analysis suite for these sampling events.

Amino DNT. As 2,4,6-TNT is biologically degraded, the two daughter products 2ADNT and 4ADNT are formed. Both of the daughter products were present in eight monitoring wells (54MW2, 54MW3, 54MW5, 54MW8, 54MW10, 54MW12, 54MW13, and 54MW14). At

Table 6-1
Analytical Results for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia
Page 1 of 3

Parameter	Remediation Goal (RG)	July 2011 (Q1)	October 2011 (Q2)	January 2012 (Q3)	April 2012 (Q4)	August 2012 (Q5)	November 2012 (Q6)	February 2013 (Q7)	May 2013 (Q8)
		54MW1							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0	0	0	0	0	0	0
		54MW2							
2,4,6-TNT	7.82	2.1	0.9	2.08	2.66	0	0	0	0.749
RDX	6.1	0.572	0	0	0.384	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	3.07	0.547	1.91	4.02	0	0.842	1.41	1.82
		54MW3							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0.53	0.18	0	0	0.405	0.303	0.309	0.59
		54MW4							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0	0	0	0	0.141	0	0
		54MW5							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0.311	0.393	0.313	0.301	0.42	0.28	0.255	0.309

Table 6-1
Analytical Results for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Parameter	Remediation Goal (RG)	July 2011 (Q1)	October 2011 (Q2)	January 2012 (Q3)	April 2012 (Q4)	August 2012 (Q5)	November 2012 (Q6)	February 2013 (Q7)	May 2013 (Q8)
		54MW6							
2,4,6-TNT	7.82	0	0	0	0	0	Dry	0	0
RDX	6.1	0	0	0	0	0	Dry	0	0
DNT Mixture	0.932	0	0	0	0	0	Dry	0	0
Perchlorate	10.9	0	0.127	0.159	0	0.175	Dry	0.16	0.171
		54MW7							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0.321	0	0	0.365	0	0.103	0.162	0.103
		54MW8							
2,4,6-TNT	7.82	0.928	0.433	0	0.301	0	0	0	0
RDX	6.1	0.761	0.567	0.493	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0.408	0.355	0.388	0.392	0.286	0.484	0.118
		54MW9							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0.229	0.262	0.217	0	0	1.07	0.923
		54MW10							
2,4,6-TNT	7.82	0.305	5.84	4.05	0	**9.17**	1.59	1.88	0.637
RDX	6.1	0	3.24	2.95	0	**7.84**	1.35	2.36	1.29
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0.325	0.258	0	3.74	0.344	0.832	0.835
		54MW11							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0	0.239	0	0	0	0.263	0.43

Table 6-1
Analytical Results for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Parameter	Remediation Goal (RG)	July 2011 (Q1)	October 2011 (Q2)	January 2012 (Q3)	April 2012 (Q4)	August 2012 (Q5)	November 2012 (Q6)	February 2013 (Q7)	May 2013 (Q8)
		54MW12							
2,4,6-TNT	7.82	**15.9**	**16.1**	**19.4**	**48**	**10.1**	7.62	6.29	**108**
RDX	6.1	0	**9.77**	**13.2**	**18.4**	1.95	**6.59**	3.79	**25**
DNT Mixture	0.932	0	0	0	0.381	0	0	0	0
Perchlorate	10.9	0	0.726	10.5	**22.8**	2	5.31	2.98	**22.7**
		54MW13							
2,4,6-TNT	7.82	0	4.09	0.699	0.979	**9.4**	0.843	0.318	4.91
RDX	6.1	0	2.59	0.614	1.14	4.77	0.855	0.642	3.2
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0.244	0.206	0.243	0.627	0.308	0.313	0.64
		54MW14							
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0
RDX	6.1	0	0	0	0	0	0	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0
Perchlorate	10.9	0	0.215	0.181	0.214	0.24	0	0	0.195

Notes:
Bold font indicates exceedance of RG.

54MW12, where the highest levels of 2,4,6-TNT have been observed, both of the daughter products are present and are increasing. The presence of 2ADNT and 4ADNT along with the decreasing concentrations of 2,4,6-TNT suggest biological degradation of 2,4,6-TNT is occurring at these locations.

