OhioEPA

State of Ohio Environmental Protection Agency

Northeast District Office

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Ted Strickland, Governor
Lee Fisher, Lieutenant Governor
Chris Korleski, Director

May 28, 2008

RE: RAVENNA ARMY AMMUNITION PLANT, PORTAGE/TRUMBULL COUNTIES, SUSPECTED MUSTARD AGENT BURIAL SITE, REPORT ON THE GEOPHYSICAL INVESTIGATION

Mr. Mark Patterson
Environmental Program Manager
Ravenna Army Ammunition Plant
8451 State Route 5
Ravenna, OH 44266

CERTIFIED MAIL

Dear Mr. Patterson:

The Ohio Environmental Protection Agency (Ohio EPA), Northeast District Office (NEDO), Division of Emergency and Remedial Response (DERR) has received and reviewed the document entitled "Report on the Geophysical Investigation for the Suspected Mustard Agent Burial Site at the Ravenna Army Ammunition Plant, Ravenna, Ohio." This document, dated February 20, 2008 and received at Ohio EPA on February 21, 2008, was prepared for the U.S. Army Corps of Engineers Louisville District, by Environmental Quality Management, Inc. and Mundell & Associates, Inc.

On April 3, 2008, Ohio EPA sent comments on the first draft of this document. All the comments have been adequately addressed in the final version of the report, and Ohio EPA has found no further deficiencies. As a result, the "Report on the Geophysical Investigation for the Suspected Mustard Agent Burial Site at the Ravenna Army Ammunition Plant, Ravenna, Ohio" has been accepted and filed.

If you have any questions or concerns, please do not hesitate to contact me at (330) 963-1249.

Sincerely,

Andrew C. Kocher
Site Coordinator
Division of Emergency and Remedial Response

ACK/kss

cc: Bonnie Buthker, Ohio EPA, DERR, SWDO
Eileen Mohr, Ohio EPA, DERR, NEDO
Katie Elgin, OHARNG
John Miller, EQM, Inc.
Rick Hockett, USACE Louisville
Glen Beckham, USACE Louisville
Mark Krivansky, USAEC

ec: Mike Eberle, Ohio EPA, DERR, NEDO
Todd Fisher, Ohio EPA, DERR, NEDO

FINAL
REPORT ON THE GEOPHYSICAL INVESTIGATION
SUSPECTED MUSTARD AGENT BURIAL SITE
RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

Contract No. W912QR-04-D-0036
Delivery Order No. 0006

Prepared for:

U.S. Army Corps of Engineers
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May 21, 2008

Geophysical Report Distribution List Final

RVAAP – 2 printed copies, 2 CDs
USACE - 2 printed copies, 3 CDs
USAEC – 1 CD
Ohio EPA – 3 printed copies, 3 CDs
OHARNG – 1 printed copy, 1 CD
EQM – 1 printed copy, 1 CD

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FIGURES

ABBREVIATIONS AND ACRONYMS

CAIS	Chemical Agent Identification Sets
COR	Contracting Officer's Representative
DOD	Department of Defense
EM	Electromagnetic
EMD	Electromagnetic Metal Detection
EQM	Environmental Quality Management, Inc.
GOCO	Government Owned Contractor Operated
GPR	Ground Penetrating Radar
GPS	Global Positioning System
IRP	Installation Restoration Program
NACA	National Advisory Committee for Aeronautics
NAD	North American Datum
OHARNG	Ohio Army National Guard
Ohio EPA	Ohio Environmental Protection Agency
QC	Quality Control
QCM	Quality Control Manager
RTLS	Ravenna Training and Logistics Site
RVAAP	Ravenna Army Ammunition Plant
SOW	Scope of Work
USACE	United States Army Corps of Engineers
USGS	United States Geologic Service
USP&FO	United States Property and Fiscal Officer
UTM	Universal Transverse Mercator

EXECUTIVE SUMMARY

The objective of this geophysical survey was to determine if mustard agent test kits had been buried in an approximate one acre area located on the western portion of the Ravenna Army Ammunition Plant (RVAAP) in Ravenna, Ohio. The EMD and EM conductivity maps indicate that buried metallic objects are found within the study area. The metallic response seen on the EM-61 could be due to any type of large metallic object/objects. Based on the results of the geophysical survey, the large metallic anomalies detected in the survey area, especially those that are trench shaped extending off of the edge of the concrete pad, are interpreted to be possible mustard agent test kits. It should be noted that steel mill slag was commonly used as fill at the installation and could possibly be the source of the metallic anomalies.

SECTION 1

PROJECT DESCRIPTION

1.1 Statement of Purpose

The objective of the project was to determine if mustard Chemical Agent Identification Sets (CAIS) had been buried in an approximate one acre area located on the western portion of the Ravenna Army Ammunition Plant (RVAAP) in Ravenna, Ohio. The suspected area, as reported by a former RVAAP employee, is located adjacent to the NACA test strip.

The CAIS were reported to be contained in metal shipping containers as described in Section 1.3. The purpose of this geophysical survey was to determine if buried metal objects exist in the study area. These objects, if present, could potentially be the mustard agent test kits. The survey results will be used by the Army to determine further action at the site.

1.2 Facility Location and Physiography

Past Department of Defense (DOD) activities at the RVAAP date to 1940 and include the manufacturing, loading, and storage of military explosives and ammunition. Until 1999, the RVAAP was identified as a 21,419-acre installation. The property boundary was resurveyed by the Ohio Army National Guard (OHARNG) over a two year period from 2002 and 2003 and the actual total acreage of the property was found to be 21,683.289 acres. As of February 2006, a total of 20,403 acres of the former 21,683 acre RVAAP have been transferred to the United States Property and Fiscal Officer (USP&FO) for Ohio for use by the OHARNG as a military training site. The current RVAAP consists of 1,280 acres in several distinct parcels scattered throughout the confines of the OHARNG Ravenna Training and Logistics Site (RTLS). The RVAAP and the RTLS are collocated on contiguous parcels of property and the RTLS perimeter fence completely encloses the remaining parcels of the RVAAP. The RTLS is in northeastern Ohio within Portage and Trumbull Counties, approximately 4.8 kilometers (3 miles) east-northeast of the city of Ravenna and approximately 1.6 kilometers (1 mile) northwest of the city of Newton Falls (Figure 1). The RVAAP portions of the property are solely located within Portage County. The RTLS (inclusive of the RVAAP) is a parcel of property approximately 17.7 kilometers (11 miles) long and 5.6

kilometers (3.5 miles) wide bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad on the south; Garret, McCormick, and Berry roads on the west; the Norfolk Southern Railroad on the north; and State Route 534 on the east (see Figures 1 and 2). The RTLS is surrounded by several communities: Windham on the north; Garrettsville 9.6 kilometers (6 miles) to the northwest; Newton Falls 1.6 kilometers (1 mile) to the southeast; Charlestown to the southwest; and Wayland 4.8 kilometers (3 miles) to the south. When the RVAAP was operational the RTLS did not exist and the entire 21,683-acre parcel was a government-owned, contractor-operated (GOCO) industrial facility. The RVAAP Installation Restoration Program (IRP) encompasses investigation and cleanup of past activities over the entire 21,683 acres of the former RVAAP and therefore references to the RVAAP in this document are considered to be inclusive of the historical extent of the RVAAP, which is inclusive of the combined acreages of the current RTLS and RVAAP, unless otherwise specifically stated.

As reported by former employees (reference the *Suspected Mustard Agent Interview*) in Attachment 1), the general location of the mustard agent CAIS is presented in Figure 2. The depth at which the CAIS may have been buried was not reported, however Section 3 presents a discussion on suspected burial depths. A more detailed location map is presented in Figure 3. Details on the specific study area are presented in Section 3 of this report.

The overall facility geology is characterized by sedimentary bedrock overlain by a thin veneer of glacial sediments consisting of tills and outwash deposits. The specific study area is relatively flat, sloping gently towards Hinkley Creek to the west and south. The area is heavily vegetated with scrub brush and trees, some of them greater than 10 inches in diameter.

1.3 Facility History

RVAAP was constructed in 1940 and 1941 for depot storage and ammunition assembly/loading. Production began in 1942 and the facility was placed on standby status in 1950. Production activities resumed from 1954 to 1957 and 1968 to 1972. Demilitarization activities, including disassembly of munitions and explosives melt-out and recovery, continued until 1992. The facility entered Modified Caretaker status in October 1993. The subject project area is reported, by former employees at the facility, to be a possible location of buried mustard agent test kits

(*Suspected Mustard Agent Interview, 2006).*

The CAIS mustard agent suspected to have been buried at the facility was developed by the Department of the Army from the 1930s through the 1960s. It was reportedly buried at RVAAP in the 1950's (*Suspected Mustard Agent Interview, 2006).* Of the various types of CAIS glass containers that have been identified as potentially containing mustard agent, all are believed to have been packed in metal, either metal paint/coffee-type cans, 55-gallon drums, or steel shipping cylinders called PIGs as described in *Description of Chemical Agent Identification Set Types, 2004* which is contained in Attachment 1 of this report (also used to reference the CAIS packaging is the document *Chemical Agent Identification Set (CAIS) Information Package, November 1995).*

According to UXO safety information on the Denix website (https://www.denix.osd.mil/), prior to the early-1970s, one of the approved procedures for disposing of CAIS was burial on training ranges or areas. When buried, CAIS were either buried in their original containers (PIGS) or loose. Normally, CAIS vials were broken before burial and decontaminant was used to neutralize any chemical agent present. Note that the Denix website references wooden containers. Based on the *Description of Chemical Agent Identification Set Types, 2004,* the only CAIS packed in non-metallic (wooden) containers was K945, however all K945 kits were accounted for by the Army and destroyed.

