NOVA RESEARCH, INC.
1900 Elkin Street, Suite 230
Alexandria, VA 22308

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Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys

Pueblo Precision Bombing and Pattern Gunnery Range #2

Victorville Precision Bombing Ranges Y and 15

Final Report

Technical Report
submitted in partial fulfillment of
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"Research and Development of Environmental and Sensor Technologies"

PREPARED FOR
THE U.S. NAVAL RESEARCH LABORATORY
4555 OVERLOOK AVE., S.W.
WASHINGTON, D.C. 20375

G.R. Harbaugh
D.A. Steinhurst

N. Khadr, SAIC, Inc.

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G.R. Harbaugh, D.A. Steinhurst, N. Khadr*

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Nova Research, Inc., 1900 Elkin Street, Suite 230, Alexandria, VA 22308
*SAIC, Inc. - ASAD, 1225 South Clark Street, Suite 800, Arlington, VA 22202

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14. ABSTRACT

As part of the ESTCP WAA Pilot Project, Nova Research, Inc. conducted a series of vehicular and man-portable geophysical surveys at the Pueblo Precision Bombing and Pattern Gunnery Range #2 and the Victorville Precision Bombing Ranges Y and 15 WAA demonstration sites. Transect surveys were conducted using the NRL MTADS magnetometer array and a man-portable EM adjunct along planned transects provided by PNNL in cooperation with SNL and the ESTCP Program Office. Approximately 2% of each site was surveyed using transect plans that were based on available archive information to insure that areas of interest matching the design criteria would be sampled with a statistically defensible probability of detection. These data were analyzed to extract anomaly locations and a measure of the anomaly magnitude using an automated anomaly detection methodology. Total coverage surveys were conducted in small areas at each site to provide additional information. In cases where the geology or terrain of the site limited the use of vehicular-towed magnetometer systems, a man-portable EM system was mobilized.

15. SUBJECT TERMS

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Abbreviations Used

Abbreviation	**Definition**
AMTADS	Airborne Multi-sensor Towed Array Detection System
AS	Analytic Signal (nT\m)
ASR	Archives Search Report
ATC	Aberdeen Test Center
BP	Blossom Point
CD-R	Compact Disk - Recordable
COG	course-over-ground
CoC	Certificate of Clearance
CSM	Conceptual Site Model
DAQ	Data Acqusition (System)
DAS	Data Analysis System
DoD	Department of Defense
DSB	Defense Science Board
DVD-R	Writable digital versatile disc
ESTCP	Environmental Security Technology Certification Program
FA	False Alarm
FAR	False Alarm Rate
FFT	Fast Fourier Transform
FUDS	Formerly -Used Defense Site
GPS	Global Positioning System
HASP	Health and Safety Plan
Hz	Hertz
IDA	Institute for Defense Analyses
MRA	Munitions Response Area
MTADS	Multi-sensor Towed Array Detection System
NRL	Naval Research Laboratory
nT	nanoTesla
PBR	Precision Bombing Range
PBR #2	Pueblo Precision Bombing and Pattern Gunnery Range #2
Pd	Probability of Detection
PNNL	Pacific Northwest National Laboratory
POC	Point of Contact
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
ROC	Reciever Operating Characteristic
RTK	Real Time Kinematic
SHERP	Safety, Health, and Emergency Response Plan
SNL	Sandia National Laboratories
SNR	Signal to Noise Ratio
TBD	To Be Determined
UTC	Universial Coordinated Time
UXO	Unexploded Ordnance
VV	Victorville
WAA	Wide Area Assessment
YTC	Yuma Test Center
ZIP (250)	Iomega ZIP disk (250 MB version)

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The P.I. would like to thank several parties who made these demonstrations possible. For the Pueblo, CO site, thanks go to the Russell, Rounds, and Simmons families as land owners / lessees / permit holders of the land involved in the demonstration site and Kurt Staton of the Comanche Nation Grasslands (U.S. Forest Service) for their cooperation and assistance in conducting this demonstration. For the Victorville, CA site, thanks go to Edythe Seehafer and Nathan Skallman from the U.S. Department of the Interior's Bureau of Land Management for their cooperation and assistance in the planning of the Victorville, CA demonstrations.

ABSTRACT

As part of the Environmental Security Technology Certification Program (ESTCP) Wide Area Assessment (WAA) Pilot Project, Nova Research, Inc. has conducted a series of vehicular and man-portable geophysical surveys at demonstration sites within the boundaries of the Pueblo Precision Bombing and Pattern Gunnery Range #2 and the Victorville Precision Bombing Ranges Y and 15, located near La Junta, CO and Victorville, CA, respectively. Transect surveys were conducted using the Naval Research Laboratory (NRL) Multi-sensor Towed Array System (MTADS) and a man-portable EM adjunct. Approximately 2% of each site was surveyed using transect plans that were designed to efficiently sample the entire site while maintaining a statistically defensible probability of traversing areas of interest (AOIs) within the site that matched the criteria developed from the available archive data. Additionally, total coverage surveys were conducted in small areas at each site to provide additional information about the sites. These surveys were conducted a) to characterize background anomaly densities in areas found to have low anomaly density in the transect surveys, b) to characterize the anomaly density falloff behavior as a function of distance from known AOIs within the site, and c) to gather further information on other AOIs as directed by the Program Office. In cases where the geology or terrain of the site limited the use of vehicular-towed magnetometer systems, a man-portable EM systems was demonstrated as a remedy.

Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys

Pueblo Precision Bombing and Pattern Gunnery Range #2

La Junta, CO

Victorville Precision Bombing Ranges Y and 15

Victorville, CA

Final Report

1. Introduction

1.1 Background

The location and cleanup of buried unexploded ordnance (UXO) has been identified as a high priority mission-related environmental requirement of the Department of Defense (DoD). The DoD UXO Response Technology Investment Strategy [1] has identified wide area assessment as one of six technology objectives, with a goal of developing capabilities to perform rapid initial assessment of large areas. The Defense Science Board (DSB) Task Force on UXO (DSB) [2] recently estimated that there are 1,400 sites suspected of containing UXO contamination covering approximately 10 million acres in the continental US. By some estimates, as much as 80% of this acreage is quite likely not contaminated with UXO at all. A suite of technologies that can accurately and rapidly delineate the areas on each site that are contaminated from those that are not contaminated would lead to an immediate payback in terms of reducing the acreage that must be carefully examined and potentially cleaned.

The Environmental Security Technology Certification Program (ESTCP) Wide Area Assessment (WAA) Pilot Program consists of a layered suite of technologies deployed as a proof-of-concept demonstration of the DSB's WAA call-to-action. The prototypical WAA site is a large area (10,000's of acres) that may contain isolated areas of concentrated UXO such as aiming points. The top layer consists of (relatively) high-flying sensors (and aircraft) (e.g. orthorectified photography), designed to detect "munitions-related features" such as target rings and craters. The next layer is a helicopter-borne magnetometer array designed to detect subsurface ferrous metal directly. The magnetometer data can be used to locate and define boundaries for targets, aim points, and OB/OD sites. The final layer is a ground survey of portions of the site using a ground-based sensor arrays. In conjunction with statistical transect planning, the ground survey will aid in defining target locations and boundaries. We have demonstrated two-such final-layer systems using a) a ground-based, towed magnetometer array system and b) a man-portable EM system.

1.2 Objective of the Demonstration

We have demonstrated a suite of data collection and analysis methodologies to support the rapid delineation of UXO contamination within a suspect site. Full-field magnetometer data were collected at two demonstration sites, Pueblo Precision Bombing and Pattern Gunnery Range #2 (Pueblo PBR #2 or Pueblo) and Victorville Precision Bombing Ranges Y & 15 (Victorville PBRs Y&15 or Victorville). Transect plans were developed by Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratories (SNL) in cooperation with the ESTCP Program Office. The transect plans were based on available archive information and designed to allow the efficient sampling of the demonstration sites for AOIs while maintaining a statistically defensible probability of traversing the types of AOIs within the demonstration site that matched the criteria developed from the available archive data and collected in the Conceptual Site Models (CSMs). Anomaly location and a measure of anomaly magnitude were extracted from these data using an automated anomaly detection methodology. This information was provided to PNNL / SNL for analysis to rapidly delineate UXO contamination sites such as impact areas and bombing targets. With the rapid pace of the automated routines, it was possible to interactively plan and execute additional transects to further resolve features of interest while the survey team was still deployed in the field. Due to surface geology and terrain limitations, the entire transect plan at the Victorville demonstration site could not be surveyed with the vehicular towed-array system. To increase the fractional transect survey coverage, additional acreage was surveyed using a man-portable, litter-carried EM61 MkII system.

Total coverage surveys were also conducted in small areas (6 – 90 acres per area) to better characterize the overall site and to support later validation efforts. The goals of the total coverage surveys were a) to characterize background anomaly densities in areas found to be quiet (low anomaly density) in the transect survey results, b) to characterize the falloff behavior of the anomaly density as a function of distance from known AOIs within the demonstration site, and c) to gather further information on AOIs identified either from the transect data or from other sources such as the high airborne results. At the Victorville site, the vehicular total coverage areas in the northern portion of the site were found to have a much higher magnetic anomaly density, ~250 anomalies/acre, than was seen in the southern portion of the site and had been seen previously at other WAA demonstration sites, 80 anomalies/acre or less. Based on site reconnaissance and considering the geology of the area, the high anomaly density was attributed to magnetically active or ‘hot’ rocks. To validate the ‘hot’ rocks assignment of the northern magnetic anomalies, man-portable EMI total coverage surveys were conducted on small subsets (0.75 to 1 acre each) of three Victorville vehicular total coverage areas including one area known to contain munitions-related material as a control and two areas in the northern portion of the site.

2. Technology Description

2.1 Technology Development and Application

2.1.1 Vehicular Magnetometer System

The vehicular portions of the demonstrations were conducted using the Naval Research Laboratory (NRL) Multi-sensor Towed Array Detection System (MTADS). The MTADS was developed with support from ESTCP. The MTADS hardware consists of a low-magnetic-signature vehicle that is used to tow a linear array of eight magnetometer sensors over large areas (25 acres / day) to detect buried UXO, Figure 2-1. The sensors are sampled at 50 Hz and typical surveys are conducted at 6 mph; this results in a sample spacing of ~6 cm along track with a horizontal sensor spacing of 25 cm. Each magnetometer measures the local magnetic field of the Earth at the sensor.

Figure 2-1 – MTADS magnetometer system

The sensor positions are measured in real-time (5 Hz) with position accuracies of ~5 cm using high performance Real Time Kinematic (RTK) Global Positioning System (GPS) receivers. All navigation and sensor data are time-stamped with Universal Coordinated Time (UTC) derived from the satellite clocks and recorded by the data acquisition computer (DAQ) in the tow vehicle. The positioning technology requires the availability of one or more known first-order survey control points[1]. The sensor, position, and timing files are downloaded periodically throughout a survey onto removable media and transferred to the data analyst for analysis.

The GPS positioning information used for data collection is shared with an onboard navigation guidance display and provides real-time navigational information to the operator. The guidance display was originally developed for the airborne adjunct of the MTADS system (AMTADS) [3]

[1] See http://www.ngs.noaa.gov/cgi-bin/ds_lookup.prl?Item=DSDATA.TXT or similar resources for the nomiclature of geodetic control points.

and is installed in the vehicle and available for operator use. Figure 2-2 shows a screenshot of the guidance display configured for vehicular use.

An integral part of the guidance display is the ability to import a series of planned survey lines (or transects) and to guide the operator to follow these transects. The display provides a left-right course correction indicator, an optional altitude indicator for aircraft applications, and color-coded flight swath overlays where the current transect is displayed in red and the other transects are displayed in black for operator reference. The survey course-over-ground (COG) is plotted for the operator in real time on the display. The COG plot is color-coded based on the RTK GPS system status. When fully operational, the COG plot is color-coded green. If the system status is degraded, the COG plot color changes from green to yellow to red (based on severity) to warn the operator and allow for on-the-fly reacquisition of the affected area. Figure 2-2 shows the operator surveying line 30 of a transect plan.

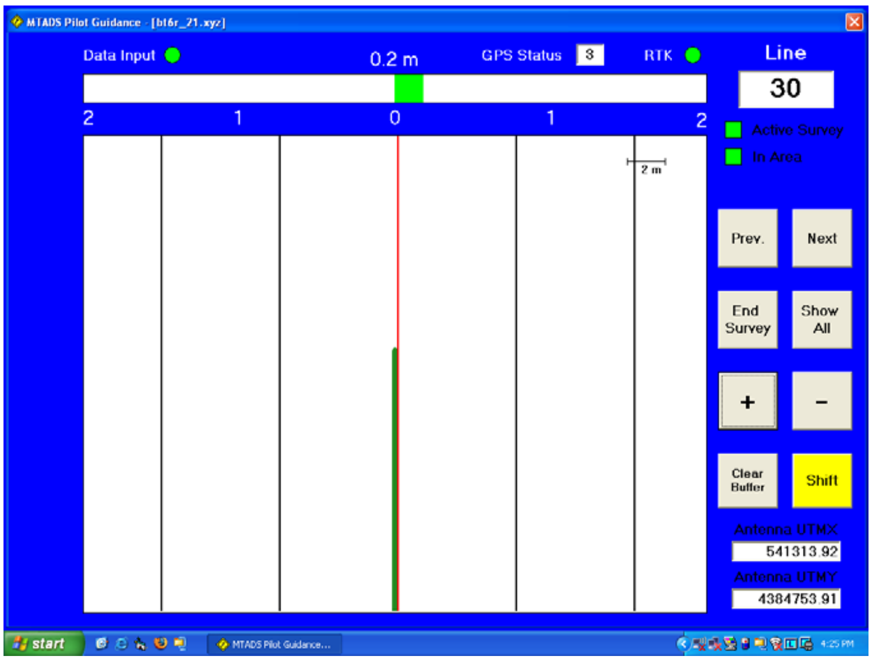

Figure 2-2 – Screenshot of MTADS Pilot Guidance Display

2.1.2 Man-Portable, Litter-Carried EM61 MkII System

A man-portable, litter-carried EMI sensor system has been developed as an adjunct of the NRL MTADS. The system hardware consists of low-metallic-content components that are used to carry a single EM61 MkII metal detector (0.5m x 1m coils, Geonics, Ltd.) over modest areas (10 lane km, 2 acres/day) to detect buried UXO. The sensors are sampled at 10 - 15 Hz and surveys are conducted at typical walking speed, ~2 mph (1 m/s). This results in a sample spacing of approximately 10 cm down track. For total coverage surveys, a horizontal sensor spacing of 75 cm is used for the 0.5m x 1.0m sensor coil.