Perchlorate. Perchlorate was detected at concentrations above the RG of 10.9 µg/L in one well, 54MW12, during the February 2012 (Q4) and May 2013 (Q8) sampling events. In February 2012, perchlorate concentrations increased to 22.8 µg/L then dropped to below the RG for the next three sampling events, and finally increased again to 22.7 µg/L in May 2013. Chloride is daughter product of perchlorate degradation. At SWMU 54, chloride is present within groundwater; however, background concentrations are too high to determine any measureable change due to perchlorate reduction. Other breakdown products for perchlorate were not included in the analysis suite for these sampling events.

The first line of evidence indicates decreasing trends in 2,4,6-TNT concentrations and the presence of daughter products, 2ADNT and 4ADNT, suggesting that natural attenuation via biological degradation of 2,4,6-TNT is occurring at SWMU 54. Overall decreasing trends in RDX and perchlorate, with the exception of 54MW12, suggest natural attenuation of RDX and perchlorate is occurring. Although declining concentrations are observed, direct evidence is not yet available to definitively demonstrate that these declines are attributable to biological degradation. To aid in determining if biological degradation is occurring, it is recommended that breakdown products for RDX and perchlorate be included in future analyses to provide more information for future MNA evaluations.

6.2 Second Line of Evidence: Geochemical Conditions

Respiratory substrates are used preferentially during microbial metabolism based on the amount of energy that can be derived from each of them. Respiratory substrates are used in the following order:

$$O_2 > NO_3^- > Fe^{+3} > ClO_4 > SO_4^{-2} > CO_2$$

Geochemical data is available for all eight quarterly groundwater sampling events at SWMU 54. Field parameters (DO, ORP, pH, temperature, and conductivity) have been collected since 2011 as part of the low-flow sampling procedures. Laboratory analysis for nitrate, sulfate, and TOC were conducted for all eight quarterly groundwater sampling events at SWMU 54. These geochemical data are discussed regarding the potential for biodegradation in the groundwater at SWMU 54.

The microbial degradation of nitro-aromatic compounds primarily occurs under nitrate-reducing conditions, whereas perchlorate requires sulfate reducing groundwater conditions.

Dissolved Oxygen (DO). The preferred terminal electron acceptor during aerobic microbial respiration is oxygen, and DO is measured to determine whether the groundwater is under aerobic or anaerobic conditions. Average DO values less than 1 mg/L, are tolerable of anaerobic microbial activities.

DO levels during the eight quarterly sampling events (early 2011 to May 2013) ranged from 0.0 to 7.81 mg/L indicating both anaerobic and aerobic conditions are present at the site. Values higher than 8 mg/L are considered erroneous record given their relative magnitude to oxygen

solubility at field temperatures and are not included in this analysis. In wells where biological degradation products are observed (54MW2, 54MW3, 54MW5, 54MW8, 54MW10, 54MW12, 54MW13, and 54MW14), DO levels (between 0 and 7.81 mg/L) indicate a flux between anaerobic and aerobic conditions, although aerobic conditions appear to be favored (**Table 6-2**). TNT has been known to be reduced under a variety of conditions (aerobic and anaerobic); however, further reduction of TNT breakdown products, including 2ADNT and 4ADNT, and reduction of RDX and perchlorate is more favorable under anaerobic conditions (Spain, 1995).

Oxidation-Reduction Potential (ORP). ORP values indicate the groundwater's reductive potential and are used to confirm the DO measurements in groundwater. ORP values less than +50 mV typically correspond to mildly reducing, anaerobic conditions, while ORP values less than -200 mV correspond to highly reducing, anaerobic conditions. As mentioned previously, TNT reduction can occur in aerobic systems, but the reduction of TNT breakdown products, RDX, and perchlorate are favored under anaerobic conditions (generally observed when ORP values are between -100 mV and 0 mV).

ORP levels during the eight quarterly sampling events (early 2011 to May 2013) ranged from -33 to 297 mV indicating both anaerobic and aerobic conditions are present at the site, although oxidating conditions appear to be favored (**Table 6-2**). ORP values and DO readings did not show a clear corresponding trend for samples taken at the same well and same sampling event. Future monitoring is required to determine groundwater ORP trends at this site.

pH. The pH for optimum microbial activity ranges from 5 to 9 standard units. Microbial activity may decrease at lower pH values. All of the total 111 historical pH data available are within this optimal pH range (**Table 6-2**). In general, the pH environment at SWMU 54 is suitable for microbial activity.

