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14. ABSTRACT

This Remedial Investigation (RI) Report presents the findings and conclusions of the RI field activities conducted at the RVAAP-062-R-01 Water Works #4 Dump Munitions Response Site (MRS) between September and October 2011 at the former Ravenna Army Ammunition Plant. The purpose of the RI is to determine whether the Water Works #4 Dump MRS warrants further response action pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the National Oil and Hazardous Substances Pollution Contingency Plan. More specifically, the RI is intended to determine the nature and extent of munitions and explosives of concern (MEC) and munitions constituents (MC) and subsequently determine the hazards and risks posed to human health and the environment by MEC and MC. Also, this RI Report presents additional data to assist in determining what remediation alternatives, if any, are appropriate. This RI report was prepared in accordance with the Army's Final Munitions Response RI/FS guidance dated November 2009.

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CB&I Federal Services LLC has completed the *Draft Remedial Investigation Report for RVAAP-062-R-01 Water Works #4 Dump MRS* at the former Ravenna Army Ammunition Plant, Portage and Trumbull Counties, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy, principles, and procedures, utilizing justified and valid assumptions, was verified. This included review of data quality objectives; technical assumptions; methods, procedures and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets customer's needs consistent with law and existing U.S. Army Corps of Engineers policy.

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Draft Remedial Investigation Report for RVAAP-062-R-01 Water Works #4 Dump MRS Version 1.0

Former Ravenna Army Ammunition Plant
Portage and Trumbull Counties, Ohio

Contract No. W912DR-09-D-0005
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Acronyms and Abbreviations

°F	degrees Fahrenheit
AEDB-R	Army Environmental Database-Restoration
AMEC	AMEC Earth and Environmental, Inc.
amsl	above mean sea level
AOC	area of concern
ARAR	applicable or relevant and appropriate requirement
Army	U.S. Army
ARNG	Army National Guard
ASR	*Final Archives Search Report*
bgs	below ground surface
Camp Ravenna	Camp Ravenna Joint Military Training Center
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
cm/s	centimeters per second
CRREL	Cold Regions Research and Engineering Laboratory
CSM	conceptual site model
DERP	Defense Environmental Restoration Program
DGM	digital geophysical mapping
DID	Data Item Description
DoD	United States Department of Defense
DQO	data quality objective
e^2M	engineering-environmental Management, Inc.
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
FS	Feasibility Study
FSAP	*Facility-Wide Sampling and Analysis Plan*
GPS	global positioning system
HA	Hazard Assessment
HE	high explosive
HHRA	human health risk assessment
HRR	*Final Military Munitions Response Program Historical Records Review*
IRP	Installation Restoration Program
IVS	instrument verification strip
lbs	pounds
MC	munitions constituents
MD	munitions debris
MEC	munitions and explosives of concern
MKM	MKM Engineering, Inc.
mm	millimeter(s)
MMRP	Military Munitions Response Program
MPPEH	material potentially presenting an explosive hazard
MRS	Munitions Response Site

Acronyms and Abbreviations (continued)

MRSPP	Munitions Response Site Prioritization Protocol
mV	millivolt(s)
NCP	*National Oil and Hazardous Substances Pollution Contingency Plan*
OHARNG	Ohio Army National Guard
QC	quality control
RI	Remedial Investigation
RTS	robotic total station
RVAAP	former Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
Shaw	Shaw Environmental & Infrastructure, Inc.
SI	Site Inspection
TBD	to be determined in the field
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USP&FO	U.S. Property and Fiscal Officer
UXO	unexploded ordnance
UXOQCS	UXO Quality Control Specialist
VSP	Visual Sample Plan®

EXECUTIVE SUMMARY

This *Remedial Investigation (RI) Report* documents the findings and conclusions of the RI field activities for the Water Works #4 Dump (RVAAP-062-R-01) Munitions Response Site (MRS) located at the former Ravenna Army Ammunition Plant (RVAAP) in Portage and Trumbull Counties, Ohio. This RI Report was prepared by CB&I Federal Services LLC under Delivery Order 0002 for Military Munitions Response Program (MMRP) environmental services at the RVAAP under the *Multiple Award Military Munitions Services Performance-Based Acquisition* Contract No. W912DR-09-D-0005. The Delivery Order was issued by the United States (U.S.) Army Corps of Engineers (USACE), Baltimore District, on May 27, 2009.

The purpose of the RI was to determine whether the Water Works #4 Dump MRS warrants further response action pursuant to the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) and the *National Oil and Hazardous Substances Pollution Contingency Plan*. More specifically, it was intended in this RI Report to determine the nature and extent of munitions and explosives of concern (MEC) and munitions constituents (MC), and to determine the potential hazards and risks posed to likely human and ecological receptors by MEC and MC.

ES.1 MRS Description

Whenever possible, existing information and data were incorporated into this RI Report. Background information related to the MRS was taken from the *Final Archives Search Report* (USACE, 2004), the *Final Military Munitions Response Program Historical Records Review* (engineering-environmental Management, Inc. [e^{2}M], 2007), and the *Final Site Inspection Report* (e^{2}M, 2008).

The Water Works #4 Dump MRS originally encompassed 6.15 acres of mostly forested area that included a small clearing located immediately north of the Water Works #4 treatment building and west of Load Line 7 in the southwestern portion of the facility. According to the *Final MMRP Historical Records Review* (e^{2}M, 2007), the Water Works #4 Dump MRS was presumably used for the intentional dumping of nonexplosive metal parts of large-caliber ordnance rounds. These dumping activities reportedly occurred from 1941 to 1949.

Prior to the 2007 site inspection (SI) field activities, large-caliber casings were reportedly found on the ground surface and partially buried throughout the wooded portion of the SI MRS boundary, as were metal parts (defined as ogives) from World War I-era 155-millimeter (mm) Mk I shrapnel projectiles. During the SI field activities, 20 inert 155 mm Mk I shrapnel projectile ogives with no energetic material were found scattered throughout

the northern wooded area of the SI MRS boundary (e^2M, 2007) and were considered as munitions debris (MD).

Several closely spaced subsurface anomalies were detected during the SI in the open field portion of the SI MRS boundary. It was recommended in the *Final Site Inspection Report* (e^2M, 2008), and subsequently approved by the stakeholders, that the MRS footprint be reduced from 6.15 to 0.77 acres to include only the open field area of the MRS where subsurface anomalies were detected, which is hereafter referred to as the "current MRS boundary." The reduced footprint area was recommended for further characterization of MEC.

During development of the *Final Work Plan Addendum for MMRP Remedial Investigation Environmental Services* (Shaw Environmental & Infrastructure, Inc. [Shaw], 2011), the MRS boundaries that were recommended in the SI Report (e^2M, 2008) were reevaluated. It was recommended that the MD consisting of the 155 mm ogives that were identified in the wooded area outside of the current MRS be further investigated for potential MEC. Therefore, the 5.38 acres removed from the MRS during the SI were reintroduced for further evaluation as part of the RI, which is hereafter referred to as the "expanded investigation area."

Current activities at the Water Works #4 Dump MRS include maintenance and natural resource management activities. The future land use at the MRS is military training.

ES.2 Summary of Remedial Investigation Activities

The preliminary MEC and MC conceptual site models (CSMs) for the MRS were evaluated based on the historical background reviews and data needs, and the data quality objectives (DQOs) were determined as outlined in the Final Work Plan Addendum (Shaw, 2011). The data needs included characterization of MEC and/or MC associated with former activities at the MRS. The DQOs were developed to ensure (1) the reliability of field sampling, chemical analyses, and physical analyses; (2) the collection of sufficient data; (3) the acceptable quality of data generated for their intended use; and (4) that valid assumptions could be inferred from the data. The DQOs for the Water Works #4 Dump MRS identified the following decision rules that were implemented in evaluating the MRS:

- Perform a Schonstedt-assisted visual survey in the expanded investigation area to identify if surface MEC or MD was present.
- Perform a geophysical investigation at the current MRS to identify buried metallic anomalies that have the potential to be MEC/MD.

- Perform an intrusive investigation of anomalies identified during the geophysical investigation to evaluate if MEC/MD was present.
- Collect incremental and/or discrete samples (surface and subsurface soil) in areas with concentrated MEC/MD to evaluate for MC, if necessary.
- Process the information to evaluate whether there were unacceptable hazards or risks to human and ecological receptors associated with MEC and/or MC, and make a determination if further investigation was required under the CERCLA process.

The initial step in evaluating the lateral extent of MEC at the Water Works #4 Dump MRS consisted of performing a Schonstedt-assisted visual survey at the expanded investigation area and 100-foot step-outs from any MEC and/or MD found along the boundary of the expanded investigation area. Following the visual survey, a digital geophysical mapping (DGM) investigation was performed at the 0.77-acre MRS to evaluate for potentially buried MEC.

Instrument-Assisted Visual Survey

The Schonstedt-assisted visual survey field activities were performed in September 2011. The area originally intended to be surveyed included the 5.38-acre expanded investigation area; however, the visual survey area was further expanded during the RI field activities to include the 0.77-acre MRS footprint. Schonstedt-assisted visual survey transects were placed using the *Visual Sample Plan*® module input of "90 percent confidence that 95 percent of transects do not contain unexploded ordnance (UXO)."

The actual Schonstedt-assisted visual survey transect distance was calculated to be approximately 3.76 miles, of which 3.01 miles were traversed in the expanded investigation area, 0.25 miles were traversed within the current MRS boundary, and 0.5 miles were traversed in 100-foot step-out areas along the boundaries of the expanded investigation area. The actual spatial coverage equated to an area of approximately 2.28 acres, under the assumption that each transect was approximately 5 feet wide. The 3.01 miles of transects for the expanded investigation area exceeded the proposed Schonstedt-assisted visual survey transect distance of 2.3 miles for this area (Shaw, 2011).

No MEC items were identified during the Schonstedt-assisted visual survey; however, five MD items were found. All five MD items were located on the ground surface at the expanded investigation area. The MD items consisted of three 155 mm Mk I shrapnel projectile ogives and two 155 mm Mk I high-explosive projectile ogives. The total weight of the MD items was approximately 10 pounds. The MD was verified as inert by the UXO-qualified personnel in the field.

Geophysical Investigation

In October 2011, Shaw performed a DGM investigation to identify areas with the potential for subsurface MEC at the Water Works #4 Dump MRS. The proposed DGM survey included full coverage (100 percent) over the current MRS boundary (Shaw, 2011). In order to meet the coverage requirement, DGM data were acquired over all accessible areas of the current MRS on lines spaced at approximately 2.5-foot intervals. A total area of 0.008 acres (350 square feet) could not be investigated due to trees and thick vegetation. The resulting coverage of the accessible areas at the current MRS represented nearly 99 percent coverage. Evaluation of the data collected during the DGM survey identified 205 single-point anomalies for potential investigation. The geophysical data indicated that the anomaly density was relatively low and dispersed throughout the current MRS.

Anomaly Selection

Following the DGM data collection and interpretation, an intrusive investigation was conducted by UXO-qualified personnel for the locations identified as potentially containing buried MEC. Since a significant percentage of the accessible areas within the current MRS was effectively covered by the DGM survey (nearly 100 percent), use of the hypergeometric statistics program that estimates the required sample size for populations was allowed for the selection of a percentage of targets rather than requiring investigation of 100 percent of the anomalies identified. Based on the statistical methodology and the automated target programs that were used, the recommended output was to investigate 93 of the 205 anomalies selected for potential investigation.

Intrusive Investigations

No MEC was identified on or below the ground surface during investigation of the 93 anomalies initially selected for intrusive investigation. Two MD items (155 mm Mk I shrapnel projectile ogives) were found at isolated locations; one on the ground surface and one at a depth of 1 inch below ground surface (bgs). These items were verified as inert by the UXO-qualified personnel in the field. Two of the 93 anomalies were not located during the initial intrusive investigation; therefore, three additional anomalies were selected for investigation to satisfy the statistical requirements. The additional target locations were biased towards geophysical signatures that had the potential to be 155 mm ogives and the initial intrusive investigation results. The three additional targets were successfully intrusively investigated and determined to be “Other Debris.” In all, 94 anomalies were successfully investigated out of the 205 identified anomalies selected for potential intrusive investigation.

A total of 114 nonmunitions items that were described as “Other Debris” as determined by the UXO teams, were found during the intrusive investigation at the remaining point-source

anomaly locations. These "Other Debris" items weighed approximately 589.2 pounds. All nonmunitions-related debris was left in place.

The depths of all the items found during the intrusive investigation ranged from just below ground surface to a maximum depth of 3.7 feet bgs. The average depth of the items identified for all locations was approximately 0.5 feet bgs.

MC Sampling

It was stated in the DQOs that incremental samples and discrete samples (surface and subsurface soil) would be collected in areas of the current MRS and expanded investigation area with concentrated MEC or MD (Shaw, 2011). No MEC was identified at the Water Works #4 Dump MRS during RI field activities and only individual MD items were found at isolated locations; therefore, sampling for MC was not warranted.

ES.3 MEC Hazard Assessment

The *Interim Munitions and Explosives of Concern Hazard Assessment (MEC HA) Methodology* (EPA, 2008) addresses human health and safety concerns associated with potential exposure to MEC at a MRS under a variety of site conditions, including various cleanup scenario and land use assumptions. However, cleanup scenarios are not usually addressed in the RI. If an explosive hazard is identified for this RI, the MEC Hazard Assessment (HA) evaluation will include the information available for the MRS up to and including the RI field activities and will provide a scoring summary for the current and future land use activities. If no explosive hazard is found at the MRS, then there will be no need to calculate a MEC HA score, since there are no human health safety concerns.

No items containing explosive filler were identified at the current MRS or expanded investigation area that were covered during both the 2007 SI and 2011 RI field activities. The results of the RI indicate that no MEC source or explosive safety hazard is present. Therefore, calculation of a MEC HA score was not warranted for the Water Works #4 Dump MRS or the expanded investigation area.

ES.4 Conceptual Site Model

The information collected during the RI field activities was used to update the MEC CSM and to determine if the development of a revised CSM for MC was required. The CSM identifies all complete, potentially complete, or incomplete source-receptor interactions for current and future land-use activities at the MRS. An exposure pathway is the course a MEC item or MC takes from a source to a receptor. Each pathway includes a source, activity, access, and receptor.

MEC Exposure Analysis

Schonstedt-assisted visual surveys were performed over a total of 3.76 miles in the current MRS and expanded investigation area. In addition, a full-coverage DGM survey and subsequent intrusive investigation were performed within the boundaries of the current MRS. During the RI field activities, five MD items were identified on the ground surface in the expanded investigation area and two MD items were found at the current MRS. One of the MD items encountered at the MRS was in subsurface soil at a maximum depth of 1 inch bgs.

To date, no MEC has been found at the Water Works #4 Dump MRS and the only MD historically found were ogives on the ground surface or subsurface soil at a maximum depth of 1 inch bgs. Ogives do not contain explosive material and are inert (Naval Explosive Ordnance Disposal Technology Division, 1994). Based on the results of the RI field activities, it is not expected that an explosive safety hazard would be present at the Water Works #4 Dump MRS; therefore, the MEC exposure pathway for surface and subsurface soil are considered incomplete for all receptors.

MEC Exposure Analysis

Based on the results of the MC sampling during the SI field activities and the MEC investigation portion of the RI field activities, it was determined that no potential source of MC was present at the Water Works #4 Dump MRS. Therefore, no media sampling was conducted at the MRS and incomplete MC pathways exist for all receptors.

ES.5 Conclusions and Recommendations

The RI was prepared in accordance with the project DQOs and included evaluations for explosives hazards and potential sources of MC that may pose threats to likely receptors. The following statements can be made for the Water Works #4 Dump MRS based on the results of the RI field activities:

- In total, 3.76 miles of Schonstedt-assisted visual survey transects were investigated during the RI and were inclusive of the current MRS (0.25 miles), the expanded investigation area (3.01 miles), and step-outs where MD was encountered along the expanded investigation area boundaries (0.5 miles).
- The 3.01 miles of Schonstedt-assisted visual survey transects at the expanded investigation area exceeded the proposed RI Schonstedt-assisted visual survey transect distance of 2.3 miles.
- Complete DGM coverage of accessible areas (0.762 acres) was conducted within the current MRS during the RI and nearly 99 percent coverage of the 0.77-acre MRS was achieved.

- The nature and extent of MEC and MD has been adequately defined at the MRS.
- During the RI field activities, individual MD items consisting of inert ogives were found on the ground surface or in subsurface soil at a maximum depth of 1 inch bgs within the current MRS and on the ground surface only in the expanded investigation area.
- 100-foot step-outs were performed from MD observed on the ground surface along the expanded investigation area boundaries, and the lateral extent of MD has been defined.
- No munitions posing an explosive hazard have been identified in or around the MRS to date; an explosive safety hazard is not anticipated to exist at the MRS.
- MC sampling was not warranted, since concentrated areas of MEC or MD were not found at the MRS during the RI field activities.

Based on these conclusions, it is determined that the Water Works #4 Dump MRS and expanded investigation area have been adequately characterized and that the DQOs presented in the Work Plan Addendum (Shaw, 2011) have been satisfied. Therefore, No Further Action is recommended for the Water Works #4 Dump MRS under the MMRP and the next course of action will be to proceed to a No Further Action Proposed Plan.

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1.0 INTRODUCTION

This *Remedial Investigation (RI) Report* documents the finding and conclusions of the RI field activities for the Water Works #4 Dump (RVAAP-062-R-01) Munitions Response Site (MRS) located at the former Ravenna Army Ammunition Plant (RVAAP) in Portage and Trumbull Counties, Ohio. This RI Report was prepared by CB&I Federal Services LLC company, under Delivery Order 0002 for Military Munitions Response Program (MMRP) environmental services at the RVAAP under the *Multiple Award Military Munitions Services Performance-Based Acquisition* Contract No. W912DR-09-D-0005. The Delivery Order was issued by the United States (U.S.) Army Corps of Engineers (USACE), Baltimore District, on May 27, 2009.

This RI Report presents the results of the RI field activities that were conducted at the Water Works #4 Dump MRS between July and October 2011. This report was developed in accordance with the *Final Work Plan Addendum for Military Munitions Response Program Remedial Investigation* (Shaw Environmental & Infrastructure, Inc. [Shaw], 2011) at the RVAAP, hereafter referred to as the Work Plan Addendum, and the *MMRP Munitions Response Remedial Investigation/Feasibility Study (RI/FS) Guidance* (U.S. Army [Army], 2009).

1.1 Purpose and Scope

Environmental cleanup decision-making under the MMRP follows the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) prescribed sequence of RI, FS, Proposed Plan, and Record of Decision. The RI serves as the mechanism for collecting data to characterize MRS conditions, determining the nature and extent of the contamination, and assessing potential risks to human and ecological receptors from this contamination. While not all munitions and explosives of concern (MEC) or munitions constituents (MC) under the MMRP constitute CERCLA hazardous substances, pollutants, or contaminants, the Defense Environmental Restoration Program (DERP) statute provides the U.S. Department of Defense (DoD) the authority to respond to releases of MEC/MC, and DoD policy states that such responses shall be conducted in accordance with CERCLA and the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP).

The purpose of the RI was to determine whether the Water Works #4 Dump MRS warrants further response action pursuant to CERCLA and the NCP. More specifically, it was intended in this RI Report to determine the nature and extent of MEC and MC and to subsequently determine the potential hazards and risks posed to likely human and ecological receptors by MEC and MC. Additional data are also presented in this RI Report to assist in the identification and evaluation of alternatives in the FS, if required.

1.2 Problem Identification

The Water Works #4 Dump was used as a dump site from approximately 1941 to 1949. Large-caliber casings were reportedly found on the ground surface and partially buried throughout the wooded area near the dump site, as were metal parts (defined as ogives) from World War I-era 155-millimeter (mm) Mk I shrapnel projectiles. At the time of the 2007 site inspection (SI), the MRS was 6.15 acres, which is hereafter referred to as the "SI MRS boundary."

As part of the SI field activities, a line-abreast magnetometer and metal-detector–assisted unexploded ordnance (UXO) survey was conducted at the open field portion of the SI MRS boundary and a meandering-path UXO survey was conducted in the wooded area where the large-caliber casings and ogives were previously reported. No MEC was found; however, 20 inert ogives considered as munitions debris (MD) were discovered scattered throughout the wooded area. Several subsurface anomalies were detected in the open field portion of the SI MRS boundary; however, the anomalies were not investigated during the SI. Sampling for MC was performed as part of the SI and no MC was identified. The *Final Site Inspection Report* recommended that the MRS footprint be reduced to include only the 0.77-acre open field area where the subsurface anomalies were detected, which is hereafter referred to as the "current MRS boundary." The SI further recommended that the reduced footprint be further characterized for MEC (engineering-environmental Management, Inc. [e^2M], 2008).

During development of the Work Plan Addendum (Shaw, 2011), the MRS boundaries that were recommended in the SI Report (e^2M, 2008) were reevaluated. It was recommended that the areas where the MD was identified in the wooded area outside of the current MRS be further investigated for potential MEC. Therefore, the 5.38 acres removed from the MRS during the SI were reintroduced for further evaluation as part of the RI, which is hereafter referred to as the "expanded investigation area."

1.3 Physical Setting

This section presents the physical characteristics of the facility, the Water Works #4 Dump MRS, and the surrounding environment that are factors in understanding fate and transport, conceptual site model (CSM), receptors, and exposure scenarios for potential human health and ecological risks. The physiographic setting, hydrology, climate, and ecological characteristics of the facility were compiled from information originally presented in the SI Report (e^2M, 2008) and the *Final Updated Integrated Natural Resources Management Plan* (AMEC Earth and Environmental, Inc. [AMEC], 2008) that was prepared for the Ohio Army National Guard (OHARNG).