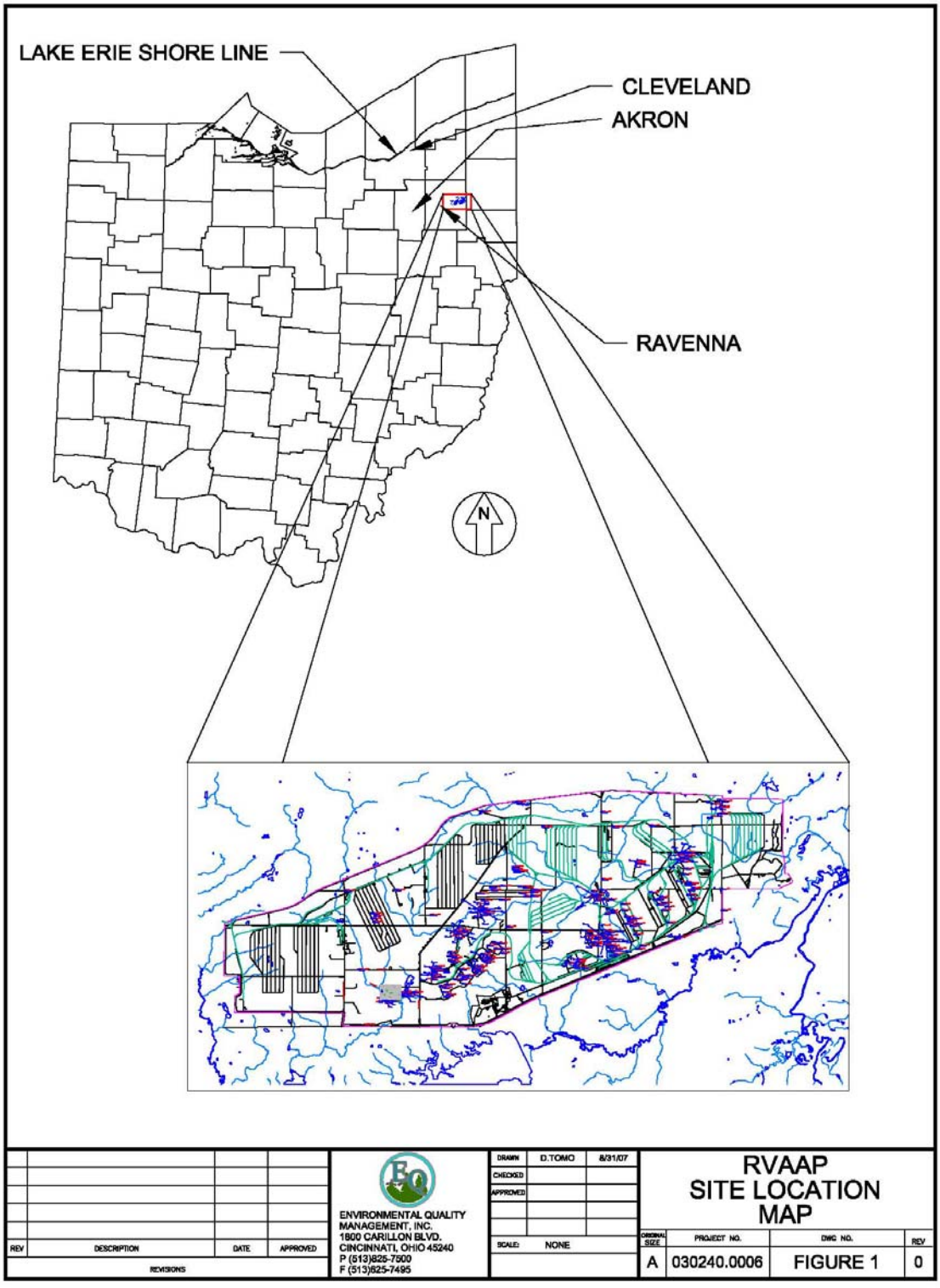
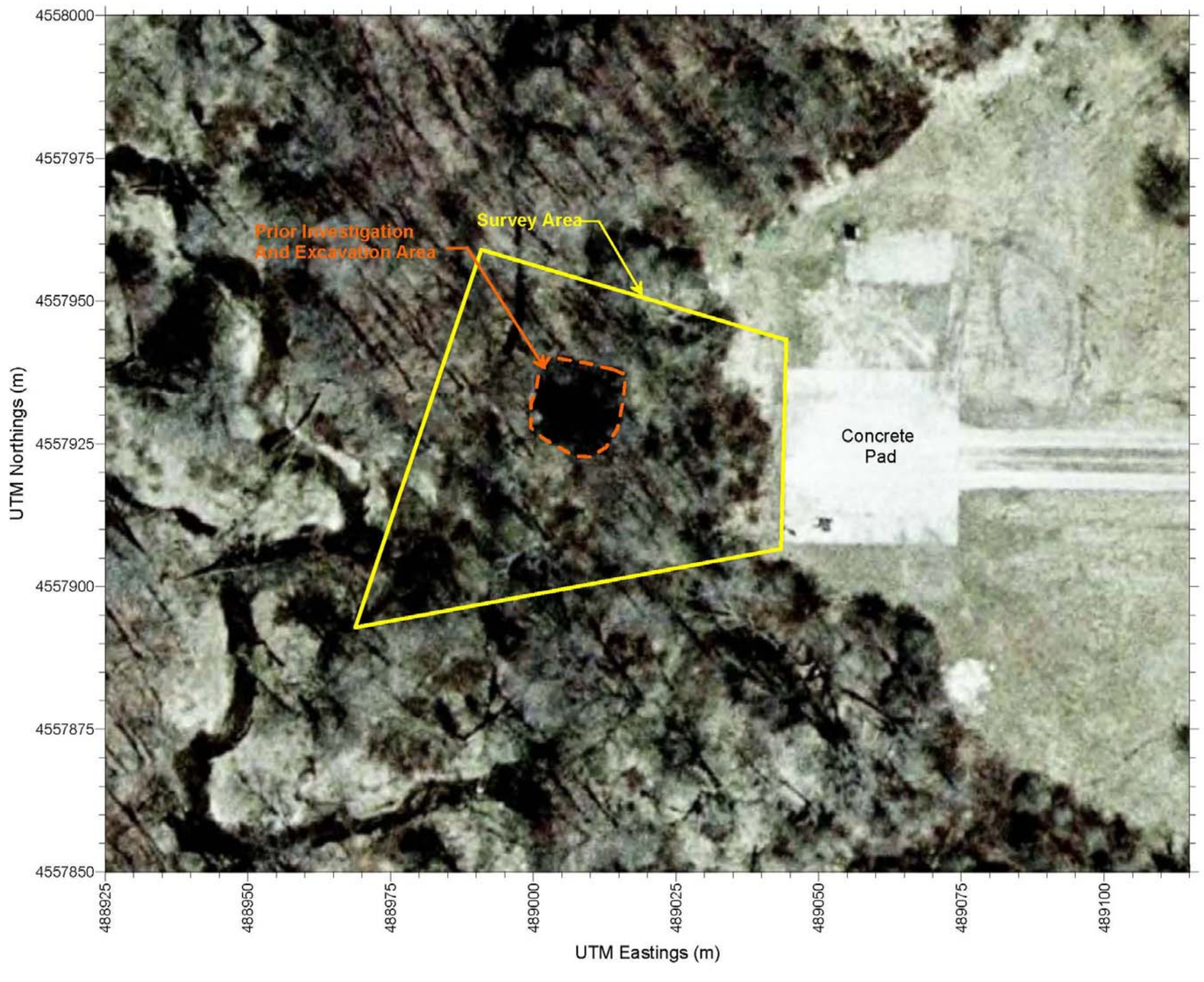


Figure 1. Site Location Map

Figure 2. Site Map



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Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

1 : 750

Site Map
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
3

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317-630-9060, Fax: 317-630-9065

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SECTION 2

METHODOLOGY

All records review and field work activities were conducted in accordance with the approved Work Plan.

2.1 Records Review

The boundaries of the suspected mustard agent burial areas have been determined to the extent practicable through a review of available records. The historical records utilized in this review include USGS topographic maps from 1908, 1960, 1970, 1977, and 1994; and USGS aerial photographs from 1952, 1960, 1970, 1982, 1994. Based on site features identified on those maps and photographs, along with information from former RVAAP employees, a possible burial location has been identified. The outline of this area has been identified on Figure 3. This area comprises the limits of the geophysical survey.

2.2 Geophysical Methodology

In order to increase the likelihood of detecting any possible mustard agent test kits and associated objects, a combination of methods were used, including electromagnetic metal detection (EMD), electromagnetic (EM) conductivity mapping, and ground penetrating radar (GPR). The EMD work was completed with an EM-61 metal detector manufactured by Geonics Ltd. Two different instruments were used for the EM conductivity mapping: an EM-31 manufactured by Geonics Ltd. and a GEM-2 broadband electromagnetic sensor manufactured by Geophex Ltd. GPR data were collected with a Noggin 250 radar system manufactured by Sensors & Software, Inc.

The EM-61 is a high-sensitivity, high-resolution, time-domain metal detector. It consists of two vertically-separated 1 meter by 1 meter coaxial coils mounted to a wheel assembly. The instrument operator pulls the coil assembly along the line of profile while data are collected nearly continuously (one reading every approximately 0.2 meters). The EM-61 is designed to take readings from the bottom coil at three successive time gates (designated as Channels 1, 2, and 3), and at the third time gate an additional reading is taken from the upper coil (designated as Channel 4).

The EM-31 is an electromagnetic ground conductivity meter used to map geologic variations, groundwater contaminants, or any subsurface feature associated with changes in ground conductivity. Ground conductivity (quad-phase) and magnetic susceptibility (in-phase) measurements are stored in a field computer for subsequent processing and analysis. The maximum depth of exploration is about six meters. The in-phase component is particularly useful for the detection of buried metallic objects and waste material.

The GEM-2 is a hand-held, digital, multi-frequency sensor capable of transmitting and receiving a digitally-synthesized arbitrary waveform containing multiple frequencies. The depth of exploration for a given earth medium is determined by the operating frequency of the sensor. By utilizing multiple frequencies to measure the earth response from several depths, an image of the three-dimensional distribution of subsurface objects can be created. The quad-phase and in-phase instrument response values are stored in a handheld computer for subsequent processing and conversion to apparent conductivity measurements using transform algorithms.

GPR data were collected using a Sensors and Software Noggin Plus GPR System equipped with shielded 250-megahertz antennae. This system is a rapid, state-of-the-art data acquisition system that collects data continuously as it is operated. The operator has an immediate view of the subsurface, and the data are stored in a computer for later printing and analysis.

2.3 Field Procedures

Prior to implementing the Geophysical study the area was staked out using GPS coordinates based on the area identified in the Work Plan. EQM met with OHARNG personnel at the study area prior to initiating any field clearing activities to identify any sensitive areas. The study area was mowed using a tractor pulled rotary mower (bush-hog) to the extent possible given the terrain and vegetation. Vegetation of less than approximately 2” in diameter was removed prior to the survey. Hand tools (chainsaws) were also used to clear the area. The area of standing water in the middle of the study area was not disturbed. The area of investigation was also cleared of surface objects, (i.e., metallic objects), which would impede data collection.

EMD and EM conductivity data were collected along grid lines spaced approximately 2 to 5 meters apart, depending upon the amount of space between the standing trees. Data were collected

nearly continuously along the lines of data collection. The position of the instruments was determined by a Trimble AG-114 global positioning system (GPS) receiver equipped with satellite based real-time differential correction (i.e. OmniSTAR). The accuracy of this GPS receiver system is one meter or less under typical conditions.

After the EMD and EM conductivity data were collected they were downloaded to a computer and processed with Surfer v. 8.0 to create color filled contour maps of instrument response (Figures 4-10). The maps were interpreted while in the field for the presence of targets of interest, and used to guide the GPR data collection. GPR data were collected in areas of interest as identified with the EM and EMD maps, and compared to GPR data collected outside the study area in order to evaluate the efficacy of GPR as a diagnostic tool for locating areas of metallic objects. Due to the conductive clayey soils and rough terrain, the quality of the GPR data was not able to discriminate between targets of interest and native anomalies. The conductive soils at the site greatly attenuated the radar signal and limited the depth of penetration to the upper two meters (six feet) of the subsurface. Also, the extremely rough terrain made it difficult for the instrument to accurately detect reflections from subsurface objects due to surface scattering and scattering from shallow native objects such as tree roots. This made it impossible to differentiate between targets of interest and native objects in the study area. It was determined that the GPR offered little benefit to the discrimination of targets of interest in the study area.

Mundell uses the minimum curvature gridding method for Surfer 8.0 when using EM61 and EM31 data rather than krieging. The krieging method tends to create artificial 'bullseyes' in the geophysical data that have been shown from experience not to correlate well with actual anomaly size and geometry. The minimum curvature for a wide range of situations tends to provide a better correlation to object location and extent. The final manner in which to confirm this at this site would be to 'ground truth' the anomalies by further investigation and excavation.

2.4 QA/QC

Mundell performs several levels of quality assurance/quality control checking during data collection and processing:

1. The EM31 instrument is calibrated twice (once at the beginning and once at the end) with the process as outlined in the operations manual; instrument is sensitive to smaller

changes in conductivity (1 to 2 millisemens).

2. Procedures include – 1) checking battery for adequate voltage, 2) checking compensation, and 3) zero (null) the IP and conductivity.

3. A portion of the site not believed to be impacted by subsurface debris, was checked for range of conductivity given (e.g., clayey soils, sandy soils).

4. The EM61 instrument is much less sensitive to quality problems since it provides a metallic material 'absent/present' kind of reading. The instrument is calibrated on a periodic basis (once a quarter) unless unusual reading ranges are observed.

5. Both the magnitude of readings as well as reading positioning using GPS system; are checked several times during the survey for accuracy of positioning with known site features, to make sure data locations are consistent. In addition, a GPS file after field collection also shows the quality of the GPS signal based on whether data was collected under any tree canopies or other interferences. This is checked when the data is referenced to site features.

6. Maps and interpretation of the data are reviewed by a Senior Scientist with 25+ years of experience to check interpretations and whether readings and results are consistent with known materials and site conditions. This is a second level of review.

7. If data is shown to be poor during either field data collection or after processing, procedures are in place for nonconformance activities, including selective data point filtering (if found to be in error), or recollection of data until quality level is achieved.