Nitrate. Following oxygen, microorganisms preferentially use nitrate (NO_3^-) as a terminal electron acceptor. Elevated nitrate concentrations may indicate the degradation of nitroaromatics (including 2,4,6-TNT) into breakdown products and favor nitrate-reducing conditions; however, elevated nitrate (>1 mg/L) is an inhibitor of perchlorate reduction (IRTC, 2008).

Nitrate levels during the last eight sampling events were generally low (overall < 1 mg/L) with concentrations ranging from non-detect to 3.0 mg/L, suggesting that perchlorate reduction is not inhibited (**Table 6-2**).

Ferrous Iron. Ferric iron is reduced to soluble ferrous iron in the groundwater where iron-reducing bacteria have been active. An increase in ferrous iron concentrations is indicative of iron-reducing conditions. Biological reduction of TNT is favored in nitrate-reducing conditions and therefore, elevated levels of ferrous iron are an indicator of favorable groundwater conditions for TNT degradation. However, the degradation of TNT breakdown products, 2ADNT and 4ADNT, RDX, and perchlorate are favored in iron-reducing conditions. Ferrous iron concentrations for all wells and all sampling events have been less than 0.2 mg/L (non-detect) indicating that iron-reducing conditions are not present at this time, or the iron has been reduced previously.

Sulfate. Biological degradation of TNT breakdown products, 2ADNT and 4ADNT, RDX, and perchlorate actively occurs under sulfate-reducing conditions. Sulfate levels greater than 20 µg/L may cause competitive exclusion (USEPA, 2008). Sulfate concentrations were measured in the groundwater during each of the eight quarterly sampling events and were greater

than 20 mg/L (ranging from 15.1 to 403 mg/L), indicating that biological degradation of 2ADNT and 4ADNT may be inhibited at SWMU 54 (**Table 6-2**).

Total Organic Carbon (TOC). Organic carbon is a required source of reduced carbon and energy needed to sustain microbial degradation of nitroaromatics and perchlorate. TOC concentrations greater than 20 mg/L are considered adequate to support microbial activity. Available TOC data from the last eight quarterly sampling events ranged from 0.524 to 7.47 mg/L (**Table 6-2**), suggesting that the area does not have sufficient natural organic carbon to sustain the microbial activity.