1.3.1 Location

The RVAAP (Federal Facility Identification No. OH213820736), now known as the Camp Ravenna Joint Military Training Center (Camp Ravenna), is located in northeastern Ohio

within Portage and Trumbull Counties and is approximately 3 miles east-northeast of the city of Ravenna. The facility is approximately 11 miles long and 3.5 miles wide. The facility is bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad to the south; Garret, McCormick, and Berry Roads to the west; the Norfolk Southern Railroad to the north; and State Route 534 to the east. In addition, the facility is surrounded by the communities of Windham, Garrettsville, Newton Falls, Charlestown, and Wayland (**Figure 1-1**).

Administrative control of the 21,683-acre facility has been transferred to the U.S. Property and Fiscal Officer (USP&FO) for Ohio and subsequently licensed to the OHARNG for use as a training site, Camp Ravenna. The restoration program involves cleanup of former production areas across the facility related to former operations under the RVAAP.

The Water Works #4 Dump MRS is an approximate 0.77-acre parcel located in the south-central portion of the facility within Portage County, north of the Water Works #4 treatment building (**Figure 1-2**). The RS is located on federal property with administrative accountability assigned to the USP&FO for Ohio. The MRS is managed by the Army National Guard and the OHARNG. **Table 1-1** summarizes the administrative description of the Water Works #4 Dump MRS. The table includes the facility Army Environmental Database-Restoration numerical designation for the MRS, the current MRS acreage, and the agencies responsible for the MRS.

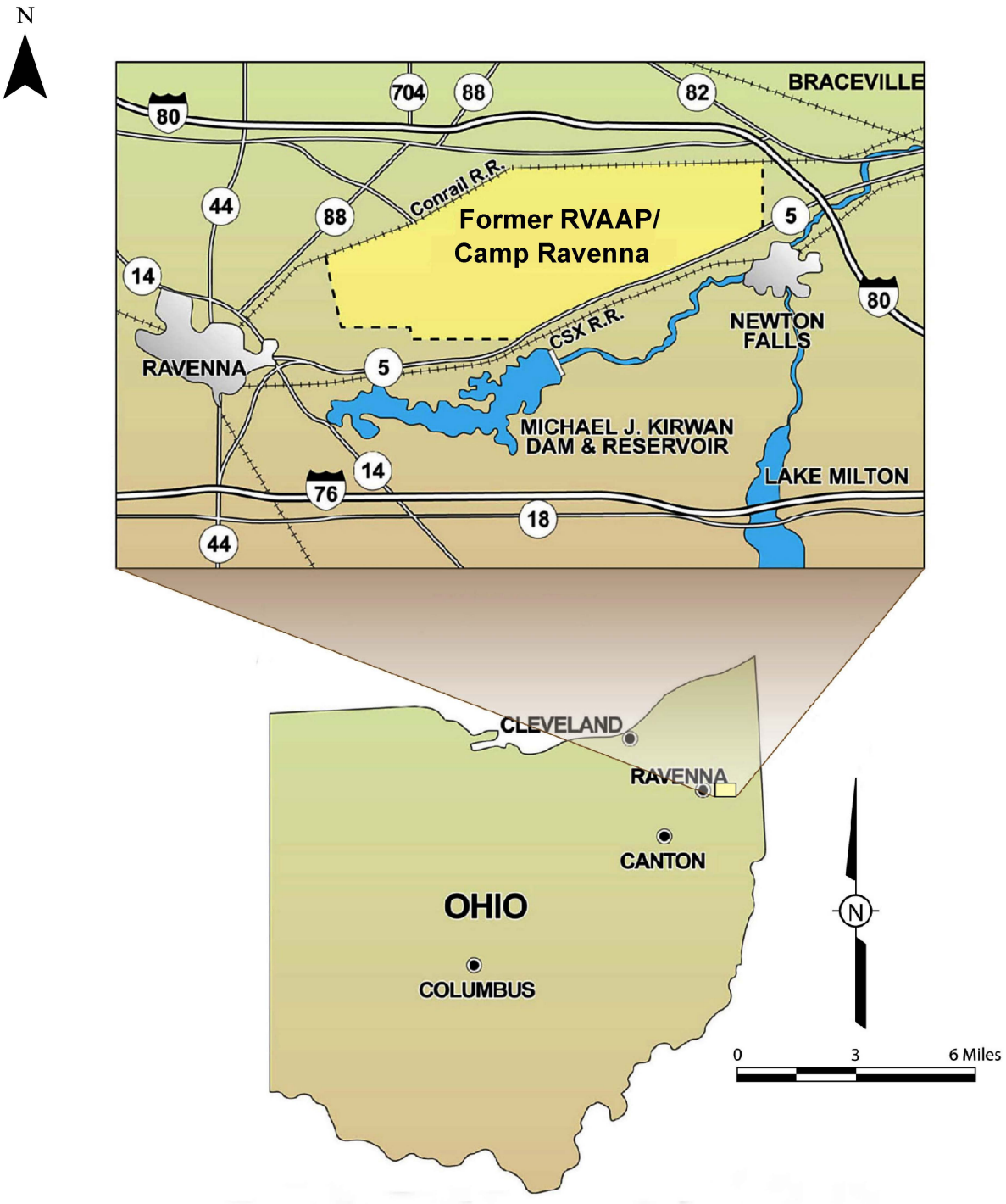
Table 1-1
Administrative Summary of the Water Works #4 Dump MRS

MRS Name	AEDB-R MRS Number	MRS Area (Acres)	Property Owner	MRS Management Responsibility
Water Works #4 Dump	RVAAP-062-R-01	0.77	USP&FO	ARNG/OHARNG

AEDB-R denotes Army Environmental Database-Restoration.
ARNG denotes Army National Guard.
MRS denotes Munitions Response Site.
OHARNG denotes Ohio Army National Guard.
RVAAP denotes former Ravenna Army Ammunition Plant.
USP&FO denotes U.S. Property and Fiscal Officer.

1.3.2 Current and Projected Land Use

This section presents the current and future land-use descriptions for the Water Works #4 Dump MRS. The future land use is based on information provided in the *RVAAP's Facility-Wide Human Health Risk Assessor Manual* (USACE, 2005), as well as information provided by the OHARNG as presented in the Work Plan Addendum (Shaw, 2011).



Note:
The Scale is for the Upper Map Only
Showing the Former RVAAP/Camp Ravenna Location

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

MILITARY MUNITIONS RESPONSE PROGRAM

FORMER RVAAP/CAMP RAVENNA
PORTAGE AND TRUMBULL COUNTIES, OHIO

CB&I Federal Services LLC
150 Royall Street
Canton, MA 02021

H:\MAMM\S\Ravenna\GIS Documents\Project Maps\MMRP\RIFS\RIFS WW\42014 Sept r1\RVAAP WW4 001 Fig1 1 SiteLoc r1.mxd Analyst: awt Date: 9/18/2014 1:28:21 PM

FIGURE 1-1 INSTALLATION LOCATION MAP

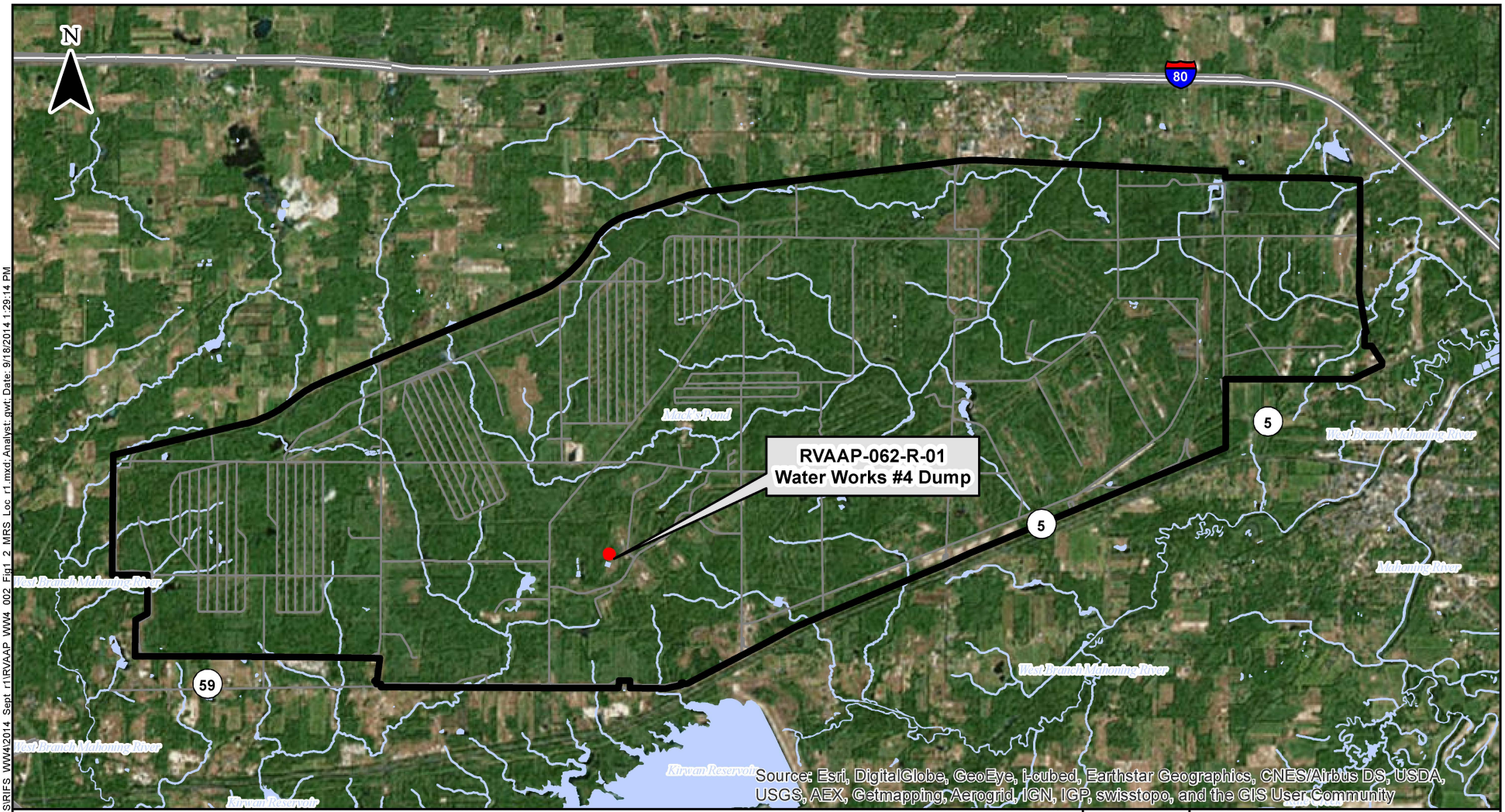


FIGURE 1-2 MRS LOCATION MAP

Current activities at the Water Works #4 Dump MRS include maintenance and natural resource management activities. Potential users identified for the MRS based on current activities include facility personnel, contractors, and potential trespassers.

The future land use for the MRS is military training. The likely receptors for the future land use are the National Guard Trainee and the Engineering School Instructor (USACE, 2005).

1.3.3 Climate

The climate at the facility is classified as humid continental, and the region is characterized by warm, humid summers and cold winters. The National Weather Service identifies the average annual precipitation for Ravenna, Ohio as 40.23 inches, with February as the driest month and July as the wettest month. **Table 1-2** reflects the annual climate and weather normally encountered at nearby Youngstown Municipal Airport.

Table 1-2
Climatic Information, Youngstown Municipal Airport, Ohio

Temperature Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Normal Maximum Temperature (ºF)	32.4	36.0	46.3	58.2	69.0	77.1	81.0	79.3	72.1	60.7	48.4	37.3
Normal Minimum Temperature (ºF)	17.4	19.3	27.1	36.5	46.2	54.6	58.7	57.5	50.9	40.9	33.0	23.4
Mean Precipitation (inches)	2.34	2.03	3.05	3.33	3.45	3.91	4.10	3.43	3.89	2.46	3.07	2.96
Mean Snowfall (inches)	13.1	9.6	10.4	2.2	0	0	0	0	Trace	0.6	4.5	12.3

Source: National Oceanic and Atmospheric Administration Climatography of the United States No. 81, Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971–2000.

ºF denotes degrees Fahrenheit.

1.3.4 Topography

The facility is located within the Southern New York section of the Appalachian Plateaus physiographic province. Rolling topography containing incised streams and dendric drainage patterns are prevalent in the province. Rounded ridges, filled major valleys, and areas covered with glacially derived unconsolidated deposits were the products of glaciation in the Southern New York section. In addition, bogs, kettle lakes, and kames are evidence of past glacial activity in the province; however, no bogs, kettle lakes, or kames were identified at the Water Works #4 Dump MRS. Old stream drainage patterns were disturbed and wetlands were created within the province because of past glacial activity (e^2M, 2008).

The topography at the Water Works #4 Dump MRS and surrounding area trends downgradient towards the southeast. The topography at the 0.77-acre MRS is relatively flat at approximately 1,150 feet above mean sea level (amsl). There is an elevation change of approximately 20 feet within the expanded investigation area that surrounds the MRS. The highest elevation is approximately 1,165 feet amsl at the northwest corner of the expanded investigation area and the lowest elevation is approximately 1,145 amsl at the southeast corner. The topography for the MRS and the surrounding area is presented in **Figure 1-3**.

1.3.5 Hydrology and Hydrogeology

The facility is located within the Ohio River Basin. The major surface stream at the facility is the west branch of the Mahoning River, which flows adjacent to the western end of the facility, generally from north to south, before flowing into the Michael J. Kirwan Reservoir. After leaving the reservoir, the west branch joins the Mahoning River east of the facility.

Surface water features within the facility include a variety of streams, lakes, ponds, floodplains, and wetlands. Numerous streams drain the facility, including approximately 19 miles of perennial streams. The total combined stream length at the facility is 212 linear miles (AMEC, 2008). No streams are present within the Water Works #4 Dump MRS.

Three primary watercourses drain the facility: (1) the south fork of Eagle Creek, (2) Sand Creek, and (3) Hinkley Creek. Eagle Creek and its tributaries, including Sand Creek, are designated as State Resource Waters. With this designation, the stream and its tributaries fall under the state antidegradation policy. These waters are protected from any action that would degrade the existing water quality.

Approximately 153 acres of ponds are found on the facility (AMEC, 2008). Most of the ponds were created by beaver activity or small man-made dams and embankments. Some were constructed within natural drainage ways to function as settling ponds for effluent or runoff. However, no ponds are present at the Water Works #4 Dump MRS.

Wetlands delineation has not been conducted at the MRS. A planning level survey (i.e., desktop review of wetlands data and resources [National Wetland Inventory maps, aerials, etc.]) for wetlands was conducted for the entire facility, including the MRS. Typical wetlands located within the facility consist of seasonally saturated wetlands, wet fields, and forested wetlands (MKM Engineering, Inc. [MKM], 2007). No wetlands were identified at the Water Works #4 Dump MRS. In addition; the MRS is not located within a floodplain.

Sand and gravel aquifers are present within the buried-valley and outwash deposits in Portage County. In general, the aquifer is too thin and localized to provide large quantities of water; however, yields are sufficient for residential water supplies. Wells located on the facility were primarily located within the sandstone facies of the Sharon Member.

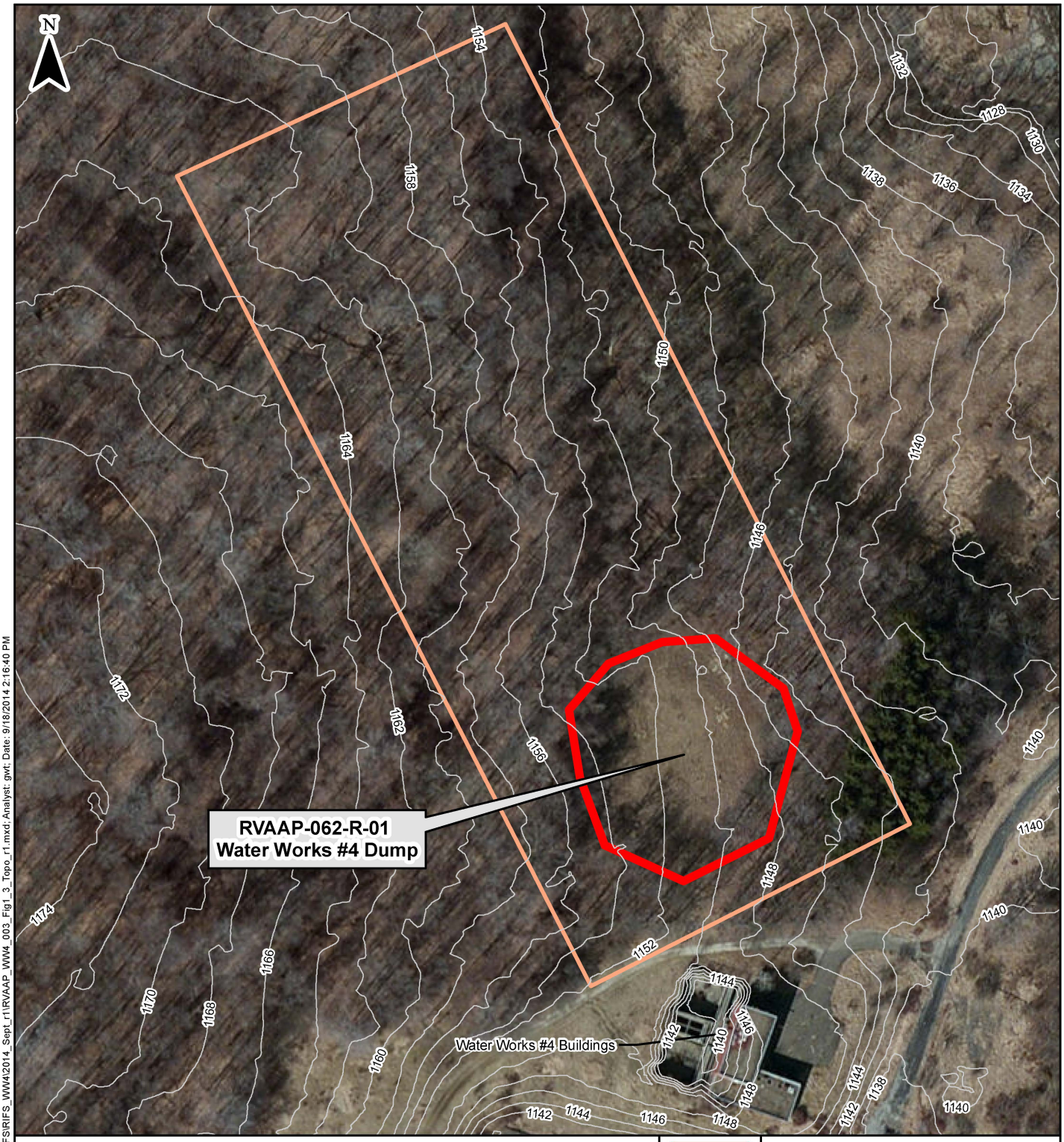


FIGURE 1-3 TOPOGRAPHY

Water Works #4 Dump Investigation Area Hydrology and Hydrogeology

Although groundwater recharge and discharge areas have not been delineated at the RVAAP, it is assumed that the extensive uplands areas at the western portion of the facility are regional recharge zones. Sand Creek, Hinkley Creek, and Eagle Creek are presumed to be major groundwater discharge areas (e^2M, 2008). The Water Works #4 Dump MRS is located at the more level, central portion of the facility and is not presumed to be located in the recharge zone.

No groundwater monitoring wells have been specifically installed for the Water Works #4 Dump MRS. Based on the facility groundwater data collected for the Facility-Wide Groundwater Monitoring Program, the groundwater elevation at the MRS and the immediate vicinity appears to be at a potentiometric high at approximately 1,100 feet amsl. The groundwater appears to flow in all directions from this higher formation. The approximate depth to groundwater in the unconsolidated aquifer at the Water Works #4 Dump MRS and the immediate surrounding area is 50 feet below ground surface (bgs) (Environmental Quality Management, Inc., 2012).

1.3.6 Geology and Soils

Based on regional geology, the facility consists of Mississippian- and Pennsylvanian-age bedrock strata, which dip to the south at approximately 5 to 10 feet per mile. The bedrock is overlain by unconsolidated glacial deposits of varying thickness.

Bedrock is overlain by deposits of Wisconsin-age Lavery Till and Hiram Till in the western and eastern portions of the facility, respectively. The thickness of the glacial deposits varies throughout the facility, ranging from ground surface in parts of the eastern portion of the facility to an estimated 150 feet in the south-central portion of the facility.

Bedrock is present near the ground surface in many locations at the facility. Where glacial deposits are still present, their distribution and character are indicative of ground moraine origin. Laterally discontinuous groupings of yellow-brown, brown, and gray silty clays to clayey silts, with sand and rock fragments are present. Glacial-age standing-water-body deposits may be present at the facility, in the form of uniform light gray silt deposits over 50 feet thick.

At approximately 200 feet bgs, the Mississippian Cuyahoga Group is present throughout most of the facility. In the northeastern corner of the facility, the Meadville Shale Member of the Cuyahoga Group is present close to the surface. The Meadville Shale Member of the Cuyahoga Group is blue-gray silty shale characterized by alternating thin beds of sandstone and siltstone.

The Sharon Member of the Pennsylvanian Pottsville Formation unconformably overlies the Meadville Shale Member of the Mississippian Cuyahoga Group. A relief of as much as

200 feet exists in Portage County, which can be seen in the Sharon Member thickness variations. The Sharon Member is made up of shale and a conglomerate.