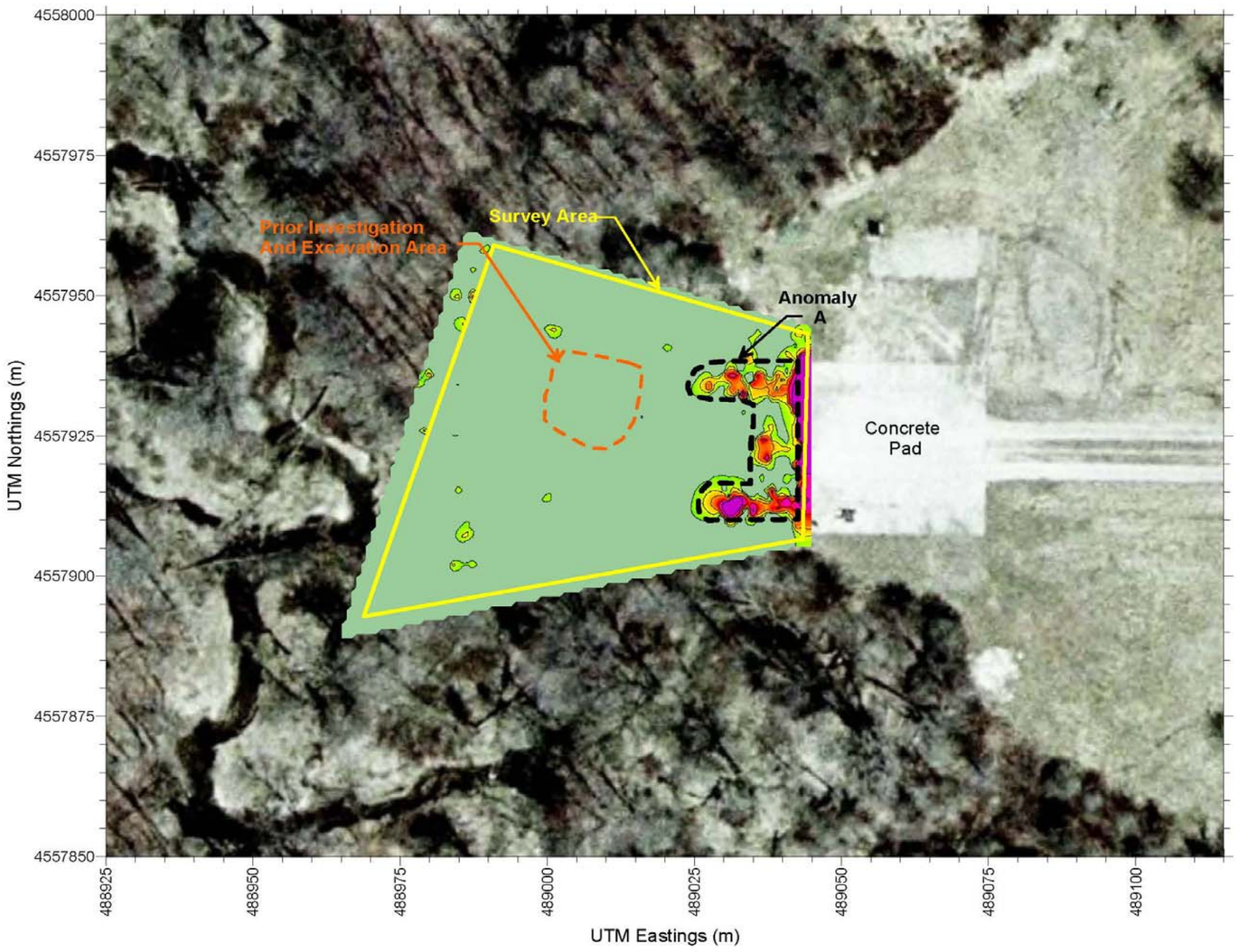
SECTION 3

GEOPHYSICAL RESULTS

3.1 Electromagnetic Metal Detection

The EM-61 channel three and channel difference maps are presented as Figures 4 and 5. The earlier time gates of the EM-61 (Channels 1 and 2) reveal the presence of a wide range of objects, and are most useful for locating all metallic objects within the study area. The last time gate (Channel 3) is a more selective view of metallic objects because it tends to indicate the locations of the most extensive and conductive objects. The additional measurement from the top coil (Channel 4) is used to filter out the effect of near-surface metallic materials, allowing for a distinction between deeper and shallower metallic objects. The filtering effect is obtained by subtracting the bottom coil response (Channel 3) from the top coil response (Channel 4) to yield the channel difference.

The EM-61 maps indicate an irregularly shaped anomaly located at the western edge of the concrete pad and extending to the west, this has been denoted as Anomaly A. The center of this anomaly is much lower in amplitude on the channel difference map, indicating that this area contains predominantly shallow metal compared to the northern and southern lobes of the anomaly. The channel three map also indicates several small anomalies, two to the north of the former excavation and four to the south. These smaller anomalies may represent targets of interest; however several similar anomalies are also located outside the study area, possibly indicating that they are unrelated to any buried mustard agent test kits. The EM-61 is a very sensitive instrument that is capable of detecting a wide range of metallic objects, ranging from nails and screws to buried drums and tanks. While the instruments used to collect terrain conductivity data of the site (the GEM-2 and EM-31), are capable of detecting metallic objects, they are designed to detect minute conductivity variations in the soil, and usually only detect metallic objects large enough to affect the conductivity value of a unit volume of soil. Thus, the fact that the GEM-2 and EM-31 did not detect the smaller EM-61 anomalies implies that those anomalies are small, shallow, and singular metallic objects not related to the targets of interest.



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800
700
600
500
400
350
300
250
200
170
140
120
100
80
60
50
40
30
0
-1000

Channel Three Response
(mV)

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Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

1 : 750

EM-61 Channel Three Map
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
4

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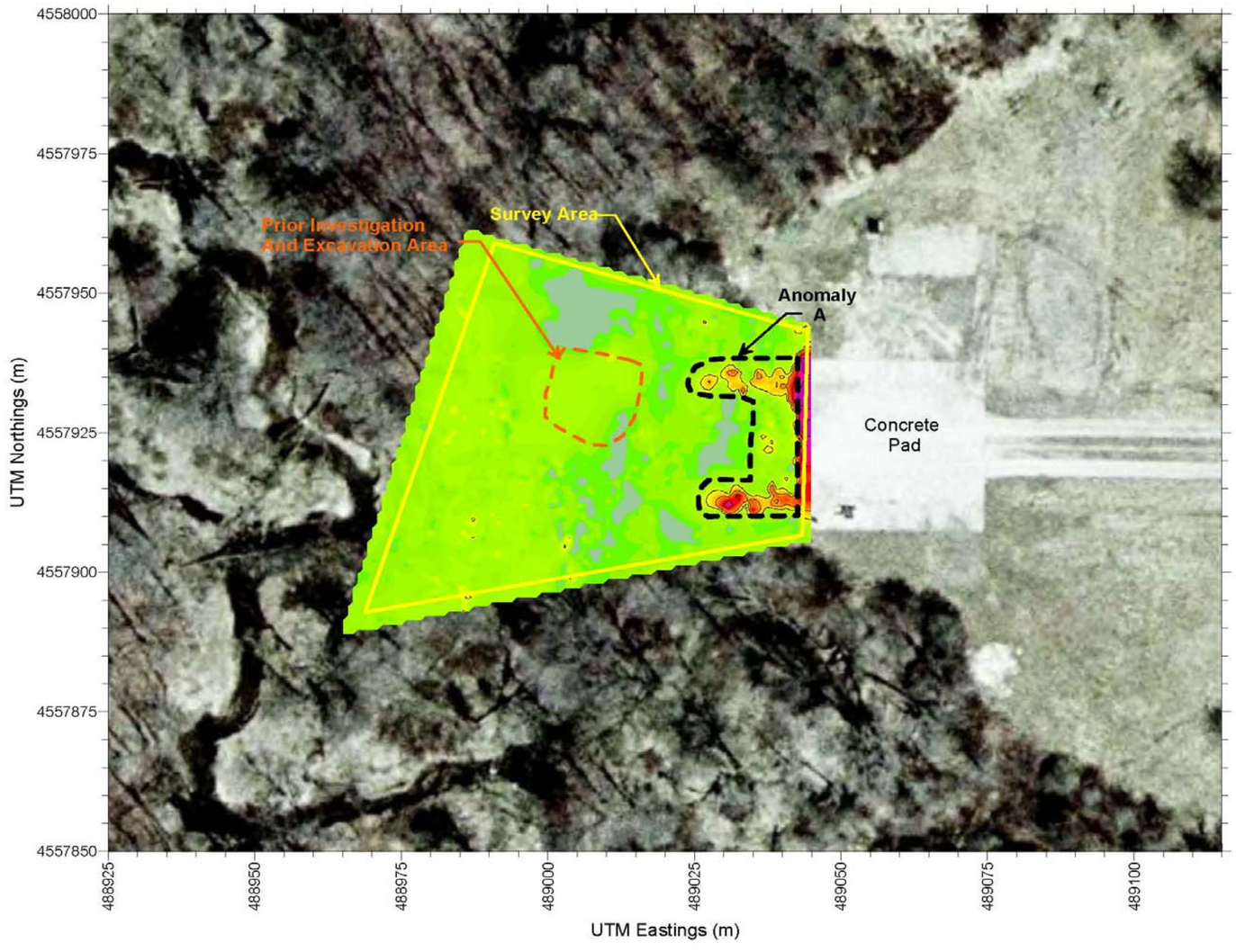

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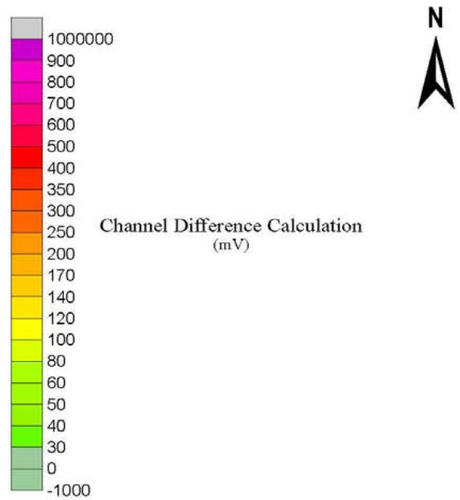

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Scale in Feet
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Scale in Meters
0 10 20 30 40 50

1 : 750

EM-61 Channel Difference Map
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
5

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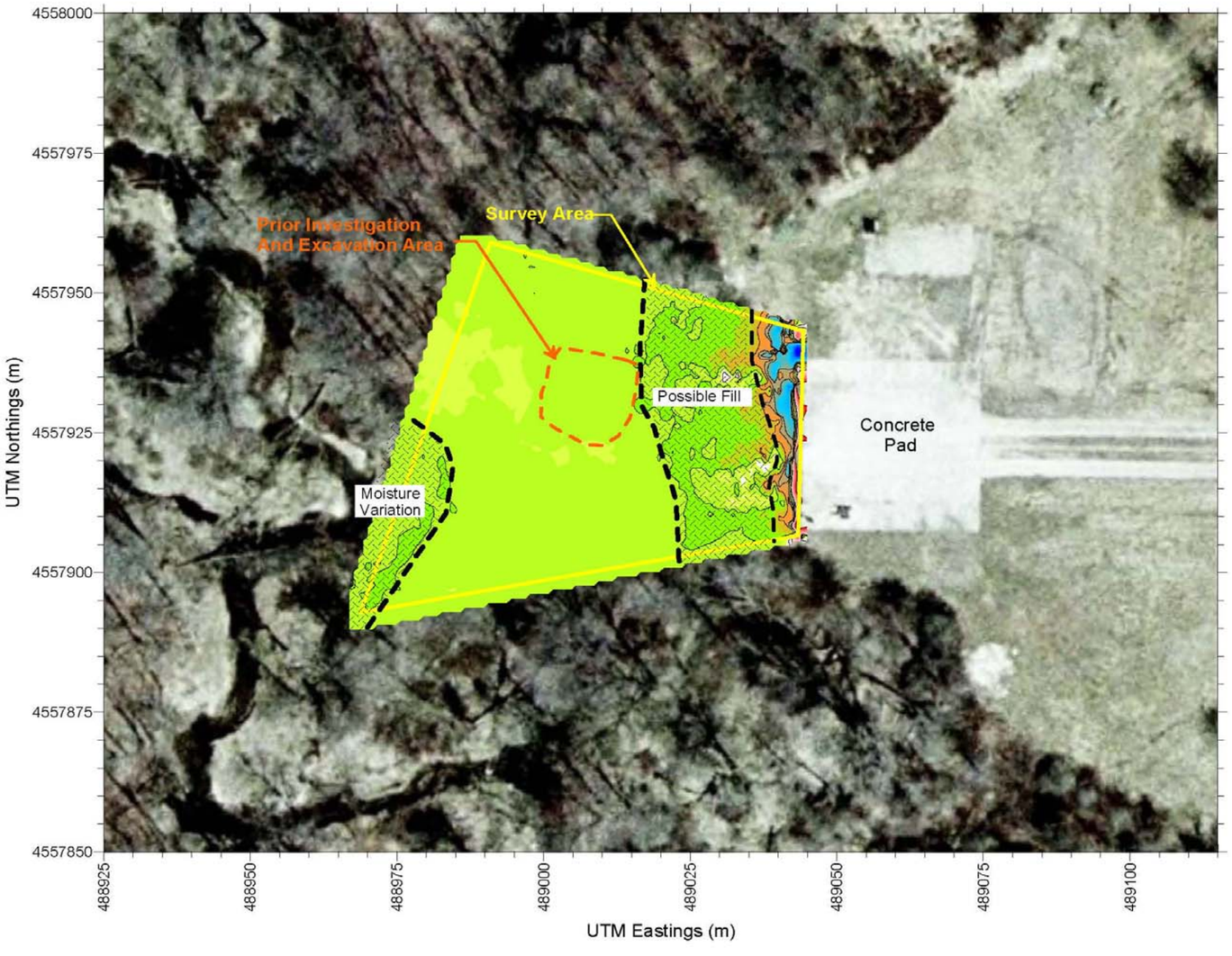
3.2 Electromagnetic Conductivity

Electrical conductivity is one of the most variable physical properties of natural materials. Certain minerals, such as native metals and graphite, conduct electricity via the passage of electrons. However, electronic conduction is generally very rare in the subsurface unless there are metallic objects present. Most minerals and sediments are insulators, and electrical current travels through soils mainly by the passage of free ions in pore waters (i.e., ionic conduction). Thus, most soils conduct electricity by electrolytic rather than electronic processes. As a result, moisture content, porosity, permeability, and water chemistry are the major controlling variables of the conductivity of soils, and in general, conductivity varies with changes in these key variables. In practice, conductivity is found to be strongly controlled by degree of water saturation and water chemistry, and the type and physical characteristics of the native sediments and bedrock. For example, fine-grained sediments, particularly clay-rich sediments such as glacial till have higher conductivity values (often in the range from 30 to 60 milliSiemens per meter, or mS/m), while coarser sediments such as sand and gravel are much more resistive (generally less than 30 mS/m). This difference in response to various types of sediments often allows identification of backfilled areas or areas of fill placement. Because there can be wide variations in moisture content, soil thickness, soil porosity and permeability related to changes in soil and/or fill type, it appears that a number of specific geologic models could explain apparent conductivity responses, resulting in non-uniqueness. As a result the variations in apparent conductivity at this site are likely to be attributed primarily to variations in the types of subsurface materials, and to a lesser degree to changes in groundwater or soil chemistry, since the apparent conductivity pattern distribution over the area does not indicate a condition that results from chemical impacts in a groundwater system being transported away from the source area.