The EM61 MkII is a pulsed-induction sensor which transmits a short electromagnetic pulse (a unipolar rectangular current pulse with a 25% duty cycle) into the Earth. Metallic objects interact with this transmitted field which induces secondary fields in the objects. These secondary fields are detected by the detection coils that are collocated with and above the transmit coil. An example is shown in Figure 2-3. The instrument consists of two air-core 0.5m x 1m coils housed in fiberglass, a backpack containing a battery and processing electronics, and an optional data logging device. The lower coil contains the transmitter and main receiver coils. The upper (receiver only) coil lies 30cm above the bottom coil. The EM61 MkII can be operated in one of two modes: 1) With 4 time “gates” (216, 366, 660, and 1266 µsec) or 2) in Differential mode, in which 3 time “gates” are measured from the bottom coil (216, 366, 660µsec), and one is measured from the top coil (at 660µsec). For the Victorville demonstration, data were collected on a laptop computer using custom software written at NRL.

Figure 2-3 – Geonics EM61 MkII coils on a test platform

The sensor position is measured in real-time (up to 20 Hz) with position accuracies of ~5 cm using the same high performance RTK GPS receivers as the vehicular array. All position and sensor data are time-stamped with or referenced to the Universal Coordinated Time (UTC) derived from the satellite clocks and recorded by the data acquisition computer (DAQ). The complete system is shown in the field in Figure 2-4. The positioning technology requires the availability of one or more known first-order survey control points. The sensor, position, and timing files are downloaded periodically throughout a survey onto removable media and transferred to the data analyst for analysis.

A WAAS-enabled handheld GPS receiver (meter-level, Garmin GPSMAP 76CS) was used for navigation during the transect portion of the demonstration using the built-in point-to-point navigation software. The manufacturer provides software for loading points and routes from a PC into the unit for this purpose.

Figure 2-4 – Man-portable, litter-carried EM61 MkII sensor system as demonstrated

2.1.3 Data Analysis Methodology

2.1.3.1 Vehicular System Data Analysis Methodology

Each data set for the vehicular system is collected using the MagLogNT software package (v2.921b, Geometrics, Inc.). The collected raw data are preprocessed on site for quality assurance purposes using standard MTADS procedures and checks. The data set is comprised of ten separate files, each containing data from a single system device. See Appendix B for further details about file contents and formats. Each device has a unique data rate. A software package written by NRL examines each file and compares the number of entries to the product (total survey time * data rate). Any discrepancies are flagged for the Data Analyst to address. Next, the data are merged and imported into a single Oasis montaj (v6.2, Geosoft, Inc.) database using custom scripts developed from the original MTADS DAS routines which have been extensively validated. An example of a working screen from Oasis montaj is shown in Figure 2-5. As part of the import process any data corresponding to a magnetometer outage, a GPS outage, or a vehicle stop / reverse, are defaulted or marked to not be further processed. Defaulted data are not deleted and can be recovered at a later time if so desired. Any long wavelength features such as the diurnal variation of the earth's magnetic field and large scale geology are filtered from the data (demedianed).

For the transect surveys, the demedianed magnetometer data are converted to analytic signal. A built-in feature of Oasis montaj is used to extract peaks above a given threshold from the analytic signal. The analytic signal is used because anomaly features which are dipolar (having both positive and negative components) in the demedianed magnetometer data are monopolar in the analytic signal. The detected anomaly locations along with the analytic signal strength at the peak of the anomaly were provided daily to the ESTCP Program Office, PNNL, and SNL for the previous day's survey results. The down-sampled transect COG (6 – 10 m spacing) was also provided at the request of PNNL / SNL.

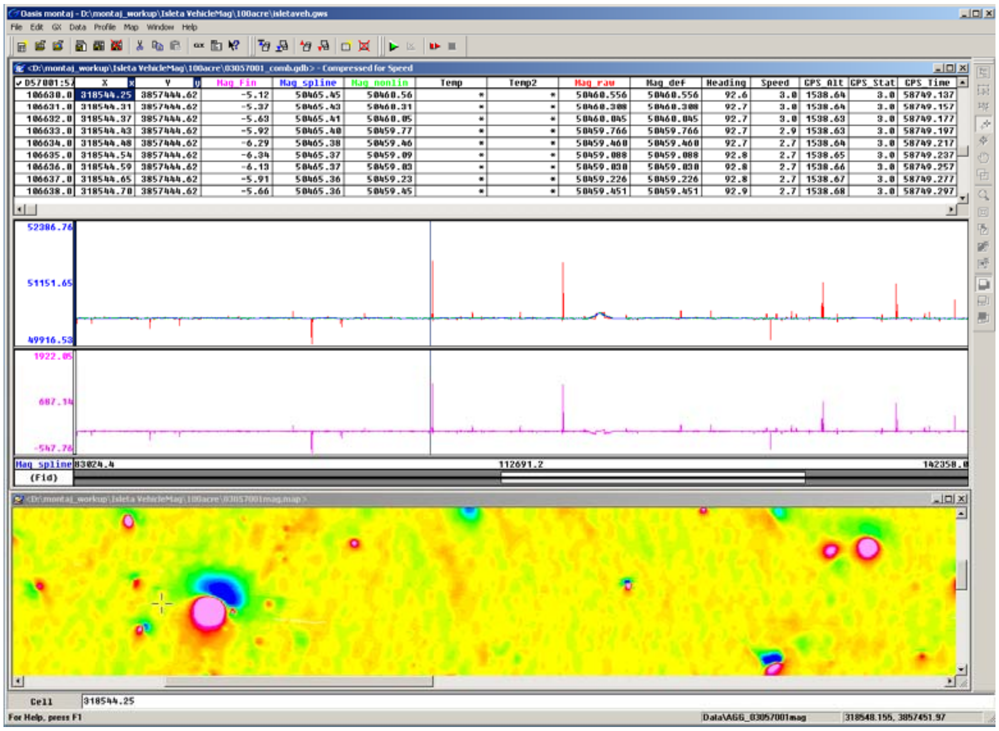

Figure 2-5 – Working screen in Oasis montaj™ of data preprocessing work flow for the MTADS system

The data analysis work flow is shown pictorially in Figure 2-6. Additional details on the methodology and its development are available in Appendix A.

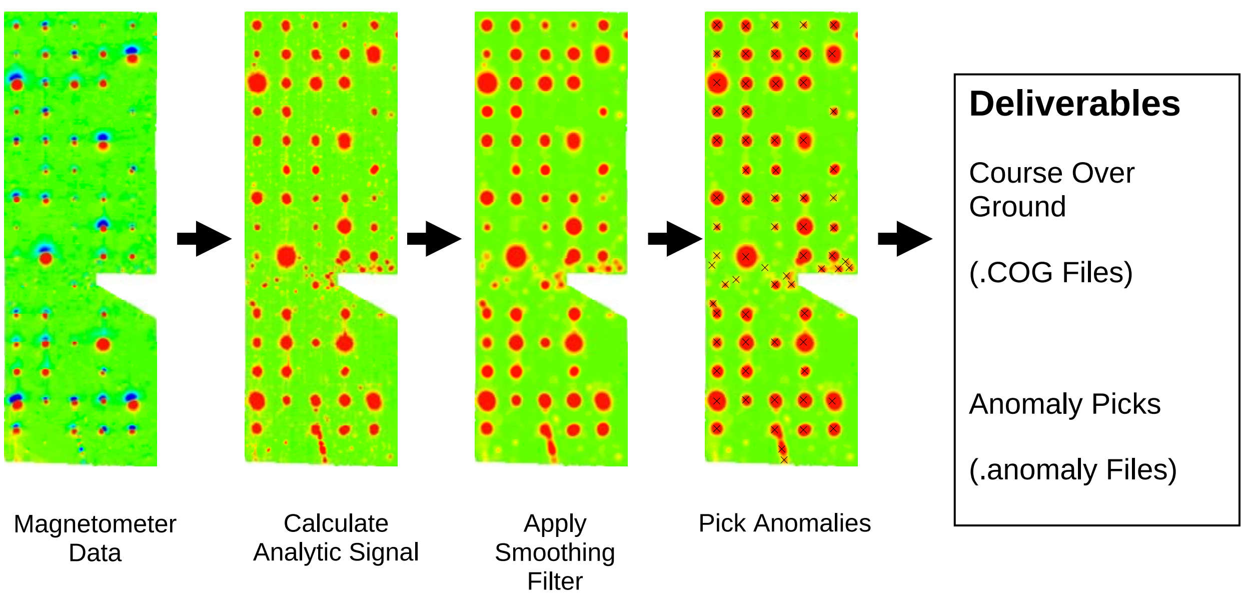

Figure 2-6 – Automatic anomaly detection scheme. Example data are from the MTADS Test Field at Blossom Point, MD. Magnetometer data are shown on a ±30 nT vertical scale. Analytic signal data are shown on a ±100 nT/m vertical scale.

For the total (100%) coverage surveys, the located demedianed magnetometer data were imported into the MTADS Data Analysis System (DAS) software for individual anomaly selection and analysis. In the case of isolated munitions in the far field (i.e. farther from the sensors than their characteristic dimension) the DAS employs resident physics-based models to determine target size, position, and depth. A spreadsheet (Excel 2003, Microsoft, Inc.) containing details of the anomaly location and fit parameters is provided. In some cases, anomalies were identified as being above background by the analyst but for which there was no reasonable fit to the dipole model. In these cases, only the center location (northing and easting) of the anomaly is reported. The located demedianed magnetometer data are also provided for archival purposes.

2.1.3.2 Man-Portable EM System Data Analysis Methodology

Each data set for the man-portable system is collected using a custom software package developed at NRL in Visual Basic (v6, Microsoft, Inc.). The collected raw data are preprocessed on site for quality assurance purposes using standard MTADS procedures and checks. The data set is comprised of several files, each containing the data from a single system device with unique data rates. The data are merged and imported into a single Oasis montaj (v6.3, Geosoft, Inc.) database using custom scripts developed from the original MTADS DAS routines which have been extensively validated. An example of a working screen from Oasis montaj is shown in Figure 2-7. As part of the import process any data corresponding to a sensor outage, a GPS outage, or a COG stop / reverse, are defaulted or marked to not be further processed. Defaulted data are not deleted and can be recovered at a later time if so desired. Any long wavelength features such as sensor drift are filtered from the data (demedianed).

For the transect surveys, there are no cross-track data from which to generate a two-dimensional representation, so anomaly selection is done looking for anomaly peaks along a downtrack profile. The EM61 MkII provides data for four time gates and the choice of which time gate to use for anomaly detection can be site-specific. Past experience has shown that for simple detection of anomalies under geologically benign conditions, the earliest time gate is typically the best time gate to use for signal–to-noise reasons. If there are sensor drift problems with gate 1 that cannot be removed simply by leveling, a later time gate can be used instead. The second gate has proven to be useful if geology in the area is apparent in the first gate. The first few data sets collected on site were examined and the first time gate was found to be acceptable for anomaly selection. The appropriateness of the choice was monitored during the demonstration. A built-in feature of Oasis montaj was then used to extract peaks above a given threshold from the data. The detected anomaly locations along with the signal magnitude at the peak of the anomaly were provided to the ESTCP Program Office. The down-sampled transect COG (~10 m spacing) was also provided.

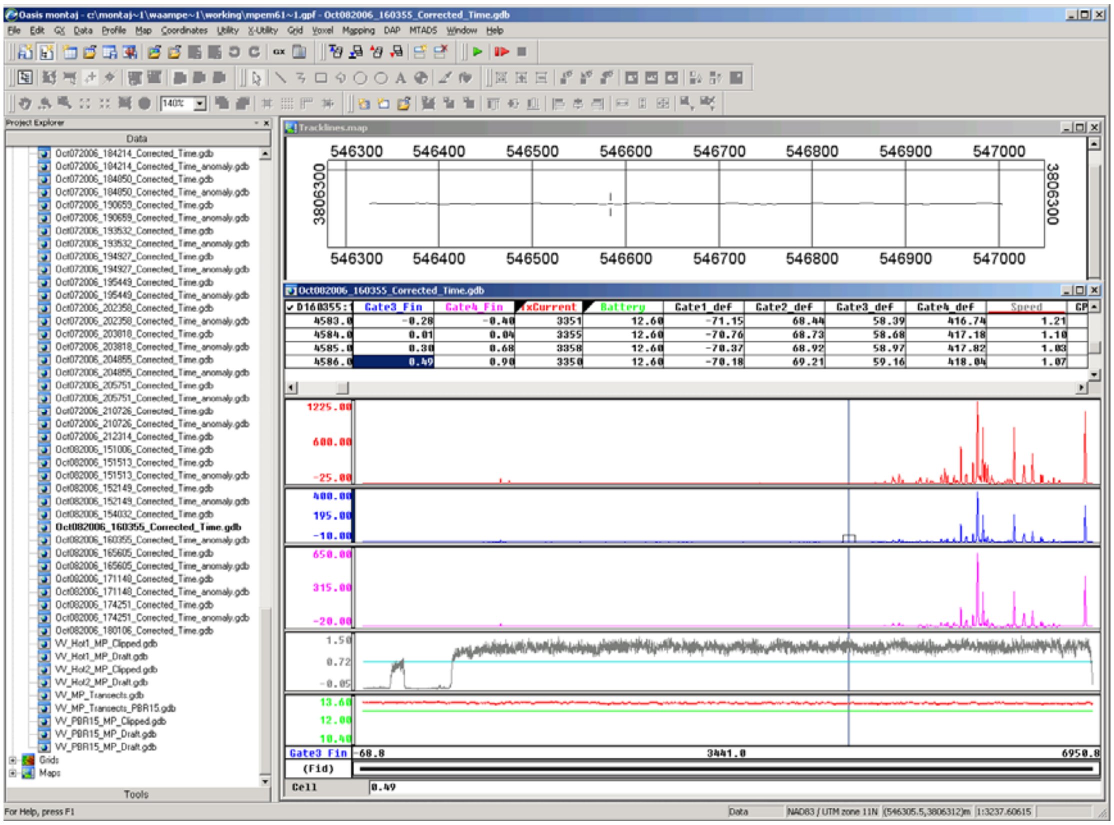

Figure 2-7 – Working screen in Oasis montaj™ of data preprocessing work flow for the MP EM system

For the total coverage (100%) surveys, the located demedianed sensor data were imported into the UX-Analyze subsystem of Oasis montaj for individual anomaly selection and analysis. UX-Analyze has been developed, in part from the MTADS Data Analysis System (DAS) software, by SAIC (formerly AETC) and Geosoft under ESTCP funding. Based on experience, the combination of lower coil time gate 3 and the upper coil time gate (both centered at a delay of 660 μs) data were used for the analysis. All anomalies with a peak intensity of greater than 4 mV in time gate 1 were analyzed. An example of a working screen from UX-Analyze is shown in Figure 2-8. A spreadsheet (Excel 2003, Microsoft, Inc.) containing details of the anomaly location and fit parameters is provided. The located demedianed sensor data are also provided for archival purposes.