Table 6-2
Analytical Parameters for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 First Quarter (July 2011) Water Quality Parameters														
pH	7.7	6.36	6.86	7.19	6.36	7.33	6.6	6.98	6.29	7.13	7.14	6.67	6.75	7.23
Conductivity (mS/cm)	0.357	0.526	0.491	0.949	0.371	0.449	0.419	0.544	0.535	1.68	0.651	0.568	0.676	0.582
Turbidity (NTU)	5.6	0	1.5	1.9	3	0.2	0	4.6	6	89.8	62.6	100	94	16.9
Dissolved Oxygen (mg/L)	4.86	2.35	4.71	0	4.87	0.68	3.91	3.53	1.23	0.51	0	3.52	0.9	1.06
ORP (mV)	130	178	121	-18	178	110	170	134	198	67	96	152	29	73
Temperature (°C)	14.12	17.07	19.82	15.52	19.88	19.32	18.87	17.86	14.3	25.19	14.94	18.38	20.09	23.76
Dissolved Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	0.2	<0.05	0.05	<0.05	0.65	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	25.2	1.09	0.967	0	0.613	0	0.119	0.639	0.233	0	0	2.79	0.439	0.242
Sulfate (mg/L)	27.1	39.8	23.6	329	15.1	27.4	61.5	40	62.2	167	93.6	38.1	38.8	33.6
TOC (mg/L)	3.9	3.51	7.26	2.51	6.14	1.95	3.17	6.05	5.1	1.61	5.97	2.64	2.55	6.73
SWMU 54 Second Quarter (October 2011) Water Quality Parameters														
pH	7.49	7.02	7.05	7.27	6.78	7.49	7.3	7.09	7.2	6.83	7.31	6.7	7.05	7.16
Conductivity (mS/cm)	0.432	0.56	0.674	0.912	0.502	0.305	0.734	0.541	0.562	0.677	0.654	0.523	0.831	0.568
Turbidity (NTU)	164	167	160	81.1	231	107	155	104	79.9	236	685	69	--	157
Dissolved Oxygen (mg/L)	0	0	0	2.44	2.68	3.8	0.1	0.05	0.06	0	0	1.72	0.37	0
ORP (mV)	102	117	107	-15	143	122	66	151	146	82	-13	144	126	73
Temperature (°C)	18.04	14.77	14.16	14.32	15.48	13.18	18.01	14.94	14.75	14.75	13.73	14.81	14.63	14.93
Dissolved Manganese (mg/L)	<0.05	<0.05	0.1	0.05	0.1	0.05	0.4	0.05	0.2	0.15	0.3	<0.05	0.35	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0	0.394	0.357	0	0.568	0.167	0	0.514	0.184	0.388	0	2	0.21	0.202
Sulfate (mg/L)	27.1	27	44.4	210	17.4	7.06	216	39.9	46.9	96.7	119	31.8	90.2	34.1
TOC (mg/L)	3.9	3.2	3.22	1.38	1.88	2.68	1.31	7.47	6.78	6.98	3.22	4.71	3.31	4.64
SWMU 54 Third Quarter (January 2011) Water Quality Parameters														
pH	7.59	7.48	7.4	7.36	7.15	7.53	7.43	7.08	7.4	7.46	7.59	6.09	7.45	7.48
Conductivity (mS/cm)	0.498	0.662	0.762	1.11	0.628	0.305	0.905	0.492	0.674	0.707	0.763	0.595	0.687	0.651
Turbidity (NTU)	8.9	15.3	19.2	55.6	32.1	72.4	26.8	66.7	36.8	1.1	6.8	---	226	0
Dissolved Oxygen (mg/L)	0	0	0	0	7.81	12.01	0	16.65	8.48	6.06	5.09	4.02	7.63	1.66
ORP (mV)	100	33	24	5	121	191	3	104	111	118	101	186	25	61
Temperature (°C)	13.2	13.91	13.26	13.04	13.58	11.93	12.73	9.72	9.65	11.16	11.4	12.86	11.53	12.91
Dissolved Manganese (mg/L)	<0.05	<0.05	0.1	0.05	0.1	0.05	0.4	0.05	0.2	0.15	0.3	<0.05	0.35	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0	0.609	0	0	0.578	0.158	0	0.401	0.174	0.572	0.158	1.94	0.237	0.241
Sulfate (mg/L)	26.3	28.2	73.7	480	20.3	4.55	249	41.5	62.5	72.7	93	37.6	53.9	32.2
TOC (mg/L)	2.1	1.8	2.39	1.16	1.42	1.94	2.38	1.66	2.78	1.66	6.71	5.09	6.63	1.68