The EM-31 and shallow (93 kHz and 47 kHz) GEM-2 maps (Figures 6, 7, and 8) indicated an area of elevated conductivity along the western edge of the concrete pad. This anomaly is interpreted as a possible area of buried mustard agent test kits and has been denoted as Anomaly 1. Another area of elevated conductivity extends westward from the concrete pad into the wooded area to a distance of approximately 6 meters. This feature likely represents a difference in soil type as it



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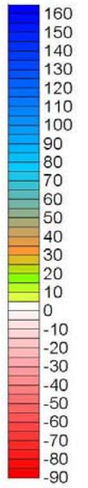

Terrain Conductivity
(mS/m)

N

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Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

1 : 750

EM-31 Terrain Conductivity Map
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
6

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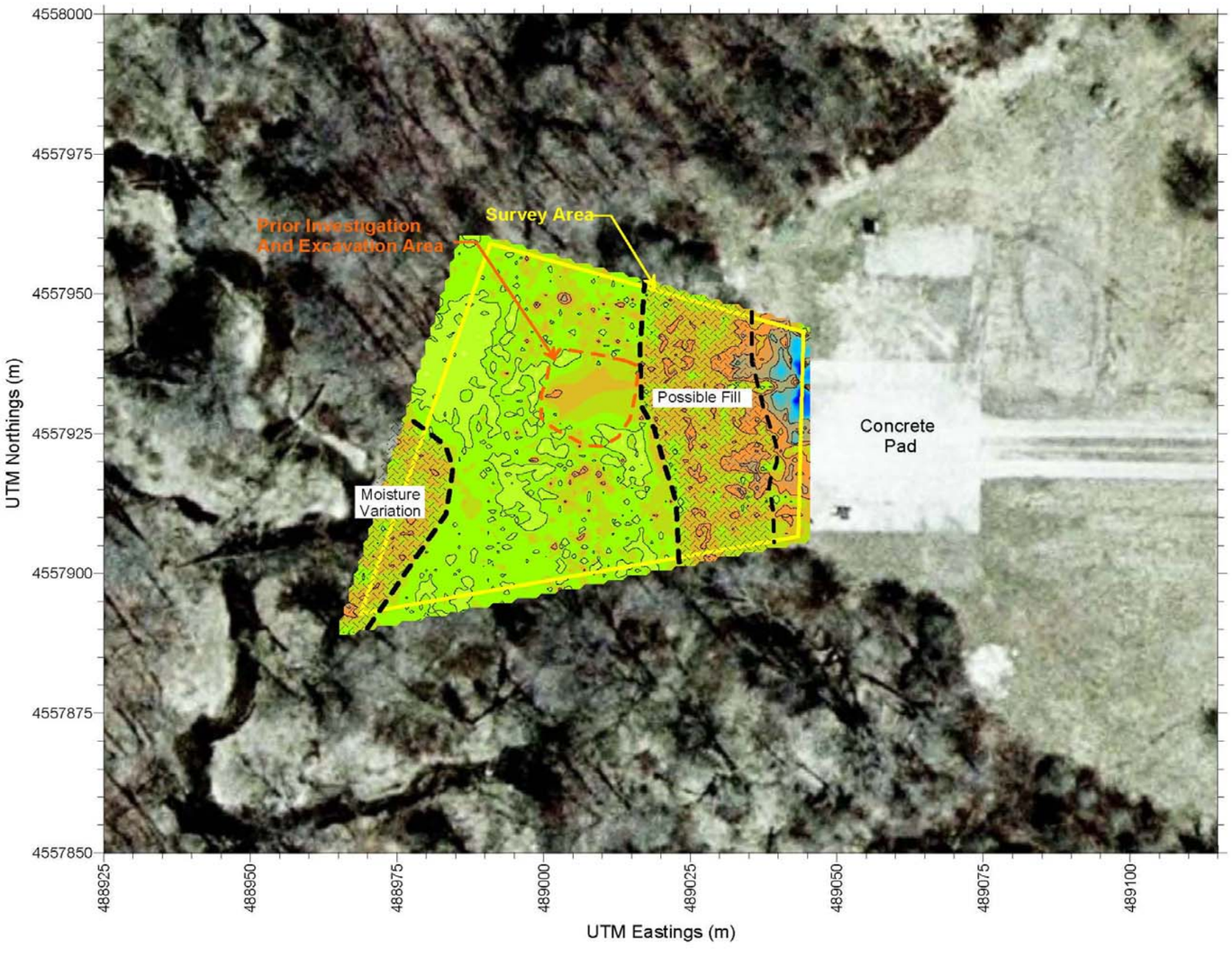

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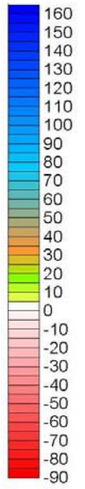

Terrain Conductivity
(mS/m)

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Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

1 : 750

Terrain Conductivity Map (93 kHz)
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
7

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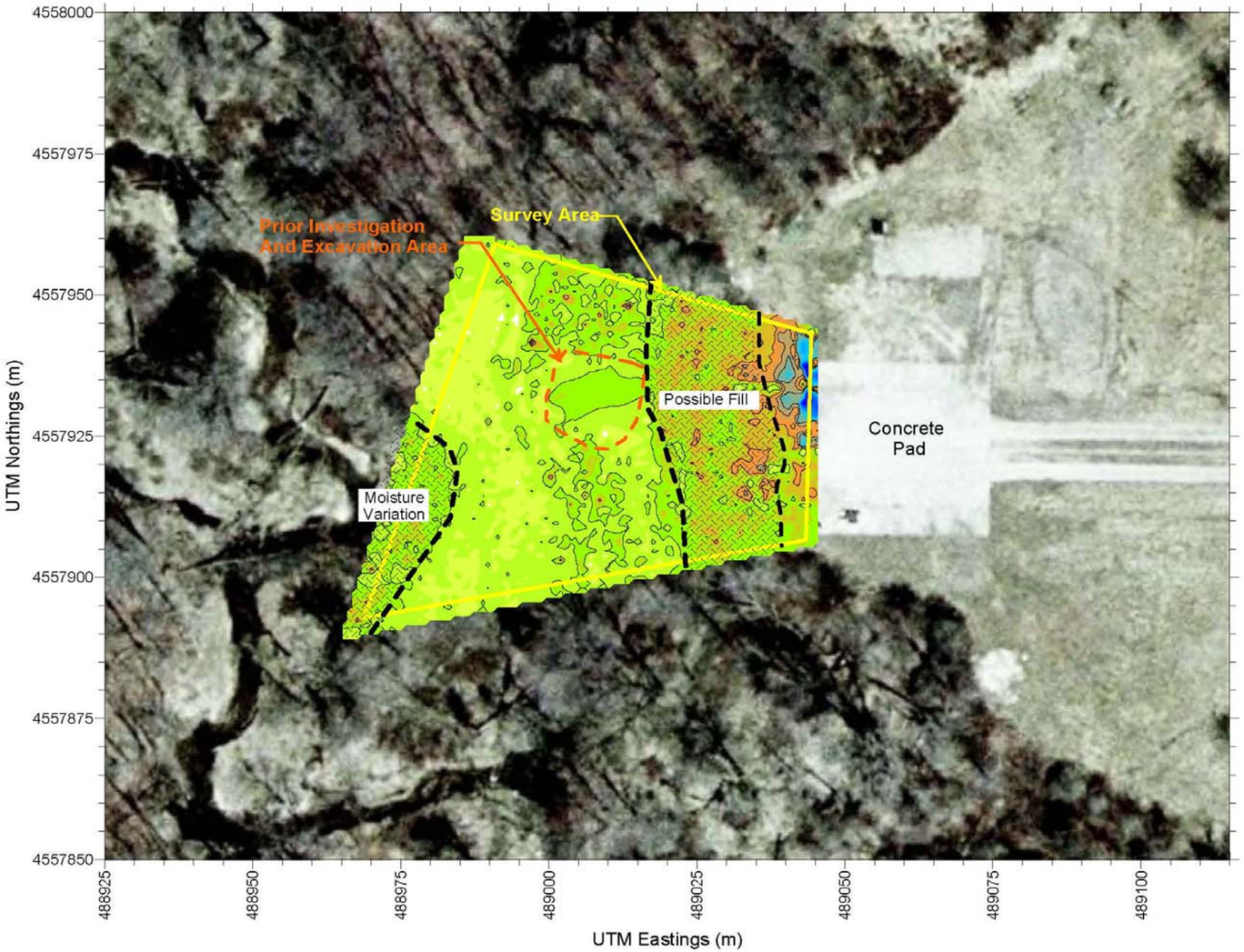

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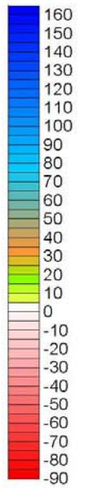

Terrain Conductivity
(mS/m)

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Golden Software's Surfer V. 8.0

Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

1 : 750

Terrain Conductivity Map (47 kHz)
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
8

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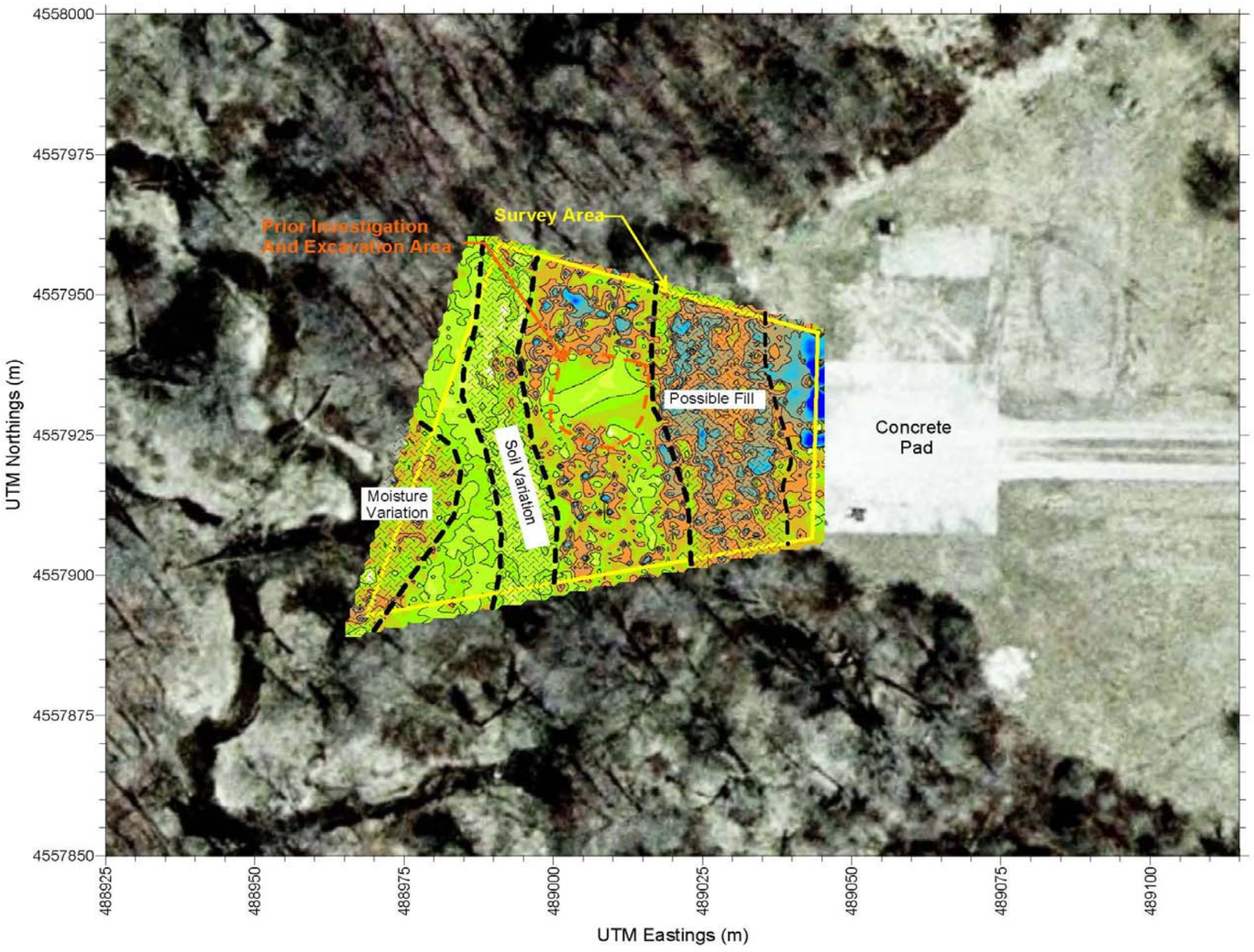
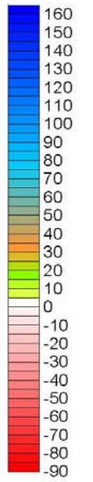
UTM Zone 17, GPS Datum WGS84

generally corresponds with a small topographic rise in the same area, which may represent fill material used to level the concrete pad and runway, or excavated soil from the previous mustard agent investigation.