The Sharon Member conglomerate unit is identified as highly porous, permeable, cross-bedded, frequently fractured, and weathered quartzite sandstone, which is locally conglomeratic and has an average thickness of 100 feet. A thickness of as much as 250 feet exists in the Sharon Conglomerate where it was deposited in a broad channel cut into Mississippian rocks. In marginal areas of the channel, the conglomerate unit may thin out to approximately 20 feet; in other places, it may be missing, owing to nondeposition on the uplands of the early Pennsylvanian erosional surface. Thin shale lenses occur intermittently within the upper part of the conglomerate unit.

The Sharon Member shale unit is identified as a light to dark gray fissile shale, which overlies the conglomerate in some locations; however, it has been eroded throughout the majority of the facility. The Sharon Member outcrops in many locations in the eastern half of the facility.

The remaining members of the Pottsville Formation overlie the Sharon Member in the western portion of the facility. Due to erosion and because the land surface is above the level of deposition, the Pottsville Formation is not found in the eastern half of the facility.

The Connoquenessing Sandstone Member, which is sporadic, relatively thin-channel sandstone comprised of gray to white coarse-grained quartz with a higher percentage of feldspar and clay than the Sharon Conglomerate, unconformably overlies the Sharon Member. The Mercer Member, which is found above the Connoquenessing Sandstone Member, consists of silty to carbonaceous shale with many thin and discontinuous lenses of sandstone in its upper part. The Homewood Sandstone Member unconformably overlies the Mercer Member and consists of the uppermost unit of the Pottsville Formation. The Homewood Sandstone Member ranges from well-sorted, coarse-grained, white quartz sandstone to a tan, poorly sorted, clay-bonded, micaceous, medium- to fine-grained sandstone. The Homewood Sandstone Member occurs as a caprock on bedrock highs in the subsurface (MKM, 2007).

The soils identified at the facility are generally derived from the Wisconsin-age silty clay glacial till. The majority of native soil at the facility has been reworked or removed during construction activities (MKM, 2007). The major soil types found at the facility are silt or clay loams, ranging in permeability from 6.0×10^{-7} to 1.4×10^{-3} centimeters per second (cm/s) (U.S. Department of Agriculture [USDA] et al., 1978).

Water Works #4 Dump Investigation Area Geology and Soils

Two native soil types, the Mahoning Silt Loam and the Mitiwanga Silt Loam, are present at the Water Works #4 Dump MRS and expanded investigation area. Both soil types have 2 to 6 percent slopes (AMEC, 2008). **Figure 1-4** depicts the soil types at the Water Works #4 Dump MRS and the expanded investigation area.

The Mahoning Silt Loam is the predominant soil type at the MRS and at the eastern portion of the expanded investigation area. This soil type is characterized with medium to rapid runoff, severe seasonal wetness, and slow permeability. The average permeability of the Mahoning Silt Loam with a 2 to 6 percent slope is 9.1×10^{-5} cm/s (USDA et al, 1978).

The Mitiwanga Silt Loam is the predominant soil type in the expanded investigation area and a small area at the west side of the MRS. This is a nearly level soil type in wide, flat areas such as the MRS and the expanded investigation area. Permeability is very slow in the subsoil and underlying glacial till with an average rate of 1.4×10^{-7} cm/s. Runoff is slow and ponding is common after heavy rains or seasonally wet weather (USDA et al, 1978).

The Water Works #4 Dump MRS is located over the Mercer Member geologic formation and the bedrock elevation ranges from 1,100 to 1,150 feet amsl (AMEC, 2008). No bedrock formations were observed or encountered at the MRS during the RI; however, bedrock at the MRS appears to be relatively shallow, at depths less than 10 feet across the MRS (USDA et al, 1978). **Figure 1-5** depicts the bedrock formation beneath the Water Works #4 Dump MRS.

1.3.7 Vegetation

The facility has a diverse range of vegetation and habitat resources. Habitats present within the facility include large tracts of closed-canopy hardwood forest, scrub/shrub open areas, grasslands, wetlands, open-water ponds and lakes, and semi-improved administration areas. Vegetation at the facility can be grouped into three categories: (1) herb-dominated, (2) shrub-dominated, and (3) tree-dominated. Tree-dominated areas are most abundant, covering approximately 13,000 acres on the facility. Shrub vegetation covers approximately 4,200 acres. A plant species survey identified 18 vegetation communities on the facility. The facility has as total of seven forest formations, four shrub formations, eight herbaceous formations, and one nonvegetated formation (AMEC, 2008).

The plant communities present at and in the vicinity of the Water Works #4 Dump MRS and the expanded investigation area are a combination of red maple woods and oak-maple-tulip tree forest classifications (AMEC, 2008), while the open field consists mainly of grasses. Vegetation at the current MRS (open field area) may have been influenced/disturbed by the former use of the land as a dumping area.

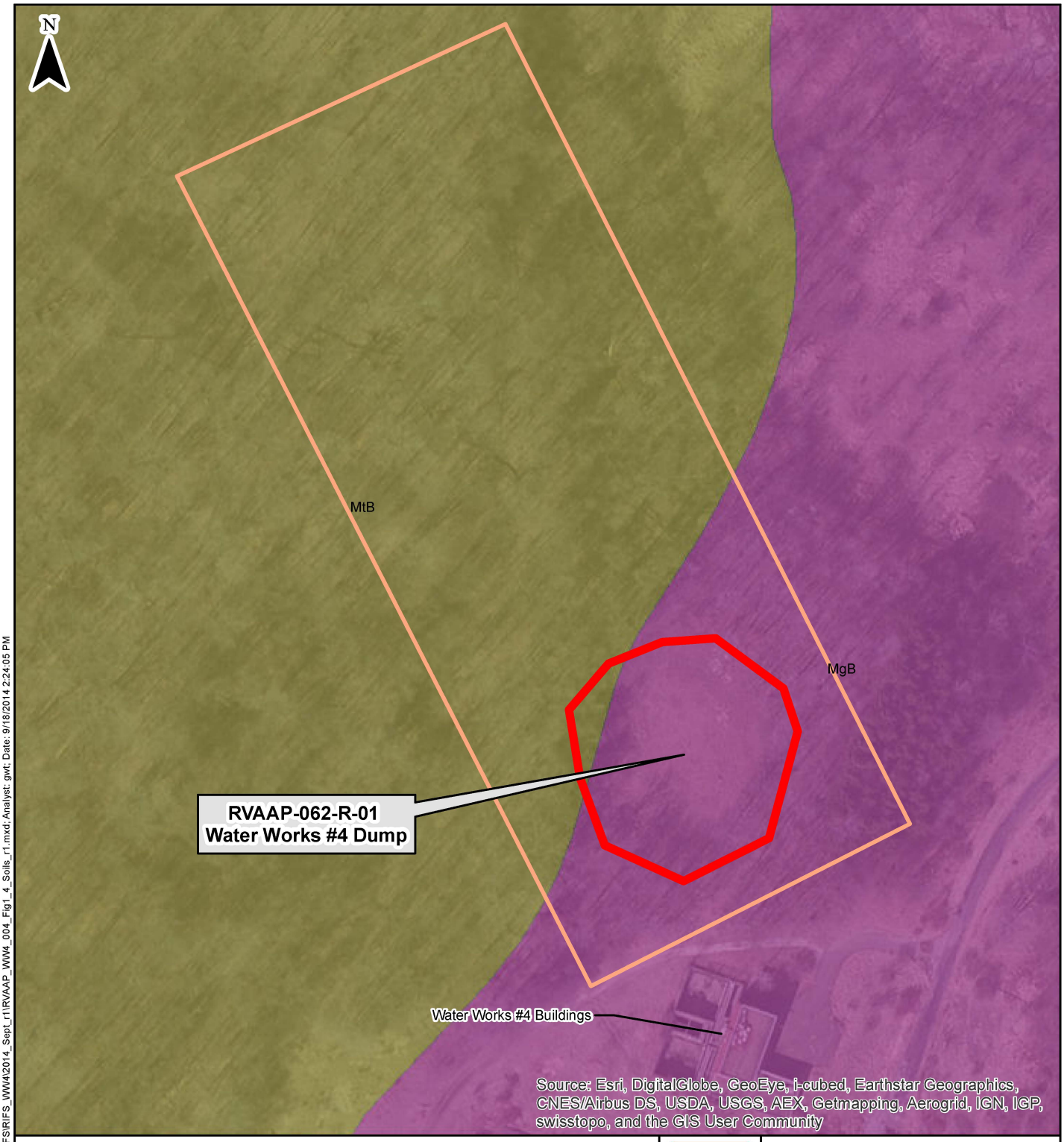


FIGURE 1-4 SOILS MAP

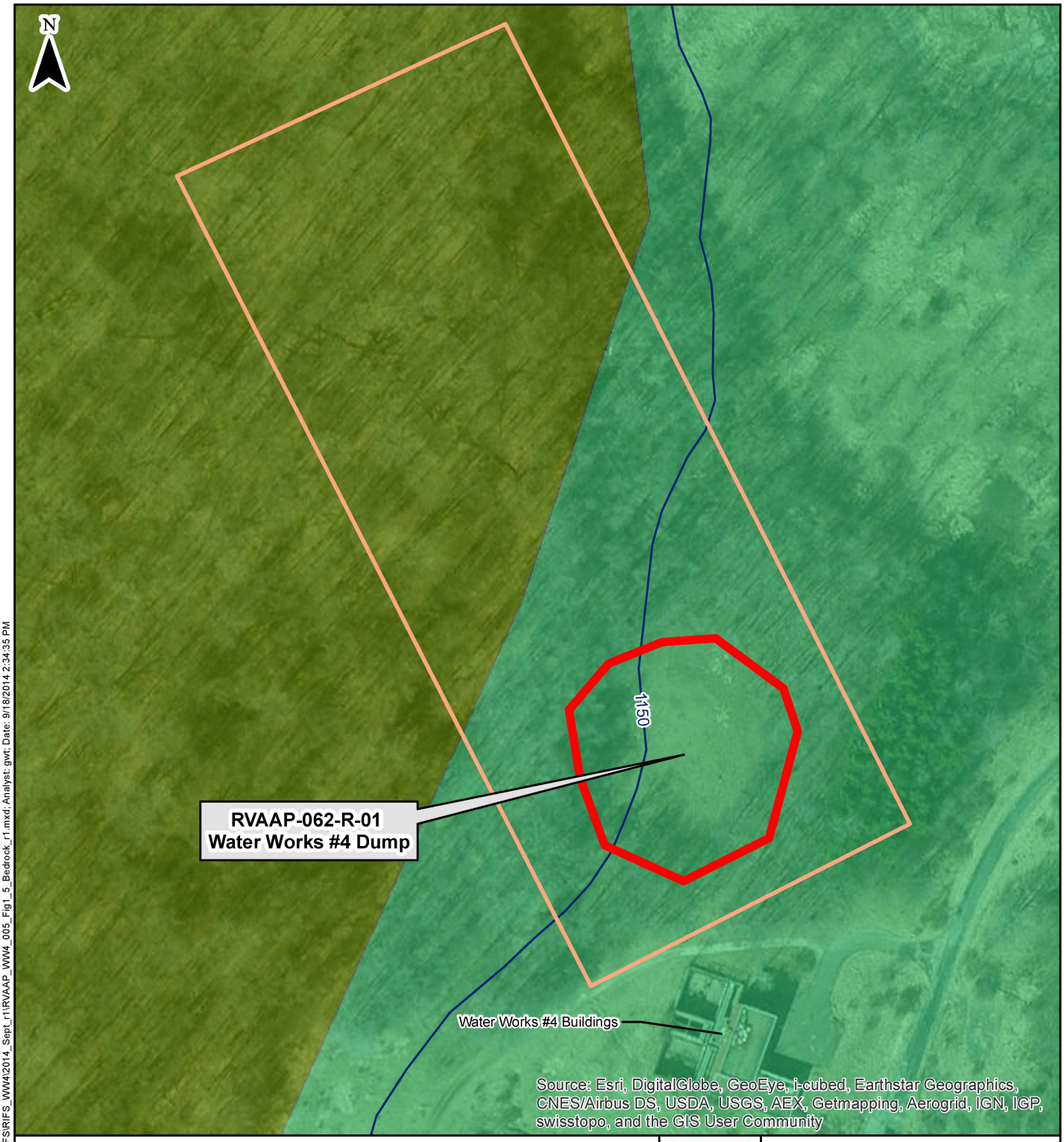


FIGURE 1-5 BEDROCK MAP

1.3.8 Threatened and Endangered and Other Rare Species

Federal status as a candidate, threatened, or endangered species is derived from the Endangered Species Act (16 U.S. Code § 1538, et seq.) and is administered by the U.S. Fish and Wildlife Service. While there are species under federal review for listing, there are currently no federally listed species or critical habitats at the facility. State-listed plant and animal species are determined by the Ohio Department of Natural Resources. Although biological inventories have not occurred within the MRS boundary and no confirmed sightings of state-listed species have been reported, there is the potential for state-listed or rare species to be within the MRS boundary. Information regarding candidate, threatened, or endangered species at the facility was obtained from the *Camp Ravenna Joint Military Training Center Rare Species List* (2010). **Table 1-3** presents state-listed species that have been identified to be on the facility by biological inventories and confirmed sightings.

Table 1-3
Camp Ravenna Joint Military Training Center Rare Species List

Common Name	Scientific Name
State Endangered	
American bittern	*Botaurus lentiginosus*
Northern harrier	*Circus cyaneus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Golden-winged warbler	*Vermivora chrysoptera*
Osprey	*Pandion haliaetus*
Trumpeter swan	*Cygnus buccinator*
Mountain brook lamprey	*Ichthyomyzon greeleyi*
Graceful underwing moth	*Catocala gracilis*
Tufted moisture-loving moss	*Philonotis fontana var. Caespitosa*
Bobcat	*Felis rufus*
Narrow-necked Pohl's moss	*Pohlia elongata var. Elongata*
Sandhill crane (probable nester)	*Grus canadensis*
Bald eagle (nesting pair)	*Haliaeetus leucocephalus*
State Threatened	
Barn owl	*Tyto alba*
Dark-eyed junco (migrant)	*Junco hyemalis*

Table 1-3 (continued)
Camp Ravenna Joint Military Training Center Rare Species List

Common Name	Scientific Name
Hermit thrush (migrant)	*Catharus guttatus*
Least bittern	*Ixobrychus exilis*
Least flycatcher	*Empidonax minimus*
Caddisfly	*Psilotreta indecisa*
Simple willow-herb	*Epilobium strictum*
Woodland horsetail	*Equisetum sylvaticum*
Lurking leskea	*Plagiothecium latebricola*
Pale sedge	*Carex pallescens*
State Potentially Threatened Plants	
Gray birch	*Betula populifolia*
Butternut	*Juglans cinerea*
Northern rose azalea	*Rhododendron nudiflorum var. Roseum*
Hobblebush	*Viburnum alnifolium*
Long beech fern	*Phegopteris connectilis*
Straw sedge	*Carex straminea*
Large St. Johnswort	*Hypericum majus*
Water avens	*Geum rivale*
Shinning lady's tresses	*Spiranthes lucida*
Swamp oats	*Sphenopholis pensylvanica*
Arborvitae	*Thuja occidentalis*
American chestnut	*Castanea dentata*
Tufted moisture-loving moss	*Philonotis fontana var. Caespitosa*
State Species of Concern	
Pygmy shrew	*Sorex hoyi*
Woodland jumping mouse	*Napaeozapus insignis*
Star-nosed mole	*Condylura cristata*
Sharp-shinned hawk	*Accipiter striatus*

Table 1-3 (continued)
Camp Ravenna Joint Military Training Center Rare Species List

Common Name	Scientific Name
Marsh wren	*Cistothorus palustris*
Henslow's sparrow	*Ammodramus henslowii*
Cerulean warbler	*Dendroica cerulea*
Prothonotary warbler	*Protonotaria citrea*
Bobolink	*Dolichonyx oryzivorus*
Northern bobwhite	*Colinus virginianus*
Common moorhen	*Gallinula chloropus*
Great egret (migrant)	*Ardea alba*
Sora	*Porzana carolina*
Virginia rail	*Rallus limicola*
Creek heelsplitter	*Lasmigona compressa*
Eastern box turtle	*Terrapene carolina*
Four-toed salamander	*Hemidactylium scutatum*
Mayfly	*Stenonema ithaca*
Coastal plain apamea	*Apamea mixta*
Willow peasant	*Brachylomia algens*
Sedge wren	*Cistothorus platensis*
State Special Interest	
Canada warbler	*Wilsonia canadensis*
Little blue heron	*Egretta caerulea*
Magnolia warbler	*Dendroica magnolia*
Northern waterthrush	*Seiurus noveboracensis*
Winter wren	*Troglodytes troglodytes*
Black-throated blue warbler	*Dendroica caerulescens*
Brown creeper	*Certhia americana*
Mourning warbler	*Oporornis philadelphia*
Pine siskin	*Carduelis pinus*

Table 1-3 (continued)
Camp Ravenna Joint Military Training Center Rare Species List

Common Name	Scientific Name
Purple finch	*Carpodacus purpureus*
Red-breasted nuthatch	*Sitta canadensis*
Golden-crowned kinglet	*Regulus satrapa*
Blackburnian warbler	*Dendroica fusca*
Blue grosbeak	*Guiraca caerulea*
Common snipe	*Gallinago gallinago*
American wigeon	*Anas americana*
Gadwall	*Anas strepera*
Green-winged teal	*Anas crecca*
Northern shoveler	*Anas clypeata*
Redhead duck	*Aythya americana*
Ruddy duck	*Oxyura jamaicensis*

Source: Camp Ravenna Joint Military Training Center Rare Species List, April 27, 2010.

1.3.9 Cultural and Archeological Resources

A number of archeological surveys have been conducted at the facility and cultural and archeological resources have been identified. The Water Works #4 Dump MRS has not been previously surveyed for cultural or archeological resources (AMEC, 2008). However, due to the disturbed nature of the area from former operations, it is unlikely that cultural/archeological resources exist at the MRS.

1.4 Facility History and Background

During operations as an ammunition plant, the RVAAP was a government-owned and contractor-operated industrial facility. Industrial operations at the RVAAP consisted of 12 munitions assembly facilities, referred to as “load lines.” Load Lines 1 through 4 were used to melt and load 2,4,6-trinitrotoluene and Composition B into large-caliber shells and bombs. The operations on the load lines produced explosive dust, spills, and vapors that collected on the floors and walls of each building. Periodically, the floors and walls were cleaned with water and steam. Following cleaning, the “pink water” waste water, which contained 2,4,6-trinitrotoluene and Composition B, was collected in concrete holding tanks, filtered, and pumped into unlined ditches for transport to earthen settling ponds. Load Lines 5 through 11 were used to manufacture fuzes, primers, and boosters. Potential contaminants

in these load lines include lead compounds, mercury compounds, and explosives. From 1946 to 1949, Load Line 12 was used to produce ammonium nitrate for explosives and fertilizers prior to use as a weapons demilitarization facility.

In 1950, the RVAAP was placed in standby status and operations were limited to renovation, demilitarization, and normal maintenance of equipment, along with storage of munitions. Production activities were resumed from July 1954 to October 1957 and again from May 1968 to August 1972. In addition to production missions, various demilitarization activities were conducted at facilities constructed at Load Lines 1, 2, 3, and 12. Demilitarization activities included disassembly of munitions and explosives melt-out and recovery operations using hot water and steam processes. Periodic demilitarization of various munitions continued through 1992.

In addition to production and demilitarization activities at the load lines, other facilities at the RVAAP include MRSs that were used for the burning, demolition, and testing of munitions. These burning and demolition grounds consist of large parcels of open space or abandoned quarries. Potential contaminants at these MRSs include explosives, propellants, metals, and waste oils. Other areas of concern (AOCs) present at the facility include landfills, an aircraft fuel tank testing facility, and various general industrial support and maintenance facilities.

Water Works #4 Dump MRS History and Background

The Water Works #4 Dump MRS originally encompassed 6.15 acres of mostly forested area that included a small clearing, located immediately north of the Water Works #4 treatment building and west of Load Line 7 in the southwestern portion of the facility. According to the *Final Military Munitions Response Program Historical Records Review* (HRR) (e^2M, 2007), the Water Works #4 Dump MRS was presumably used for the intentional dumping of nonexplosive metal parts of large-caliber ordnance rounds. These dumping activities reportedly occurred from 1941 to 1949.

Large-caliber casings were previously found scattered lying on the ground surface and partially buried throughout the wooded area north of the clearing, as were metal parts (defined as ogives) from World War I-era 155 mm Mk I shrapnel projectiles (e^2M, 2007). During the SI field activities, 20 inert 155 mm Mk I shrapnel projectile ogives with no energetic material were found scattered throughout the northern wooded area that was part of the MRS during the SI. Several closely spaced subsurface anomalies were detected during the SI field activities in the open field portion of the MRS. It was recommended in the SI Report (e^2M, 2008), and subsequently approved by the stakeholders, that the MRS footprint be reduced from 6.15 to 0.77 acres to include only the open field area of the MRS where subsurface anomalies were detected. Further discussion of the SI field activities performed at the MRS is presented in Section 1.5.3, "2008 e^2M Site Inspection Report."

During development of the Work Plan Addendum (Shaw, 2011), the current MRS boundaries were reevaluated and it was determined that although few subsurface anomalies were detected in the wooded areas formerly considered part of the SI MRS boundary, MD consisting of the 155 mm ogives were identified in these areas and required further investigation for MEC. Therefore, the 5.38 acres removed from the MRS during the SI were reintroduced for further evaluation as part of the RI (i.e., the expanded investigation area). **Figure 1-6** depicts the current MRS boundaries, significant features of interest at the MRS, and the expanded investigation area.