Table 6-2
Analytical Parameters for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia
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Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 Fourth Quarter (April 2012) Water Quality Parameters														
pH	5.42	5.19	5.38	5.33	4.99	5.76	5.57	5.38	5.46	5.48	5.59	5.05	5.32	5.5
Conductivity (mS/cm)	0.958	1.12	1.46	0.001	0.891	0.73	1.58	1.21	1.26	1.73	1.4	1.35	0.981	1.2
Turbidity (NTU)	2.5	4.4	2.4	125	70.1	318	38	3.4	65.3	30.8	94.7	37	312	36
Dissolved Oxygen (mg/L)	7.36	7.18	2.24	23.45	10.47	6.49	2.01	7.43	11.29	2.83	5.8	9.44	7.1	5.55
ORP (mV)	-30	236	225	180	168	132	162	134	145	61	36	267	116	149
Temperature (°C)	13.37	12.44	12.02	11.56	20.98	19.09	12.57	14.69	14.21	15.5	14.11	12.67	15.52	12.69
Dissolved Manganese (mg/L)	<0.05	<0.05	0.1	0.5	<0.05	0.05	0.4	0.05	0.2	0.1	0.3	<0.05	0.35	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0	1.33	0	0	0.677	0.129	0.231	0.483	0.139	0	0	2.65	0.294	0.386
Sulfate (mg/L)	34.9	34.9	80	432	14	14.9	69.4	40.1	56	221	104	37.9	35.4	29.3
TOC (mg/L)	1.8	1.57	1.18	1.82	2.33	5.46	0.99	2.36	3.01	2.4	2.68	2.34	3.51	1.09
SWMU 54 Fifth Quarter (August 2012) Water Quality Parameters														
pH	7.08	6.94	6.71	7.05	6.71	7.47	7.03	6.87	6.84	6.71	7.06	6.61	6.97	7.05
Conductivity (mS/cm)	0.395	0.722	0.644	0.968	0.58	0.363	0.817	0.599	0.752	0.693	0.715	0.665	0.697	0.625
Turbidity (NTU)	4.1	43	19	14	23	0	7.4	19	5.2	0.8	10.8	48	95	9.2
Dissolved Oxygen (mg/L)	5.34	0	0	0.23	3.96	4.84	0	2.78	0.56	0.4	0	0.33	1.75	0
ORP (mV)	212	65	209	-33	200	134	128	125	-10	47	-22	226	135	-13
Temperature (°C)	13.89	13.49	12.93	15.06	13.44	16.52	13.66	13.7	14.09	13.93	13.64	13.71	16.12	14.08
Dissolved Manganese (mg/L)	<0.05	<0.05	0.05	0.05	<0.05	0.05	0.05	0.05	0.2	0.05	0.05	<0.05	0.3	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.600	0.190	0.613	3.00	0.728	0.120	3.00	0.581	1.80	0.594	1.80	1.06	0.681	0.214
Sulfate (mg/L)	26.1	95.5	23.8	378	18.0	15.7	186	41.8	87.2	102	97.6	27.0	38.2	31.8
TOC (mg/L)	0.721	2.00	2.00	1.10	2.00	1.00	1.02	2.00	2.00	1.37	2.00	2.00	1.05	2.04
SWMU 54 Sixth Quarter (November 2012) Water Quality Parameters														
pH	7.63	7.21	6.97	7.03	6.99	Dry	7.31	7.23	7.23	7.29	7.28	7.6	5.72	7.3
Conductivity (mS/cm)	0.443	0.62	0.561	1.01	0.612	Dry	0.826	0.628	0.784	0.779	0.698	0.635	0.918	0.6
Turbidity (NTU)	2.9	11.4	0.2	17	5.5	Dry	46	3.9	27.7	4.7	2.5	2.4	35	43
Dissolved Oxygen (mg/L)	1.44	0.86	4.09	1	1.01	Dry	0.56	2.71	1.14	0.38	1.1	0.26	0.95	0.45
ORP (mV)	148	141	145	72	167	Dry	59	101	-28	43	117	135	209	100
Temperature (°C)	10.03	13.43	12.22	11.27	11.21	Dry	10.83	11.98	11.35	13.61	12.95	13.99	12.26	10.61
Dissolved Manganese (mg/L)	0.05	0.05	0.05	0.05	0.05	Dry	0.05	0.05	0.2	0.05	0.05	0.1	0.3	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	Dry	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.600	0.327	0.656	3.00	0.944	Dry	1.80	0.403	1.80	0.381	0.600	2.86	0.369	0.600
Sulfate (mg/L)	31.3	35.4	22.9	403	21.5	Dry	179	60.3	199	151	99.1	49.8	76.7	39.0
TOC (mg/L)	1.96	2.68	3.29	2.93	4.31		3.72	4.90	6.73	5.55	5.88	3.41	2.00	2.12