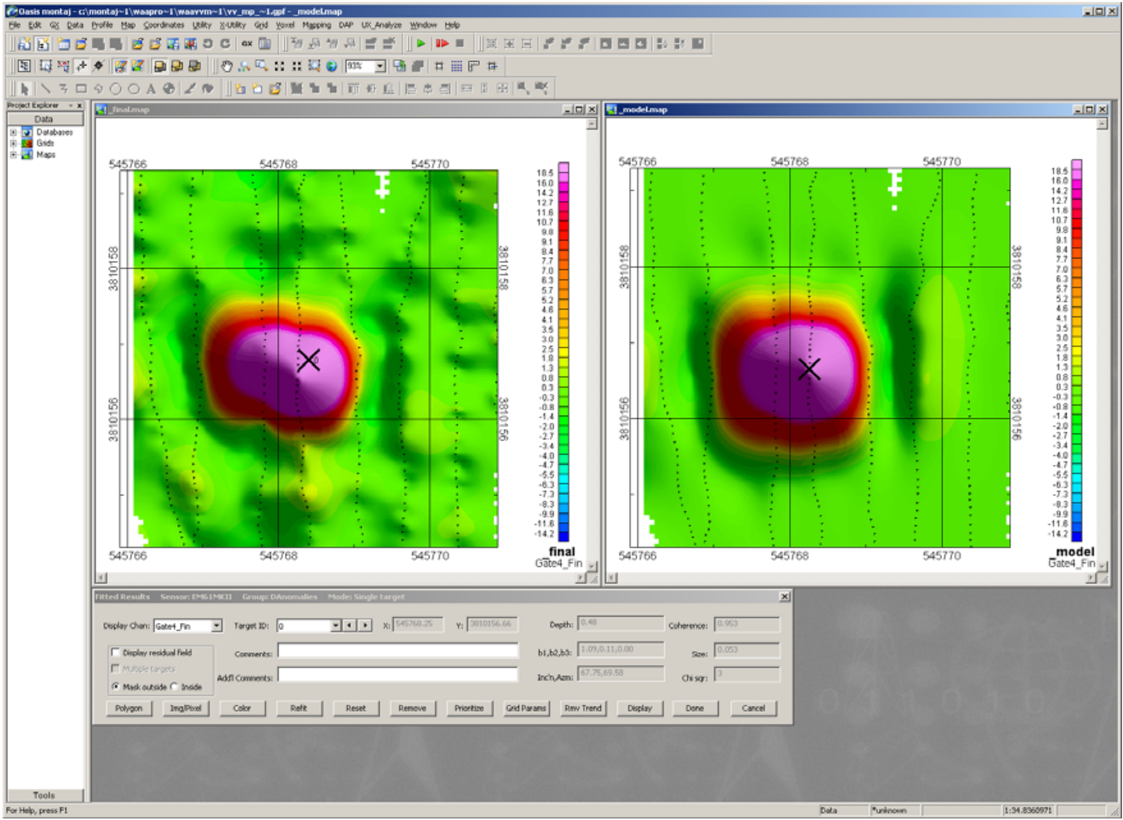

Figure 2-8 – Screenshot of the UX-Analyze working screen

2.2 Previous Testing of the Technology

The performance of the vehicular MTADS has been demonstrated at several seeded and live ranges sites over the last decade [4-9]. The MTADS has demonstrated probabilities of detection of 95 to 97% and location accuracies of better than 15 cm with the magnetometer system [7]. The vehicular MTADS has been selected to serve as the ground truth for several ESTCP-supported demonstrations of potential wide area survey systems [3,10,11].

As an example of the performance of the MTADS, the results from the survey of the Target S1 at Isleta Pueblo, NM [11] are discussed here briefly. For the Isleta demonstration, a portion of the site was blind seeded by the ESTCP Program Office with a variety of inert munitions. A total coverage survey was conducted over the site. The anomaly list generated by the MTADS team was then submitted to a neutral third party for independent evaluation. The results were representative of the past performance of the MTADS system. Analyzed anomalies were classified into 6 priority categories where 1 is likely UXO, 3 is unlikely UXO, 4 is unlikely a clutter item, and 6 is likely a clutter item. The probability of detection, P_d, and the cumulative alarm rate were determined for including each successive category (from 1 to 6). P_d is the fraction of emplaced items detected and the false alarm rate is given as picks per hectare not corresponding to an emplaced item. For the emplaced items at this demonstration, 89% of the emplaced items ($P_d = 0.89$) were detected and placed in the first three categories with a False Alarm Rate (FAR) of 7 / hectare. The location performance metrics were mean errors of -1 and 4 cm for easting and northing, respectively, with a standard deviation of 12 and 13 cm for the same. As demonstrated previously, there was no improvement in detection by widening the detection radius from 1.0 to 1.5 m. The detection radius defines how large an error in reported position can still be considered a detection of the emplaced item.

Several hundred detected anomalies were selected for remediation to determine the performance of the systems involved in the overall demonstration. The evaluation metric used was the location difference between the reported location of the anomaly by the MTADS and the actual location reported by the remediation contractor. As was seen for the emplaced items, a large majority of the anomaly picks fall well within the more restrictive 1.0-m halo. The detailed location performance was a mean miss distance of 35 cm. 90% of the anomaly picks were within 59 cm and 95% were within 77 cm of actual remediated location of the anomaly. As was seen for the emplaced items, a large fraction of the remediated anomalies corresponding to munitions or munitions-related fragments were categorized in the first three priority groups with 95% being captured in the first two priority groups.

2.3 Advantages and Limitations of the Technology

On large open ranges the vehicular MTADS provides an efficient survey technology. Surveys with the magnetometer array often exceed production rates of 20 acres per day. UXO items with gauges larger than 20mm are typically detected to their likely burial depths. The detection performance of MTADS magnetometer, EM61 MkII, and GEMTADS arrays for the range of munitions types and sizes emplaced at the Standardized UXO Demonstration sites are documented in References 12 and 13 and the references within. This process has to date involved a human operator manually selecting the data corresponding to individual anomalies. Each data segment is then processed by a physics-based algorithm incorporated into the MTADS DAS software.

While this methodology has proven highly successful in the past, it is not fast enough to support the rapid data requirements for the transect surveys conducted as part of the WAA Pilot Project. A faster, more automated method has been developed and now demonstrated at the Pueblo PBR #2 and Victorville PBRs Y & 15 WAA demonstration sites. The location and amplitude of anomalies with amplitudes above an empirically-determined threshold were reported to the ESTCP Program Office, PNNL, and SNL along with the survey COG for reference. This rapid feedback of information allowed for an interactive planning and execution of additional transects and total coverage surveys while the demonstration was ongoing.

The presence of certain non-navigable terrain features such as ravines without good crossing points, concentrated boulder fields, and other non-navigable features such as the combination of steep rises with loose, sandy soils limited the areas that could be surveyed by the tow vehicle and sensor array. A man-portable EM61 MkII-based adjunct of the MTADS was developed and demonstrated as a remedy to this problem. The MP EM system was able to access areas not accessible to the tow vehicle using a sensor technology that was less affected by the local geology than the magnetometer system. The cost comes in decreased rate of advance (10 lane-km/day) and reduced cross-track sensor coverage and count (one 1m wide sensor).

3. Demonstration Design

3.1 Performance Objectives

Performance objectives for the demonstration are given in Table 3-1 and Table 3-2 to provide a basis for evaluating the performance and costs of the technology to be demonstrated. Table 3-1 covers the primary performance objectives of this demonstration relating to the detection of target areas and non-target areas within the overall survey area. Table 3-2 contains secondary demonstration objectives/metrics relating to the extraction of additional information about the detected target areas and the anomalies within those areas. These objectives are for the technology being demonstrated only. Overall project objectives will be given in the overall demonstration plan generated by ESTCP. The final column, 'Actual Performance Objective Met?' is added during the discussion in Section 4, Performance Assessment.

Table 3-1 – Primary Transect Performance Objectives/Metrics and Confirmation Methods

Type of Performance Objective	Performance Criteria	Expected Performance (Metric)	Performance Confirmation Method
Primary Metrics (Relating to Detection of Target Areas and Target-free Areas)			
Qualitative	*Reliability and Robustness*	*General Observations*	*Operator feedback and recording of system downtime (length and cause)*
	Terrain / Vegetation Restrictions	*General Observations*	*Correlation of areas not surveyed to available data (topographical maps, etc.)*
Quantitative	*Survey Rate*	*15 acres / day*	*Calculated from survey results*
	Data throughput	*All data from day x processed for anomalies and submitted by end of day x+1*	*Analysis of records kept / log files generated while in the field*
	Percentage of Assigned Coverage Completed	*>95% as allowed by topography*	*Calculated from survey results*
	Transect Location	*95% within 2 meters of requested transects*	*Calculated from survey results*

Table 3-2 – Secondary Transect Performance Objectives/Metrics and Confirmation Methods

Type of Performance Objective	Performance Criteria	Expected Performance (Metric)	Performance Confirmation Method
Secondary Metrics (Relating to Characterization of Target Areas)			
Qualitative	*Ability of Analyst to Visualize Targets from Survey Data*	*All targets in survey area identified*	*Data Analyst feedback and comparison to total-coverage data / other demonstrators results*
Quantitative	*Location of Inverted Anomalies*	*< 0.15 m horizontal* *< 30% vertical*	*Validation Sampling (100% survey) and/or Remediation Sampling (digging)*
	Probability of False Alarm	*<5% of identified anomalies correspond to no ferrous metal source*	*Validation Sampling (100% survey) and/or Remediation Sampling (digging)*
	Signal to Noise Ratio (SNR) for Calibration Items	*+/- 10% of expected from Standardized UXO Technology Demonstration Site Performance*	*Comparison of Calibration Target results to documented Standardized UXO Technology Demonstration Site performance*
	Data Density	*> 60 pts / m^2*	*Calculated from survey results*

3.2 Pueblo Precision Bombing and Pattern Gunnery Range #2

The former Pueblo Precision Bombing and Pattern Gunnery Range #2 (Pueblo PBR#2) is located in Otero County, Colorado, approximately 20 miles south of the town of La Junta, CO [14]. The training range encompasses approximately 68,000 acres and consists of a bombing camp with two runways and nine precision bombing targets, a suspected 75mm air-to-ground target, along with an air-to-ground pattern gunnery range. This area was used for cattle grazing until the War Department assumed control of the lands in 1942. The WAA Pilot Project demonstration area encompasses approximately 7,400 acres of the overall Pueblo PBR #2 site and includes Targets 3 and 4 along with the Suspected 75mm Range AOI. See Reference 14 for additional discussion. The coordinates for the Pueblo PBR#2 demonstration site are given in Table 3-3.

3.2.1 Geodetic Control Monuments

Another performer within ESTCP's WAA Pilot Project, Sky Research, Inc. has established eight geodetic survey points in the general area of the demonstration site. The coordinates of all eight points are given in Table 3-4 (horizontal datum: North American Datum of 1983, 1992 Adjustment (NAD83/92); vertical datum: North American Vertical Datum of 1988 (NAVD88); geoid model: National Geodetic Survey Geoid03).

Table 3-3 – Coordinates for the Approximate Corners of the WAA Pilot Project Pueblo PBR #2 demonstration site

Point	Latitude	Longitude	Northing (m)	Easting (m)
			UTM Zone 13N, NAD83	
SW	37° 39' 52.662290656" N	103° 42' 02.32095666" W	4,169,400.00	614,600.00
MW1	37° 42' 02.421430304" N	103° 42' 00.05663171" W	4,173,400.00	614,600.00
MW2	37° 42' 01.969283698" N	103° 41' 19.22920282" W	4,173,400.00	615,600.00
NW	37° 44' 44.166511803" N	103° 41' 16.36838703" W	4,178,400.00	615,600.00
NE	37° 44' 42.784290086" N	103° 39' 13.81346694" W	4,178,400.00	618,600.00
ME1	37° 43' 05.249205491" N	103° 39' 15.57919156" W	4,175,393.27	618,600.00
ME2	37° 43' 05.360723355" N	103° 39' 25.35768396" W	4,175,393.27	618,360.54
SE	37° 39' 50.892927079" N	103° 39' 24.40635276" W	4,169,400.00	618,469.76

Table 3-4 – Survey Control Points Installed for the WAA Pilot Project at the Pueblo PBR #2 site

Point Name	Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	Elevation (m)
	NAD83			UTM Zone 13N, NAD83		NAVD88
Sky CP1	37° 39' 31.00828" N	103° 39' 23.98352" W	1397.643	4168787.291	618488.902	1418.797
Sky CP2	37° 39' 31.81861" N	103° 38' 50.55881" W	1393.904	4168824.039	619307.531	1415.076
Sky CP3	37° 38' 38.47452" N	103° 39' 56.81331" W	1401.753	4167156.697	617707.526	1422.860
Sky CP4	37° 39' 57.22970" N	103° 39' 23.93856" W	1396.392	4169595.462	618478.424	1417.560
Sky CP5	37° 44' 38.76102" N	103° 40' 42.21410" W	1439.133	4178245.156	616438.238	1460.417
Sky CP6	37° 44' 16.35566" N	103° 39' 18.00019" W	1453.184	4177583.970	618509.241	1474.494
Sky CP7	37° 42' 07.59478" N	103° 38' 13.14673" W	1365.804	4173638.425	620154.391	1387.077
Sky CP8	37° 43' 01.02076" N	103° 42' 11.45205" W	1468.740	4175202.188	614295.936	1489.925

3.2.2 Testing and Evaluation Plan

3.2.2.1 Demonstration Set-Up and Start-Up

3.2.2.1.1 Base Camp Facilities

The MTADS vehicular system was mobilized to the Pueblo PBR #2 site in a U.S. Navy-owned 53-ft trailer. The tow vehicle, the magnetometer trailer, notebook computers for the analysis team, GPS equipment, batteries and chargers, office equipment, radios and chargers, tools, equipment spares, and maintenance items, and magnetometers were transported in the trailer. Harris Transportation Company, a government-contract transportation firm delivered the trailer to the demonstration site upon the arrival of the field team on site.

Due to the remoteness of the demonstration area, no essential support services were available on-site. Accordingly, Nova Research made provisions to acquire all of the requisite supplies, materials, and facilities from local rental firms. An office trailer was provided for data processing and analysis, as a communications center, for battery storage and charging stations, electronics repair station, and as storage for spares and supplies. This trailer was provided with AC power, heating, and cooling. A second 8' x 40' trailer was used to garage and for the secure storage of the MTADS vehicle and sensor platform. Power to the trailers was provided by a diesel field generator (50 kW range) that was also used to recharge the vehicle, radios, and GPS batteries overnight. Communications among on-site personnel was provided by hand-held VHF radios, with a base station located in the office trailer. Radios were provided to all field and office personnel. The availability of cellular phone communications on site was non-continuous but was available in portions of the site. Fuel storage was provided for the generator and portable toilets were provided to support all field and office crews. Figure 3-1 shows the arrangement of this logistics support at the Pueblo PBR #2 site. Due to the distance from the WAA Base Camp to the survey areas at the southern end of the Pueblo PBR #2 site, an additional limited-scope Auxiliary Base Camp was established at the intersection of Roads B and 23, shown in Figure 3-2. A second 8' x 40' trailer was provided to garage and for secure storage of the MTADS vehicle and sensor platform along with a 5 kW generator for battery charging.