1.5 Previous Investigations

This section briefly summarizes the investigations as it pertains to the facility MRS discussed in this RI Report. This information was obtained primarily from the SI Report (e^2M, 2008).

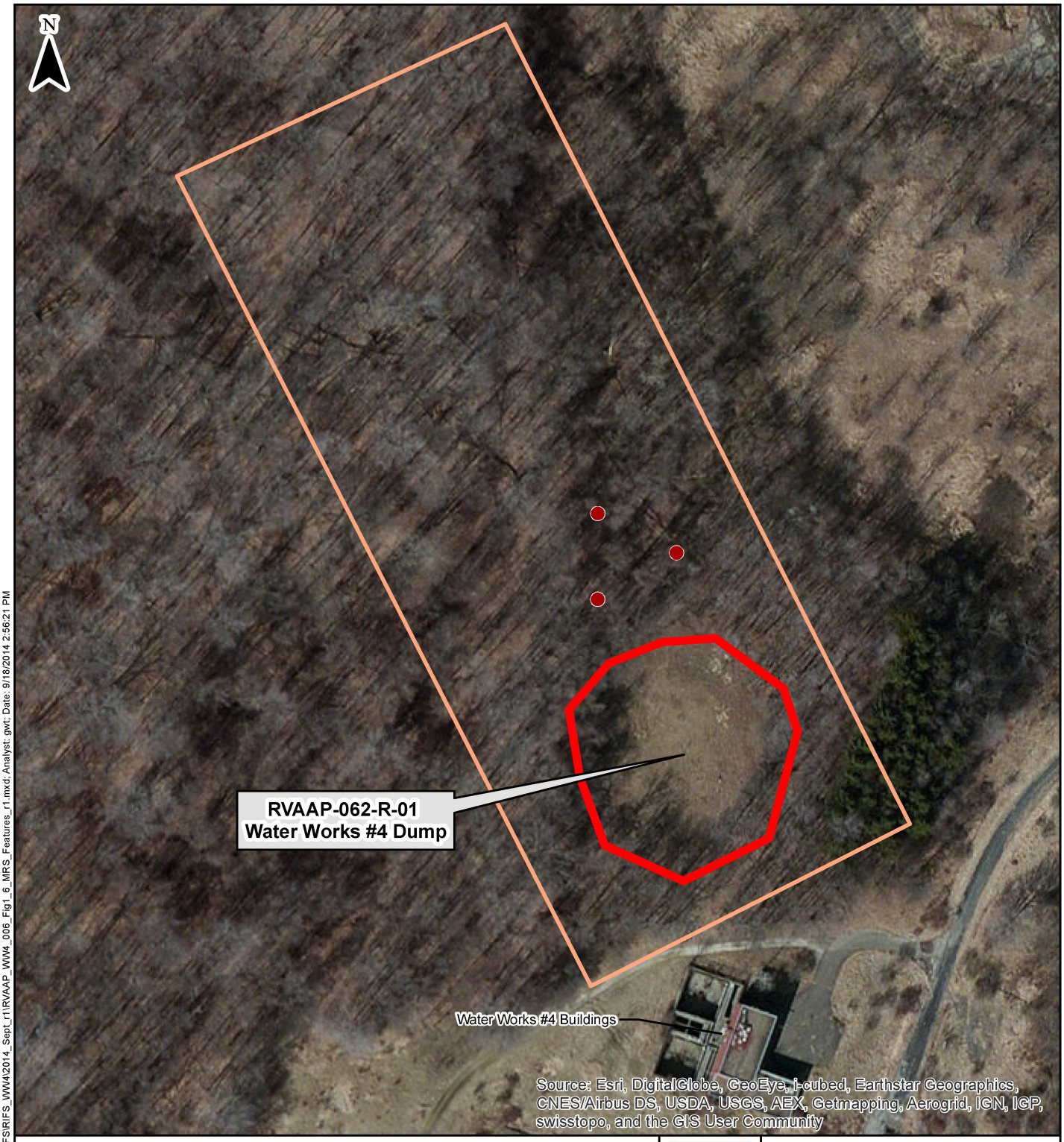
1.5.1 2004 USACE Archives Search Report

The USACE conducted an archives search in 2004 under the DERP as a historical records search and SI for the presence of MEC at the facility (USACE, 2004). The *Final Archives Search Report* (ASR) identified 12 AOCs as well as 4 additional locations with the potential for MEC. Based on the ASR, Ramsdell Quarry Landfill, Erie Burning Grounds, Open Demolition Area #1, Load Line 12 and Dilution/Settling Pond, Building 1200 and Dilution/Settling Pond, Quarry Landfill/Former Fuze and Booster Burning Pits, 40mm Firing Range, Building 1037—Laundry Waste Water Sump, Anchor Test Area, Atlas Scrap Yard, Block D Igloo, and Tracer Burning Furnace were identified as potential MRSs containing MEC. Confirmed MEC was identified at Open Demolition Area #2, Landfill North of Winklepeck, Load Line 1 and Dilution/Settling Pond, and Load Line 3 and Dilution/Settling Pond. The ASR did not identify the Water Works #4 Dump MRS to have a potential for MEC since only inert metal parts had been observed.

1.5.2 2007 e^2M Historical Records Review

The HRR was performed by e^2M in January 2007. The primary objective of the HRR was to perform a limited-scope records search to document historical and other known information on MRS identified at the facility, to supplement the U.S. Closed, Transferring, and Transferred Range/Site Inventory, and to support the technical project planning process designed to facilitate decisions on those areas where more information was needed to determine the next step(s) in the CERCLA process.

Of the 19 MMRP-eligible MRSs identified during the U.S. Army Closed, Transferring, and Transferred Inventory, the HRR identified 18 MRSs that qualified for the MMRP due to the demolition and/or dump activities conducted on the MRS that resulted in the possible



MRS Boundary

Site Inspection MRS Boundary and Expanded Investigation Area

MD Item Identified During 2007 Site Inspection

0 130 260 Feet

Projection : NAD_1983_UTM_Zone_17N

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FIGURE 1-6 SITE FEATURES MAP

presence of MEC and/or MC, and where the releases occurred prior to September 2002 (e^2M, 2007). These 18 MRSs identified during the HRR included the following:

- Ramsdell Quarry Landfill (RVAAP-001-R-01)
- Erie Burning Grounds (RVAAP-002-R-01)
- Open Demolition Area #2 (RVAAP-004-R-01)
- Load Line #1 (RVAAP-008-R-01)
- Load Line #12 (RVAAP-012-R-01)
- Fuze and Booster Quarry (RVAAP-016-R-01)
- Landfill North of Winklepeck (RVAAP-019-R-01)
- 40mm Firing Range (RVAAP-032-R-01)
- Firestone Test Facility (RVAAP-033-R-01)
- Sand Creek Dump (RVAAP-034-R-01)
- Building #F-15 and F-16 (RVAAP-046-R-01)
- Anchor Test Area (RVAAP-048-R-01)
- Atlas Scrap Yard (RVAAP-050-R-01)
- Block D Igloo (RVAAP-060-R-01)
- Block D Igloo TD (RVAAP-061-R-01)
- Water Works #4 Dump (RVAAP-062-R-01)
- Areas Between Buildings 846 and 849 (RVAAP-063-R-01) (now identified as "Group 8")
- Field at the Northeast Corner of the Intersection (RVAAP-064-R-01)

Following the HRR, the Field at the Northeast Corner of the Intersection (RVAAP-064-R-01), otherwise known as the Old Hayfield MRS, was classified as an operational range. This MRS was removed from eligibility under the MMRP, reducing the number of active MRS at the RVAAP to 17.

The Water Works #4 Dump was identified in the U.S. Army Closed, Transferring, and Transferred Inventory as a 6.15-acre wooded MRS that was used as a dump area. The HRR assumed the release mechanism was the intentional dumping of nonexplosive metal parts of large-caliber ordnance rounds. MD was observed on the ground surface as well as partially buried; however, a subsurface evaluation had not been performed. It was determined in the

HRR that there was the potential for MEC to be buried in the subsurface at the MRS and that the presence or absence of MC at the MRS had not been confirmed (e^2M, 2007).

1.5.3 2008 e^2M Site Inspection Report

In 2007, e^2M conducted an SI at each of the 17 MRSs under the MMRP. The primary objectives of the SI were to collect the appropriate amount of information to support recommendations of "no further action, immediate response, or further characterization" concerning the presence of MEC and/or MC at each of the MRSs. The SI also included a review of the HRR for each applicable MRS. Out of the 17 MRSs evaluated during the SI phase, 14 were recommended for further characterization under the MMRP, including the Water Works #4 Dump MRS (RVAAP-062-R-01). A summary of the of the SI Report recommendations for the Water Works #4 Dump MRS is presented in **Table 1-4**.

Table 1-4
Site Inspection Report Recommendations

MRS	MRSPP Priority	Recommendations	Basis for Recommendation	
			MEC	MC
Water Works #4 Dump (RVAAP-062-R-01)	6	Further characterization of MEC at reduced MRS footprint.	MEC potentially present in subsurface.	No MC detected above screening criteria.

MC denotes munitions constituents.
MEC denotes munitions and explosives of concern.
MRS denotes Munitions Response Site.
MRSPP denotes Munitions Response Site Prioritization Protocol.

At the time of the SI, the size of the Water Works #4 Dump MRS was approximately 6.15 acres, which included the open field portion where dumping activities occurred and the wooded area where large-caliber casings and ogives were previously documented. As part of the SI field activities, a line-abreast magnetometer and metal-detector-assisted UXO survey were conducted at the open field portion of the MRS and a meandering-path UXO survey was conducted in the wooded area where the large-caliber casings and ogives were previously reported. No MEC was found; however, 20 inert ogives were discovered scattered throughout the wooded area. Several subsurface anomalies were detected in the open field portion of the MRS; however, the nature of anomalies remained unknown, since an intrusive investigation was not performed during the SI. The areas investigated during the SI field activities are presented in **Figure 1-7**.

A composite surface soil sample (RVAAP-WW4-SS-1) was collected from the open field portion of the MRS during the SI using the Cold Regions Research and Engineering Laboratory (CRREL) seven-wheel sample method, and no MC was detected above the U.S.

Environmental Protection Agency (EPA) Preliminary Remediation Goals, the screening criteria used at the time of the SI. Since no MC was identified above the screening criteria, additional characterization of MC was not recommended for the MRS (e^2M, 2008).

Based on the SI results, it was recommended in the SI Report (e^2M, 2008) that the MRS be reduced to include only the 0.77-acre open field portion of the MRS (**Figure 1-7**). The new footprint was recommended for further characterization of MEC to evaluate the subsurface anomalies detected at this area during the SI field activities.

The SI Report (e^2M, 2008) assigned the Water Works #4 Dump MRS a Munitions Response Site Prioritization Protocol (MRSPP) priority of 6. The MRSPP is a funding mechanism typically performed during the preliminary assessment/SI stage to prioritize funding for MRSs on a priority scale of 1 to 8 with a Priority 1 being the highest relative priority. Based on the MRSPP score presented in the SI Report (e^2M, 2008), the Water Works #4 Dump MRS was selected for inclusion for further characterization under the MMRP.

1.6 Remedial Investigation Report Organization

The contents and order of presentation of this RI Report are based on the requirements of *MMRP RI/FS Guidance* (Army, 2009). Specifically, this RI Report includes the following sections:

- **Section 1.0**—Introduction
- **Section 2.0**—Project Objectives
- **Section 3.0**—Characterization of MEC and MC
- **Section 4.0**—Remedial Investigation Results
- **Section 5.0**—Fate and Transport
- **Section 6.0**—MEC Hazard Assessment
- **Section 7.0**—Human Health Risk Assessment
- **Section 8.0**—Ecological Risk Assessment
- **Section 9.0**—Revised Conceptual Site Model
- **Section 10.0**—Summary and Conclusions
- **Section 11.0**—References

Appendices included at the end of this RI are as follows:

- **Appendix A**—Digital Geophysical Mapping Report

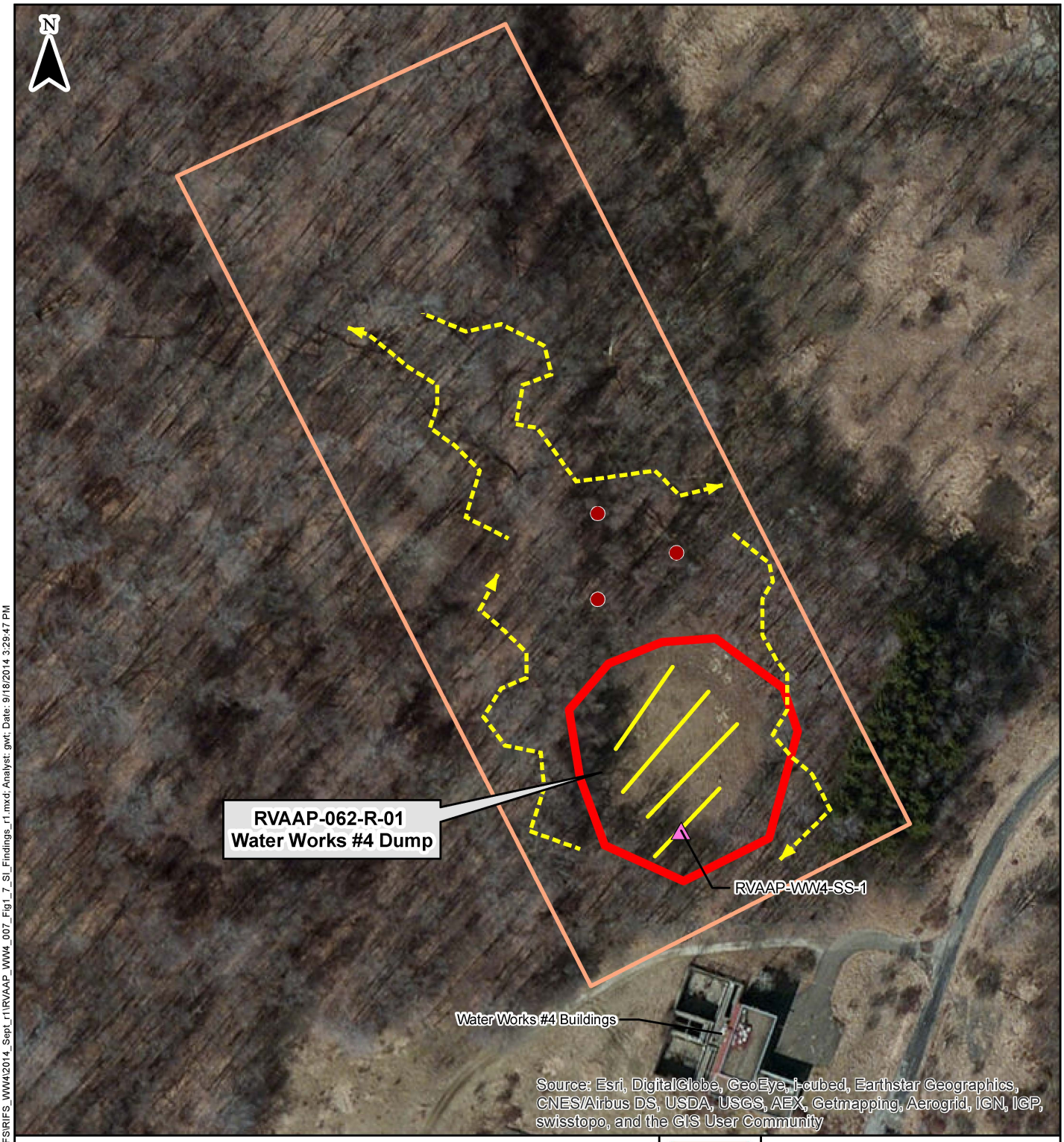

FIGURE 1-7 SI FIELDWORK AND FINDINGS

- **Appendix B**—Photograph Documentation Log
- **Appendix C**—Schonstedt-assisted Visual Survey and Intrusive Investigation Results
- **Appendix D**—Statistical Analysis of Intrusive Findings
- **Appendix E**—Munitions Debris Shipment and Disposal Records
- **Appendix F**—Munitions Response Site Prioritization Protocol Worksheets

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2.0 PROJECT OBJECTIVES

This chapter presents the preliminary CSM for the Water Works #4 Dump MRS based on historical information, identifies data gaps associated with the preliminary CSM, and details the data quality objectives (DQOs) necessary to achieve the project objectives.

A CSM for an MRS provides an analysis of potential exposures associated with MEC and/or MC and an evaluation of the potential transport pathways MEC and/or MC take from a source to a receptor. Each pathway includes a source, activity, access, and receptor component, with complete, potentially complete, or incomplete exposure pathways identified for each receptor. Each component of the CSM analysis is discussed below:

- **Sources—**Sources are those areas where MEC or MC have entered (or may enter) the physical system. A MEC source is the location where material potentially presenting an explosive hazard (MPPEH) or ordnance is situated or is expected to be found. A MC source is a location where MC has entered the environment.
- **Activity—**The hazard from MEC and/or MC arises from direct contact because of some human or ecological activity. Interactions associated with activities describe ways that receptors are exposed to a source. For MEC, movement is not typically significant, and interaction will occur only at the source area as described above, limited by access and activity. However, there can be some movement of MEC through natural processes such as frost heave, erosion, and stream conveyance. For MC, this can include physical transportation of the contaminant and transfer from one medium to another through various processes such that media other than the source area can become contaminated. Interactions also include exposure routes (ingestion, inhalation, and dermal contact) for each receptor. Ecological exposure can include coming into contact with MEC or MC lying on the ground surface or through disturbing buried MEC/MC while burrowing.
- **Access—**Access is the ease in which a receptor can be exposed to a source. The presence of access controls help determine whether an exposure pathway to a receptor is complete, as fences or natural barriers can limit human access to a source area. Furthermore, the depth of MEC items and associated MC in subsurface soils may also limit access by a receptor. Ease of entry for adjacent populations (i.e., lack of fencing) can facilitate trespassing at the MRS, either intentional or accidental.
- **Receptors—**A receptor is an organism (human or ecological) that contacts a chemical or physical agent. The pathway evaluation must consider both current

and reasonably anticipated future land use and activities, as receptors are determined on that basis. If present, MEC and/or MC on the ground surface and near the surface can be accessed by potential receptors.

A pathway is considered complete when a source (MEC) is known to exist and when receptors have access to the MRS while engaging in some activity that results in contact with the source. A pathway is considered potentially complete when a source has not been confirmed, but is suspected to exist and when receptors have access to the MRS while engaging in some activity which results in contact with the source. Lastly, an incomplete pathway is any case where one of the four components (source, activity, access, or receptors), is missing from the MRS.

In general, the CSM for each MRS is intended to assist in planning, interpreting data, and communicating MRS-specific information. The CSMs are used as a planning tool to integrate information from a variety of resources, to evaluate the information with respect to project objectives and data needs, and to evolve through an iterative process of further data collection or action. A discussion of the preliminary CSM identified for the Water Works #4 Dump MRS, as presented in the SI Report (e^2M, 2008), is presented in the following section. The data collected during the RI are evaluated in the following chapters and incorporated into this model as discussed in Section 9.0, "Revised Conceptual Site Model."

2.1 Preliminary Conceptual Site Model and Project Approach

The preliminary CSM for the Water Works #4 Dump MRS is based on MRS-specific data and general historical information including literature reviews, maps, training manuals, technical manuals, and field observations. The preliminary CSM was originally developed during the 2007 SI based on guidance from Engineer Manual 1110-1-1200, *Conceptual Site Models for Ordnance and Explosives (OE) and Hazardous, Toxic, and Radioactive Waste (HTRW) Projects* (USACE, 2003a) and is represented by the diagrams provided as **Figure 2-1** and **Figure 2-2** for MEC and MC, respectively. A summary of each of the factors evaluated for the preliminary CSM is discussed below:

- **Sources—**The SI identified the intentional dumping of nonexplosive metal parts of large-caliber MEC items as the primary MEC source at the Water Works #4 Dump MRS. However, the type and origin of MEC/MD present at the MRS was unknown. During the 2007 SI field activities, no MEC items were identified on the ground surface; however, anomalies were detected in the subsurface. As such, there was the potential for MEC in the subsurface. One composite surface soil sample was collected at the open field portion of the MRS during the SI field activities and no MC was identified.

- **Activity—**Human activities considered for the preliminary CSM included natural resource management, maintenance activities, and security patrols that were performed at an infrequent basis.
- **Access—**Access to the Water Works #4 Dump MRS at the time of the SI was not restricted. With the exception of the facility perimeter fence, there were no known access controls present at the Water Works #4 Dump MRS.
- **Receptors—**At the time of the SI, current and reasonably anticipated future land-use receptors included installation personnel and contract workers (including maintenance personnel), soldiers, regulatory personnel, and possibly trespassers and hunters. The SI Report (e^2M, 2008) considered biota to be state-listed species identified as being present at the facility. If present, MEC and/or MD and associated MC on the ground surface and near the surface could have been accessed by receptors.