Table 6-2
Analytical Parameters for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia
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Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 Seventh Quarter (February 2013) Water Quality Parameters														
pH	7.85	6.89	6.76	7.52	6.56	7.08	7.4	7.03	7.04	6.69	7.09	6.36	6.96	7.45
Conductivity (mS/cm)	0.465	0.682	0.504	1.01	0.417	0.293	0.474	0.498	0.487	0.542	0.687	0.464	0.37	0.619
Turbidity (NTU)	0	20	9	16	0	44.3	16	9.2	10.9	13.2	2	14.2	6.8	1.2
Dissolved Oxygen (mg/L)	0.71	1.43	6.97	0.53	9.19	9.28	2.83	5.36	8.28	2.97	0.58	1.27	8.39	0.47
ORP (mV)	-5	156	171	-56	168	72	12	168	194	125	169	168	158	56
Temperature (°C)	12.17	8.28	11.98	12.09	11.18	13.15	11.48	9.89	9.74	11.22	10.14	10.31	7.98	12.26
Dissolved Manganese (mg/L)	0.05	<0.05	0.1	0.05	<0.05	0.05	0.1	0.05	0.2	0.1	0.25	<0.05	0.2	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.600	0.315	0.423	3.00	0.636	0.209	0.205	0.336	0.510	0.477	0.346	1.95	0.501	0.600
Sulfate (mg/L)	27.1	36.8	25.3	340	15.5	4.29	34.2	44.6	117	70.1	120	35.8	23.1	41.1
TOC (mg/L)	1.19	0.916	1.07	1.35	1.00	1.50	0.791	1.00	2.09	1.14	1.88	1.21	0.683	1.46
SWMU 54 Eighth Quarter (May 2013) Water Quality Parameters														
pH	7.82	6.52	7.06	7.51	6.83	7.33	7.41	7.47	7.95	6.94	7.59	6.78	6.97	7.31
Conductivity (mS/cm)	0.452	0.315	0.499	1.021	0.4	0.494	0.674	0.596	0.521	0.537	0.592	0.665	0.44	0.608
Turbidity (NTU)	3	0.2	1.4	6.2	8.9	7.1	0.5	1.6	5.2	1.4	0.3	3.8	0.2	6.4
Dissolved Oxygen (mg/L)	0.136	2.74	3.55	1.05	3.28	1.29	3.24	0.4	7.58	2.43	1.17	2.54	1.4	4.13
ORP (mV)	223.2	254.3	273.6	257.1	283.1	128.4	282.7	255.1	244.2	287.8	255.8	292.4	284	296.5
Temperature (°C)	14.51	12.22	13.31	11.73	12.2	13.48	12.74	13.32	11.12	12.89	12.42	13.28	12.84	13.42
Dissolved Manganese (mg/L)	0.05	0.05	0.05	0.05	<0.05	<0.05	0.05	0.05	0.1	0.05	0.05	<0.05	0.15	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.368	0.988	0.911	3.00	1.60	0.600	1.10	0.600	0.637	0.740	0.647	4.03	1.05	0.543
Sulfate (mg/L)	26.1	24.1	29.0	329	15.7	14.0	137	41.1	96.7	48.8	89.4	47.6	29.2	37.0
TOC (mg/L)	0.949	1.68	1.36	0.619	1.06	2.41	0.793	1.00	1.38	1.00	0.635	1.36	0.817	0.583

Notes:
mS/cm - milliseimens per centimeter
NTU - Nephelometric Turbidity Unit
mV - millivolts
°C - degrees Celsius
mg/L - milligrams per liter

7.0 SUMMARY AND CONCLUSIONS

Fourteen (14) groundwater monitoring wells have been sampled on a quarterly basis for 2 years at SWMU 54. Additionally, in the fourth and eighth quarters of monitoring, five pore water sample locations were monitored in the New River. Samples collected in the first eight quarters were analyzed for explosives, perchlorate, and MNA indicators. Sample results were compared to MCLs, tap water SLs, and RGs to evaluate whether MNA is occurring at the site. This report presents the results of the first through eighth quarters of sampling and also summarizes the data from the first 2 years of sampling.

Based on contaminant concentrations and biological indicator parameters measured in groundwater at the site, MNA processes including biodegradation (for 2,4,6-TNT only), sorption, dilution, dispersion, and chemical stabilization are occurring at SWMU 54. The data also suggest that the MNA processes are preserving plume stability and decreasing nitroaromatic and perchlorate mass.

In summary, the following conclusions and recommendations were made regarding the potential for MNA in contaminated groundwater at SWMU 54:

- Additional sampling is required to obtain a more complete data set for the evaluation of site characteristics and determine trends.
- Additional analyses for RDX breakdown products (including DNX, MNX, and TNX) and perchlorate breakdown products (chlorate and chlorite) should be included in future sampling plans to provide information on the potential degradation of these products in site groundwater.
- Decreases in 2,4,6-TNT and the presence of daughter products 2ADNT and 4ADNT suggest that incomplete biological degradation has occurred, which may be aiding in removing mass in the groundwater.