Evident on the deeper (13 kHz and 4 kHz) GEM-2 maps (Figures 9 and 10), and to a lesser extent on the EM-31 and shallow GEM-2 maps, is an area of elevated conductivity at the southwestern edge of the study area and a narrow low conductivity bisecting the study area. Both anomalies are interpreted as differences in soil type and/or moisture content. The anomaly at the southwest corner is likely due to increased moisture in the soil surrounding the nearby creek. The narrow low conductivity anomaly is especially notable on the deepest (4 kHz) GEM-2 map and generally corresponds with a small brook or minor creek that runs through the study area. The low conductivity values possibly indicate that the sediment underlying this feature is sand and/or gravel.



LEGEND



Terrain Conductivity
(mS/m)

N

All figures are generated using
Golden Software's Surfer V. 8.0

Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

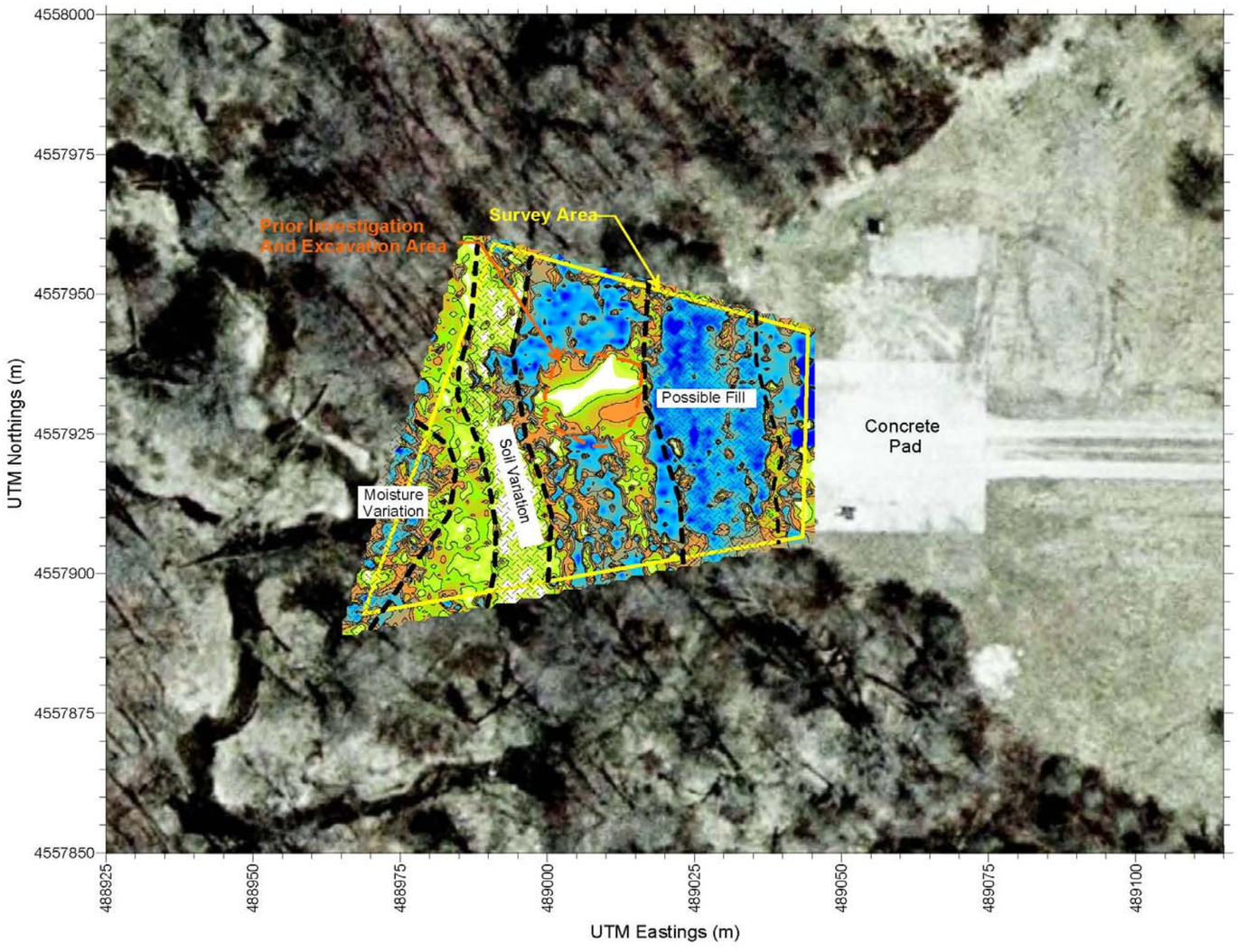
1 : 750

Terrain Conductivity Map (13 kHz)
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

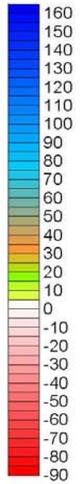
FIGURE
9

MUNDELL & ASSOCIATES, INC.
Consulting Professionals for the Earth & Environment
110 South Downey Avenue
Indianapolis, Indiana 46219
317-630-9060, Fax: 317-630-9065

UTM Zone 17, GPS Datum WGS84



LEGEND



Terrain Conductivity
(mS/m)

N

All figures are generated using
Golden Software's Surfer V. 8.0

Scale in Feet
0 20 40 60 80 100

Scale in Meters
0 10 20 30 40 50

1 : 750

Terrain Conductivity Map (4 kHz)
Geophysical Investigation:
Suspected Mustard Agent Burial Site
Former Ravenna Army Ammunition Plant
Ravenna, Ohio
MUNDELL Project No. M07028

FIGURE
10

MUNDELL & ASSOCIATES, INC.
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Indianapolis, Indiana 46219
317-630-9060, Fax: 317-630-9065

UTM Zone 17, GPS Datum WGS84

SECTION 4

CONCLUSIONS

The EMD and EM conductivity maps indicate that buried metallic objects are found within the study area. The metallic response seen on the EM-61 could be due to any type of large metallic object/objects. Based on the results of the geophysical survey, the large metallic anomalies detected in the survey area, especially those that are trench shaped extending off of the edge of the concrete pad, are interpreted to be possible mustard agent test kits. It should be noted that steel mill slag was commonly used as fill at the installation and could, possibly be the source of the metallic anomalies. Specifically, the EM-61 metal detection results indicate the presence of buried metallic objects near the western edge of the concrete pad (Anomaly A on Figures 4 and 5), and the EM-31 and shallow GEM-2 conductivity maps show an area of elevated conductivity in the same general area (Anomaly 1 on Figures 6-10). From the results it is likely that substantial portions of this metallic debris may be buried within 5-feet of the ground surface, although accumulations of materials could exceed this depth in some areas. After some testing with GPR was completed at the site, this geophysical method was determined to be of little value in further characterizing these anomalies due to severe signal attenuation from conductive, clayey soils. If further specificity is desired in order to confirm the EMD and EM interpretations more exactly, it will be necessary to investigate these anomalies with excavation and direct observation.

Contract No. W912QR-04-D-0036
May 2008

ATTACHMENT 1

SUSPECTED MUSTARD AGENT INTERVIEW/DESCRIPTION OF CHEMICAL AGENT IDENTIFICATION SET TYPES

SUSPECTED MUSTARD AGENT INTERVIEW
20 JULY 2006

DRAFT #2

SUSPECTED MUSTARD AGENT INTERVIEW
20 July 2006
At Building 1037, RVAAP

1 On 20 July 2006, the following people met to interview two local members of the public who may have some knowledge of potential mustard agent burial area(s).

Charlene and Ray McDaniel	Public
Jeff Lock and his daughter Sarah (RVAAP RAB member)	Public
LTC Thomas Tadsen	Ohio Army National Guard (OHARNG)
Tim Morgan	OHARNG
Katie Elgin	OHARNG
Eileen Mohr	Ohio EPA
Andrew Kocher	Ohio EPA
Irv Venger	RVAAP
Glen Beckham	Corps of Engineers - Louisville
Dave Brancato	Corps of Engineers - Louisville
Rick Hockett	Corps of Engineers - Louisville
John Jent	Corps of Engineers - Louisville
Paul Zorko	Corps of Engineers - Louisville

2 Ray McDaniel
Started at the RVAAP in 1942 and worked there until 1984, but was in the navy from 1943 to 1945.
Was President of APCO (Atlas Powder Company) Conservation Club for many years.
Was involved in many renovation projects, including the Boy Scout Pond.
Was a foreman of engineering.
Charlene McDaniel (Wife of Ray McDaniel) - Worked at RVAAP and was secretary of the APCO Conservation Club for many years until her retirement.
Ray and Charlene established a scholarship fund of which Tim Morgan was the first recipient.
Ray and Charlene are still very active in the APCO Fish and Wildlife Conservation Club.
The Natural Resources Program dates to a large competitive archery program from which 15 % of proceeds went into the scholarship program.
The scholarship program has a current endowment of about $66,000.

3 LTC Tom Tadsen asked Jeff Lock - What do you know about the Mustard Agent locations ?

4 Jeff Lock
Had been in the army from 1966 – 1969.
After discharge from the army he worked at RVAAP at the east side "round house".
Said that in 1969 a government agency shipped mustard agent across country. - Mr. Lock believed it was secret program. He said the shipment experienced a train derailment, and that was the only way the public knew about it.
His dad, Henry Lock, also worked at the RVAAP.
At that time, the only communications were by radios that had a relatively short range.
One day when Jeff was at the round house, his dad signed off indicating he was also at the round house, but with a real weak signal- (WHICH INDICATED THAT HIS DAD WAS NOT CLOSE BY).
Jeff later told his dad that he didn't believe he had signed off near the round house, and asked his dad what had really happened, and where he was when he signed off.

His dad said he couldn't tell him. Jeff threatened to go to the press if Henry didn't tell him where he was, and what happened.
Henry said that mustard gas containers were buried previously, and they were sent out to dig them up and check on the integrity of the containers.
Henry told him he was informed that the information was classified, and he could never discuss it with anyone.
He said further that Henry told him where they were buried, but that he couldn't check the integrity of all of them, because part of the burial site was now covered by the National Advisory Committee for Aeronautics (NACA) concrete runway.

Tim Morgan - Asked Jeff where was the train derailment you mentioned ?
Jeff Lock- Out west somewhere.. The derailment was reported in newspapers, and he recalled that it occurred during warm weather.

5 Ray McDaniel
When re-doing Water Works 3, they were deciding whether to put in a feed line to Kirwan Reservoir or dam Hinckley Creek where it exits the installation and flood the upstream impounded area to get additional water.
Somebody ask him if he knew where the mustard agent was buried.
He told them that to the best of his knowledge, it was about 1000' west of Hinkley Creek, inside an area fenced with chain link and railroad ties used as fence posts, and totally overgrown with vegetation in side of the fence – while deer ate up vegetation around the outside of the fence.
Railroad ties were also present at Hinckley Creek to facilitate crossing the creek.
He took the Corps of Engineers project personnel to the site.
The decision was made to take the feed line to Kirwan Reservoir, rather than flood Hinckley Creek.
The Kirwan Reservoir feed line was constructed, but never used.

6 LTC Tom Tadsen - Asked if Ray McDaniel could be more definitive about the mustard agent location.
Ray McDaniel - Said it was near the west end of NACA, across Hinkley Creek.
There was a bridge made of railroad ties across Hinckley Creek to access the site.

Eileen Mohr- Asked Ray McDaniel how big the area was.
Ray McDaniel – Said the entire site was less than 100' square.

He said the last time he visited the site, there was log across Hinkley Creek.
He also said the site was about 1000 yards from the end of the NACA runway, and was not a big area.

Tim Morgan - Asked Ray McDaniel if the location was along the old power line right-of-way.
Ray McDaniel said No- It was in the area where he used to hunt deer, known as Barney's (cattle grazing) lease.

LTC Tom Tadsen- Asked what was the time frame of that mustard agent burial ?
Ray McDaniel – Said he thought it occurred while he was away during WW II, not in late 1940's. He added that Open Demolition Area #1 was not active during WW II.

LTC Tom Tadsen - Noted that the originally fenced area is the current site designated RVAAP-28.