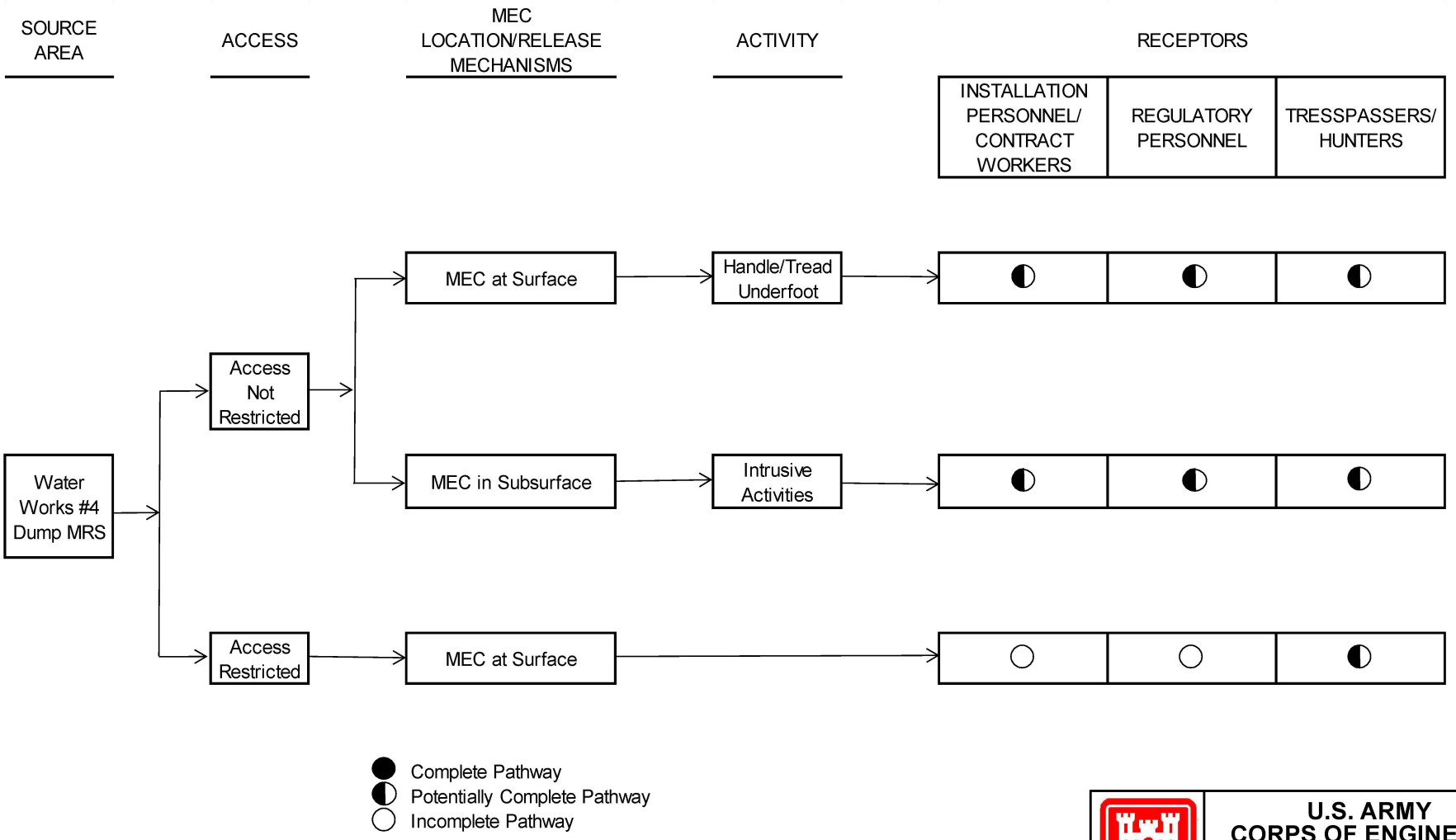
The information collected during the SI was used to prepare the preliminary CSM for MEC and MC for the Water Works #4 Dump MRS and to identify all complete, potentially complete, or incomplete source-receptor interactions for the MRS (e^2M, 2008). Since there was no conclusive evidence that MEC was not buried at the open portion of the MRS, the SI Report identified the potential MEC exposure pathway for human receptors as the disturbance of subsurface soil. The SI Report concluded that transport of buried MEC was unlikely, although frost heave could bring items to the ground surface (**Figure 2-1**). MC consisting of one metal constituent was found at the MRS during the SI, but dismissed as nonmunitions related. Therefore, the exposure and transport pathways for MC for all receptors were considered incomplete (**Figure 2-2**).

2.2 Preliminary Identification of Applicable or Relevant and Appropriate Requirements and "To Be Considered" Information

Applicable or relevant and appropriate requirements (ARARs) and "to be considered" guidance for future anticipated and reasonable remedial actions at the facility under the MMRP are currently under development. The identified ARARs and "to be considered" guidance will be included in the follow-on documents to this RI Report as required per the CERCLA process.

2.3 Data Quality Objectives and Data Needs

The DQOs and data needs were determined at the planning stage and are outlined in the Work Plan Addendum (Shaw, 2011). The data needs included characterization of MEC and/or MC associated with former activities at the MRS. The DQOs were developed to



Source: Final Site Inspection Report, Ravenna Army Ammunition Plant, Ohio (e^2M, 2008)

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Canton, MA 02021

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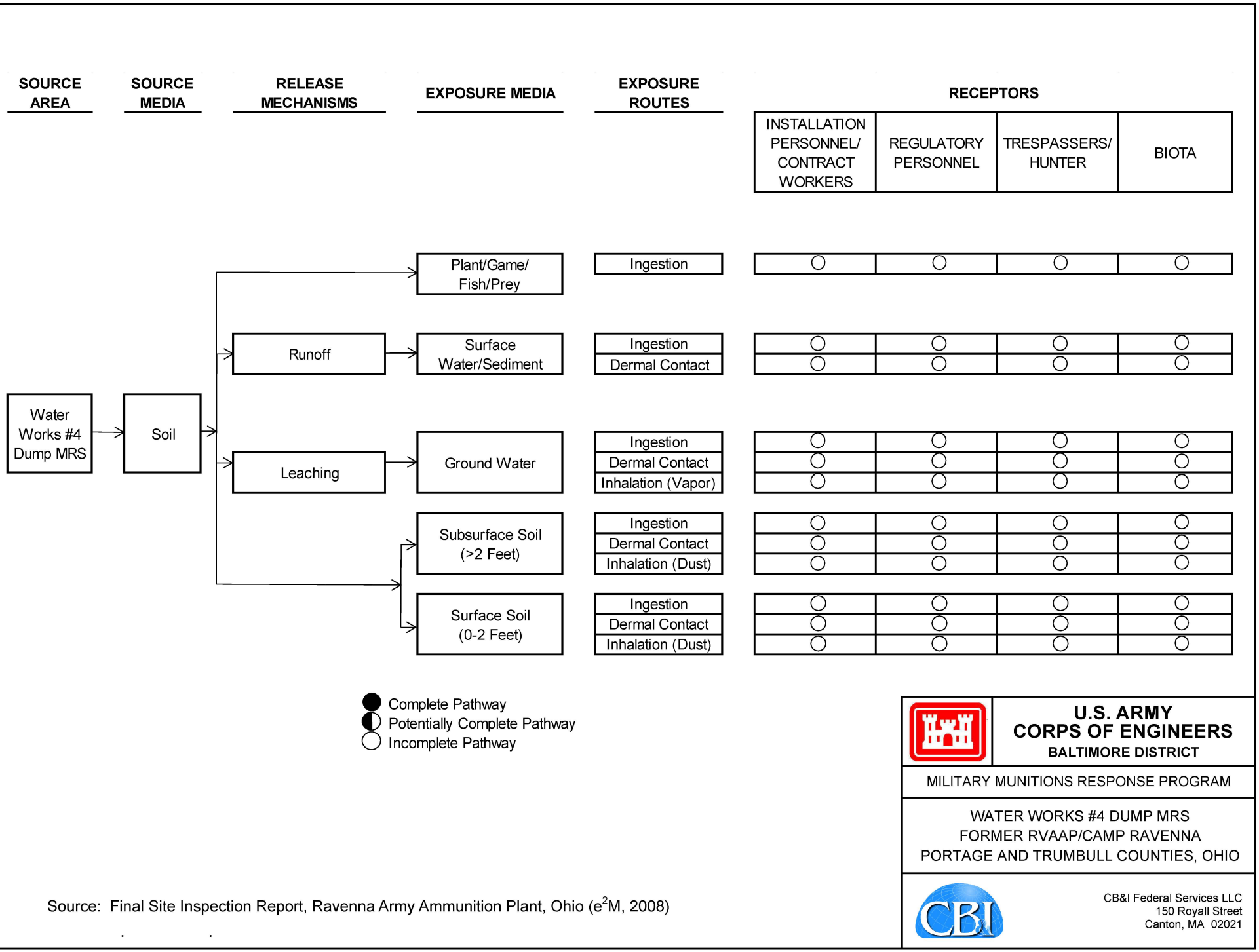
FIGURE 2-1 PRELIMINARY MEC CONCEPTUAL SITE MODEL



Source: Final Site Inspection Report, Ravenna Army Ammunition Plant, Ohio (e^2M, 2008)

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FIGURE 2-2 PRELIMINARY MC CONCEPTUAL SITE MODEL

ensure (1) the reliability of field sampling, chemical analyses, and physical analyses; (2) the collection of sufficient data; (3) the acceptable quality of data generated for their intended use; and (4) that valid assumptions could be inferred from the data.

2.3.1 Data Quality Objectives

The DQOs were developed for MEC in accordance with the *Facility-Wide Sampling and Analysis Plan for Environmental Investigations at the RVAAP* (Science Applications International Corporation [SAIC], 2011) (FSAP) and the EPA *Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW* (2000). **Table 2-1** identifies the DQO process at the Water Works #4 Dump MRS as presented in the Work Plan Addendum (Shaw, 2011).

Table 2-1
Data Quality Objectives Process at the Water Works #4 Dump MRS

Step	Data Quality Objectives
1. State the problem.	The Water Works #4 Dump was reportedly used as a dump site from approximately 1941 to 1949. Large-caliber casings and ogives from 155 mm projectiles have been found on the ground surface and partially buried. The type and origin of MEC potentially present remains unknown. At the conclusion of the SI Report (e^2M, 2008), the MRS was reduced in size. However, MD was observed outside of the current MRS boundary during the SI. Based on this information, there is a potential for MEC/MD on the surface and subsurface in the current MRS and expanded investigation area. In addition, there is a potential for environmental impacts from MC associated with the Water Works #4 Dump.
2. Identify the decision.	The goal of the investigation at the Water Works #4 Dump MRS and expanded investigation area is to identify the areas impacted with MEC/MD. MC sampling may be performed in order to further characterize the type and amount of contamination associated with munitions activities at the MRS based on the decision rules discussed in Step 5. The information obtained during the RI will be used to assess the risk and hazards posed to human health and the environment.
3. Identify inputs to the decision.	• Historical information • Schonstedt-assisted visual survey transects • DGM survey • Intrusive investigation • Incremental and discrete environmental media sampling (as needed)
4. Define the study boundaries.	The RI will be performed within the Water Works #4 Dump MRS boundaries as defined at the conclusion of the SI as well as the area removed from the MRS during the SI.

Table 2-1 (continued)
Data Quality Objectives Process at the Water Works #4 Dump MRS

Step	Data Quality Objectives
5. Develop a decision rule.	In order to confirm the absence of MEC/MD outside the MRS, a Schonstedt-assisted visual survey will be performed in the expanded investigation area. Schonstedt-assisted visual survey transects will be placed using the VSP module input that "90 percent confidence that 95 percent of transects do not contain UXO." Complete (100 percent) DGM coverage will be performed in all accessible areas within the current MRS boundary. Since full coverage is proposed, the number of anomalies investigated will be based on a prioritized ranking system and statistical sampling. Additional sampling for MC was not recommended for the Water Works #4 Dump MRS in the SI since MC results were below screening criteria. However, incremental or discrete samples may be collected if concentrated MEC/MD items are identified during the target anomaly investigation based on the DGM field activities. The number of samples required will be coordinated with USACE and the Ohio EPA prior to collection.
6. Specify limit of decision errors.	QC procedures are in place so that all fieldwork is performed in accordance with applicable standards. Further details on the QC process to be implemented during the RI are located in Section 4.0 of the Work Plan Addendum (Shaw, 2011).
7. Optimize the design for obtaining data.	The information gathered as part of the field investigation at the Water Works #4 Dump MRS and expanded investigation area will be used to determine what risks or hazards, if any, are present. Shaw will perform a MEC Hazard Assessment to identify the potential MEC hazards. In addition, an MRS-specific HHRA and ERA will be performed on the analytical results if data is collected. If unacceptable risks or hazards to human health and the environment are determined to exist at the MRS at the conclusion of the investigation, then the MRS will be identified for further evaluation under the CERCLA process.

CERCLA denotes Comprehensive Environmental Response, Compensation, and Liability Act of 1980.
DGM denotes digital geophysical mapping.
ERA denotes ecological risk assessment.
HHRA denotes human health risk assessment.
MC denotes munitions constituents.
MD denotes munitions debris.
MEC denotes munitions and explosives of concern.
mm denotes millimeter(s).
MRS denotes Munitions Response Site.
Ohio EPA denotes Ohio Environmental Protection Agency.
QC denotes quality control.
RI denotes Remedial Investigation.
SI denotes Site Inspection.
USACE denotes U.S. Army Corps of Engineers.
UXO denotes unexploded ordnance.
VSP denotes Visual Sample Plan®.

2.3.2 Data Needs

For MEC, data needs include determining the types, locations, condition, and quantity of MEC items present at the MRS so that the potential hazard to human health can be assessed and remedial decisions can be made. The DQOs were developed in accordance with the FSAP (SAIC, 2011), EPA guidance (2000), and experience with MRSs containing MEC. These data needs for MEC were evaluated using the most applicable methods and technologies that are discussed in the following chapters.

For MC, data needs include sufficient information to characterize the MRS and to perform a baseline human health risk assessment (HHRA) and an ecological risk assessment (ERA) if concentrated areas of MEC/MD are present at the MRS. More specifically, the data needed are concentrations of MC associated with the MRS in media that pose an exposure pathway for human health and ecological receptors. Samples for MC were only to be collected if concentrated area of MEC and/or MD were identified at the MRS (Shaw, 2011).

2.4 Data Incorporated into the RI

Whenever possible, existing data are incorporated into this RI. The following is a summary of the existing data and how the existing data were used:

- **Historical Records Review—**The HRR (e^2M, 2007) provides historical documentation regarding the MRS and identifies the types of activities previously conducted, the types of munitions used, and historical finds and incidents. These data were used to identify the expected baseline conditions and other hazards that may be present.
- **Installation Restoration Program Data—**Data collected under the Installation Restoration Program (IRP) at various MRSs include analytes considered MC associated with previous activities at the MRS, although not all analytes are considered as MC. The IRP data set may be incorporated with sampling data collected during the MMRP RI on a site-by-site basis in order to close data gaps. The Water Works #4 Dump MRS does not overlap with any IRP AOCs and there is no IRP data to review for incorporation into this RI Report.
- **Site Inspection Data—**The MMRP SI conducted at the facility in 2007 (e^2M, 2008) provides reconnaissance data identifying surface MD that was used in conjunction with historical aerial photography data to preliminarily delineate areas with munitions-related activity. A composite surface soil sample and a duplicate were collected at the Water Works #4 Dump MRS during the 2007 SI field activities to confirm the presence or absence of MC. The sample was collected using the CRREL seven-wheel sample method and no MC was identified. The

Work Plan Addendum (Shaw, 2011) prescribed that soil samples were required if concentrated areas of MEC and/or MD were found at the MRS during the RI field activities. The type of sampling method (incremental or discrete) would depend on the distribution and depth of the MEC/MD encountered. Due to uncertainties between the Work Plan Addendum sample methods and the CRREL seven-wheel sample method; if samples were collected during the RI, then they should not be compared with the SI sample. In addition, any samples collected during the RI fieldwork would be considered representative of current conditions associated with MEC or MD at the MRS. Therefore, if no samples are collected during the RI field activities, then concentrated areas of MEC and/or MD were not encountered and the evaluation of previously collected data will not be required in this RI Report.

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3.0 CHARACTERIZATION OF MEC AND MC

This chapter documents the approaches used to investigate MEC and MC at the Water Works #4 Dump MRS and the expanded investigation area in accordance with the DQOs presented in Section 2.0, "Project Objectives." The MEC and MC characterization activities were conducted in accordance with Section 3.0, "Field Investigation Plan," of the Work Plan Addendum (Shaw, 2011).

3.1 MEC Characterization

Subsurface anomalies have been identified within the current MRS, and based on the historical dumping activities, it was determined in the SI reporting stage that there is a potential for buried MEC/MD. For the RI, the characterization of MEC was expanded to include the 5.38-acre area of the SI MRS boundary that was removed at the conclusion of the SI (i.e., the expanded investigation area). The initial step in evaluating the lateral extent of MEC at the Water Works #4 Dump MRS consisted of performing a Schonstedt-assisted visual survey at the expanded investigation area and 100-foot step-outs from any MEC and/or MD found along the boundary of the expanded investigation area. Following the visual survey, a full-coverage digital geophysical mapping (DGM) investigation was performed at the 0.77-acre MRS to evaluate for potentially buried MEC.

Schonstedt-assisted visual surveys were proposed in the expanded investigation area in order to determine the lateral extent of MD and possible MEC associated with past observations of MD on the ground surface. Since buried MEC and/or MD were not anticipated in the expanded investigation area, DGM was not proposed in this area. However, the Work Plan Addendum (Shaw, 2011) did provide contingency that if evidence of potential buried MEC and/or MD was observed, a DGM survey and intrusive investigation would be performed in the expanded investigation area. Although not originally proposed in the Work Plan Addendum (Shaw, 2011), the Schonstedt-assisted visual survey investigation was further expanded during the RI field activities to include the MRS footprint as well.

The following sections summarize the Schonstedt-assisted visual survey, geophysical survey, and subsequent intrusive investigation that were performed at the Water Works #4 Dump MRS and the expanded investigation area. The results of the Schonstedt-assisted visual survey, DGM survey, and intrusive investigation activities are discussed in Section 4.0, "Remedial Investigation Results."

3.1.1 Schonstedt-assisted Visual Survey Activities

In September 2011, Schonstedt-assisted visual survey field activities were performed within the expanded investigation area in accordance with the Work Plan Addendum (Shaw, 2011).

The visual survey area was further expanded during the RI field activities to include the 0.77-acre MRS footprint that was not originally proposed in the Work Plan Addendum (Shaw, 2011). Schonstedt-assisted visual survey transects were placed using the *Visual Sample Plan*® (VSP) module input of "90 percent confidence that 95 percent of transects do not contain UXO."

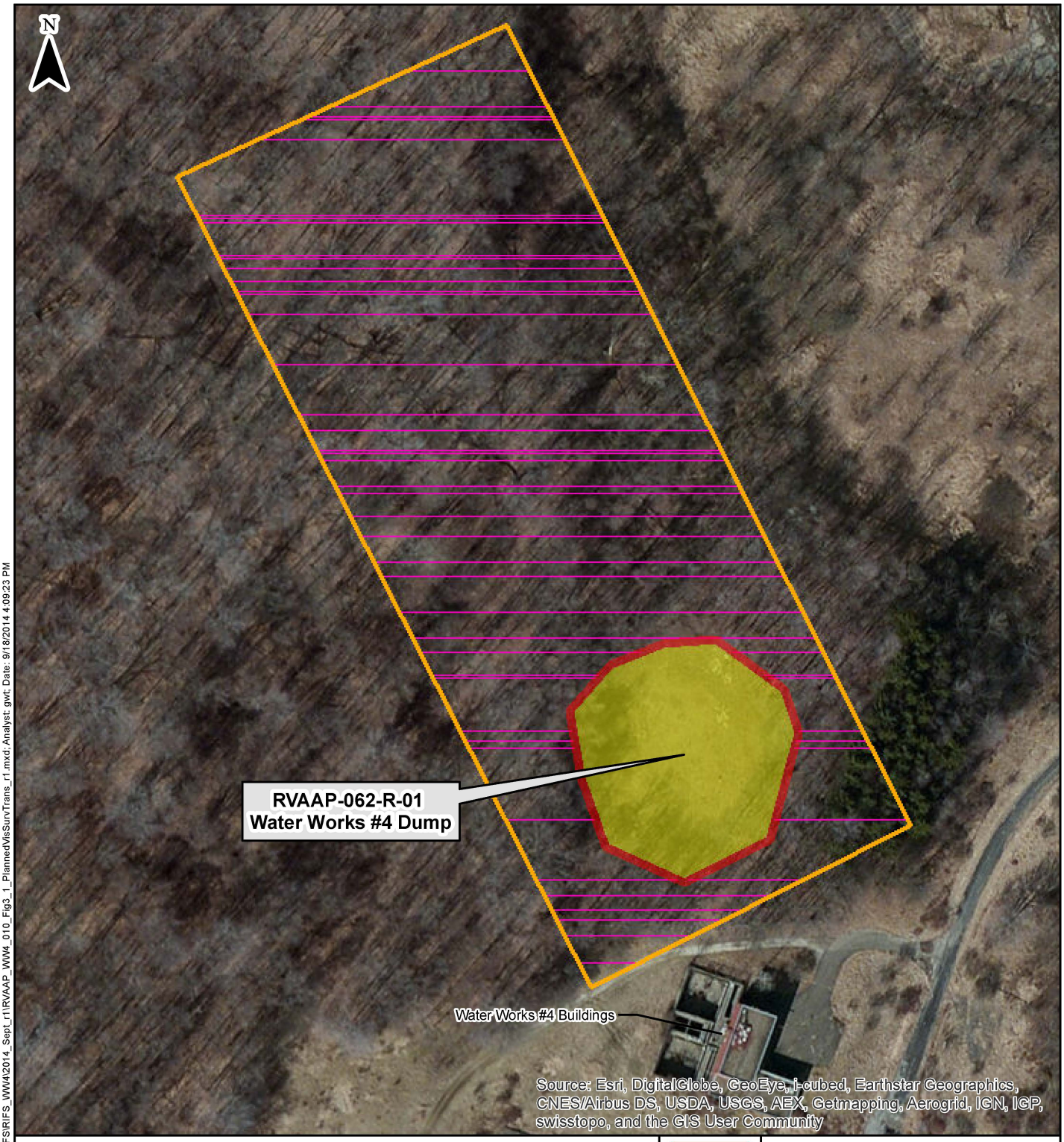
The Schonstedt-assisted visual survey was performed by UXO-qualified personnel. The instrumentation used for detecting and logging the locations of any MEC and/or MD identified consisted of a Schonstedt Model 52CX flux-gate magnetometer and a Trimble GeoXH Handheld global positioning system (GPS), respectively.