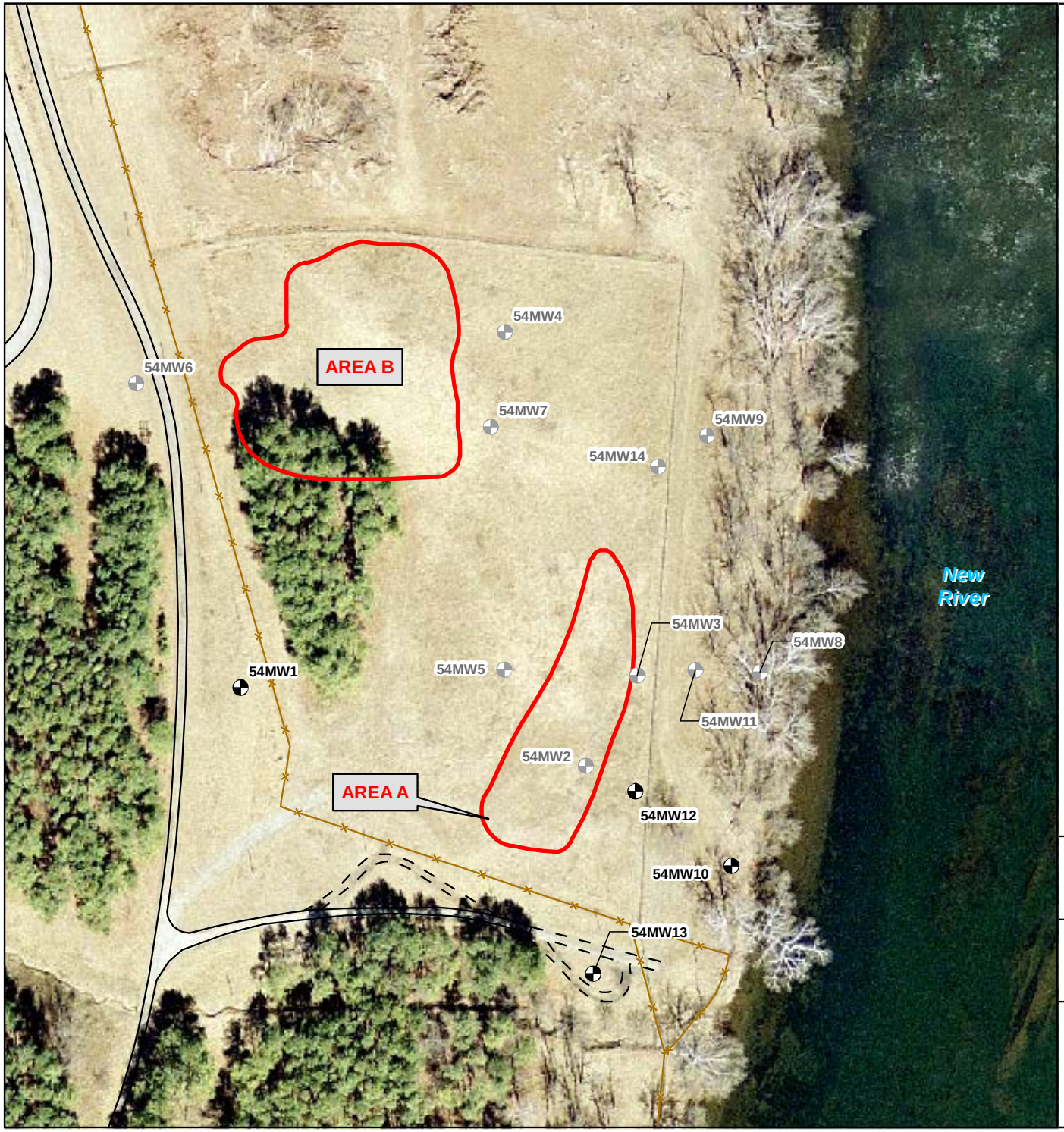
Geochemical parameters also indicate that groundwater conditions are generally aerobic, thereby supporting biological degradation of 2,4,6-TNT; however, do not currently support biological degradation of 2ADNT, 4ADNT, RDX, and perchlorate.

The source removal efforts at SWMU 54 appear to have been effective in significantly lowering the site-wide COCs in groundwater. Eleven (11) of the 14 monitoring well locations (54MW1 through 54MW9, 54MW11, and 54MW14) have had concentrations below site selected RGs eight consecutive quarters for 2,4,6-TNT, DNT mixture, RDX, and perchlorate. As per the *Final SWMU 54 MNA IMWP* (Shaw, 2011a), it is recommended that these wells be removed from future MNA sampling.