Tim Morgan – Asked if Ray McDaniel had any idea of the quantity of mustard agent.
Ray McDaniel- Said he doesn't know, but doesn't suspect that it was very much.

7 Irv Venger- Asked Ray McDaniel if he any idea what was involved [redacted]
Ray McDaniel responded no.
About the same time they were cleaning out the Water Works 3, they took out many 155 mm shrapnel artillery projectiles, metallic debris, ball bearings (shrapnel), grape shot shells (unloaded) from WW I, etc.
They cleaned out the existing pond and turned it into three ponds to treat spent brine solution from water treatment.

8 LTC Tom Tadsen tasked Jeff Lock- What time frame did his dad work there (at RVAAP) ?
Jeff- Said his dad worked from early on- in 1940's, then was activated for service during WW II.

9 Eileen Mohr - Asked Ray McDaniel if the WW3 ponds were cleaned well.
Ray McDaniel - Said they cleaned out the pond pretty well. It looked like they got most of the material out, but wasn't sure.
The APCO stocked the ponds with fish, and did surveys of the ponds with a guy from Princeton, IN.
They certified that the water was good, and had good strong springs in the south pond, 12 – 16 ' deep.
He said the center pond is very shallow.
He also said the north pond is the only pond that ever received spent brine solution from the WW3.

10 LTC Tom Tadsen – Asked Jeff Lock when he had worked at the arsenal.
Jeff Lock – Said from1965 as summer help at the Winklepeck Burning Ground- then (except for a stint in the Army- came back in Feb 1969) to the end of 1969 full time.
He worked at the east round house and left in late 1970 or 71 to attend Kent State.
Jeff said he had been raised until 8 on the Portage Ordnance Depot side of the arsenal, on old Rt 80, near the Bolton farm.

Dave Brancato- Asked Jeff Lock if he could clarify when radio signal was faint, why he noted it.
Jeff Lock - Said the radios had a very short range, and he knew that he was getting the signal from far away from the east round house, even though his dad indicated he was close to the round house.

11 LTC Tom Tadsen – Asked Ray McDaniel what kind of digging equipment the Arsenal had that could dig a hole deep enough to investigate for the mustard agent containers.
Ray McDaniel- Said that the Arsenal had clam shells, but doesn't really remember.

LTC Tom Tadsen- Had asked Ray McDaniel about equipment because he was trying to determine how deep the containers might have been buried.
Ray McDaniel- Said by 1969, he would think that if any containers were excavated, they would only find rust, and perhaps some minor breakdown chemicals.
He said that any container would have rusted, and the chemicals leached out by then.
He could see at the time, how if they flooded the area (instead of the Kirwan feed line) there could have been a problem, because it would have flooded a large area, including the alleged mustard agent burial site.

12 LTC Tom Tadsen - Asked Ray McDaniel when they were considering building the large pond.
Ray McDaniel- Said they had two proposals, a 500 acre lake or put in pipeline to Kirwan Reservoir.
After they started, the environmental people complained about trees and land that might be destroyed or torn up etc, and forced them to bury the lines.
WW3 was the baby of COL Girard, who was in charge at the time.

LTC Tom Tadsen- Asked Ray McDaniel if that was that mid to late 70's
Ray McDaniel - Yes, it was during the late 70's.

Tim Morgan- Says he has seen plans for the 500 acre lake, and also plans for a golf course.
Ray McDaniel - Said the Bolton Barn was used as office, the Portage Ordnance Depot (POD) had upgraded it for $250,000.
He remembers transferring liquor from the Colonel's house to the Bolton Barn.

13 Irv Venger - Asked Jeff Lock what Henry Lock's job was.
Jeff Lock - Said his dad was a fork lift driver, truck driver, supervisor of the railroad track crew, and supervisor of truck repair.
Ray McDaniel said Jeff's dad worked in Roads and Grounds.

14 Irv Venger - Said that if there had been a derailment, EOD (explosives ordnance disposal) people would been called out.
He said there should be a record of the accident with the Army's Technical Escort Unit (TEU).

Jeff Lock - Said it could have involved mustard agent or something else, and that if it was something clandestine, it would be sneaky.

15 Ray McDaniel - Said the Bolton Barn was the headquarters of the Portage Ordnance Depot.
He also said he served as a security guard there.
He remembers heavily armed escorts every week when they went to pick up the cash payroll.
He said the ROD had a lumber yard, and he did much work there.
He said the railroad yard at the west end (POD) was only for shipping materials out.

16 Irv Venger- Asked Jeff Lock if he had any feel for any location on or under the NACA concrete runway.
Jeff Lock – Said he doesn't know, but suspects it would be at one end.

17 Ray McDaniel - Related a funny story about the NACA people who would stay there overnight in campers. Ray had hunted raccoons in the same area one night. They were close to the trailers, shot about 10 raccoons, got into his car, and drove up South Patrol Road to Greenleaf, where he was greeted by two patrol cars that were checking on the shooting.

18 Paul Zorko - Asked Jeff Lock if having worked at the round house, he had heard any mention of buried munitions or underground storage tanks at the round house.
Jeff Lock - Said no.

19 Ray McDaniel asked whatever happened to the asbestos in the tanks at the tank farm ?
Irv Venger - Said the Army sold the material and removed the tanks.

20 LTC Tom Tadsen- Asked Ray McDaniel if he knew when the NACA runway was built.
Ray McDaniel - Said he thought in the early 40's, but at that time he wasn't involved in those activities at all.
Paul Zorko- Said the Corps will look into when construction of NACA facilities took place.
John Jent – Said that the NACA facilities clearly show up on the 1951 aerial photographs.

21 Paul Zorko asked if any NACA personnel would have flown in and out ?
LTC Tom Tadsen- They would have flown in and out in support aircraft.

22 John Jent said that in 1978 the Army was doing environmental assessments of the installations.
A suspected "Mustard Agent Burial Site" was reported and so was included as one of the environmental sites.
He said he had called Huntsville U.S. Army UXO Center of Expertise in late 90's and got much information from them.

23 Paul Zorko: Concerning the recent Archive Search Report, he contacted the Army Chemical Corps historian @ Aberdeen Proving Ground, MD.
The historian provided a bill of lading indicating that one railcar load of mustard went from RVAAP to the Bluegrass Army Depot (BGAD) in 1943, escorted by an Army TEU (Technical Escort Unit).

24 LTC Tom Tadsen: Noted that RVAAP has an isolation track. This track could have been used for safe haven (overnight secure storage of loaded railcars of explosives or chemical agents traveling cross-country) of a mustard agent shipment. The bill of lading itself does not indicate that there was any long-term storage of mustard agent at RVAAP.
Ray McDaniel concurred. He said that safe haven was very common, and that it could have been an overnight stop for a train with mustard agent.
LTC Tom Tadsen – Asked the Corps to check to see if BGAD has a receiving document for the 1943 shipment.
Jeff Lock – Said he thought the material (mustard agent) was probably secretly buried and not removed off from the site.

25 Tim Morgan- Asked Ray McDaniel if he could indicate on an aerial photograph the approximate location of the suspected mustard agent burial site.
Ray McDaniel looked the aerial photograph over and fingered the exact location adjacent to the old NACA power line that is thought to be the site.

After a short break, the group drove to the west end of the NACA runway.

LTC Tom Tadsen took Jeff Lock, Sarah Lock, and Ray McDaniel to the west end of the NACA runway and showed them the 1969 investigation pit where a rusty 55-gallow drum and 7 rusty cans were removed in 1969.

After some discussion, LTC Tom Tadsen and Jeff Lock agreed that a limited geophysical investigation from that pit to the west end of the NACA runway would be beneficial.

Jeff Lock stressed that the Army might want to reiterate to the public that the containers were metal and that in all probability, they rusted out years ago.

LTC Tom Tadsen mentioned that, even if the containers had rusted out, the magnetometer tests would pick up the residual iron oxide. If the burial site extended beneath the west end of the concrete runway, the magnetic trail would lead us there.

DESCRIPTION OF CHEMICAL AGENT IDENTIFICATION SETS

ATTACHMENT 4

APPENDIX 1

DESCRIPTION OF CHEMICAL AGENT IDENTIFICATION SET TYPES

4-1-1 BACKGROUND SUMMARY

Chemical agent identification sets (CAIS) were developed and manufactured by the Department of the Army (DA) from the 1930s through the 1960s. Approximately 110,000 sets were manufactured. They were distributed to the Department of Defense (DoD) installations for use by all services in training for identifying the various chemical agents that may be encountered on a battlefield.

In April 1971, the DA declared the CAIS obsolete. In 1978 and 1980, two consolidation efforts were completed to gather existing CAIS that were not expended during training and were still in storage at various DoD installations. The consolidation was accomplished at Rocky Mountain Arsenal, Denver, Colorado. All CAIS located at Rocky Mountain Arsenal were destroyed in the CAIS disposal program. A total of 21,458 CAISs were destroyed in the pilot test program in 1979 and during the actual CAIS disposal program from May 1981 through December 1982. However, not all CAIS were accounted for. To date, some unaccounted CAIS have been discovered at isolated storage locations. Periodically, CAIS will continue to be found in this manner, and will need to be destroyed.

4-1-2 CLASSIFICATIONS OF CHEMICAL AGENT IDENTIFICATION SETS

The 17 different sets of CAIS have been classified by both variety and type or Department of Defense Identification Code (DODIC) number groupings. The following paragraphs explain these various classification systems. One type of CAIS, the K945, which was the only set to have contained the nerve agent GB, was completely accounted for and destroyed at RMA by incineration. The K945 kits were produced in very limited quantities and issued to only a few locations. The K945 CAIS were never used for training purposes. Since no K945 CAIS are believed to have survived, they are not addressed in this attachment.

4-1-2.1 Variety

CAIS has been classified into three varieties, as described in the following paragraphs.

a. *Sniff Set.* One major variety of CAIS was an instructional sniff set that contained agents and industrial chemicals impregnated on charcoal. The set was intended for use indoors to instruct military personnel in recognizing the odors of the agents. These sets contained only small amounts of agent.

b. *Sealed Pyrex™ Tubes.* A second variety, designed for use outdoors, consisted of

agents and industrial chemicals (pure, also known as neat, or in chloroform solution) in sealed Pyrex™ tubes. These glass ampules would be detonated, creating an agent cloud. Soldiers would then try to identify the agent based on its odor and other characteristics. These sets typically contained more total agent than the instructional sniff sets.

c. *Bulk Mustard.* A third variety were those containing larger quantities of mustard. These CAIS were used in decontamination training by purposely contaminating the terrain or equipment with mustard and then teaching the soldiers how to don protective clothing and decontaminate the area or equipment. These CAIS contained relatively large quantities of pure mustard relative to both the sniff sets and sealed Pyrex™ tubes.

4-1-2.2 Type or Department of Defense Identification Code Groupings

CAIS has been grouped into seven types or DODIC groupings. Six types are shown as follows. The seventh was the K945 training set, M72, which has been accounted for completely.

a. K941 - toxic gas set, M1
b. K942 - toxic gas set, M2
c. K951 and K952 - identification sets, M1
d. K953 and K954 - Identification sets, AN-M1A1
e. K955 - Navy training set
f. X302 and X545 through X552 - replacement sets

4-1-3 SUMMARY OF CHEMICAL AGENT IDENTIFICATION SETS

Tables 4-1-1 and 4-1-2 summarize the various CAIS. Table 4-1-1 addresses the classification and packaging, and Table 4-1-2 provides a summary of CAIS chemical agents and industrial chemicals and their applicable state and Resource Conservation and Recovery Act (RCRA) waste codes.