The planned transects for the expanded investigation area were uploaded to the GPS and the visual sweep team navigated along the planned transects using the GPS in waypoint mode. The GPS was configured to record position data at maximum intervals of 1 minute along each transect to create a permanent record of where the visual sweep team actually walked. If MEC or MD was identified along the transect path, the location was recorded in the GPS along with a brief description of the findings. In order to ensure that the lateral extent of MEC and MD was being adequately evaluated, a 100-foot step-out distance was proposed from any suspect items identified along the boundary of the investigation area. The GPS track path and findings along each transect were uploaded to the project geographical information system on a daily basis. **Figure 3-1** shows the planned Schonstedt-assisted visual survey coverage area at the Water Works #4 Dump expanded investigation area as presented in the Work Plan Addendum (Shaw, 2011).

The actual Schonstedt-assisted visual survey transect distance was calculated to be approximately 3.76 miles, of which 3.01 miles were traversed in the expanded investigation area, 0.25 miles were traversed within the current MRS boundary, and 0.5 miles were traversed in step-out areas along the boundaries of the expanded investigation area. The actual spatial coverage equates to an area of approximately 2.28 acres, assuming each transect is approximately 5 feet wide. The 3.01 miles of transects for the expanded investigation area exceed the proposed Schonstedt-assisted visual survey transect distance of 2.3 miles for this area presented in the Work Plan Addendum (Shaw, 2011).

3.1.1.1 Field Instrument Quality Control

Prior to the Schonstedt-assisted visual survey operations, a brief test program was performed at a test strip established at the MRS for field instrument quality control (QC) measures. The objectives of the test program were to validate that the Schonstedt magnetometer handheld sensor met the project objectives, ensure that the instrument settings and survey parameters were optimized and the sensor was functioning properly on a daily basis, and certify the sweep personnel performing the magnetometer and dig and Schonstedt-assisted visual survey



MRS Boundary With 100% DGM Coverage

Expanded Investigation Area

Proposed Transects

0 130 260 Feet

Projection : NAD_1983_UTM_Zone_17N

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MILITARY MUNITIONS RESPONSE PROGRAM

WATER WORKS #4 DUMP MRS
FORMER RVAAP/CAMP RAVENNA
PORTAGE AND TRUMBULL COUNTIES, OHIO

CB&I Federal Services LLC
150 Royall Street
Canton, MA 02021

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FIGURE 3-1 PLANNED VISUAL SURVEY TRANSECTS

tasks. This ensured that consistent data of known quality were being collected.

Prior to performing the Schonstedt-assisted visual surveys, inert seed items consisting of industry standard objects were buried at the depth and orientation indicated and separated along the analog test strip at intervals of approximately 5 to 10 feet. The industry standard objects consisted of 1-inch by 4-inch (small), 2-inch by 8-inch (medium), and 4-inch by 12-inch (large) pipe nipples made from Schedule 40 black carbon steel from McMaster Carr Hardware (or equivalent). After burial of the inert seed items, the UXO Quality Control Specialist (UXOQCS) conducted a test program using experienced operators, whereby the handheld detector settings were optimized and documented for the soil conditions and reliable detection of the seed items.

3.1.2 Geophysical Survey Activities

In October 2011, Shaw performed a DGM investigation to identify areas with the potential for subsurface MEC at the Water Works #4 Dump MRS. The proposed DGM survey presented in the Work Plan Addendum (Shaw, 2011) required full-coverage (100 percent) over the current MRS. In order to meet the coverage requirement, DGM data were acquired over all accessible areas of the current MRS on lines spaced at intervals of approximately 2.5 feet. Approximately 0.008 acres (350 square feet) could not be investigated due to trees and thick vegetation. The resulting coverage of the accessible areas at the current MRS represented nearly 99 percent coverage. The *Digital Geophysical Mapping Report for the Water Works #4 Dump MRS (RVAAP-062-R-01),* hereafter referred to as the DGM Report, is presented in **Appendix A** and provides a comprehensive review of the DGM survey at the MRS with regards to data acquisition, processing and analysis, anomaly reacquire, and results of the DGM QC program.

Geophysical instruments used for the DGM survey consisted of an EM61-MK2 time-domain electromagnetic instrument and a Leica 1200 robotic total station (RTS) positioning system. The EM61-MK2 system used at the Water Works #4 Dump MRS consisted of two 1-meter by 0.5-meter rectangular coils arranged in a coaxial geometry and separated by 40 centimeters. The coils were mounted on a wheeled platform 16 inches (42 centimeters) above the ground surface. The team that performed the DGM survey consisted of a geophysicist and a UXO technician.

The DGM system used for the Water Works #4 Dump MRS investigation and other MRSs at the facility was initially validated during the start-up phase of the project at an instrument verification strip (IVS) located near Load Line 7. The results of the initial IVS effort are documented in the *Instrument Verification Strip Technical Memorandum in support of Digital Geophysical Mapping Activities for Military Munitions Response Program Remedial Investigation Environmental Services* that is presented in the DGM Report in **Appendix A**. A

localized test strip at the Water Works #4 Dump MRS was used to ensure the functionality of the DGM system on a daily basis during DGM activities at the MRS as discussed in Section 3.1.1.1, "Field Instrument Quality Control."

A discussion of the MRS preparation activities for the DGM investigation, the data collection process, and summary of the DGM results are presented in the following sections.

3.1.2.1 Civil Survey

A Registered Ohio Land Surveyor established four survey monuments at the Water Works #4 Dump MRS. Each monument was established with third order horizontal accuracy (residual error less than or equal to 1 part in 10,000). The survey monuments were used to provide positional data to set up the RTS, which streamed positional data directly to the EM61-MK2. All of the survey data documenting site features and obstructions are referenced to the established survey monuments.

For QC purposes, the RTS positioning system was used to reacquire a known, fixed location each time the system was set up on one of the four survey monuments. Per the project metrics defined in the Work Plan Addendum (Shaw, 2011), static measurements for the positioning system were required not to exceed 0.5 foot. The RTS positioning system provides centimeter level accuracy, and 100 percent of location checks satisfied the metric.

3.1.2.2 Data Collection and MRS Coverage

A one-dimensional transect survey methodology was employed to collect uniform geophysical data at the Water Works #4 Dump MRS. The DGM data were acquired over all accessible areas of the current MRS, which resulted in nearly 100 percent spatial coverage (99 percent or 0.762 acres). At the accessible areas, greater than 99 percent of the data were acquired at a line spacing of less than 3.3 feet, which meets the metric specified in Section 3.13.13 of the Work Plan Addendum (Shaw, 2011). The general DGM procedures performed for data acquisition at the Water Works #4 Dump MRS consisted of the following:

- The DGM survey area was reviewed by performing a MRS walkover. Special attention was paid to difficult terrain and the presence of obstacles, including evaluation of surface MEC, which would create potential safety issues.
- The positioning system was set up at a documented control point of known location or a location was determined by using a minimum of two known control points (i.e., RTS). The location control was checked by at least one "check shot" to a different control point of known location.
- DGM system instrument functional checks were performed at the start and end of each day and the results were documented.

- DGM data were collected over the area in a systematic fashion with respect to the terrain, vegetation, and obstacles present. The acquisition protocol used navigation techniques proven at the IVS.
- Field logs were used to document MRS conditions during data collection. The field logs included information and observations regarding the data collection process, weather, field conditions, data acquisition parameters, and quality checks performed. The positioning system was used to document the presence of significant MRS features related to terrain, vegetation, and cultural features so these features could be accounted for during the interpretation of the data.

At the end of each day, the field geophysicist uploaded the DGM data to a field computer where the data were archived, backed up, and initially processed and analyzed. The data were also transferred to the Shaw Processing Center in Concord, California on a daily basis for processing and review by the data processor. The raw and final processed data were transferred to USACE at intervals specified in Data Item Description (DID) MMRP-09-004, *Geophysics* (USACE, 2009).

Figure 3-1 provides the area of DGM coverage proposed in the Work Plan Addendum (Shaw, 2011). A summary and discussion of the DGM data is in Section 4.0, "Remedial Investigation Results."

3.1.2.3 Data Processing and Interpretation

The geophysical data were processed, analyzed, and interpreted using the methods and approach outlined in the Work Plan Addendum (Shaw, 2011). An 8-millivolt (mV) threshold for Channel 2 of the EM61-MK2 was used initially to select 212 anomalies for potential investigation. From previous experience at the RVAAP, locations that have signal strengths (Channel 2) greater than 8 mV are more likely to be MEC/MD than locations with signal strengths less than 8 mV. Important factors that were considered during the interpretation process include the following:

- Data acquisition methodology (full coverage as is the case for Water Works #4 Dump MRS)
- Types of MEC most likely present at the MRS based on historical data
- Anomaly shape and signal intensity in relation to the spatial sample density (along track and across track)
- Anomaly time constants
- Local background conditions

- Presence of surrounding anomalies (anomaly density)
- Presence of cultural features and sources of interference
- Anomaly characteristics from the IVS items

After evaluation of the 212 selected anomalies, it was determined that three of the anomalies were just outside of the MRS boundary, two were the result of metal nails intentionally placed for QC checks, and two were the result of "noise" from the DGM team stopping at the end of a line segment. Therefore, the total number of anomalies selected for potential investigation was reduced from 212 to 205. The data processing and interpretation procedures used to evaluate the anomalies are provided in the DGM Report in **Appendix A**.

3.1.2.4 Geophysical Quality Control Program

The geophysical field QC procedures consisted of tests performed at the start and end of each day to ensure the geophysical sensor and positioning equipment were functioning properly and the data were of sufficient quantity and quality to meet the RI objectives in the Work Plan Addendum (Shaw, 2011). The performance metrics for the DGM system were derived from a combination of DID MMRP-09-004, *Geophysics* (USACE, 2009) and DID WERS-004.01, Attachment D, Table D-1—*Performance Requirements for RI/FS using DGM Methods* (USACE, 2010). Quality objectives and metrics associated with MRS coverage, signal quality during data acquisition, anomaly reacquire, and the intrusive investigation were also developed from the referenced documents.

The DGM field team and the data processor/analyst reviewed and documented the results of the DGM QC program on a Microsoft© Excel spreadsheet that was updated on a daily basis and delivered to the client for approval. Additional details of the DGM QC program are included in the DGM Report in **Appendix A**.

3.1.3 Anomaly Investigation Activities

Following the completion of the DGM survey in October 2011, anomaly selection, reacquisition, and an intrusive investigation was conducted to assess the potential for buried MEC and MD at the Water Works #4 Dump MRS. This section presents a discussion of the target dig list development and the intrusive investigation procedures performed for the evaluation of MEC and MD at the MRS.

3.1.3.1 Target List Development

To determine the number of anomalies to sample in order to characterize the nature and extent of MEC at the Water Works #4 Dump MRS, the hypergeometric statistical method was applied. Use of such a statistical sampling method is in accordance with guidance

provided in Engineer Manual 1110-1-4009, *Military Munitions Response* (USACE, 2007), which states the following:

> "When there are, on average, more than 50 anomalies per acre then it may be necessary to statistically sample the anomalies. Statistical sampling should be applied such that the results of the sampling will meet the data needs and the DQOs of the characterization project. The method for statistically sampling the anomalies should take into the account the objectives of the characterization effort. Different sampling strategies should be employed if the objective is to confirm the presence of MEC or the number of MEC related items. Furthermore, if the statistical sampling is based on anomaly characteristics (amplitude or size) then some sampling of anomalies which don't meet the criteria should be sampled to validate the selection process."

The hypergeometric method for determining the number of anomalies to sample (n) is based on the following equation:

$$n = Nz^2pq/(E^2(N-1) + z^2pq)$$

Where:

N = population size
z = confidence level
E = allowable error
p = probability
q = $1-p$

Using input parameters of 95 percent confidence (z), 10 percent probability (p), and 5 percent error limits (E), 93 anomalies, representing nearly 45 percent of the total population of 205 anomalies (N), were selected and met the DQOs. The 93 locations were transferred to a dig sheet and provided to Shaw's geographical information system department for inclusion in the ShawMEC database for the facility that is used to track the investigation results. The program used to pick the actual locations of the target anomalies in order to eliminate manually biasing the process was the "RANDBETWEEN" function in Microsoft© Excel.

The Microsoft© Excel "HYPGEOMDIST" function was used as a QC measure to check the results of the approved statistics module following the intrusive investigation. A discussion of the results of the statistical analysis of the intrusive program findings is presented in further detail in Section 4.0, "Remedial Investigation Results."

3.1.3.2 Anomaly Reacquisition and Investigation Procedures

For the anomaly reacquire task, the field geophysicists used the dig sheet coordinates to guide the reacquisition of each anomaly location. The area around each anomaly was

scanned with an EM61-MK2 and the optimum dig location marked with a pin flag. The "x-y" coordinate offset for each individual anomaly were digitally recorded by the anomaly reacquire crew using a handheld personal digital assistance device and the information was uploaded to the project database at the end of each day.

All anomaly investigation activities were performed by UXO-qualified personnel. The UXO-qualified personnel used a Schonstedt magnetometer to investigate anomalies. These personnel used hand tools to unearth an item and as the excavation progressed toward the anomaly source, the UXO technician continued to use the Schonstedt magnetometer to determine the item location both horizontally and vertically. Reacquisition of any sampling or dig sheet locations (i.e., interpreted location) was performed to approximately 0.5 foot of the coordinates specified on the dig sheet.

Once found, the item was determined if it was MEC, MD, or other metallic material. Once the item was determined not to be MEC it was temporarily removed from the excavation hole and a Schonstedt magnetometer was used to confirm no additional ferrous items were located beneath the first item. Once confirmed that the source had been identified and no MEC or MD was present, the item was replaced and the soil was returned back into the investigation hole in reverse order from which it was excavated. The UXO-qualified personnel were also conscious of encountering any cultural artifacts associated with historical cultural or archeological resources.

3.1.3.3 Anomaly Investigation Documentation

All anomalies identified during the intrusive investigation and anomaly reacquisition activities were logged and recorded in accordance with DID MMRP-09-004, *Geophysics* (USACE, 2009). The ShawGeo and/or ShawMEC software was used to record any discrepancies between the dig sheet location and the actual required location and to note any anomalies that could not be investigated. The intrusive investigation results are further discussed in Section 4.0, "Remedial Investigation Results."

3.1.3.4 Anomaly Field Quality Control

Ground-truth excavation data reported on anomaly-specific dig sheets were the primary basis for field QC. The dig sheets documented the item description; location; and approximate weight, shape, orientation, and depth. The dig sheets were reviewed by the field geophysicist on a daily basis to determine whether the excavation data were representative of the millivolt reading for the selected anomaly. Anomalies that were not representative of the excavation results were revisited by the field geophysicist and the UXOQCS.

3.2 MC Characterization

The DQOs in the Work Plan Addendum (Shaw, 2011) stated that incremental samples and discrete samples (surface and subsurface soil) would be collected in areas of the MRS with concentrated MEC or MD. No MEC was identified at the Water Works #4 Dump MRS during the field activities and only single pieces of MD, which were verified as inert, were encountered within the current MRS boundary and the expanded investigation area; therefore, sampling for MC was not warranted.

4.0 REMEDIAL INVESTIGATION RESULTS

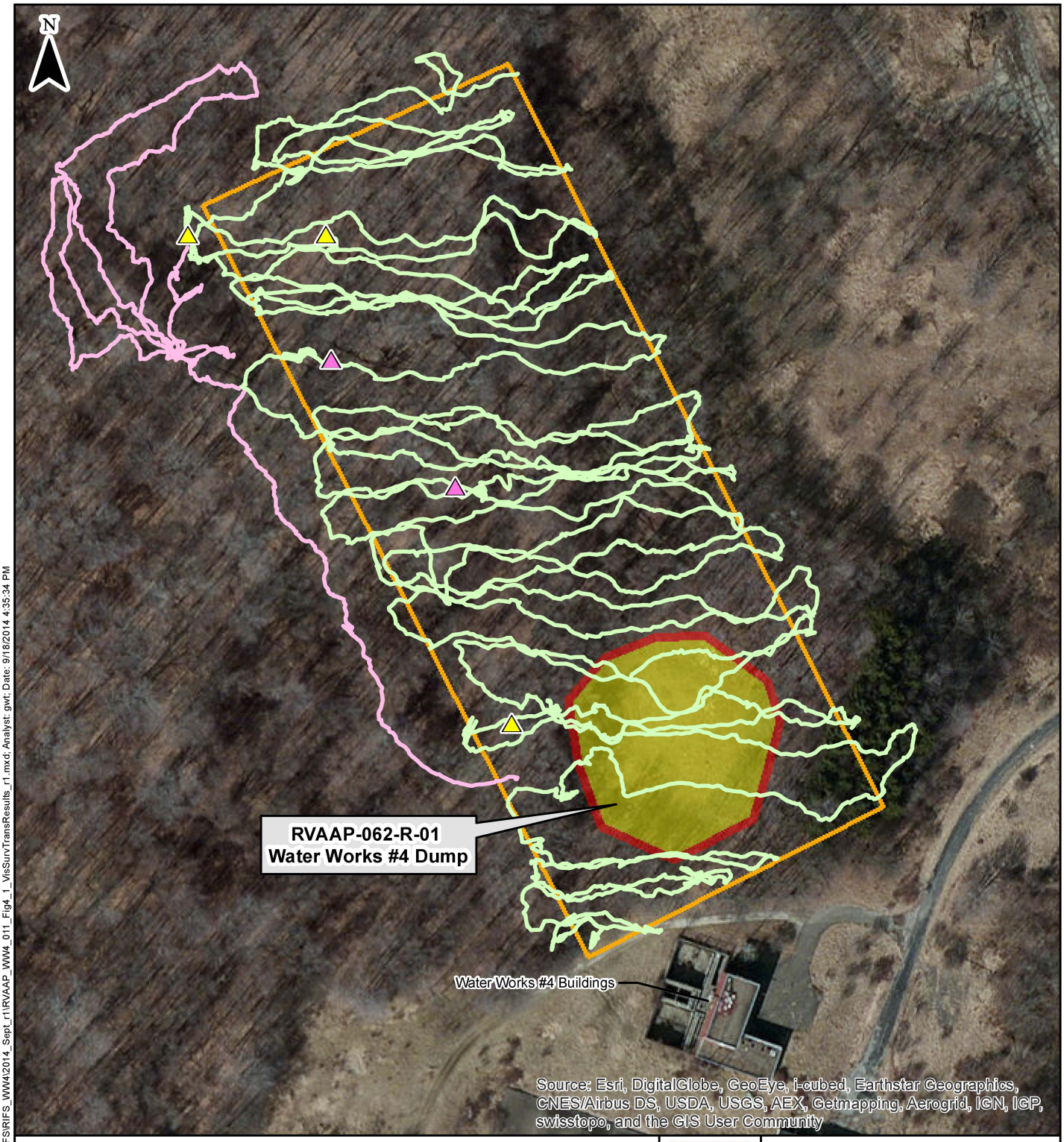
This chapter presents a discussion of the results of the RI data that were collected for MEC at the Water Works #4 Dump MRS in accordance with the procedures discussed in Section 3.0, "Characterization of MEC and MC." These results were used to determine the nature and extent of MEC and subsequently determine the potential hazards posed to human and ecological receptors. Once the hazards were determined, they were integrated into the preliminary CSMs developed during the SI (e^2M, 2008) that are presented in Section 2.0, "Project Objectives." Photographs of the RI field activities performed at the MRS are presented in **Appendix B**.

The following sections present the results of the RI field activities that were performed to achieve the DQOs defined in Section 2.3.1, "Data Quality Objectives," and define the nature and extent of MEC and/or MD in the surface and subsurface at the Water Works #4 Dump MRS. These efforts included a combination of visual and DGM surveys and intrusive investigations that were conducted in accordance with the Work Plan Addendum (Shaw, 2011).

4.1 Schonstedt-assisted Visual Survey Results

A Schonstedt-assisted visual survey was performed in accordance with Section 3.2.6 of the Work Plan Addendum (Shaw, 2011) at the expanded investigation area. The Schonstedt-assisted visual survey was further expanded during the RI field activities to include the current MRS boundary not included in the Work Plan Addendum (Shaw, 2011) and step-outs along the expanded investigation area boundary where MD was encountered. The primary objective of the Schonstedt-assisted visual survey was to characterize for possible MEC on the ground surface and shallow surface soil at the expanded investigation area. In all, a total of 3.76 miles of Schonstedt-assisted visual survey transects were performed, which consisted of 3.01 miles of transect at the expanded investigation area, 0.25 miles of transects within the current MRS boundary, and 0.5 miles of additional transects associated with step-out areas along the boundaries of the expanded investigation area. Each transect consisted of a sweep width of approximately 5 feet and equates to a total area coverage of 2.28 acres.