Pore water samples PW-1, PW-3, PW-5, PW-8, and PW-9 have had no detections of explosives or perchlorate in 2 years of sampling. As per the *Final SWMU 54 MNA IMWP* (Shaw, 2011a), it is recommended that the pore water sample locations be removed from future MNA sampling.

Explosives and perchlorate concentrations through eight quarters of groundwater sampling do not appear to indicate biodegradation at well locations 54MW10, 54MW12, and 54MW13 (SWMU 54 Area A wells). Based on the localized distribution of elevated constituents and the generally declining concentrations site-wide, a groundwater remedy at SWMU54 does not appear necessary at the time. However, the eighth quarter of sample collection reported the most

elevated concentrations of COCs reported at monitoring location 54MW12, warranting additional, expanded monitoring at these locations. It is our recommendation that groundwater monitoring continues on a quarterly basis at well locations 54MW10, 54MW12, and 54MW13, with additional MNA parameters including: RDX degradation intermediates DNX, TNX, and MNX, and perchlorate degradation intermediates chlorite and chlorate. In addition to monitoring wells 54MW10, 54MW12, and 54MW13, monitoring well 54MW1 will continue to be monitored as an upgradient well, despite meeting the criteria for being removed from the network. The updated monitoring network is depicted on **Figure 7-1.**



LEGEND

- Monitoring Well (Current MNA Network)
- Monitoring Well (Removed From Network)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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

FIGURE 7-1
SWMU 54
Updated MNA Monitoring Network
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR2\RFAAP_Fig7-1_SWMU54_Updated_MNA_Network_2012_2013_MNA_rpt.mxd (12/12/2013)

8.0 REFERENCES

Brannon and Pennington, 2002. *Environmental Fate and Transport Process Descriptors For Explosives*. Prepared for U.S. Army Corps of Engineers. May 2002.

Interstate Technology and Regulatory Council (IRTC) (Perchlorate Team), 2008. *Remediation Technologies for Perchlorate Contamination in Water and Soil*. Interstate Technology and Regulatory Council, Washington, DC.

IT Corporation (IT), 2001. *Facility-Wide Background Study*. Radford Army Ammunition Plant, Virginia. Final Report. Delivery Order No. 0008, Contract No. DACA31-94-D-0064.

Parsons Engineering Science, Inc. (Parsons), 1996. *RCRA Facility Investigation for Solid Waste Management Units 17, 31, 48, and 54 at Radford Army Ammunition Plant, Virginia.* Prepared for U.S. Army Environmental Center.

Shaw Environmental, Inc. (Shaw), 2011a. *SWMU 54 Monitored Natural Attenuation Interim Measures Work Plan*. Radford Army Ammunition Plant, Virginia. Final Report.

Shaw Environmental, Inc. (Shaw), 2011b. *SWMU 54 Interim Measures Completion Report*. Radford Army Ammunition Plant, Radford, Virginia. April 2011.

Spain, J.C. 1995. *Biodegradation of nitroaromatic compounds.* Annual Review of Microbiology, 49: 523-555.

URS Corporation (URS), 2003. *Final Master Work Plan, Quality Assurance Plan, Health and Safety Plan*. Radford Army Ammunition Plant, Radford, Virginia. Prepared for the U.S. Army Corps of Engineers, Baltimore District. August 2003.

URS Corporation (URS), 2008. *Solid Waste Management Unit 54 RCRA Facility Investigation/ Corrective Measures Study Report*. Radford Army Ammunition Plant, Radford, Virginia. September 2008.

U.S. Environmental Protection Agency (USEPA), 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater,* EPA/600/R-98/128, Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, P.E. Haas, R.N. Miller, J.E. Hansen, and F.H. Chapelle, Cincinnati, Ohio.

U.S. Environmental Protection Agency (USEPA), 2000. *Permit for Corrective Action and Waste Minimization*: Pursuant to the Resource Conservation and Recovery Act as Amended by the Hazardous and Solid Waste Amendment of 1984, Radford Army Ammunition Plant, Radford, Virginia. VA1210020730.

U.S. Environmental Protection Agency (USEPA), 2011. *Regional Screening Levels (SL) Table.* Developed by Oak Ridge National Laboratory under Interagency Agreement with USEPA. Dated June 2011. On-line: http://www.epa.gov/reg3hwmd/risk/human/SLoncentration_table/Generic_Tables/index.htm