Figure 3-1 – Photograph of the WAA Base Camp at the Pueblo PBR#2 WAA demonstration site showing the relative locations of the trailers, etc.

3.2.2.1.2 Demonstration Set-up

Upon arrival on site, the team personnel received and unpacked the 53' trailer and established the base camp. The RTK GPS base station receiver and radio link were set up on one of the available established control points. At the Pueblo PBR #2 site, control points CP5, 6, and 1 were used as required to provide coverage to the current working area. A network of radio repeaters was used to extend the useful range of the RTK radio link on an as-needed basis.

Figure 3-2 – Photograph of the Auxiliary Base Camp at Pueblo PBR#2 WAA demonstration site

Next, the sensor system was assembled and tested for proper operation. The magnetometer trailer was connected to the tow vehicle and the system was powered up. The connectivity of the magnetometers to the DAQ computer and the establishment of normal SNR performance were verified along with the operational state of the vehicle RTK system.

3.2.2.1.3 Calibration Lane and Objects

The demonstration team and representatives of the ESTCP Program Office emplaced a lane of calibration items south of the Pueblo PBR #2 WAA Base Camp between the Base Camp and the demonstration area. The schedule of calibration items emplaced for the site is given in Table 3-5. A multi-pass magnetometer survey of the proposed calibration strip was conducted prior to emplacement and the quietest area in terms of geology was selected for the calibration items. The composition of the ground in the selected area was approximately 0.5 m of soil and broken rock on top of a hard rock layer. Consequently, emplacement depths were limited to 60 cm. Once the items were emplaced and photographed, the positions of each item's nose and tail were recording using RTK GPS. The holes were refilled with the removed material and leveled. A single pass magnetometer survey was conducted over the emplaced items. Prior to operating out of the Auxiliary Base Camp, Sphere #1 was relocated to near the Auxiliary Base Camp for calibration purposes. This location for Sphere #1 at the Auxiliary Base Camp is also given in Table 3-5.

3.2.2.2 Period of Operation

The main portion of the demonstration was accomplished from Tuesday, August 30th through Saturday, October 22nd, 2005. Operations were conducted in three portions as detailed in tabular form in Table 3-6. The originally scheduled second survey portion was broken into two portions due to unscheduled maintenance required on the tow vehicle.

3.2.2.3 Field Work Daily Regimen

The Site Safety Officer would conduct a 'tail-gate' safety meeting prior to beginning the day's efforts each day that personnel were on site. The topic(s) for each day's meeting were at the discretion of the Site Safety Officer and focused on safety issues relating to the day's planned work. The RTK GPS base station receiver and radio link were then established on one of the site's available established control points.

Table 3-5 – Schedule of Ground-based System WAA Calibration Items for Pueblo PBR #2

ID	UTM Zone 13N		Actual	
	Easting (m)	Northing (m)	Depth (cm)	Grid Azimuth (deg)
North Calibration Lane				
Sphere #1 (Driver Side)	616,434.500	4,178,732.403	0	N/A
Sphere #2 (Passenger Side)	616,435.459	4,178,732.109	0	N/A
155mm Projectile #2	616,441.180	4,178,749.703	35	35
60 mm Mortar #2	616,447.267	4,178,768.742	30	46
105mm Projectile #2	616,453.828	4,178,787.621	60	44
105mm Projectile #1	616,459.639	4,178,806.967	45	178
81mm Mortar #2	616,465.341	4,178,825.771	43	69
81mm Mortar #1	616,469.792	4,178,839.941	25	20
155mm Projectile #1	616,474.350	4,178,854.198	50	46
60 mm Mortar #1	616,478.260	4,178,868.186	10	148
37mm Sim #2	616,481.220	4,178,877.825	10	57
37mm Sim #1	616,484.096	4,178,887.419	5	160
South Calibration Sphere				
Sphere #1 (Driver Side)	618,349.507	4,168,713.105	0	N/A

Two systems performance checks were conducted at the beginning of each work day when transects data were being collected. A period (5-6 minutes) of quiet, static data was collected and submitted to the Data Analyst for validation. A data collection sortie would then be conducted over the calibration items. This sortie was repeated at the end of the work day as well. On a few occasions it was not possible to collect the end-of-day calibration data due to site closure due to weather or equipment malfunction bringing about an abrupt end to the day's efforts.

Preventative maintenance inspections were conducted at least once a day by all team members, focusing particularly on the tow vehicle and sensor trailer. Any deficiencies were addressed according to the severity of the deficiency. Parts, tools, and materials for many maintenance scenarios are available in the system spares inventory located on site. Routine tools and supplies, for example spare tires for the tow vehicle and sensor trailer, were carried in the chase vehicle which accompanied the tow vehicle onto the site. Status on break-downs / failures that resulted in long-term delays in surveying was reported to the WAA Project Manager as appropriate.

Table 3-6 – Pueblo PBR #2 Survey Demonstration Deployment Schedule

Date (2005)	**Planned Action**
Week of August 15th	Pack trailer at Blossom Point.
Friday, August 19th	Trailer leaves Blossom Point for Pueblo PBR #2.
Tuesday, August 23th	Trailer arrives Pueblo PBR #2.
Sun, August 28th	Personnel arrive La Junta; unpack trailer, assemble MTADS system.
Mon, Aug 29th	Scout demonstration area, emplace and survey calibration items.
Tue, Aug 30th	Begin ground surveys.
Fri, Sep 16th	Pause ground surveys. Personnel departs site.
Sun, Oct 2th	Personnel return to La Junta.
Mon, Oct 3rd	Resume ground surveys.
Fri, Oct 7th	Pause ground surveys, arrange for vehicle maintenance.
Sat, Oct 8th – Tue, Oct 11th	Personnel depart La Junta.
Mon, Oct 17th	Personnel return to La Junta, reassemble vehicle.
Tue, Oct 18th	Resume ground surveys.
Sat, Oct 22th	Complete ground surveys.
Sun, Oct 23th	Pack trailer.
Mon, Oct 24th	Personnel depart La Junta.
Thu, Nov 10th	Trailer departed Pueblo PBR #2.
Mon, Nov 14th	Trailer arrives at Blossom Point, MD.
Week of Nov 28th	Submit Data Report to ESTCP.

3.2.3 Transect Magnetometer Survey Results

The transect plans provided by PNNL / SNL were based on archive data (CSM v0) and WAA Pilot Project goals. The transect plans were divided into three categories: 1) North / South transects to interrogate the entire PBR #2 demonstration site for the actual positions and footprints of Targets 3 and 4 as noted in CSM v0 and to locate any additional similar features of interest, 2) East / West transects to interrogate the Suspected 75mm Range area of interest for possible features of interest, and 3) Additional transects requested by PNNL / SNL / ESTCP Program Office based on the results of items 1 & 2 or other data.

For the first category, two transect designs were prepared by PNNL/SNL. The first, sparse design was based on traversing 100-lb practice bomb targets and features of interest with a 99% probability of traversing a 1000 ft circular target or feature of interest. The transects were oriented N/S with a 308 m spacing. The second, conservative design was based on finding 500-ft diameter, circular 100-lb practice bomb targets with a 99% probability of traversing the target or feature of interest. The transects were oriented N/S with a 154 m spacing. This design leveraged the data already collected as part of the sparse design and adds an additional transect equally spaced between each pair of sparse transects.

For the second category, two designs were prepared by PNNL/SNL to cover the Suspected 75mm Range. The first, sparse design was based on a 99% probability of traversing a 100 m x 400 m elliptical target or feature of interest. The transects were oriented E/W with 400 m spacing and leveraged the N/S transects already collected. The second, conservative design was based on a 99% probability of traversing a 100 m diameter, circular feature of interest. The transects were oriented E/W with 100 m spacing and leveraged the N/S transects already recorded. This design leverages the data already collected as part of the sparse design and added three additional transect equally spaced between each pair of sparse E/W transects.

For the third category, 17 100-m spacing E/W transects starting from 50m north of the southern boundary of the demonstration site were surveyed to further define the footprint of Target 4. Four additional areas of interest were also identified from the N/S transect data by PNNL / SNL, labeled Areas 23, 25, 26, 27. Based on CSM v1, four additional AOIs were identified. In these AOIs, transect plans of 4 – 10 transects were designed and surveyed. As an example, a portion of the N/S transect plan is shown in Figure 3-3 along with the COG of the transect data collected on September 5, 2005. Figure 3-4 shows the results of all transect data collected in the course of this demonstration. The COGs are shown as purple lines and each detected anomaly is shown as a filled circle.

The total acreage covered by transect surveys was 143 acres, or approximately 2% of the total 7,400 acres site. Natural topology (ravines, plateau faces, trees, etc.) and man-made obstructions (e.g. fences) made it difficult and impractical to complete each transect in a single survey. Therefore each transect was broken into one or more segments in the field. The flexibility of the MTADS Pilot Guidance software allows for this to be done easily and on the fly. The exact details of the area covered by each survey file are given in the Demonstration Data Report [15].

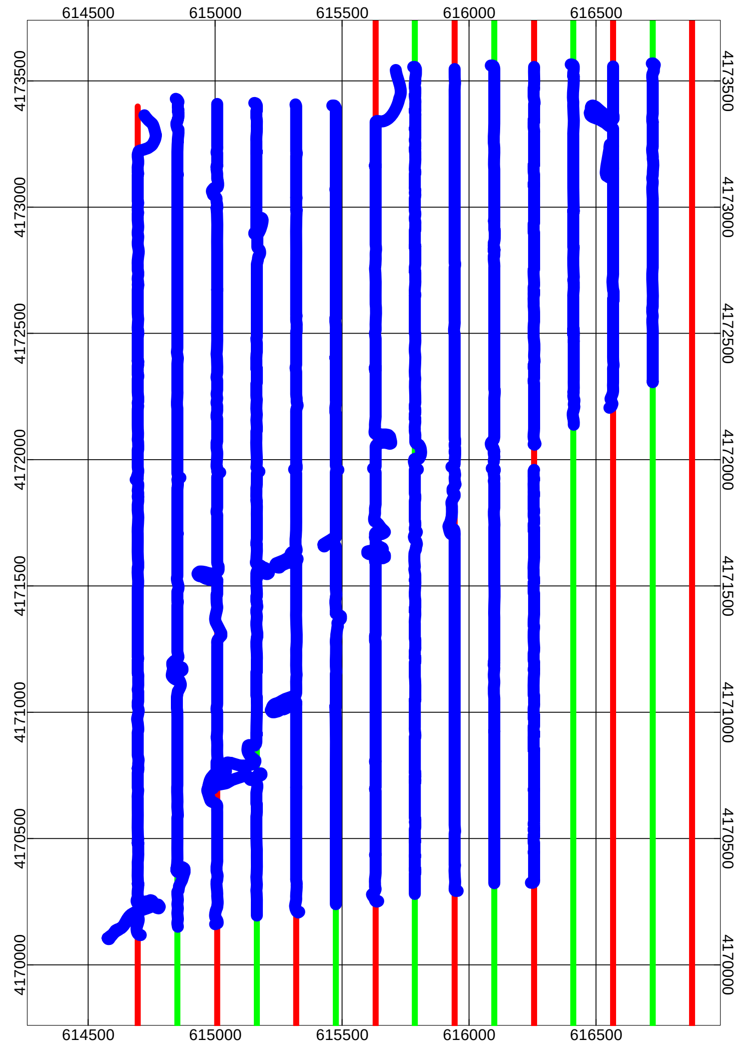

Figure 3-3 – Sparse transect plan shown in red, additional transects for conservative approach shown in green. Actual survey COGs shown in blue for Julian date (05248, September 5, 2005).

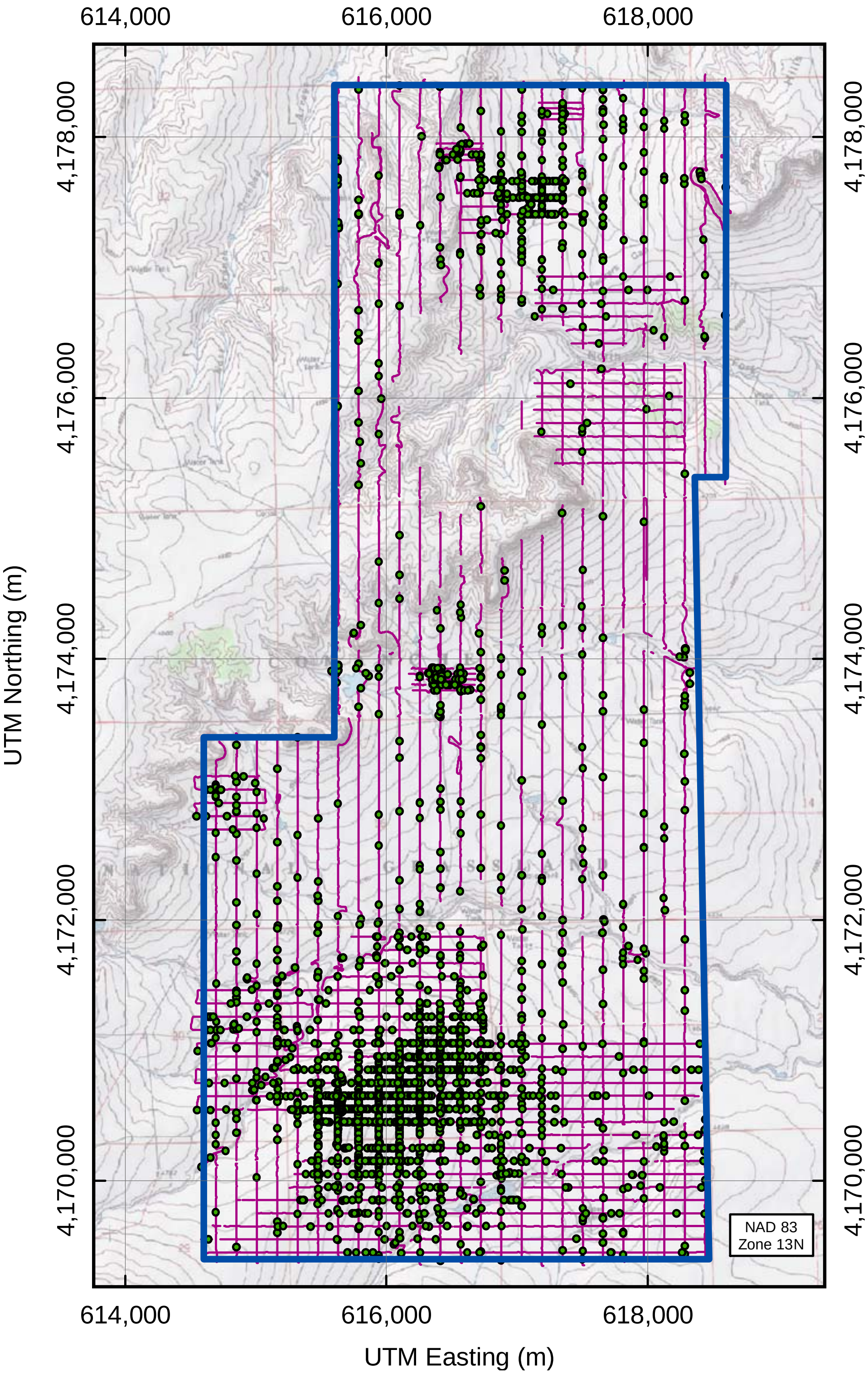

Figure 3-4 – Map showing the transect survey results for the Pueblo PBR #2 demonstration site. Transect COGs are shown as purple lines and individual detected anomalies are shown as filled circles.