4-1-4 DETAILED DESCRIPTION OF CHEMICAL AGENT IDENTIFICATION SETS

4-1-4.1 Set K941 - Toxic Gas Set, M1 (Figure 4-1-1)

a. *Old stock number:* FSN 1365-219-8574

b. *Timeframe of use:* World War II (WWII) to late 1950s

Table 4-1-1. Summary of Chemical Agent Identification Sets Classifications and Original Packaging

CAIS DODIC	Types(Nomenclature, Model)	Varieties	Outer Container	Agent Container, (Number of Containers)	Containers per Packaging
K941	Toxic gas set, M1	Bulk mustard	PIG	Bottle (24)	4 bottles per pressure sealed can[a] with 6 pressure sealed cans[a] per PIG
K942	Toxic gas set, M2	Bulk mustard	Drum	Heat-sealed bottle (28)	1 heat-sealed bottle per pressure sealed can[a] with 28 pressure sealed cans[a] per drum
K951,K952	Identification set, M1	Sealed Pyrex™ tubes	PIG	Ampule (48)	12 ampules per press-fit can[b] with 4 press-fit cans[b] per PIG
K953, K954	Identification set, AN-M1A1	Sealed Pyrex™ tubes	PIG	Ampule (48)	12 ampules per press-fit can[b] with 4 press-fit cans[b] per PIG
K955	Navy Identification set	Sniff set	Wooden box	Bottle (7)	1 bottle per sealed can[c] with 7 sealed cans[c] per box
X302, X545 through 552	Navy Replacement set	Sniff sets	Wooden box	Bottle (2)	1 bottle per sealed can[c] with 2 sealed cans[c] per box

Notes:

[a] coffee-can-type key
[b] cookie can lid
[c] paint can lid

Table 4-1-2. Summary of Chemical Agent Identification Sets DODIC's and the Chemical Agents/Industrial Chemicals Contents

Chemical Agents/ Industrial Chemicals	N	CC			CHLOROFORM				CC	N		N	SOLIDS		
	H[a]	(H)[a]	(HN)	(L)	H[a] 5%	HN 10%	L 5%	PS 50%	(PS)	CK	GA Sim	CG	CG Sim	CN	DM
Department of Defense Identification Codes (DODIC)	D004-D011, D022, D028, D043; P999	D004-D011, D022, D028, D043; P999	D004-D011, D022, D028, D043; P999	D004-D011, D022, D028, D043; P999	D004-D011, D022, D028, D043; P999	D004-D011, D022, D028, D043; P999	D004-D011, D022, D028, D043; P999			P033		P095			
K941(24)	B_{24}														
K942(28)	B_{28}														
K951/2(46)					A_{12}		A_{12}	A_{12}				A_{12}			
K953/4(48)					A_8	A_8	A_8			A_8	A_8	A_8			
K955(7)		$(B)_2$		(B)					(B)				B	B	B
X302(2)			$(B)_2$												
X545(2)													B_2		
X546(2)														B_2	
X547(2)		$(B)_2$													
X548(2)				$(B)_2$											
X549(2)															B_2
X550(2)			$(B)_2$												
X551(2)			$(B)_2$												
X552(2)									$(B)_2$						

[----------Chemical Agents to be Neutralized ----------] [---------- Industrial Chemicals to be Repackaged ----------]

Note:
[a] H = H/HS/HD

KEY: $B_{\#}$=Bottle$_{\text{Number of}}$ $A_{\#}$=Ampule$_{\text{Number of}}$ (B)=Bottle with Charcoal A=Ampule with Chloroform

N = Neat CC = Charcoal

c. *Chemical agents and amounts:* Twenty-four bottles, each containing approximately 103 milliliters (ml) of sulfur mustard (H/HS/HD) or distilled mustard (HD) for a total of 2.5 liters per set.

d. *Packaging:*

1. *Bottle:* Twenty-four round, glass, 4-ounce bottles, each with a small plastic screw top. Heat-resistant paint on the bottles indicates "H" or "HD", "TOXIC GAS SET, M1".

2. *Can:* Four bottles are packed in 0.5-inch layers of sawdust within a pressure sealed metal can. The round cans are 5.5 inches in diameter and 6.25 inches high. Each can has a coffee-can-type key on the bottom for opening.

3. *PIG:* Six metal cans are packed into a steel shipping cylinder known as a PIG. The PIG is 6.625 inches in diameter, approximately 40 inches long, and 0.145 inches thick. The open end of the PIG is closed by a flange end-cover called a flange blank. The flange blank is 9.25 inches in diameter and is secured by eight bolts tightened over a 0.125-inch-thick lead gasket. The empty PIG weighs approximately 80 pounds.

4-1-4.2 Set K942 - Toxic Gas Set, M2 (Figure 4-1-2)

a. *Old stock number:* FSN 1365-563-4146

b. *Timeframe of use:* Korean War era

c. *Chemical agents and amounts:* Twenty-eight bottles, each containing approximately 118 mL of mustard (H, HD, or HS) for a total of 3.3 liters per set.

d. *Packaging:*

1. *Bottle:* Twenty-eight round, glass bottles are heat-sealed at one end. Reference is made to this glass container as an ampule; however, it is more similar to a bottle. It is 1.875 inches in diameter and 4.625 inches high.

2. *Can:* Each bottle has its own metal can. The round metal can is 2.68 inches in diameter and 6.34 inches high. Each can has a coffee-can-type key on the bottom for opening.

3. *Drum:* Twenty-eight cans are packed in a cold-rolled carbon steel drum. The drum is 14 inches in diameter, 14 inches high, and 0.0375 inches thick (20 gauge). There are two layers of cans (14 cans per layer). The cans are separated into individual compartments by fiberboard packaging.

Note: Some of CAIS K942 were repackaged into press-fit cans (as found in the K951). There were two bottles per can with vermiculite or sawdust used as a

packing material. Four cans were packaged into a PIG (like the K941 PIG).

4-1-4.3 Set K951 - War Gas Identification Set, Detonation, M1; and Set K952 - War Gas Identification Set, Instructional, M1 (Figure 4-1-3)

a. *Old stock number:* FSN 1365-025-3273 (K951), FSN 1365-025-3783 (K952)

b. *Timeframe of use:* Early 1930s to late 1950s

c. *Chemical agents and amounts:* Forty-eight glass ampules, of which there are 12 ampules each of 4 different chemical agents/industrial chemicals. Sulfur mustard and lewisite (L) chemical agent ampules contain approximately 40 mL of solution (chemical agent in chloroform) for a total of 960 mL of solution with chemical agent per set, or 48 mL of chemical agent per set.

1. Twelve ampules of 5-percent sulfur mustard in chloroform, each with 2 mL sulfur mustard in 38 mL chloroform for a total of 24 mL sulfur mustard and 456 mL chloroform.

2. Twelve ampules of 5-percent L in chloroform, each with 2 mL L in 38 mL chloroform for a total of 24 mL L and 456 mL chloroform.

3. Twelve ampules of 50-percent PS in chloroform, each with 20 mL PS in 20 mL chloroform for a total of 240 mL PS and 240 mL chloroform.

4. Twelve ampules of neat CG, not in chloroform, each with 40 mL CG for a total of 480 mL CG.

d. *Packaging:*

1. *Ampule:* Each ampule is made of Pyrex™ and is hermetically sealed. The ampule is 1 inch in diameter and 7.5 inches long.

2. *Cardboard Tube:* Each ampule is packed in a cardboard container (mailing-tube type) with a metal screw-cap top. Each tube has the agent type indicated by agent symbol on the cardboard container.

3. *Can:* Twelve cardboard containers, each packaged into a press-fit metal can. The can is 5.5 inches in diameter and 9.25 inches high. Originally, three ampules of each of the four chemical agent/industrial chemicals were packaged in each can.

4. *PIG:* Four cans are packed into a steel cylinder known as a PIG. The PIG is 6.625 inches in diameter, approximately 40 inches long, and 0.145 inches thick. The open end of the cylinder is closed by a flange end-cover called a flange blank. The flange blank is 9.25 inches in diameter and is secured by eight bolts tightened over a 0.125 inch-thick lead gasket. The empty PIG weighs approximately 80 pounds.

Note: The only difference between the K951 and K952 sets is that the K951 was issued with blasting caps that were packed and shipped in a separate container. The blasting cap container is not processed by the Rapid Response System.

4-1-4.4 Set K953 - War Gas Identification Set, Detonation, AN-M1A1 and Set K954 - War Gas Identification Set, Instructional, AN-M1A1 (Figure 4-1-3)

a. *Old stock number:* FSN 1365-323-7728 (K953), FSN 1365-338-0735 (K954)

b. *Timeframe of use:* Korean War era

c. *Chemical agents and amounts:* Forty-eight glass ampules of which there are eight ampules each of six different chemical agents/industrial chemicals. Distilled mustard (HD), nitrogen mustard (HN-1) and lewisite (L) agent ampules containing approximately 40 mL of solution (chemical agent in chloroform). This is a total of 960 mL of solution with agent, per set or 64 mL of chemical agent per set.

1. Eight ampules of 5-percent HD in chloroform, each with 2 mL HD in 38 mL chloroform for a total of 16 mL HD and 304 mL chloroform.

2. Eight ampules of 10-percent HN-1 in chloroform, each with 4 mL HN-1 in 36 ml chloroform for a total of 32 mL of HN-1 and 288 mL chloroform.

3. Eight ampules of 5-percent L in chloroform, each with 2 mL L in 38 mL chloroform for a total of 16 mL L and 304 mL chloroform.

4. Eight ampules of neat CG for a total of 320 mL.

5. Eight ampules of neat CK for a total of 320 mL.

6. Eight ampules of GA simulant (mixture of ethyl malonate, oenanthic ether, and benzonitrile) for a total of 320 mL.

d. *Packaging:* These sets are packed in ampules, cans, and PIG containers similar to the K951 and K952 as explained in paragraph C-4.3 d., one difference being that originally just two ampules of each of the six chemical agent/industrial chemicals were packaged in each can.

Note: The only difference between the K953 and K954 sets is that the K953 was issued with blasting caps that were packed and shipped in a separate container. The blasting cap container is not processed by the Rapid Response System.

4-1-4.5 Set K955 - Set, Gas Identification, Instructional, M1 (Navy) (Figure 4-1-4)

a. *Old stock number:* FSN 1365-368-6154

b. *Timeframe of use:* Late 1930s to WWII

c. *Chemical agents and amounts:* Seven glass bottles with three chemical agent bottles, each containing 25 mL of chemical agent, for a total of 75 mL of chemical agent per set. Four of the bottles each contain 3 ounces (90cc) of activated charcoal on which chemical agent/industrial chemical is absorbed (described as follows).

1. Two bottles of sulfur mustard absorbed on charcoal - 25 mL of sulfur mustard each or 50 mL total.

2. One bottle of L absorbed on charcoal - 25 mL of L.

3. One bottle of PS absorbed on charcoal - 25 mL of PS.

4. One bottle of Triphosgene (CG simulant) - 3 grams of solid.

5. One bottle of CN - 15 grams of solid.

6. One bottle of DM - 15 grams of solid.

d. *Packaging:*

1. *Bottle:* The seven, round, glass bottles are 4-ounce bottles with a ground-glass stopper that is usually coated (sealed). As previously noted, the bottles frequently contain charcoal.

2. *Can:* Each bottle has its own green metal can. The sealed cans are 4.25 inches in diameter and 6.75 inches high. They have a paint-can-type lid that is sealed.

3. *Box:* The box is a hinged-cover wooden box that resembles a foot locker and measures 30.375 inches long, 15.5 inches wide, and 11.75 inches high. The inside of the box is divided into eight sections. Seven of the sections contain sealed metal cans in sawdust, and the eighth has instructions.

4-1-4.6 Set X302 - Replacement Set, Gas Identification, Instructional (Navy) (Figure 4-1-5)

a. *Old stock number:* FSN 1365-038-5183

b. *Timeframe of use:* WWII to Korean War era

c. *Chemical agents and amounts:* Two bottles each contain 3 ounces (90cc) of activated charcoal on which 25 mL of chemical agent is absorbed (described as follows). This is a total of approximately 50 mL of chemical agent per set.

1. One bottle of HN-1 absorbed on charcoal - 25 mL.

2. One bottle of HN-3 absorbed on charcoal - 25 mL.

d. *Packaging:*

1. *Bottle:* Each bottle is a 4-ounce round bottle with a ground-glass stopper that is usually wax coated.

2. *Can:* Each bottle has its own metal can. The cans are 4.25 inches in diameter and 6.75 inches high, with a paint-can-type lid that is sealed. One bottle is packed with sawdust in the can.

3. *Box:* The wooden box has a hinged cover and measures 7.5 inches wide, 16 inches long, and 11.75 inches high. The box is divided into two sections. Each section contains a can with a bottle that is surrounded by packing material.