No MEC items were identified during the Schonstedt-assisted visual survey; however, five MD items were found. All five MD items were located on the ground surface in the expanded investigation area. The UXO technicians verified the MD as inert and determined the quantities while in the field. The MD consisted of three 155 mm Mk I shrapnel projectile ogives and two 155 mm Mk I high explosive (HE) projectile ogives. The total weight of the MD items was approximately 10 pounds (lbs). **Figure 4-1** identifies the results of the Schonstedt-assisted visual survey and the locations where the MD items were found. The results and descriptions of the Schonstedt-assisted visual survey findings at the Water Works #4 Dump MRS are presented in **Appendix C**.



MRS Boundary With 100% DGM Coverage

Expanded Investigation Area

Visual Survey Transect (3.26 mi)

Step Out Transect (~.5 mi)

MD-155mm Mk1 HE Projectile Ogive

MD-155mm MK1 Shrapnel Projectile Ogive

0 70 140 Feet

Projection : NAD_1983_UTM_Zone_17N

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FIGURE 4-1 VISUAL SURVEY RESULTS

4.2 Geophysical Survey Results

A total of 0.762 acres of full-coverage DGM data were collected within the current MRS boundary. Data were acquired in all accessible areas of the MRS and the area surveyed equates to nearly 99 percent coverage. The remaining 0.008 acres (350 square feet) could not be investigated due to trees and thick vegetation. The data were processed and interpreted consistent with the Work Plan Addendum (Shaw, 2011).

Evaluation of the data collected during the DGM identified 212 anomalies that ranged in intensity from 8 mV to 950 mV (Channel 2). Three of the anomalies were just outside of the MRS boundary, two anomaly detections were the result of metal nails intentionally placed for QC checks, and the two other anomaly detections were the result of "noise" from the DGM team stopping at the end of a line segment. Therefore, the number of total anomalies selected for potential investigation was reduced to 205 items. In general, the geophysical data indicated that the anomaly density at the MRS was relatively low and dispersed throughout the MRS.

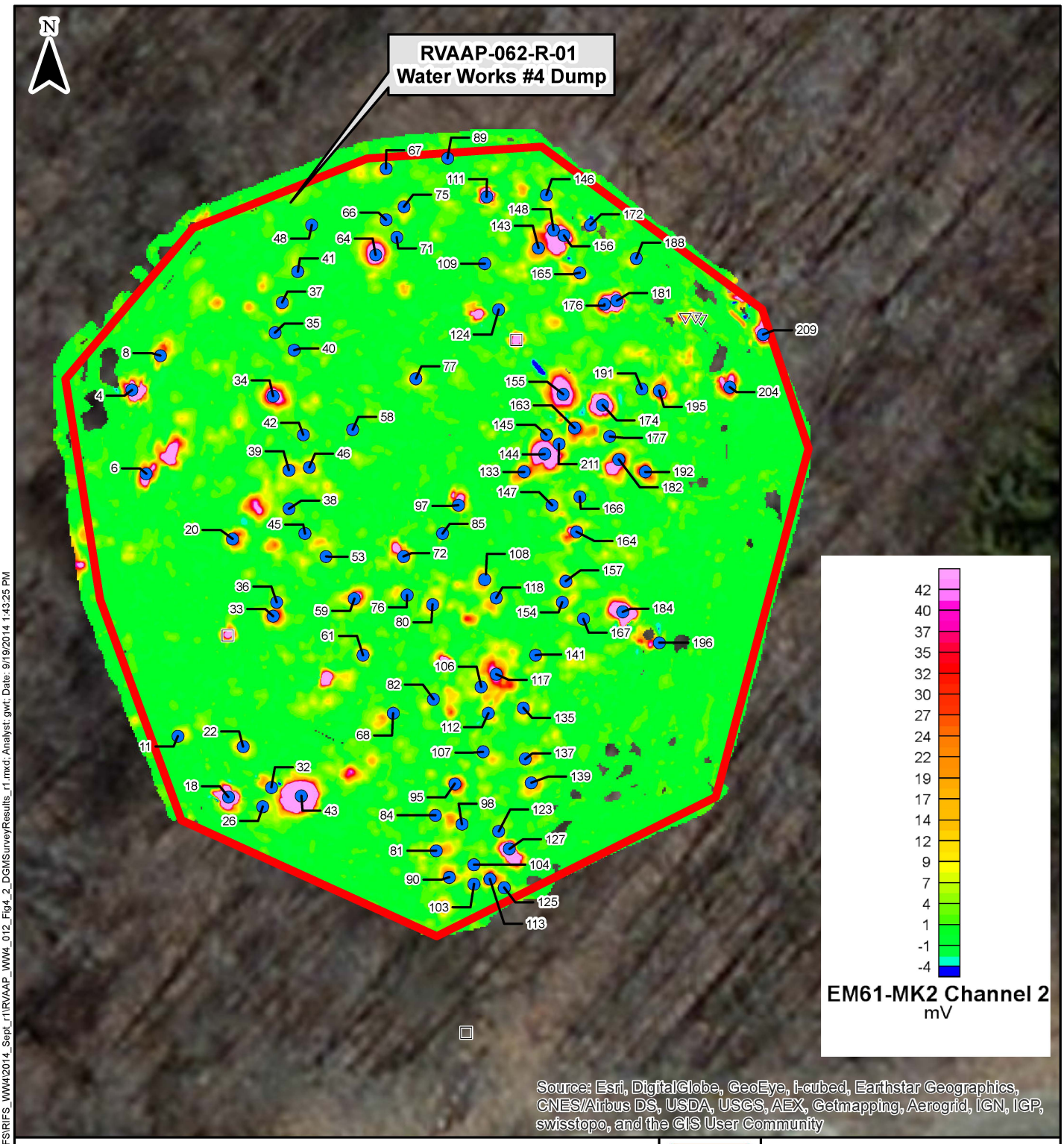
Figure 4-2 displays the results of the EM61-MK2 DGM survey and provides a sensitive color-scale that highlights all single-point anomalies above a signal threshold of 8 mV. A comprehensive discussion of the DGM survey results is presented in the DGM Report in **Appendix A**.

4.3 Geophysical Quality Control Results

The DGM data were processed and interpreted consistent with the Work Plan Addendum (Shaw, 2011). Data were acquired in all areas void of trees and thick vegetation. The DGM quality objectives and metrics were achieved for all data collected. The geophysical data files generated during the DGM activities consist of field data and QC test files. This data and the results of the DGM quality objectives and metrics are discussed and presented in further detail in the DGM Report in **Appendix A**.

4.4 Intrusive Investigation Results

Ninety-three of 205 anomalies, which represent nearly 45 percent of the anomalies within the MRS, were originally selected for intrusive investigation based on the anomaly selection and prioritization process presented in the Work Plan Addendum (Shaw, 2011) and discussed in Section 3.1.3.1, "Target List Development." All of the anomalies selected for intrusive investigation were manually investigated by hand digging. The anomalies identified by the DGM effort were selected randomly and are distributed throughout the current MRS.



MRS Boundary
Anomaly Location Investigated
Cultural Feature/Surface Metal
Control Point (QC)

0 40 80 Feet

Projection : NAD_1983_UTM_Zone_17N

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FIGURE 4-2 DGM SURVEY RESULTS

During the initial anomaly investigation, the 93 selected target anomalies were intrusively investigated and no MEC was identified on or below the ground surface. However, two target anomalies (targets 4 and 209) were identified as MD consisting of 155 mm Mk I shrapnel projectile ogives. These anomalies were found at isolated locations; one on the ground surface (target 209) and one at a depth of 1 inch bgs (target 4). Both anomalies were verified as inert by the UXO-qualified personnel. The total weight of the MD items found at the MRS was approximately 9 lbs.

Two anomalies (targets 154 and 172) were not located during the initial intrusive investigation. The anticipated location of target 154 was investigated to 4 feet bgs and was found to be the same fractured water pipe associated with target 156. Target 172 could not be resolved due to its close proximity to a tree.

After reviewing the initial intrusive investigation results, three additional anomalies (targets 148, 174, and 176) were selected for investigation to satisfy the statistical requirements of at least 93 target anomalies. The additional target locations were biased towards geophysical signatures that had the potential to be 155 mm ogives, the MD items identified during the Schonstedt-assisted visual survey, and the initial intrusive investigation. The three additional targets were successfully intrusively investigated and determined to be "Other Debris." In all, 94 anomalies were successfully investigated out of the 205 identified anomalies selected for potential intrusive investigation.

A total of 114 nonmunitions items that were described as "Other Debris" by the UXO teams in the field were found during the intrusive investigation at the remaining point-source anomaly locations. These "Other Debris" items weighed approximately 589.2 lbs. All nonmunitions-related debris was left in place.

The depths of the all items found during the intrusive investigation ranged from just below ground surface to a maximum depth of 3.7 feet bgs. The average depth of the items identified for all locations was approximately 0.5 feet bgs. **Figure 4-3** shows the intrusive investigation results and locations where the MD items were found. The results and descriptions of the point source anomaly intrusive investigation at the Water Works #4 Dump MRS are included in **Appendix C**.

Thirty-seven anomaly locations were randomly selected for post-excavation QC with the EM61-MK2 following the intrusive investigation in accordance with the Work Plan Addendum (Shaw, 2011). The purpose of the post-excavation QC was to perform intrusive anomaly verification to ensure that at a 90-percent confidence, less than 5 percent of the remaining anomalies were "unresolved" (i.e., there was a low probability that a significant item related to MEC was present within the dig locations that were not checked post-excavation). The number of post-excavation QC anomalies was selected using the DID WERS-004.01, *Geophysics, Attachment D, Table D-1 Performance Requirements for RI/FS*

Study Using DGM Methods (USACE, 2010) in accordance with the Work Plan Addendum (Shaw, 2011). *Attachment D* provides default parameters for RI/FS projects where no MEC has been recovered. At one location (target 64), a steel culvert was left in place, and the residual signal was greater than 4 mV. At all of the remaining locations, the residual signal from the sensor was less than 4 mV (Channel 2), and no additional anomalies were required to be checked.

As discussed in Section 3.1.3.1, "Target List Development," a statistical approach was used to quantify the intrusive findings of the RI. Two MD items, consisting of 155 mm Mk I shrapnel projectile ogives, were identified during the intrusive investigation. Since no MEC was found during the intrusive investigation, and based on the statistical approach used to select the number of anomalies to investigate, there is a 99 percent probability there is no MEC present at the remaining 111 anomaly locations that were not investigated during the RI field activities. These results support the DQOs established in the Work Plan Addendum (Shaw, 2011). A summary of the statistical analysis of the intrusive findings is presented in **Appendix D**.

Based on the intrusive findings, the number of anomalies investigated in an unbiased manner, Schonstedt-assisted visual survey findings, and results of the intrusive anomaly verification and feedback process, no explosive safety hazard or MEC source is present at the Water Works #4 Dump MRS.

4.5 Management and Disposal of Munitions Debris

This section presents the management and disposal practices for the MD items that were encountered during the RI field activities at the Water Works #4 Dump MRS. In all, approximately 19 lbs. of MD, as determined by the UXO team in the field, were recovered during the Schonstedt-assisted visual survey and intrusive investigation activities at the MRS. Once the items were verified as MD by the UXO technician, they were placed into 55-gallon drums for disposal off site. The drums were documented as "material documented as safe" and were transported to a designated area at the Open Demolition Area #2 MRS for temporary storage. The drums were labeled as "Scrap Steel" and on May 11, 2012, the drums were shipped off the facility for demilitarized disposal at Demil Metals, Inc. in Glencoe, Illinois. Waste shipment documentation for MD disposal is presented in **Appendix E** and is inclusive of all MD that was generated by Shaw at the Water Works #4 Dump MRS and other facility MRSs investigated under the MMRP between September 8, 2011, and May 10, 2012.

FIGURE 4-3 INTRUSIVE INVESTIGATION RESULTS

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5.0 FATE AND TRANSPORT

This intent of this chapter is to describe the fate of chemicals detected in the environment and potential transport mechanisms for MEC and MC identified at the Water Works #4 Dump MRS. Contaminant fate refers to the expected final state that an element, compound, or group of compounds will achieve following release to the environment. Contaminant transport refers to migration mechanisms of MEC and MC away from the source area.

5.1 Fate and Transport of MEC

Transport of MEC at a MRS is dependent on many factors, including precipitation, soil erosion, and freeze/thaw events. These natural processes, in addition to human activity, may result in some movement (primarily vertical) of MEC if present at the MRS. The result of these mechanisms and processes is a potentially different distribution of MEC than the one that may have existed at the time of original release. In addition, MEC items may corrode or degrade based on weather and climate conditions and thereby release MC into the environment. No MEC or a significant quantity of MD that may justify a concern for potential MEC was found at the MRS or surrounding expanded investigation area. Therefore, an explosive hazard is not anticipated to exist and a discussion on the fate and transport of MEC at the MRS was not warranted.

5.2 Fate and Transport of MC

Any buried MEC/MD or MEC/MD items exposed to the atmosphere may corrode or degrade based on weather and climate conditions and thereby release MC into the environment. No MEC was found at the Water Work #4 Dump MRS during the RI field activities; however, two ogives considered as MD were encountered at a maximum depth of 1 inch bgs. It was apparent from the corroded conditions of the MD items encountered during the RI field activities that the MD items had succumbed to oxidation caused by exposure to moisture in the subsurface. The amount of MD that was found at the MRS was minimal, the items were not concentrated at a single location, and they were inert; therefore, it is unlikely that there would be a significant release of MC associated with remaining MD at the MRS. As such, MC sampling was not warranted and discussion on the fate and transport of MC at the MRS is not applicable.

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6.0 MEC HAZARD ASSESSMENT

In accordance with the Work Plan Addendum (Shaw, 2011), an evaluation of the MEC hazard at the Water Works #4 Dump MRS was to be prepared in accordance with the *Interim Munitions and Explosives of Concern (MEC) Hazard Assessment (HA) Methodology* (EPA, 2008). The MEC HA allows a project team to evaluate the potential explosive hazard associated with an MRS given current conditions and under various cleanup, land use activities, and land use control alternatives; however, cleanup scenarios are not usually addressed in the RI. It was developed through a collaborative, consensus approach to promote consistent evaluation of potential explosive hazards at MRSs (EPA, 2008). The MEC HA methodology addresses human health and safety concerns associated with potential exposure to MEC at a MRS, but does not address hazards (explosive or toxic) posed by chemical warfare materiel, MEC that is present underwater, nor environmental or ecological hazards that may be associated with MEC.

No items containing explosive filler were identified at the MRS or the expanded investigation area during either the 2007 SI or 2011 RI field activities and there is no explosive safety hazard present. Based on the findings of the RI field work, the calculation of a MEC HA score was not warranted for the Water Works #4 Dump MRS or the expanded investigation area.

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7.0 HUMAN HEALTH RISK ASSESSMENT

The purpose of a HHRA is to document whether MRS conditions may pose a risk to current or future receptors and to identify which, if any, MRS conditions need to be addressed further in the CERCLA process. Since no MEC or concentrated areas of MD were identified between the SI and RI field activities, media sampling for MC was not warranted. Therefore, an HHRA was not required for inclusion in this report.

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8.0 ECOLOGICAL RISK ASSESSMENT

An ERA evaluates the potential for adverse effects posed to ecological receptors from potential releases at a MRS. Since no MEC or concentrated areas of MD were identified between the SI and RI field activities, media sampling for MC was not warranted. Therefore, an ERA was not required for inclusion in this report.

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9.0 REVISED CONCEPTUAL SITE MODEL

This chapter presents the revised CSM at the Water Works #4 Dump MRS based on the results of the data collected for the RI and previous information provided in the SI Report and the HRR (e^2M, 2007). The preliminary CSM for MEC and MC was discussed in Section 2.0, "Project Objectives," and the summary of the RI results were presented in Section 4.0, "Remedial Investigation Results." Following the integration of the RI results into the CSM, the MRSPP evaluation for the MRS was reevaluated to include the results of the RI.

9.1 MEC Exposure Analysis

This section summarizes the RI data results for the MEC exposure pathway analyses for the MRS. As discussed in Section 2.1, "Preliminary Conceptual Site Model and Project Approach," each pathway includes a source, activity, access, and receptor, with complete, potentially complete, and incomplete exposure pathways identified for each receptor. A pathway is considered complete when a source (MEC) is known to exist and when receptors have access to the MRS while engaging in some activity that results in contact with the source. A pathway is considered potentially complete when a source has not been confirmed, but is suspected to exist and when receptors have access to the MRS while engaging in some activity which results in contact with the source. Lastly, an incomplete pathway is any case where one of the four components (source, activity, access, or receptors), is missing from the MRS.

9.1.1 Source

A MEC source area is the location where MPPEH or other forms of ordnance are expected to be found. The Water Works #4 Dump MRS was reported to have been used for the intentional dumping of nonexplosive metal parts of large-caliber ordnance rounds. These dumping activities reportedly occurred from 1941 to 1949 and resulted in the potential for MEC and/or MD to be present in the surface soil and subsurface soil at Water Works #4 Dump MRS (e^2M, 2008).

The UXO survey activities performed during the 2007 SI identified 20 inert ogives (155 mm Mk I shrapnel projectile ogives) on the ground surface in the expanded investigation area that were considered as MD. In addition, subsurface anomalies were identified within the current MRS. The SI Report (e^2M, 2008) determined that the extent of MEC buried within the current MRS was not fully understood and that further investigation of the buried anomalies was necessary. Based on historical operations at the MRS, any MEC source would be expected to be found in surface and/or subsurface soils.

To date, no MEC items have been observed at the current MRS or the expanded investigation area. During the RI Schonstedt-assisted visual survey activities, five MD items that consisted of three 155 mm Mk I shrapnel projectile ogives and two 155 mm Mk I HE projectile ogives were identified on the ground surface in the expanded investigation area. Two MD items, both 155 mm Mk I shrapnel projectile ogives, were found at the current MRS during the intrusive investigation. The maximum depth of the MD found at the MRS was 1 inch bgs. The MD recovered from the current MRS and the expanded investigation area is consistent with MD identified during previous investigations.

The only evidence of munitions at the current MRS and expanded investigation area are the 155 mm Mk I shrapnel projectile ogives and 155 mm Mk I HE projectile ogives, which are considered MD. These MD items have either been historically documented in the ASR (USACE, 2004), the HRR (e^2M, 2007), the SI Report (e^2M, 2008), or were observed during the RI field activities. An ogive is a curved surface used to form the streamlined nose of a bullet or other projectile. Ogives do not contain explosive material and are inert. Separation of the ogive from the remainder of the projectile would only occur during demilitarization operations (not because of firing) and the ogive will typically shatter during the detonation process when the round is functioned as designed (Naval Explosive Ordnance Disposal Technology Division, 1994). Based on the MD found to date and the results of the RI and previous investigations, no explosive safety hazard is present in surface or subsurface soils at the Water Works #4 Dump MRS.

9.1.2 Activity

Activity describes ways that receptors are exposed to a source. Current activities at the Water Works #4 Dump MRS include maintenance and natural resource management activities. Biota activities may include occasional meandering, occupation, and burrowing activities at the investigation area by assorted species. The future land use for the MRS is military training (USACE, 2012).

9.1.3 Access

Access describes the degree to which a MEC source or environment containing MEC is available to potential receptors. There is a perimeter fence that helps prevent unauthorized access to the installation. The MRS boundary is marked with Siebert stakes and signage warning receptors about the MRS to help deter access.

9.1.4 Receptors

A receptor is an organism (human or ecological) that comes into physical contact with MEC. Human receptors identified for the Water Works #4 Dump MRS include both current and future land users. Potential users associated with the current activities at the MRS include facility personnel, contractors, and potential trespassers (e^2M, 2007). The National Guard

Trainee and the Engineering School Instructor are the Representative Receptors for the future land use at the MRS, military training (USACE, 2012). The National Guard Trainee is considered the most exposed of the current and future potential users to any MEC that may be present at the MRS.

Ecological receptors (biota) are based on animal species that are likely to occur in the terrestrial habitats at the MRS. The primary MRS-specific biota identified for the MRS include terrestrial invertebrates (earthworms), voles, shrews, robins, foxes, barn owls, and hawks (USACE, 2003c).

9.1.5 MEC Exposure Conclusions

The information collected during the RI was used to update the preliminary CSM for MEC at the Water Works #4 Dump MRS and to identify actual, potentially complete, or incomplete source-receptor interactions for the MRS, for current and anticipated future land uses. Evaluation of end-use receptors for future land use in the revised CSM is consistent with the HHRA approach presented in the *RVAAP's Facility-Wide Human Health Risk Assessor Manual* (USACE, 2005). The revised MEC Exposure Pathway Analysis is presented on **Figure 9-1**.

Schonstedt-assisted visual surveys were performed over a total of 3.76 miles in the current MRS and expanded investigation area. In addition, a full-coverage DGM survey and subsequent intrusive investigation was performed within the boundaries of the current MRS. During the RI field activities, five MD items were identified on the ground surface in the expanded investigation area and two MD items were found at the current MRS. One of the MD items encountered at the MRS was in subsurface soil at a maximum depth of 1 inch bgs.

To date, no MEC has been found at the Water Works #4 Dump MRS and the only MD historically found are ogives on the ground surface and subsurface soils at a maximum depth of 1 inch. Ogives do not contain explosive material and are inert. Based on the results of the RI field activities, no explosive safety hazard is present at the Water Works #4 Dump MRS. Therefore, the MEC exposure pathways for surface and subsurface soil are considered incomplete for all receptors.