3.2.4 Total Coverage Magnetometer Survey Results

In addition to the transect surveys covering the Pueblo PBR #2 demonstration site, several small areas (30 – 85 acres) were selected for total coverage surveys. Areas were selected in cooperation with the ESTCP Program Office to achieve three objectives: 1) Collect data in areas identified by the transect surveys as "quiet" to determine the background anomaly density for the WAA demonstration site, 2) Collect data near Targets 3 and 4 to evaluate the anomaly density. By starting near the target and moving away in several steps, it is possible to map the anomaly density falloff as one moves away from the Target, and 3) Collect addition data on the Suspected 75mm Range AOI in support of the transect survey results. These surveys were conducted as typical MTADS magnetometer surveys with a line spacing of 2.0 m (tire next to tire spacing). Collected and processed magnetometer data were exported from the Oasis montaj environment and loaded into the MTADS DAS software for individual anomaly analysis. The archived magnetometer data and the detailed anomaly lists for each area are provided in the Demonstration Data Report [15]

Figure 3-5 shows the total coverage area anomaly maps superimposed on the WAA demonstration site topographical map. Table 3-6 contains a summary of the total coverage survey results. Column three lists the number of anomalies extracted by the operator in the DAS in each area and column five lists the number of those anomalies which could be fit using the resident dipole model to a coherence value of 0.85 or better.

Table 3-6 – Pueblo PBR #2 Total Coverage Area Result Summary

Target	Area	Number of Anomalies	Anomalies / Acres	Number of Dipole Fits	Acres
Target 4	BT4 Center	938	85	873	11.0
	1C	1095	28	938	38.8
	1B	245	7	242	33.9
	1A	169	5	168	33.6
Target 3	3A	2112	60	1830	35.4
	3B	520	14	519	36.3
	3C	207	6	206	35.7
Simmons Area		72	1	72	85.0
Suspected 75mm Range	2A	148	5	148	31.0
	2B	83	2	83	36.8

An 85-acre area was selected in the northern portion of Section 10, referred to as the Simmons Area in reference to the ranchers who currently lease the area (Brian and Janet Simmons), as a "quiet" area for determining the background anomaly level. The transect survey results indicated that this area had very few anomalies with only a single anomaly detected by the transect surveys within the Simmons Area total coverage area. Figure 3-6 presents the magnetometer data anomaly map for the Simmons Area.

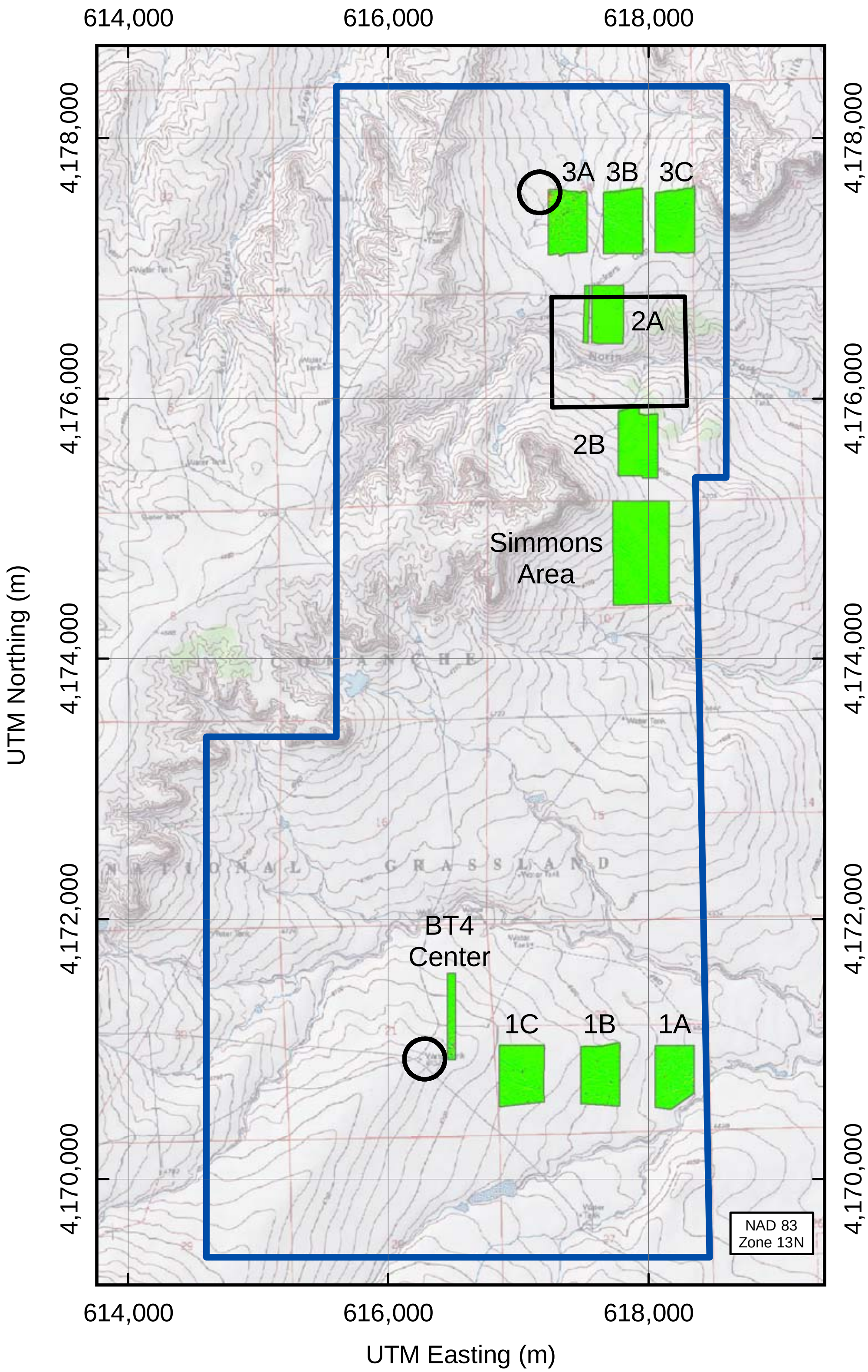

Figure 3-5 – Pueblo PBR #2 Total Coverage Survey Results

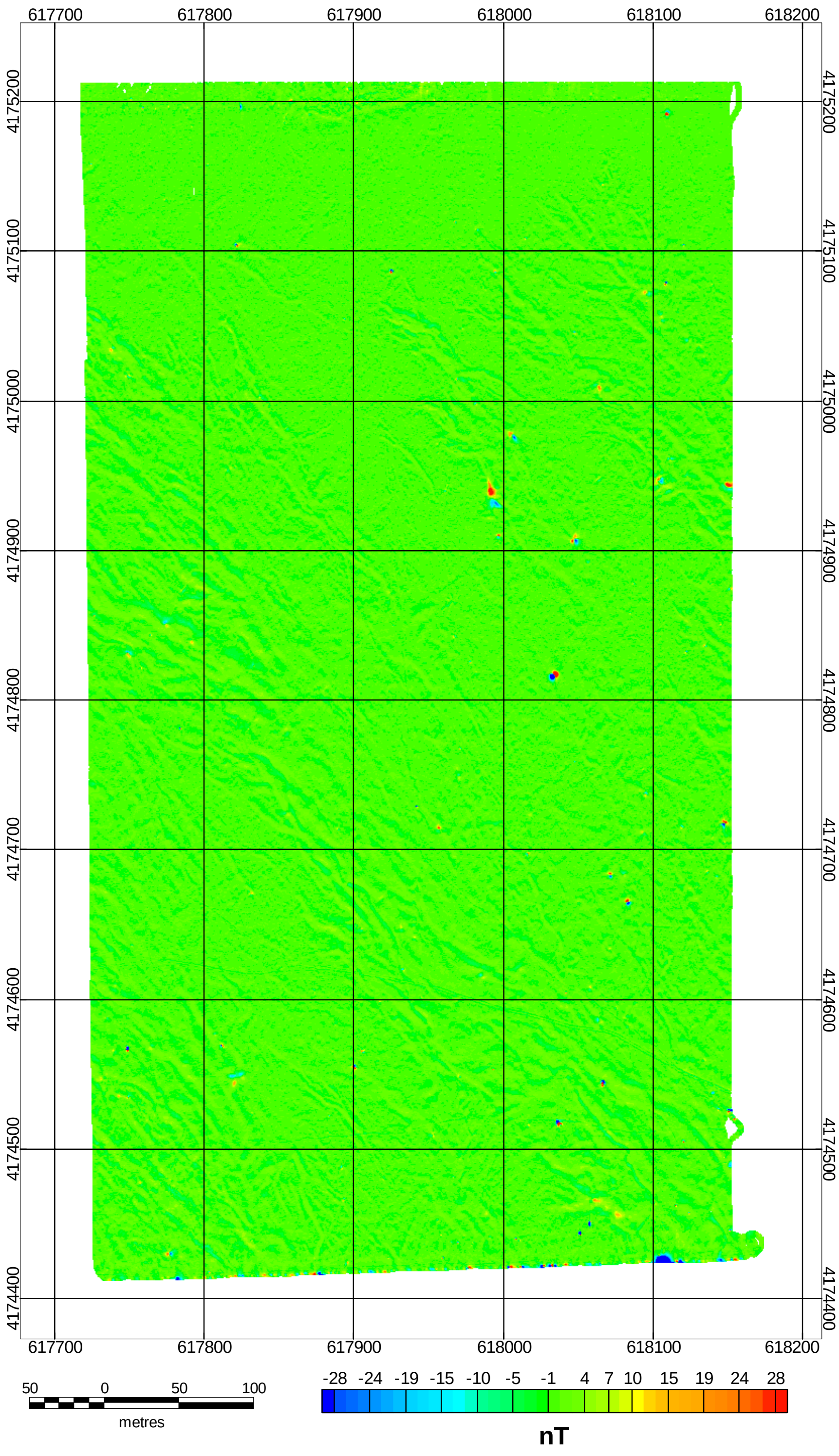

Figure 3-6 – Magnetometer Anomaly Map of the Pueblo PBR #2 Simmons Area

Four total coverage areas were surveyed in the vicinity of Target 4, located in the southern part of the WAA demonstration site. The three main total coverage areas are labeled Area 1A, 1B, and 1C with Area 1C being the closest to Target 4 and Area 1A the furthest area to the east. The area BT4 Center was part of an earlier survey scheme developed to map the anomaly density falloff from Target 4 which was altered to the Area 1A – 1C plan at the request of the lessees/landowners involved (Ralph and Russell Rounds). The BT4 Center data consist of 4 acres and are presented for completeness. Figure 3-7 through Figure 3-10 present the magnetometer data anomaly maps for Areas 1C, 1B, 1A, and BT4 Center respectively.

Three total coverage areas were surveyed in the vicinity of Target 3, located in the northern part of the Pueblo PBR #2 demonstration site. The three total coverage areas are labeled Area 3A, 3B, and 3C with Area 3A being the closest to Target 3. Figure 3-11 through Figure 3-13 present the magnetometer data anomaly maps for Areas 3A, 3B, 3C respectively.

Two total coverage areas were surveyed in the vicinity of the Suspected 75mm Range area of interest, located in the northeastern portion of the Pueblo PBR #2 demonstration site. The two total coverage areas are labeled Area 2A and 2B with Area 2A located in the northwestern corner of the Suspected 75mm Range area of interest and Area 2B located in the southeastern corner. Figure 3-14 and Figure 3-15 present the magnetometer data anomaly maps for Areas 2A and 2B respectively. Area 2A is split vertically on the western side by a barbed wire fence and cattle guard on the road. The survey was stopped several swath widths on either side of the fence to limit the impact of the fence on the data collected. The southeastern portion of Area 2A also had a large number of small trees and cactus which resulted in small areas where data could not be collected.