4-1-4.7 Sets X545 Through X552 - Replacement Sets (Navy) (Figure 4-1-5)

The following eight types of replacement sets were used by the Navy to replace components of the K955 and X302 sets. The replacement sets X545 through X552 contain two bottles with each bottle having either approximately 25 mL of chemical agent/industrial chemical absorbed on activated charcoal, or a solid industrial chemical as outlined below. They were packaged in the same manner as the X302 (paragraph 4-1-4.6).

a. X545 - triphosgene, CG simulant, (no charcoal)
- 6 grams of solid per set
- old FSN 1365-608-5322

b. X546 - CN (no charcoal)
- 30 grams of solid per set
- old FSN 1365-608-5323

c. X547 - H/HS/HD absorbed on charcoal
- 50 mL per set
- old FSN 1365-608-5324

d. X548 - L absorbed on charcoal
- 50 mL per set
- old FSN 1365-608-5325

e. X549 - DM (no charcoal)
- 30 grams of solid per set
- old FSN 1365-608-5326

f. X550 - HN-1 absorbed on charcoal
- 50 mL per set
- old FSN 1365-608-5327

g. X551 - HN-3 absorbed on charcoal
- 50 mL per set
- old FSN 1365-608-5328

h. X552 - PS absorbed on charcoal
- 50 mL per set
- old FSN 1365-608-5328

COMMENT/RESPONSE TABLES

REPORT ON THE GEOPHYSICAL INVESTIGATION
SUSPECTED MUSTARD AGENT BURIAL SITE
RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO
COMMENT RESPONSE TABLE

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
USACE (K. Krantz)					
U-1	2, 1.2			Remove the bolded text	Agreed.
U-2	Figures			Be sure they are in order. Figure 2 was before figure 1.	This sequencing error will be corrected.
U-3	8, 2.1			I believe the figure referenced should be Figure 3.	Agreed.
U-4	11, 3.1			1st sentence, add a space after "and" in ".....Figures 4 and5".	Agreed.
U-5	14, 3.2			2nd paragraph, the next to the last sentence needs editing. It should say something like "..... it appears that a number of specific geologic models....."	The sentence will be revised as follows: *…it appears that a number of specific geologic models…*
USACE (R. Hockett)					
	1, 1.1, 7th line in 1st paragraph			Replace “are presumably” with “could potentially be”	Agreed.
U-6	8, section 2.2, 4th and 6th lines in 1st paragraph			Use consistent presentation of “Limited”	Ltd. Will be used consistently.
U-7	9, Section 2.3			Add a brief discussion of site clearing activities, OHARNG coordination, and any other pre-geophysical work you think is notable	The following text will be included in Section 2.3: *Prior to implementing the Geophysical study the area was staked out using GPS coordinates based on the area identified in the Work Plan. EQM met with OHARNG personnel at the study area prior to initiating any field clearing activities to identify particular areas of concern. The study area was mowed using a tractor pulled rotary mower (bush-hog) to the extent possible given the terrain and vegetation. Vegetation of less than approximately 2” in diameter was removed prior to the survey. Hand tools (chainsaws) were also used to clear the*

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
					area. The area of standing water in the middle of the study area was not disturbed. *The area of investigation was also cleared of surface objects, (i.e., metallic objects), which would impede data collection.*
U-8	Somewhere in doc			Add a statement that the work was done in accordance with the approved Work Plan	The following sentence will be added to Section 2: *All records review and field work activities were conducted in accordance with the approved Work Plan.*
U-9	9, Section 2.3,			Replace "mustard agent test kits." with "metallic objects."	Agreed.
U-10	10			Explain why GPR didn't discriminate. That discussion is in the conclusions, and should be here also.	The following text will be added to Section 2.3: *Due to the conductive clayey soils and rough terrain, the quality of the GPR data was not able to discriminate between targets of interest and native anomalies. The conductive soils at the site greatly attenuated the radar signal and limited the depth of penetration to the upper two meters (six feet) of the subsurface. Also, the extremely rough terrain made it difficult for the instrument to accurately detect reflections from subsurface objects due to surface scattering and scattering from shallow native objects such as tree roots. This made it impossible to differentiate between targets of interest and native objects in the study area.*
U-11	11, 2nd paragraph	2nd paragraph.		I don't understand the second to last sentence: '…there are no EM conductivity anomalies corresponding to these areas…". But the first sentence on the page suggests that the EM-61 reveals the presence of a wide range of conductive objects. Seems contradictory.	The last 2 sentences of Section 3.1 will be deleted and the following text inserted: *The EM-61 is a very sensitive instrument that is capable of detecting a wide range of metallic objects, ranging from nails and screws to buried drums and tanks. While the instruments used to collect terrain conductivity data of the site (the GEM-2*

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
					and EM-31), are capable of detecting metallic objects, they are designed to detect minute conductivity variations in the soil, and usually only detect metallic objects large enough to affect the conductivity value of a unit volume of soil. Thus, the fact that the GEM-2 and EM-31 did not detect the smaller EM-61 anomalies, implies that those anomalies are small, shallow, and singular metallic objects not related to the targets of interest.
U-12	Figure 4			Add EM units to legend	Agreed.
U-13	14, 2nd paragraph, 15th line			Add "that" between "models" and "could"	See response to Comment No. U-5.
U-14	14, 2nd paragraph, 16th line			Delete "in reality"	Agreed
U-15	14, End of second paragraph			Offer an explanation as to why the conductivity variations are thought to be variations in types of subsurface materials rather than the other possible explanations.	The last sentence in this paragraph will be revised to read: *As a result, the variations in apparent conductivity at the study area are likely to be attributed primarily to variations in the types of subsurface materials, and to a lesser degree to changes in groundwater or soil chemistry, since the apparent conductivity pattern distribution over the area does not indicate one that results from chemical impacts in a groundwater system being transported away from the source area.*
U-16	18, 2nd line on page			Add "or excavated soil from the previous mustard agent investigation." to the end of the sentence.	Agreed.
U-17	Throughout document			Draft docs should have line numbers.	Agreed. Line numbers were inadvertently omitted from the report.
ARMY (I. Venger)					

REPORT ON THE GEOPHYSICAL INVESTIGATION
SUSPECTED MUSTARD AGENT BURIAL SITE
RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO
COMMENT RESPONSE TABLE

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
A-1	General		No line numbers throughout.	Insert line numbers for all drafts reports.	Agreed. Line numbers were inadvertently omitted from the report.
A-2	Distribution Page		Do not use vernacular.	Substitute Printed Copy for Hard Copy.	Agreed
A-3	Before Page 1		Include an Executive Summary..2 or 3 sentences.	Sentence 1 of 1.1 and 2 or 3 sentences from the conclusions should do it.	The following text will be added as an Executive Summary: *The objective of the project was to determine if mustard agent test kits had been buried in an approximate one acre area located on the western portion of the Ravenna Army Ammunition Plant (RVAAP) in Ravenna, Ohio. The electromagnetic metal detection (EMD) and electromagnetic (EM) conductivity maps indicate that buried metallic objects are found within the study area. Based on the historical information presented by former RVAAP employees, there is a reasonable possibility that these metallic objects may be mustard agent test kits. The EMD and EM conductivity maps indicate that buried metallic objects are found within the study area. Based on the historical information presented by former RVAAP employees there is a reasonable possibility that these metallic objects may be mustard agent test kits.*
A-4	Appendix or Attachment		Use tabs to identify sections		Agreed - colored labeled sheets will be used to identify sections within the attachment.
A-5	Pg 21		I would like to see Section 4 inserted immediately after the statement of purpose Sect. 1.1.		EQM feels that it may be confusing to the reader to introduce the conclusions from the study before discussing the results. The inclusion of an executive summary summarizing the conclusions introduces the results of the study for the reader.
A-6	1.1		Sentence 2 seems redundant.	Change to read: "The suspected area, as reported by a former RVAAP employee, is	Agreed

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
				located adjacent to the NACA test strip."	
A-7	1.1		Include the CAIS acronym in sentence 1.		Agreed
A-8	1.1 last sentence		Change to "The survey will be used by the Army to determine…"		
A-9	1.2 line 2		Delete handling		Agreed.
A-10	2.3 line 1		Change to read	"…collected along grid lines…"	Agreed
A-11	Pg 21		Consider the probability that the metallic hits are steel mill slag as it is common within the installation.	Agreed.	The second sentence in Section 4 will be deleted and the following text inserted: *The metallic response seen on the EM-61 could be due to any type of large metallic object/objects. Based on the historical information presented by former RVAAP employees the large metallic anomalies detected in the survey area, especially those that are trench shaped extending off of the edge of the concrete pad, are interpreted to be possible mustard agent test kits. It should be noted that steel mill slag was commonly used as fill at the installation and could, possibly be the source of the metallic anomalies.*
Ohio EPA					
Ohio EPA (A. Kocher)					
O-1	General		The "Disclaimer Statement" states that that EQM, Inc. and the United States Government do not warrant the accuracy of the contents of this report. This "Disclaimer Statement" implies that the data collected in this report may not be accurate or adequate: therefore the need for further review seems unnecessary. This comment applies to all Disclaimer Statements on all RVAAP documents.	This statement should be removed or modified. The Disclaimer Statement may state that the data collected within the report was collected with best available technology and in accordance with the manufacturer's specifications. The data was also interpreted with the best current knowledge, and current computer modeling programs.	The Disclaimer Statement is now required for all preliminary draft and draft versions of reports under review per the *Ravenna Army Ammunition Plant Delivery Document Formatting Guidelines.* This does not imply that the information is not accurate, rather that the report is under review. The Disclaimer Statement is removed for the final version of the report once all review comments have been resolved.
O-2	Pg. v		The "Abbreviations and Acronyms" list is missing CAIS, DOD, NACA, USP&FO,	Please add these acronyms to this list.	These acronyms will be added to the list.

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
			CSX, GOCO, IRP, and GPS.		
O-3	Section 1.1		The left text alignment of the text is crooked/offset or paragraph indentations are missing.	Please fix.	The text has been reformatted to be fully justified throughout.
O-4	Page 8, Line 13		The word anecdotal is an opinion or adjective that is unnecessary.	Please remove this word.	The word anecdotal will be removed.
O-5	Page 10, Lines 5-7		Please elaborate the processes and methods used in Surfer v.8.0.	Please elaborate on the processes and/or methods (e.g., geostatistical gridding method).	The following text will be added to the second paragraph on Page 10: *Mundell uses the minimum curvature gridding method for Surfer 8.0 when using EM61 and EM31 data rather than krieging. The krieging method tends to create artificial 'bullseyes' in the geophysical data that have been shown from experience not to correlate well with actual anomaly size and geometry. The minimum curvature for a wide range of situations tends to provide a better correlation to object location and extent. The final manner in which to confirm this at this site would be to 'ground truth' the anomalies by further investigation and excavation.*
O-6	General		This report does not include a Section discussing QA/QC.	Please include a Section discussing QA/QC, and the reason why or why not it was performed (e.g., QA/QC plots of the EM-31 and EM-61).	The following text will be added as Section 2.4: *Mundell performs several levels of quality assurance/quality control checking during data collection and processing:* *a. The EM31 instrument is calibrated twice (once at the beginning and once at the end) with the process as outlined in the operations manual; instrument is sensitive to smaller changes in conductivity (1 to 2 millisemens).*

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
					b. Procedures include – 1) checking battery for adequate voltage, 2) checking compensation, and 3) zero (null) the IP and conductivity. *c. A portion of the site not believed to be impacted by subsurface debris, was checked for range of conductivity given (e.g., clayey soils, sandy soils).* *d. The EM61 instrument is much less sensitive to quality problems since it provides a metallic material 'absent/present' kind of reading. The instrument is calibrated on a periodic basis (once a quarter) unless unusual reading ranges are observed.* *e. Both the magnitude of readings as well as reading positioning using GPS system; are checked several times during the survey for accuracy of positioning with known site features, to make sure data locations are consistent. In addition, a GPS file after field collection also shows the quality of the GPS signal based on whether data was collected under any tree canopies or other interferences. This is checked when the data is referenced to site features.* *f. Maps and interpretation of the data are reviewed by a Senior Scientist with 25+ years of experience to check interpretations and whether readings and results are consistent with known materials and site conditions. This is a*

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
					second level of review. *g. If data is shown to be poor during either field data collection or after processing, procedures are in place for nonconformance activities, including selective data point filtering (if found to be in error), or recollection of data until quality level is achieved.*
O-7	Figures 4-10		These figures include the maps created using Surfer v.8.0.	Please add that these maps were created using Surfer v.8.0 and also add the site name "Suspected Mustard Agent Burial Site." In addition (if possible) add the estimated depth of the anomaly and/or the maximum depth of the anomaly.	It would be difficult to add the 'estimated depth of anomaly' or 'maximum depth of anomaly' other than that described in the report. For geophysical investigations it is preferred to have that included only in the report, since it requires the reader to go into the report to for a full explanation of the findings, rather than assuming the figure provides all information. The legend will be revised to include the site name and that the map was created in Surfer v.8.0.
OHARNG (K. Elgin)					
NG-1	Pg 1, Line 8-10		"Based on historical information presented by former RVAAP employees the large metallic anomalies detected in the survey area, especially those that are trench shaped extending off the edge of the concrete pad are interpreted to be possible mustard agent test kits." Here you are implying that based on testimony from former employees, the large metal anomalies are mustard kits. I think what you want to say is that your survey results revealed large metal anomalies that are interpreted as being mustard kits.		

Comment Number	Page or Sheet	New Page or Sheet	Comment	Recommendation	Response
			Suggested Rephrase: "Based on the results of the geophysical survey, the large metallic anomalies detected in the survey area, especially those that are trench shaped extending off the edge of the concrete pad, are interpreted to be possible mustard agent test kits." This also needs change on Page 21, Line 9.		
NG-2	Pg 3 and throughout		Check your paragraph justification throughout the document. You have full justified and left justified. Just pick one and be consistent.		The text has been reformatted to be fully justified throughout.
NG-3	Figure 1 Site Location Map		Put "Cleveland" in the right location on the map and fix the distortion of the map (the northern counties looked misshaped)		The map as presented shows the actual boundary of Cuyahoga County which extends into Lake Erie. Cleveland is actually in the right location. The program EQM uses for maps is unable to remove the county boundaries that extend into Lake Erie. A new map from another source will be found to resolve this issue.
	Pg 9, Line 21		"EQM met with OHARNG personnel at the study area prior to initiating any field clearing activities to identify particular areas of concern." Since "areas of concern" have a different meaning to the restoration team and the public than what is meant here, I would change the end of the sentence to "… to identify any sensitive areas."		

Agreed.