9.2 MC Exposure Analysis

Based on the results of the MC sampling during the SI field activities and the MEC investigation portion of the RI field activities, it was determined that no potential source of MC is present at the Water Works #4 Dump MRS. Therefore, no media sampling was conducted at the MRS and incomplete pathways exist for MC for all receptors.

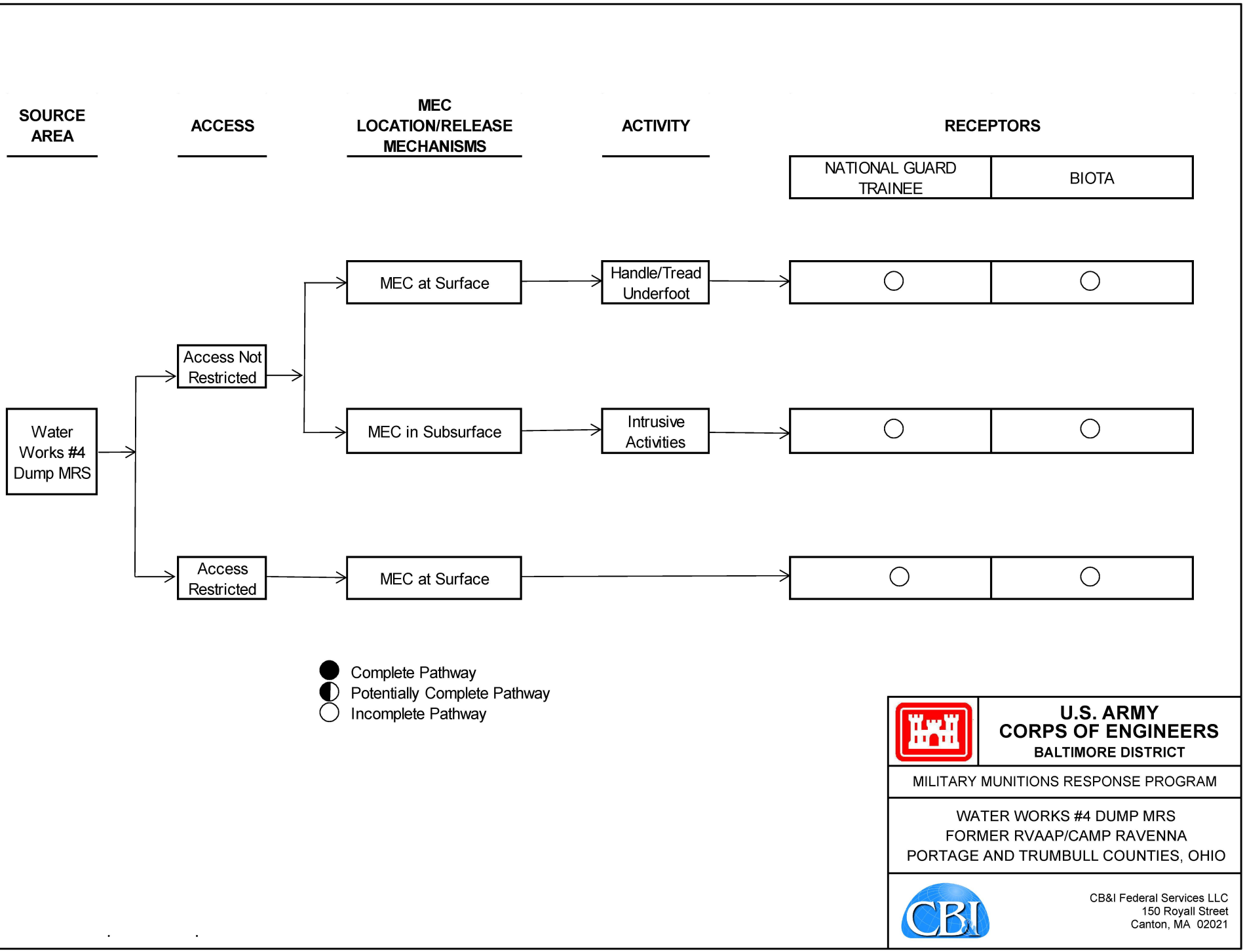

FIGURE 9-1 REVISED MEC CONCEPTUAL SITE MODEL

9.3 Uncertainties

The primary uncertainty related to the evaluation of the RI results at the Water Works #4 Dump MRS is associated with the incomplete record of the historical operations at the MRS. Review of the HRR (e^2M, 2007) indicates that the Water Works #4 Dump MRS was used for the intentional dumping of nonexplosive metal parts of large-caliber ordnance rounds between 1941 and 1949. However, specific details on these dumping activities were never documented. No MEC was found during the RI or any of the previous investigations at the MRS and the findings of MD only support the reports that only nonexplosive items were dumped at the MRS.

In order to determine the quantity and type of MEC present, if any, a combination of Schonstedt-assisted visual surveys, DGM surveys, and anomaly investigations were performed at the Water Works #4 Dump MRS and the expanded investigation area for the RI. Schonstedt-assisted visual survey transects were placed in the expanded investigation area using the VSP module input of "90 percent confidence that 95 percent of transects do not contain MEC." The DGM survey coverage for the RI was designed based on complete (100 percent) coverage of the current MRS due the minimal size (0.77 acres) of the current MRS, and the actual DGM coverage was nearly 99 percent. The number of anomalies requiring intrusive investigation was designed based on a hypergeometric statistics module that estimates the required sample size for populations. Ninety-four single-point source anomaly locations (over 45 percent of the identified 205 single-point anomalies) were successfully investigated at the current MRS. No MEC was found during the RI field activities. Further, the statistical approach used to quantify the intrusive findings of the RI indicates there is a 99 percent probability there is no MEC present at the remaining 111 anomaly locations that were not investigated during the RI field activities. These results satisfy the DQOs and reduce the uncertainties that MEC are present at the MRS.

9.4 Munitions Response Site Prioritization Protocol

The DoD proposed the MRSPP (32 Code of Federal Regulations Part 179) to assign a relative potential risk priority to each defense MRS in the MMRP Inventory for response activities. These response activities are to be based on the overall conditions at each location, taking into consideration various factors related to explosive safety and environmental hazards (68 Federal Regulations 50900 [32 Code of Federal Regulations 179.3]). The revised MRSPP document for the Water Works #4 Dump MRS is being prepared separately and is included in this RI Report as **Appendix F** for reference only.

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10.0 SUMMARY AND CONCLUSIONS

This chapter summarizes results of the RI field activities conducted at the Water Works #4 Dump MRS. The purpose of this RI is to determine whether the Water Works #4 Dump MRS warrants further response action pursuant to CERCLA and the NCP. More specifically, the RI is intended to determine the nature and extent of MEC and MC and to subsequently determine the potential hazards and risks posed to likely human and environmental receptors by MEC and MC. The RI also presents additional data to assist in the identification and evaluation of alternatives in the FS, if required. As a result of the investigation activities, the objectives of the RI have been satisfied. A summary of the RI results is presented in **Table 10-1**.

Table 10-1
Summary of Remedial Investigation Results

Investigation Area	Investigation Method	Proposed Coverage (Acres)	Actual Coverage (Acres)	MEC/MD Found?	MC Detected?
MRS	DGM	0.77	0.762	Yes (MD)	NS
Expanded Investigation Area (non-MRS)	Visual Survey	1.38	1.82	Yes (MD)	
MRS		---	0.15	No	
Step-outs (non-MRS)		TBD	0.30	Yes (MD)	

--- denotes area not originally proposed for investigation.
DGM denotes digital geophysical mapping.
MC denotes munitions constituents.
MD denotes munitions debris.
MEC denotes munitions and explosives of concern.
MRS denotes Munitions Response Site.
NS denotes not sampled.
TBD denotes to be determined in the field.

10.1 Summary of Remedial Investigation Activities

Information from the Water Works #4 Dump MRS relating to the potential presence of MEC and associated MC were compiled and evaluated in this RI Report. The sources of this information were obtained from previous investigations and historical records including the ASR (USACE, 2004), the HRR (e^2M, 2007), and the SI Report (e^2M, 2008).

The preliminary CSM for the MRS was evaluated based on the historical background reviews and data needs, and the DQOs were determined as outlined in the Work Plan

Addendum (Shaw, 2011). The data needs included characterization of MEC and/or MC associated with former activities at the MRS. The DQOs were developed to ensure (1) the reliability of field sampling, chemical analyses, and physical analyses; (2) the collection of sufficient data; (3) the acceptable quality of data generated for their intended use; and (4) that valid assumptions could be inferred from the data. The DQOs for the Water Works #4 Dump MRS identified the following decision rules that were implemented in evaluating the MRS:

- Perform a Schonstedt-assisted visual survey in the expanded investigation area to identify if surface MEC or MD was present.
- Perform a geophysical investigation at the current MRS to identify buried metallic anomalies that have the potential to be MEC/MD.
- Perform an intrusive investigation of anomalies identified during the geophysical investigation to evaluate if MEC/MD was present.
- Collect incremental and/or discrete samples (surface and subsurface soil) in areas with concentrated MEC/MD, if necessary, to evaluate for MC.
- Process the information to evaluate whether there were unacceptable hazards or risks to human and ecological receptors associated with MEC and/or MC, and make a determination if further investigation was required under the CERCLA process.

10.1.1 Instrument-Assisted Visual Survey

In September 2011, a Schonstedt-assisted visual survey was performed at the wooded area north of the open field that was formerly part of the MRS during the 2007 SI (i.e., the expanded investigation area). The Schonstedt-assisted visual survey investigation was further expanded during the RI field activities to include the open field portion that constitutes the current MRS that was not originally included in the Work Plan Addendum (Shaw, 2011). The total transects distance for the Schonstedt-assisted visual survey was 3.76 miles, which equates to area coverage of approximately 2.28 acres, where each transect was 5 feet wide. Five MD items consisting of 155 mm Mk I shrapnel projectile ogives and 155 mm Mk I HE projectile ogives were identified on the ground surface in the expanded investigation area and were consistent with the MD items described in the SI Report (e^2M, 2008). No MEC items were identified on the ground surface during the Schonstedt-assisted visual survey.

10.1.2 DGM Investigation

In October 2011, a DGM investigation was performed to identify areas with the potential for subsurface MEC and/or MD at the 0.77-acre Water Works #4 Dump MRS. A full-coverage DGM survey was performed over all accessible areas within the current MRS, and the spatial coverage equates to nearly 99 percent (0.762 acres) DGM coverage at the MRS.

10.1.3 Anomaly Selection

Evaluation of the data collected during the DGM survey identified 205 single-point anomalies for potential investigation. In general, the geophysical data indicate that the anomaly density at the MRS is relatively low and dispersed throughout the MRS.

10.1.4 Intrusive Investigation

Following the completion of the DGM survey, reacquisition and intrusive investigation activities for the locations identified as potentially containing buried MEC and/or MD were performed in October 2011 based on an analysis of the DGM survey data. Ninety-three single-point source anomaly locations were identified for intrusive investigation to characterize the nature and extent of MEC using a statistics module in accordance with the approved Work Plan Addendum (Shaw, 2011). Three additional target locations were added following the initial intrusive investigation after two of the original targets could not be adequately located. In all, 94 anomalies (45 percent of the identified 205 anomalies) were ultimately investigated as part of the intrusive activities. The intrusive investigation resulted in finding two MD items on the ground surface and in subsurface soils at a maximum depth of 1 inch bgs. The MD items were identified as 155 mm Mk I shrapnel projectile ogives. No MEC was found during the intrusive activities.

10.1.5 MC Sampling

The DQOs stated that incremental samples and discrete samples (surface and subsurface soil) would be collected in areas with concentrated MEC or MD. No MEC was identified at the Water Works #4 Dump MRS during the RI field activities and sampling for MC was not warranted.

10.2 MEC Hazard Assessment

The *MEC HA Methodology* (EPA, 2008) addresses human health and safety concerns associated with potential exposure to MEC at a MRS under a variety of site conditions, including various cleanup scenarios and land use assumptions. However, cleanup scenarios are not usually addressed in the RI. If an explosive hazard is identified for this RI, the MEC HA evaluation will include the information available for the MRS up to and including the RI field activities and will provide a scoring summary for the current and future land use activities. If no explosive hazard is found at the MRS, then there will be no need to calculate a MEC HA score, since there are no human health safety concerns.

No items containing explosive filler were identified at the current MRS or expanded investigation area that were covered during both the 2007 SI and 2011 RI field activities. The results of the RI indicate that no MEC source or explosive safety hazard is present.

Therefore, calculation of a MEC HA score was not warranted for the Water Works #4 Dump MRS or the expanded investigation area.

10.3 Conceptual Site Model

The information collected during the RI field activities was used to update the CSM for MEC and to evaluate if the development of a revised CSM for MC was warranted. The purpose of the CSM is to identify all complete, potentially complete, or incomplete source-receptor interactions for reasonably anticipated future land-use activities at the MRS. An exposure pathway is the course a MEC item or MC takes from a source to a receptor. Each pathway includes a source, activity, access, and receptor.

10.3.1 MEC Exposure Analysis

Schonstedt-assisted visual surveys were performed over a total of 3.76 miles in the current MRS and expanded investigation area. In addition, a full-coverage DGM survey and subsequent intrusive investigation was performed within the boundaries of the current MRS. During the RI field activities, five MD items were identified on the ground surface in the expanded investigation area and two MD items were found at the current MRS. One of the MD items encountered at the MRS was in subsurface soil at a maximum depth of 1 inch bgs.

To date, no MEC has been found at the Water Works #4 Dump MRS and the only MD historically found are ogives on the ground surface and subsurface soils at a maximum depth of 1 inch. Ogives do not contain explosive material and are inert. Based on the results of the RI field activities, it is not expected that an explosive safety hazard is present at the Water Works #4 Dump MRS; therefore, the MEC exposure pathway for surface and subsurface soil are considered incomplete for all receptors.

10.3.2 MC Exposure Analysis

Based on the results of the MC sampling during the SI field activities and the MEC investigation portion of the RI field activities, it was determined that no potential source of MC was present at the Water Works #4 Dump MRS. Therefore, no media sampling was conducted at the MRS and incomplete MC pathways exist for all receptors.

10.4 Uncertainties

The primary uncertainty related to the evaluation of the RI results at the Water Works #4 Dump MRS is associated with the incomplete record of the historical operations at the MRS. Review of the HRR (e^2M, 2007) indicates that the Water Works #4 Dump MRS was used for the intentional dumping of nonexplosive metal parts of large-caliber ordnance rounds between 1941 and 1949. However, specific details on these dumping activities were never documented. No MEC was found during the RI or any of the previous investigations at the

MRS and the findings of MD only support the reports that only nonexplosive items were dumped at the MRS.

In order to determine the quantity and type of MEC present, if any, a combination of Schonstedt-assisted visual surveys, DGM surveys, and anomaly investigations were performed at the Water Works #4 Dump MRS and the expanded investigation area for the RI. Schonstedt-assisted visual survey transects were placed in the expanded investigation area using the VSP module input of "90 percent confidence that 95 percent of transects do not contain MEC." The DGM survey coverage for the RI was designed based on complete (100 percent) coverage of the current MRS due the minimal size (0.77 acres) of the MRS, and the actual DGM coverage was nearly 99 percent. The number of anomalies requiring intrusive investigation was designed based on a hypergeometric statistics module that estimates the required sample size for populations. Ninety-four single-point source anomaly locations (over 45 percent of the identified 205 single-point anomalies) were intrusively investigated at the current MRS. No MEC was found during the RI field activities. Further, the statistical approach used to quantify the intrusive findings of the RI indicates there is a 99 percent probability that there is no MEC present at the remaining 111 anomaly locations that were not investigated during the RI field activities. These results satisfy the DQOs and reduce the uncertainties that MEC are present at the MRS.

10.5 Conclusions and Recommendations

The RI was prepared in accordance with the project DQOs and included evaluations for explosives hazards and potential sources of MC that may pose threats to likely receptors. The following statements can be made for the Water Works #4 Dump MRS based on the results of the RI field activities:

- In total, 3.76 miles of Schonstedt-assisted visual survey transects were investigated during the RI and were inclusive of the current MRS (0.25 miles), the expanded investigation area (3.01 miles), and step-outs where MD was encountered along the expanded investigation area boundaries (0.5 miles).
- The 3.01 miles of Schonstedt-assisted visual survey transects at the expanded investigation area exceeded the proposed RI Schonstedt-assisted visual survey transect distance of 2.3 miles.
- Complete DGM coverage of accessible areas (0.762 acres) was conducted at the current MRS during the RI and nearly 99 percent coverage of the 0.77-acre MRS was achieved.
- The nature and extent of MEC and MD has been adequately defined at the MRS.

- During the RI field activities, individual MD items consisting of inert ogives were found on the ground surface or in subsurface soil at a maximum depth of 1 inch bgs within the current MRS and on the ground surface only in the expanded investigation area.
- 100-foot step-outs were performed from MD observed on the ground surface along the expanded investigation area, and the lateral extent of MD has been defined.
- No munitions posing an explosive hazard have been identified in or around the MRS to date; an explosive safety hazard is not anticipated to exist at the MRS.
- MC sampling was not warranted, since concentrated areas of MEC or MD were not found at the MRS during the RI field activities.

Based on these conclusions, it is determined that the Water Works #4 Dump MRS and expanded investigation area have been adequately characterized and the DQOs presented in the Work Plan Addendum (Shaw, 2011) have been satisfied. Therefore, No Further Action is recommended for the Water Works #4 Dump MRS under the MMRP and the next course of action will be to proceed to a No Further Action Proposed Plan.

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Appendix A
Digital Geophysical Mapping Report

Appendix B
Photograph Documentation Log

Appendix C
Schonstedt-assisted Visual Survey and Intrusive Investigation Results

Appendix D
Statistical Analysis of Intrusive Findings

Statistical Analysis of Intrusive Findings at the Water Works #4 Dump MRS

It is challenging to predict the occurrence of munitions and explosives of concern (MEC) in a population of anomalies when only a portion of the anomalies are investigated and no MEC is identified in the sample population. In order to meet this challenge, a Bayesian statistical approach is warranted instead of a classical statistical approach. The Bayesian approach is applicable, as it uses the information from the sampled anomaly population in conjunction with previous knowledge regarding the occurrence of MEC to predict the occurrence of MEC in the unsampled population of anomalies. For the investigation at the Water Works #4 Dump Munitions Response Site (MRS) an assumption was made that the percentage of MEC items is between 1 and 0.1 percent (i.e., 1 in 100 or 1 in 1,000 anomalies are MEC).

The Bayesian approach is a valid method to predict the occurrence of MEC for the anomalies that were not investigated at the Water Works #4 Dump MRS. In total, 205 anomalies were identified using digital geophysical mapping and 94 of these were randomly selected and intrusively investigated. For comparative purposes, the mean value of the MEC among the 205 anomalies identified was estimated to be 1 percent, 4 percent, or 50 percent before any intrusive information was acquired. The assumption that 4 percent and 50 percent of the anomalies at the MRS are MEC is intended to provide information that errs on the side of conservatism. **Table D-1** presents a summary of the Bayesian approach and estimations used to predict the probability of MEC at unsampled anomalies at the Water Works #4 Dump MRS.

Table D-1
Probabilities of Remaining MEC for Unsampled Anomalies

Estimated Mean Population of MEC	Probability that there is no MEC in Remaining 111 Unsampled Anomalies	95th Percentile of Prediction Distribution for Count of MEC in Remaining 111 Unsampled Anomalies	99th Percentile of Prediction Distribution for Count of MEC in Remaining 111 Unsampled Anomalies
1%	0.99	0	0
4%	0.97	0	1
50%	0.46	4	6

MEC denotes munitions and explosives of concern.

If the mean MEC population at the MRS is estimated to be 1 percent and 4 percent then the predicted probability that there is no MEC in the remaining 111 samples using the actual intrusive results is 99 and 97 percent, respectively. In the case where the mean MEC population is estimated to be 50 percent, there is only a 46 percent prediction probability that

there is no MEC in the remaining 111 anomalies based on the intrusive results. In this scenario, 194 of the anomalies would need to be sampled to obtain a prediction probability of 95 percent that there is no MEC in the remaining four samples. Based on the results of the intrusive investigation as well as previous investigations, Shaw assumed *a priori* that MEC was at 1 percent or less.

After observing the initial *m* sample anomalies and counting the number of anomalies, *y*, that are MEC, the Bayesian estimator of the mean proportion, $\hat{p}_B$, of MEC is as follows:

$$\hat{p}_B = \left(\frac{m}{\alpha+\beta+m}\right)\left(\frac{y}{m}\right) + \left(\frac{\alpha+\beta}{\alpha+\beta+m}\right)\left(\frac{\alpha}{\alpha+\beta}\right)$$

This estimator is a weighted linear combination of the sample proportion, *y/m*, and the *a priori* beta distribution mean of $\alpha/(\alpha+\beta)$. Thus the Bayesian estimator can never be zero even when *y/m* is zero. Note however, that as *m* gets larger, the estimated proportion approaches *y/m*.

Once the proportion is estimated in the Bayesian framework, the predictive distribution for the count of MEC in the unsampled anomalies is readily obtained and follows a beta-binomial distribution. This distribution can be used to predict the count of MEC in the remaining unsampled anomalies. Assuming *a priori* that MEC was at 1 percent or less, no MEC items are anticipated in the remainder of samples.

References:

Lee, Peter M., 1989. *Bayesian Statistics*, Oxford University Press, New York, New York.

Casella, George and R. Berger, 1990. *Statistical Inference*, Wadsworth & Brooks, New York, New York.

Appendix E
Munitions Debris Shipment and Disposal Records

Appendix F
Munitions Response Site Prioritization Protocol Worksheets