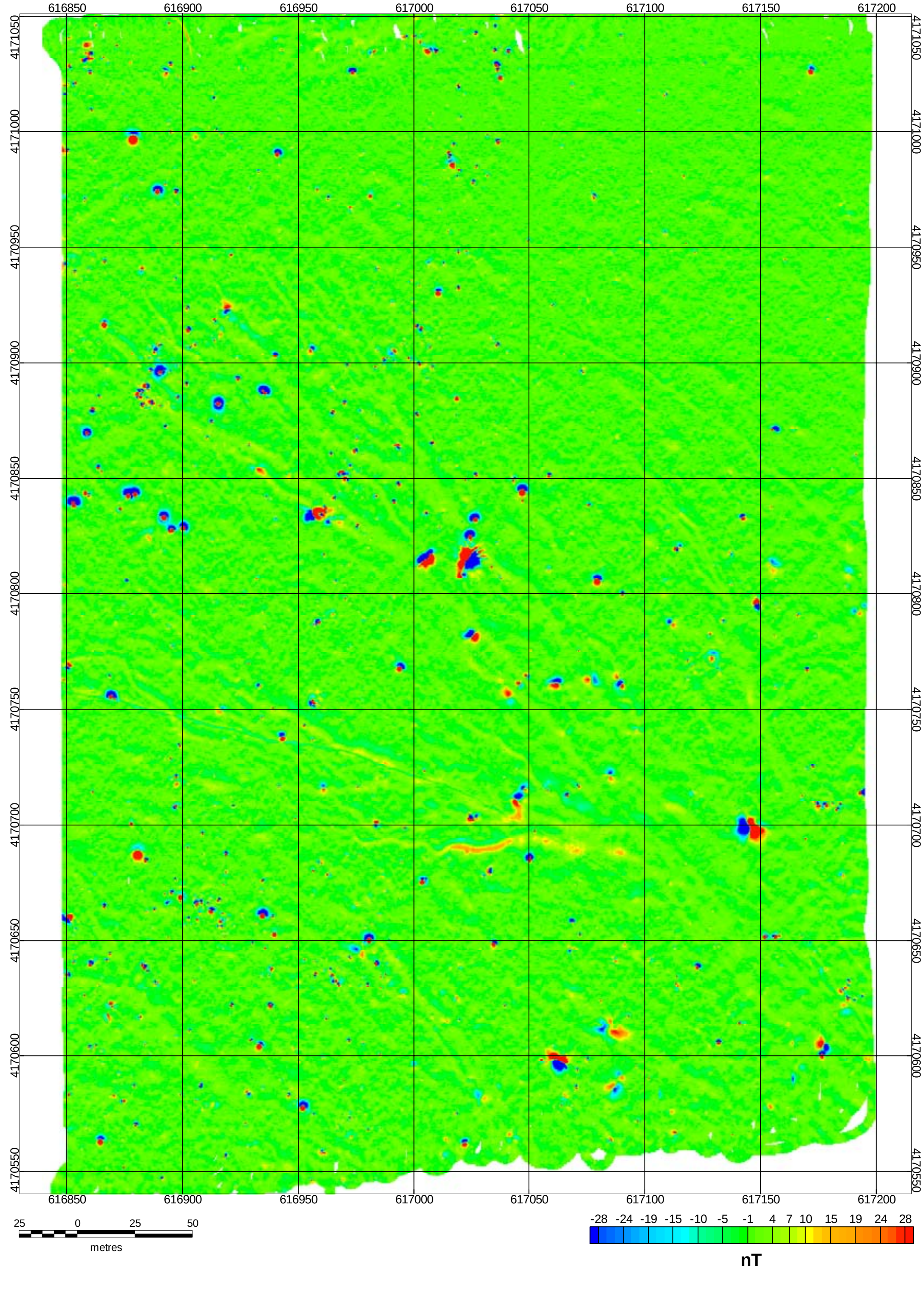

Figure 3-7 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 1C

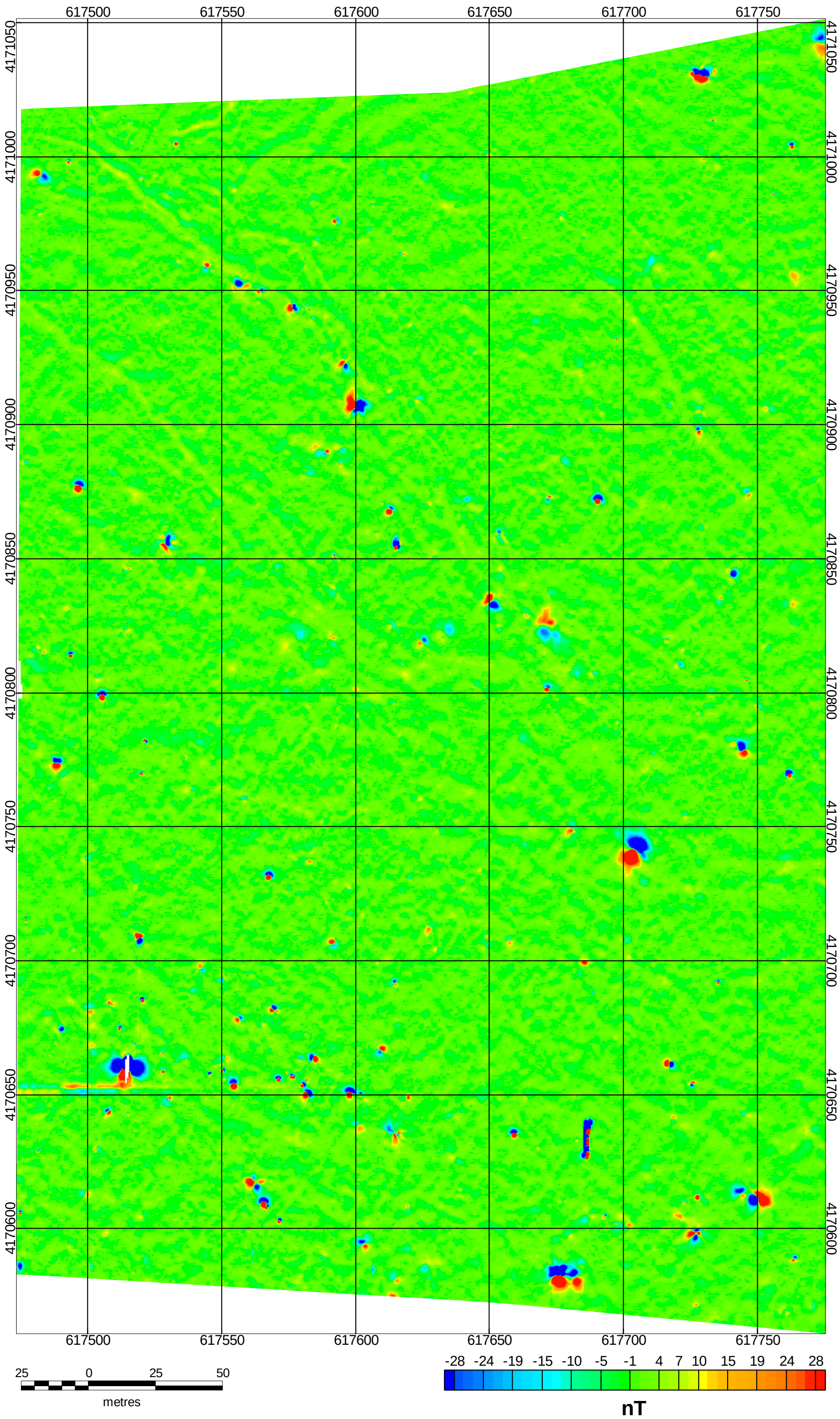

Figure 3-8 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 1B

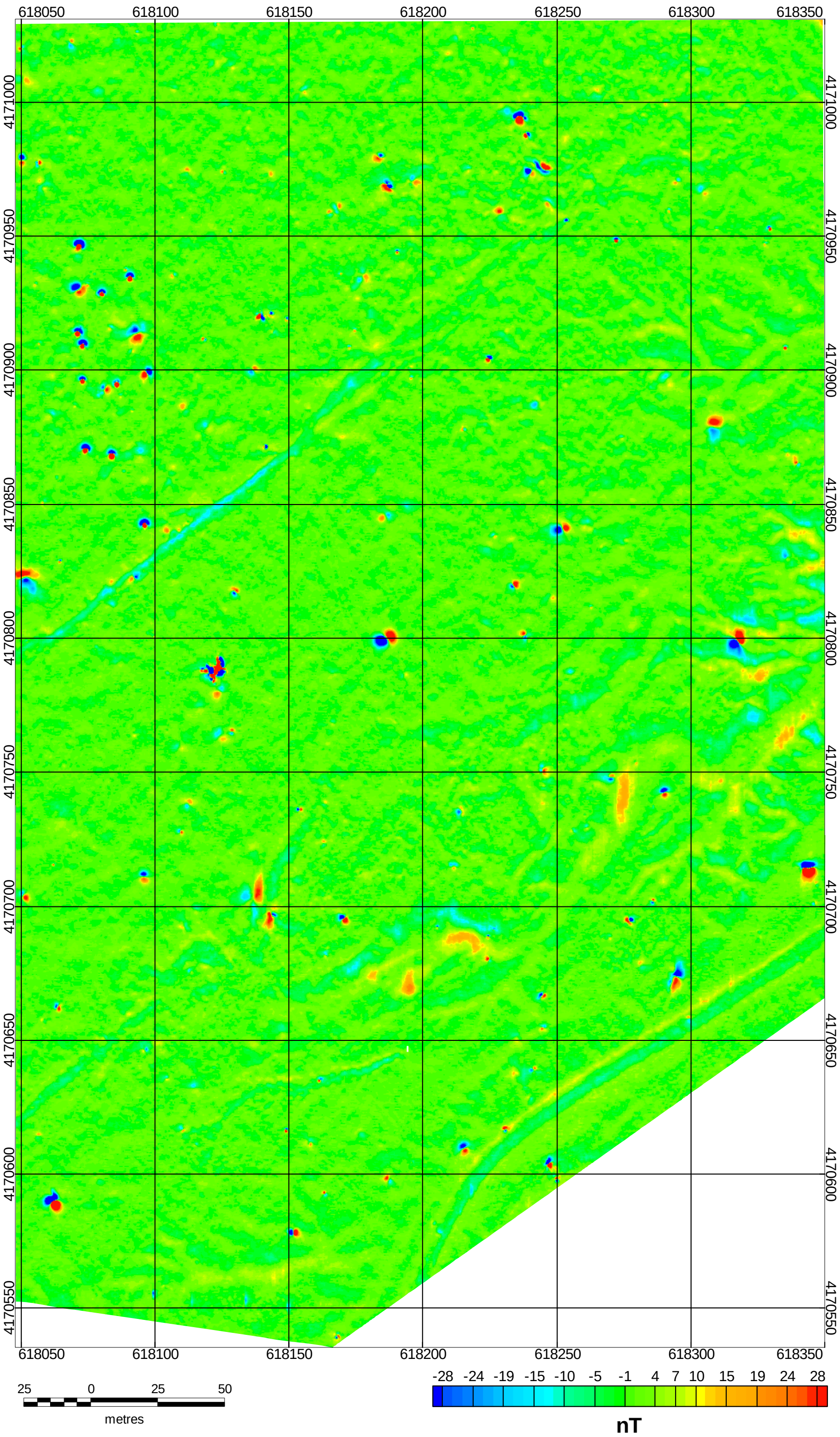

Figure 3-9 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 1A

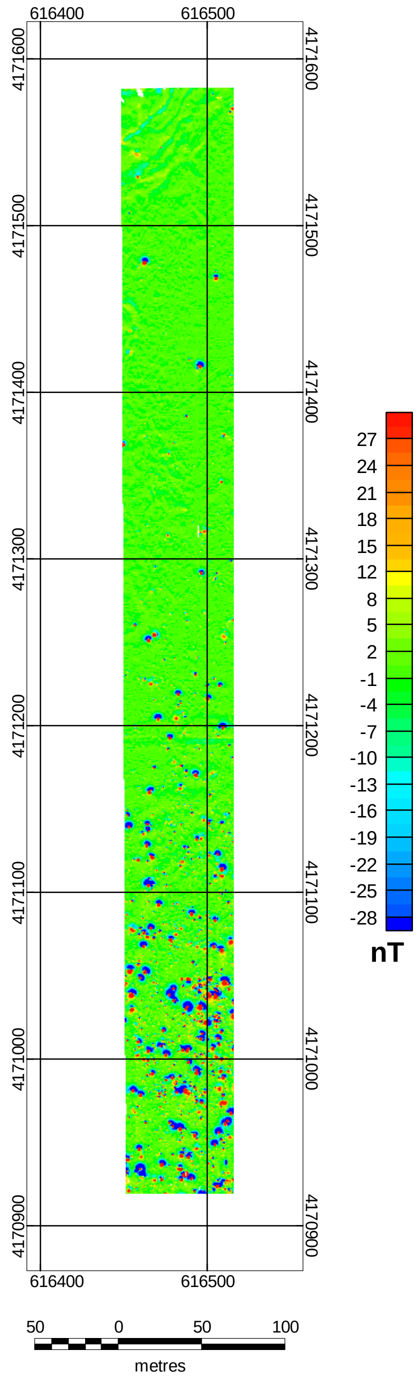

Figure 3-10 – Magnetometer Anomaly
Map of Pueblo PBR #2 Area BT4 Center

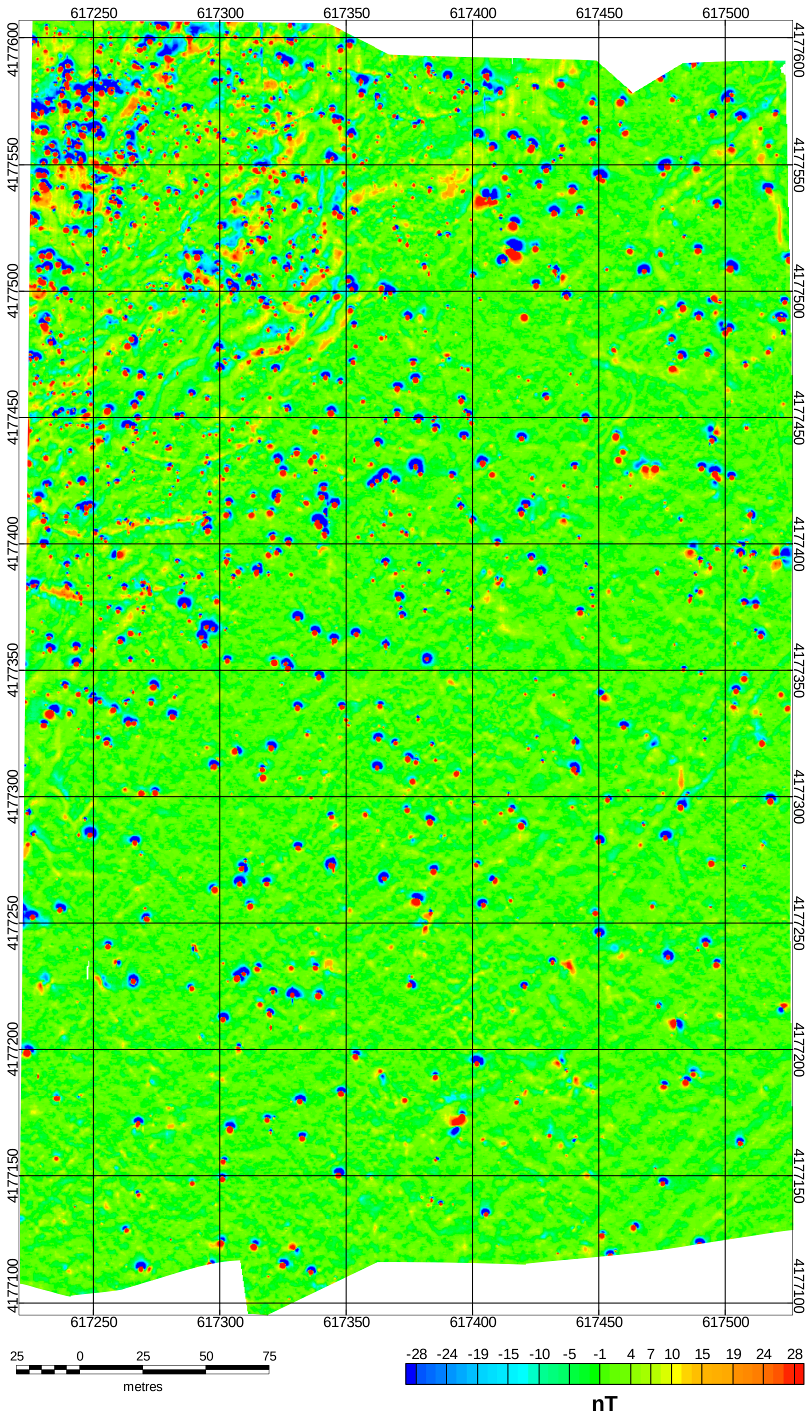

Figure 3-11 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 3A

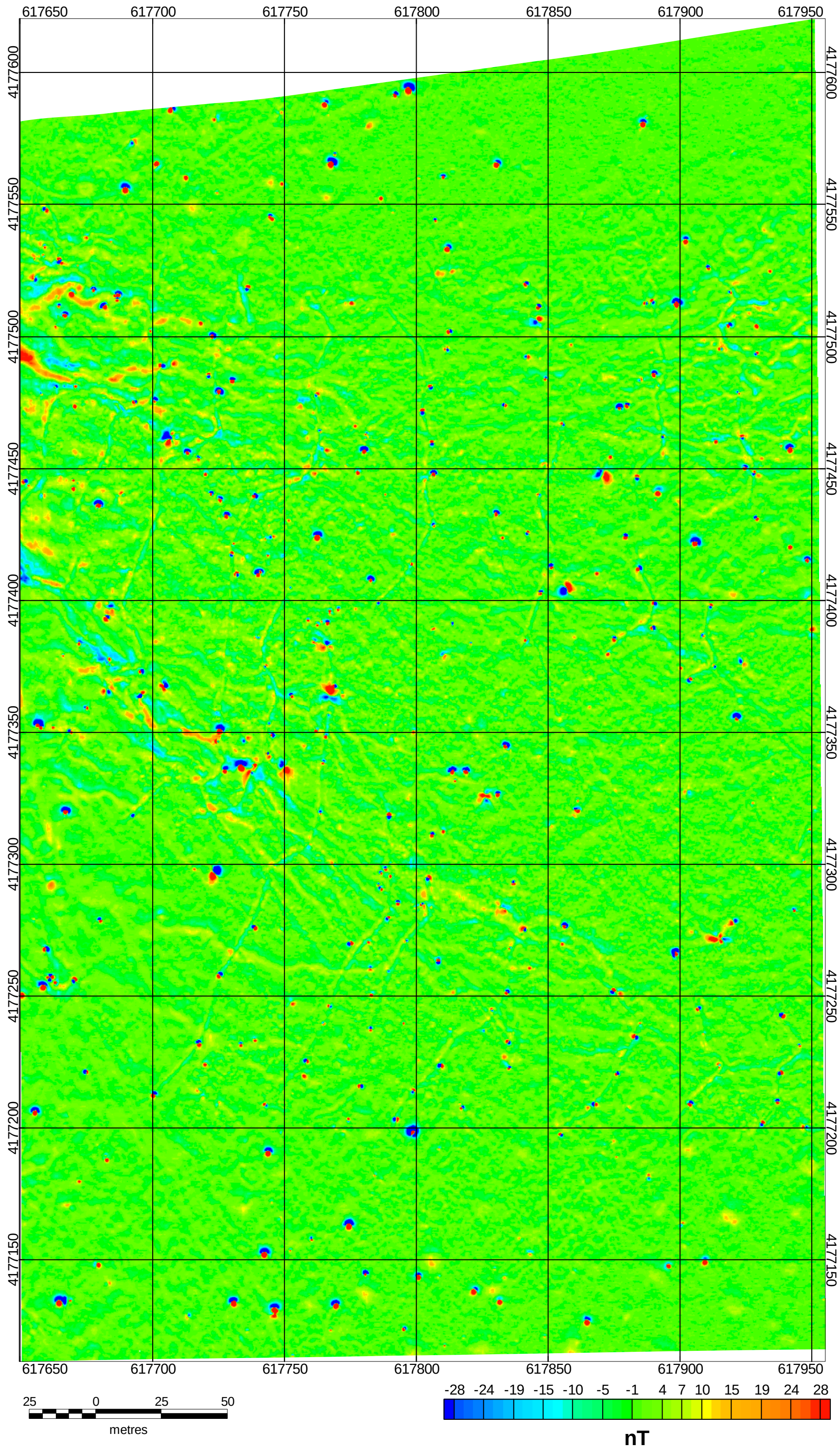

Figure 3-12 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 3B

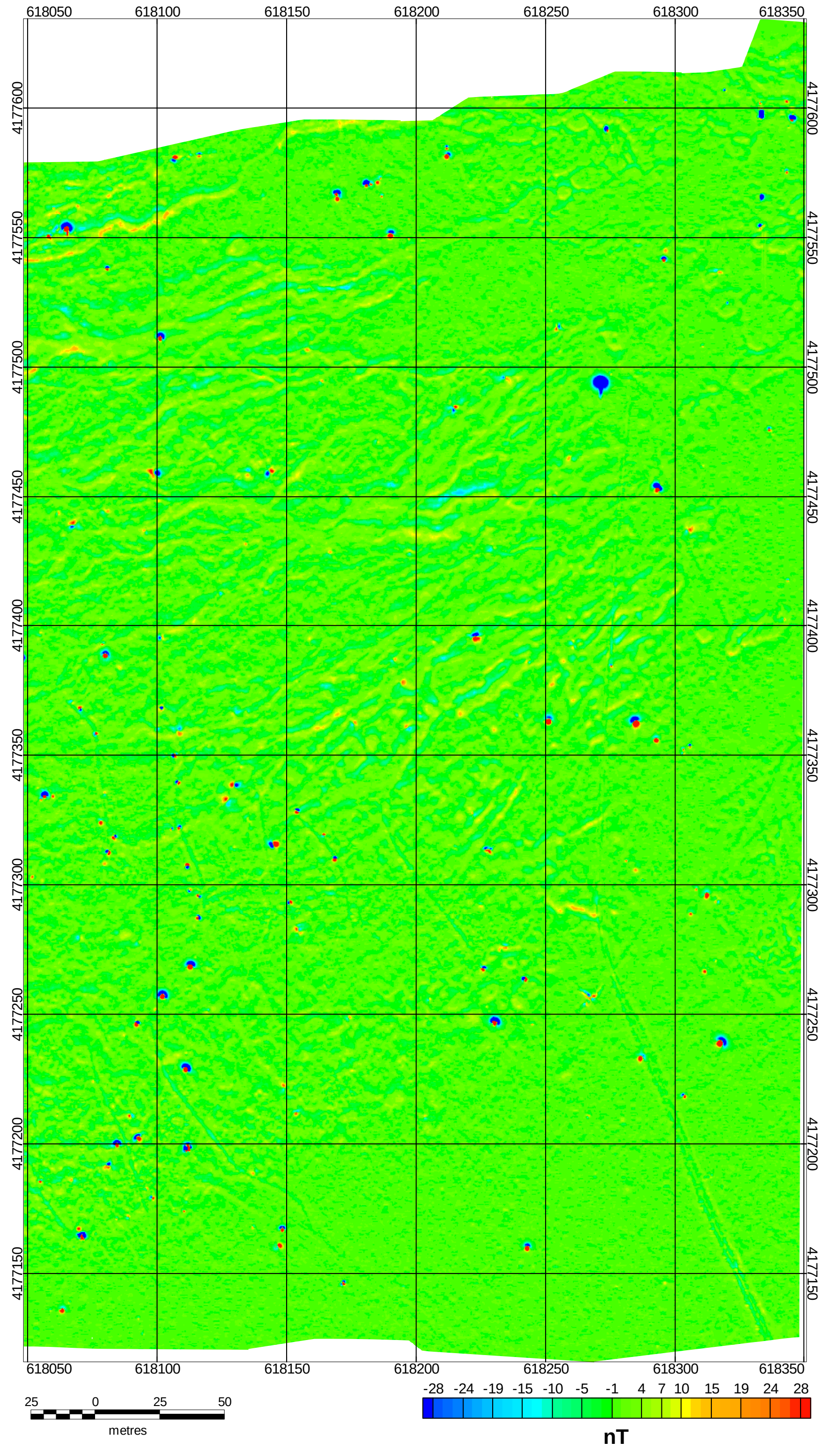

Figure 3-13 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 3C

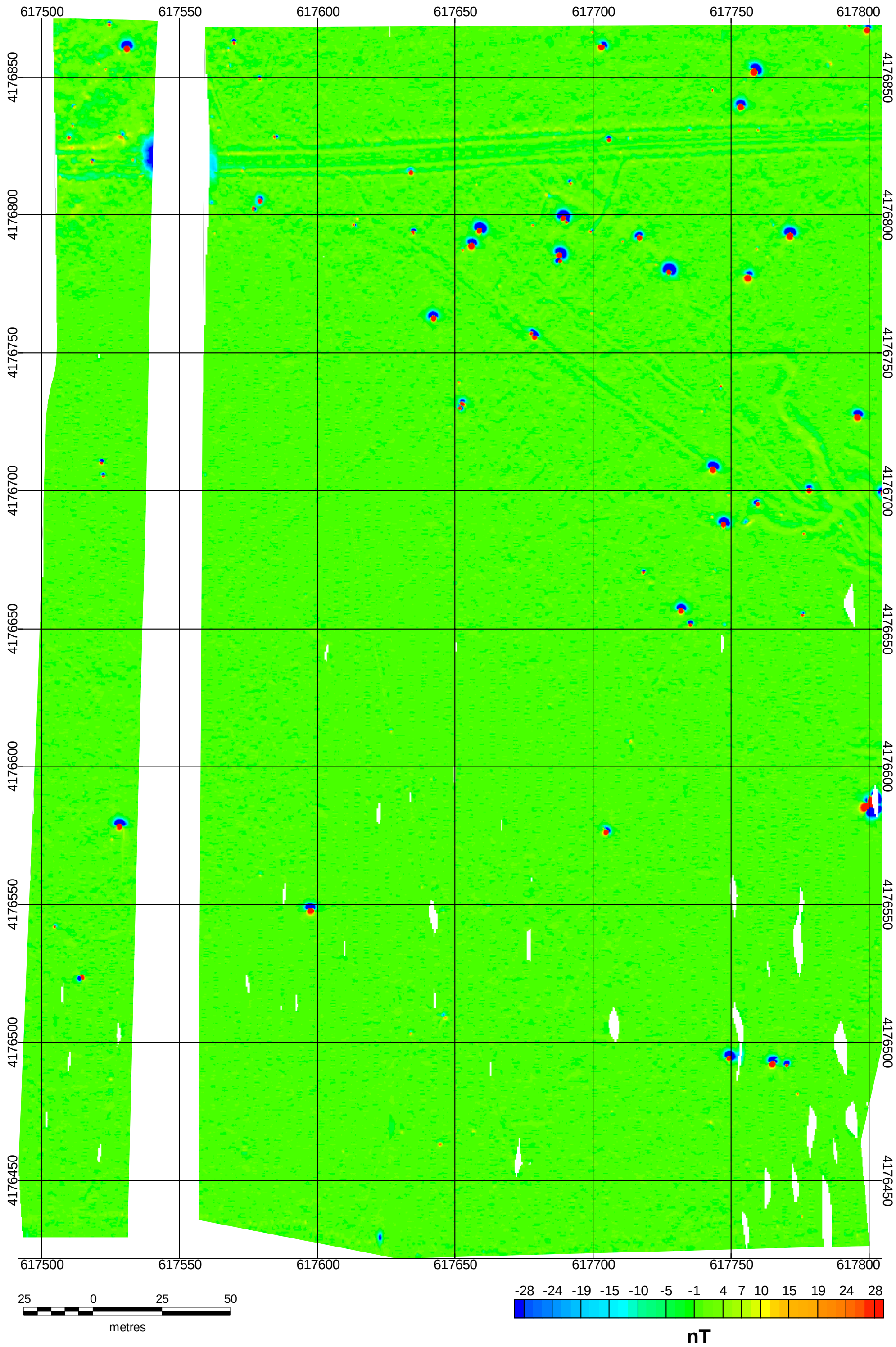

Figure 3-14 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 2A

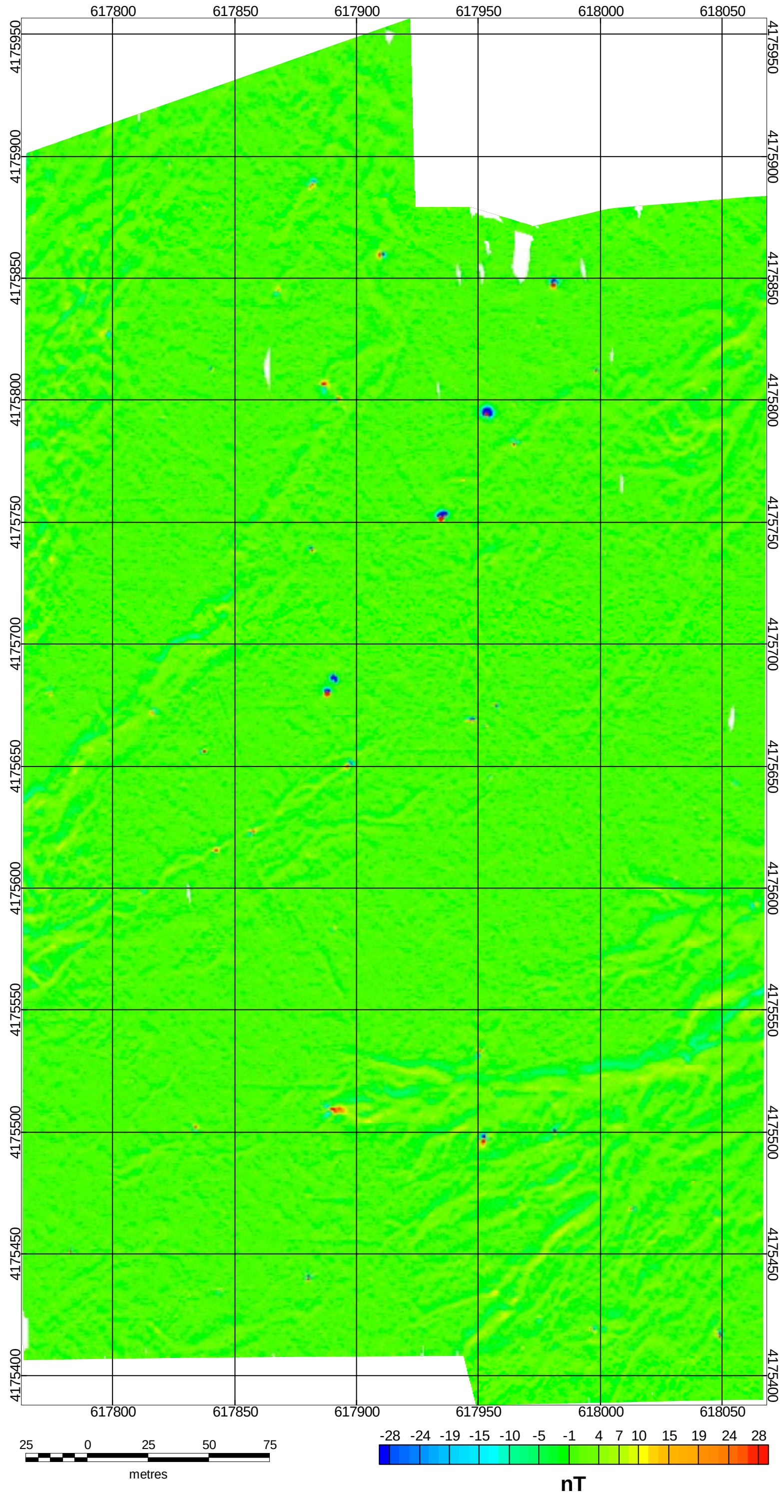

Figure 3-15 – Magnetometer Anomaly Map of Pueblo PBR #2 Area 2B

3.2.5 Calibration Item Results

As mentioned in Section 3.2.2.1.3, a calibration strip of munitions and munitions stimulants was emplaced between the WAA Base Camp and the northern boundary of the Pueblo PBR #2 demonstration site during the vehicular survey. Additionally a 16-lb shotput was emplaced near the Auxiliary Base Camp during use. Table 3-5 gives a schedule of the emplaced items and parameters (i.e. depth and orientation). This calibration strip was surveyed at the beginning and end of each work day in which transect data were collected. Each field day involving transect surveys commenced with collection of a 5-6 minute static survey after the sensors had been warmed up and RTK GPS was established. After the static survey, the calibration strip was surveyed. At the end of the field day, the calibration lane was surveyed again prior to system shutdown in the same direction. To evaluate the data from the calibration items, the peak positive demedianed magnetometer value for each emplaced item in each survey was determined. A sub-area within the calibration lane identified to be relatively free of anomalies was used for each data set to extract a small area of the magnetometer data. The sub-area data were then used to determine the driving background level for each survey. Figure 3-16 shows a magnetometer anomaly map of the calibration strip. The midpoint positions of the emplaced items, as determined by RTK GPS waypointing, are shown as open circles.

3.3 Victorville Precision Bombing Ranges Y and 15

The Victorville WAA Demonstration site includes the former Victorville Precision Bombing Ranges Y and 15. These Ranges are two targets within a much larger complex of bombing targets that are the Victorville Formerly Used Defense Site (FUDS). According the Archives Search Report (ASR) for the Victorville FUDS, the Victorville Precision Bombing Ranges Y and 15 are part of a bombing target complex of approximately 23 targets for the training of both pilots and bombardiers of the Army Air Force West Coast Training Center. The Victorville Army Flying School Bombing Ranges (East and North ranges) were part of the Advanced Twin Engine Bombardier School and the Advanced Flying School #4 located at Victorville Army Air Base. The ranges were used from 1942-1945. Most of the 23 bombing targets were used for precision bombing practice using aiming circles. A Certificate of Clearance (COC) issued on 20 October 1947 states the land use is "suitable for grazing and/or mining only" and referred to a number of targets within the larger Victorville MRA.

The Victorville WAA Pilot Project Demonstration site encompasses approximately 5,500 acres of the Victorville FUDS. Victorville Precision Bombing Range Y consists of 4,862 acres and the adjoining PBR 15 comprises 640 acres. The two targets are located approximately 42 miles southeast of the town of Victorville, CA. The approximate coordinates for the survey area are given in Table 3-7.

3.3.1 Geodetic Control Monuments

Nova Research contracted Merrill-Johnson Engineering, Inc. of Victorville, CA to establish eight geodetic survey points within the demonstration area prior to field operations at the Victorville WAA site. The ortho-photography and LiDAR data collections occurred prior to the installation of these monuments. The demonstrator installed eight temporary monuments of their own labeled TAR1 – 8.

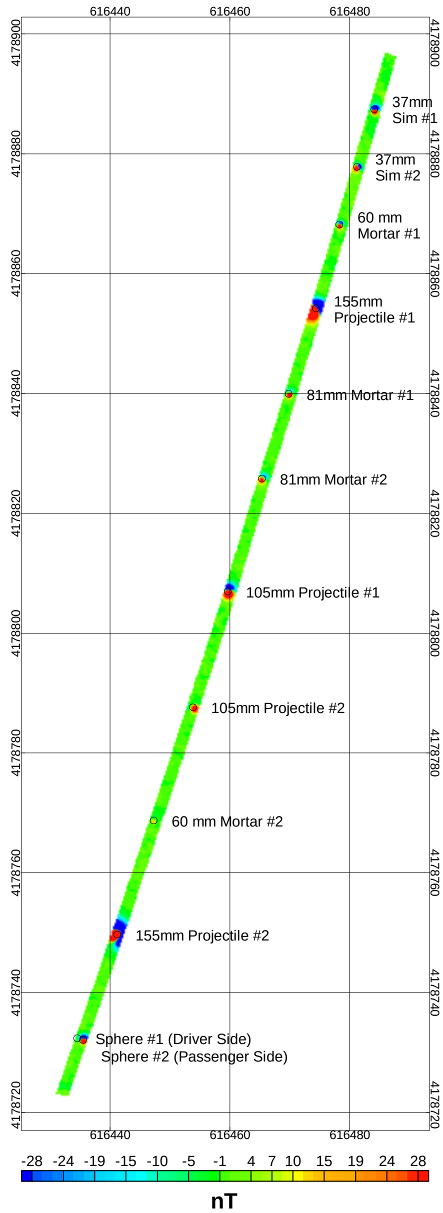

Figure 3-16 – Magnetometer anomaly map of the calibration strip emplaced between the WAA Base Camp and the WAA Demonstration site at Pueblo PBR #2

Merrill-Johnson placed each "NOVA" monument within a few meters of the corresponding "TAR" monument and additionally reacquired each of the "TAR" monuments. The coordinates of all eight points are given in Table 3-8 (horizontal datum: North American Datum of 1983 (NAD83/CORS96); vertical datum: North American Vertical Datum of 1988 (NAVD88); geoid model: National Geodetic Survey Geoid03).

Table 3-7 – Coordinates for the Approximate Corners of the WAA Pilot Project Victorville Demonstration Site

Point	Latitude	Longitude	Northing (m)	Easting (m)
	NAD83/CORS96		UTM Zone 11N, NAD83	
SW	34° 23' 24.23165" N	116° 32' 03.73678" W	3,805,505.15	542,802.43
NW	34° 26' 02.02266" N	116° 32' 02.62074" W	3,810,365.54	542,808.59
NE	34° 25' 59.25292" N	116° 28' 51.46962" W	3,810,303.94	547,687.46
SE	34° 23' 22.26526" N	116° 28' 53.16285" W	3,805,468.19	547,668.98
MS1	34° 23' 22.39906" N	116° 29' 25.00656" W	3,805,468.19	546,855.84
MS2	34° 23' 23.06145" N	116° 30' 29.58979" W	3,805,480.45	545,206.62
MS3	34° 23' 50.70619" N	116° 30' 29.16476" W	3,806,332.01	545,213.34
MS4	34° 23' 51.70337" N	116° 31' 32.23687" W	3,806,355.06	543,602.81
SW	34° 23' 24.11198" N	116° 31' 32.58011" W	3,805,505,15	543,598.02

Table 3-8 – Survey Control Points Installed for the WAA Pilot Project at Victorville PBRs Y and 15

Point Name	Latitude	Longitude	Ellipsoid Height (m)	Northing (m)	Easting (m)	Elevation (m)
	NAD83/CORS96			UTM Zone 11N, NAD83		NAVD88
NOVA1	34° 23’ 33.52094” N	116° 31’ 37.98792" W	796.508	3,805,794.320	543,458.584	827.468
NOVA2	34° 24’ 43.87014” N	116° 31’ 57.55568" W	806.430	3,807,958.890	542,948.957	837.407
NOVA3	34° 25’ 40.60227” N	116° 31’ 25.90349" W	802.874	3,809,710.110	543,748.763	833.857
NOVA4	34° 25’ 45.29604” N	116° 30’ 25.98072" W	766.682	3,809,861.999	545,277.478	797.660
NOVA5	34° 25’ 54.04117” N	116° 29’ 31.19413" W	815.236	3,810,138.272	546,674.434	846.207
NOVA6	34° 25’ 05.62289” N	116° 29’ 12.10592" W	833.047	3,808,649.345	547,169.158	864.016
NOVA7	34° 24’ 38.08707” N	116° 30’ 10.61886" W	753.645	3,807,793.744	545,679.707	784.621
NOVA8	34° 23’ 33.07497” N	116° 29’ 40.35276" W	775.151	3,805,795.067	546,462.335	806.123

3.3.2 Testing and Evaluation Plan

3.3.2.1 Demonstration Set-Up and Start-Up

3.3.2.1.1 Base Camp Facilities

The MTADS vehicular system was mobilized to the site in a U.S. Navy-owned 53-ft trailer. The tow vehicle, the magnetometer trailer, notebook computers for the analysis team, GPS equipment, batteries and chargers, office equipment, radios and chargers, tools, equipment spares, and maintenance items, and magnetometers were transported in the trailer. Harris Transportation Company, a government-contract transportation firm delivered the trailer to the demonstration site upon the arrival of the field team on site. The MTADS Man-Portable (MP) EM system was mobilized to the Victorville site by a traditional shipping company. The necessary GPS equipment, batteries and chargers, and a modest collection of office equipment, radios and chargers, tools, equipment spares, and maintenance items were shipped to a local (Palm Springs, CA) FedEx shipping office and held for pickup by the advance team member.

Due to the remoteness of the demonstration area, no essential support services were available on-site. Accordingly, Nova Research made provisions to acquire all of the requisite supplies, materials, and facilities from local rental firms. For the vehicular survey, an office trailer was provided for data processing and analysis, as a communications center, for battery storage and charging stations, electronics repair station, and as storage for spares and supplies. This trailer was provided with AC power, heating, and cooling. A second 8' x 40' trailer was used to garage and for the secure storage of the MTADS vehicle and sensor platform. Power to the trailers was provided by a diesel field generator (50 kW range) that was also used to recharge the vehicle, radios, and GPS batteries overnight. Communications among on-site personnel was provided by hand-held VHF radios, with a base station located in the office trailer. Radios were provided to all field and office personnel. The availability of cellular phone communications on site was non-continuous but was available in portions of the sites. Fuel storage was provided for the generator and portable toilets were provided to support all field and office crews. Figure 3-17 shows the arrangement of the logistics support at the base camp for the Victorville vehicular survey. Due to the uncontrolled nature of the Victorville site as an open vehicular recreational area, site security was required for the base camp overnight and 24/7 Friday through Sunday. The services of a local security firm were retained to provide this service. Due to the short duration and scope of the MP EM demonstration at the Victorville site, little was required in the way of support on-site. Power was provided on-site by a gas-powered field generator (2 kW range) to recharge equipment batteries during the day. Batteries were also charged overnight in the field team's hotel rooms. A portable toilet was provided onsite to support the field team.

Figure 3-17 – Photograph of the WAA Base Camp at the Victorville PBRs Y and 15 WAA demonstration site showing the relative locations of the trailers, etc.

3.3.2.1.2 Demonstration Set-up

Upon arrival on site for the vehicular demonstration, the team personnel received and unpacked the 53’ trailer and established the base camp. For both demonstrations, the RTK GPS base station receiver and radio link were set up on one of the available established control points. At the Victorville PBRs Y & 15 site, the control point NOVA1 was used exclusively and no radio repeaters were required.

Next, the sensor systems were assembled and tested for proper operation. For the vehicular system, the magnetometer trailer was connected to the tow vehicle and the system was powered up. The connectivity of the magnetometers to the DAQ computer and the establishment of normal SNR performance were verified along with the operational state of the vehicle RTK system. For the MP EM system, the sensor array was assembled and the establishment of normal SNR performance was verified along with the operational state of the RTK GPS system

3.3.2.1.3 Calibration Lane and Objects

A lane of calibrations items was emplaced by the demonstration team near the base camp. The schedule of emplaced calibration items is given in Table 3-9. A section of ATV trail near the base camp was selected as a possible location for the calibration lane. The trail was attractive for stability reasons due to the relatively hard-packed soil as compared to other areas near by. A magnetometer survey of the proposed area was conducted, comprised of several passes to verify the area as reasonably clear of anomalies prior to emplacement. The items were emplaced in a roughly North / South line with 20-m spacing between the larger items and 10-m spacing for the smaller items. Each item was digitally photographed in place and positions recorded for the nose and tail of each item using RTK GPS. In the case of the spheres and the vertical 37mm stimulant, only one position was recorded. The holes were then backfilled with the removed material and leveled. A single pass magnetometer survey was conducted over the calibration lane after installation. The data were submitted to the Data Analyst for analysis including SNR and detection. For reference, the Earth’s magnetic field parameters (computed with the IGRF model using the 2005 data set) are Total Field 48467.5 nT, Inclination 59.6°, Declination 12.8°.

The inclination of the emplaced items was such that a range of solid angles with respect to the Earth's magnetic field were represented.

3.3.2.2 Field Work Daily Regimen

The Site Safety Officer would conduct a 'tail-gate' safety meeting prior to beginning the day's efforts each day that personnel were on site. The topic(s) for each day's meeting were at the discretion of the Site Safety Officer and focused on safety issues relating to the day's planned work. The RTK GPS base station receiver and radio link were then established on one of the site's available established control points.

Two systems performance checks were conducted at the beginning of each work day when transects data were being collected. A period (5-6 minutes) of quiet, static data was collected and submitted to the Data Analyst for validation. A data collection sortie would then be conducted over the calibration items.

Table 3-9 – Schedule of Ground-based System Victorville WAA Calibration Targets

Item	Depth	Azimuthal Orientation of Nose or Thread Section
16-lb shotput	10 cm 25 cm	N/A N/A
37mm simulator	10 cm 30.5 cm	North (N/S) Vertical
60mm mortar	10 cm 25 cm	North (N-S) 45° (NE)
81mm mortar	25 cm 40 cm	East (E-W) 45° (NE)
105mm projectile	40 cm 60 cm	North (N-S) East (E-W)
155mm projectile	50 cm 100 cm	East (E-W) 45° (NE)

This sortie would be repeated at the end of the work day as well. On a few occasions it was not possible to collect the end-of-day calibration data due to site closure due to weather or equipment malfunction bringing about an abrupt end to the day's efforts.

During the MP EM demonstration, each field day commenced with warming up the sensor for a minimum of 30 minutes while the RTK GPS network was being established and the team was deploying to the day's survey area. Static tests of the sensor platform were conducted each survey day. Generally, during a period of high GPS PDOP (Positional Dilution of Precision) at approximately 9:00 am each day, a static survey was collected to monitor the static sensor levels for the EM61 MkII. GPS data were collected during this survey but they suffer from the reduced accuracy of the high PDOP event. Since the primary goal of the static data collection was to evaluate the EM61 MkII sensor and not the positioning which had previously evaluated, this compromise was authorized by the Quality Assurance Officer (QAO) to enhance productivity. A data set was collected for 5-10 minutes while the sensor platform was kept stationary and all team members standing away from the platform. Every effort was made to minimize the movement of personnel and equipment during the survey. The calibration strip was not available for the MP EM demonstration. In lieu of such, one of our standard calibration objects, a 4” Aluminum (Al) sphere was placed on a visually-identified clear area and used as an ad hoc calibration object to test system response at the beginning and end of each day. The exact location of the sphere at each measurement was not independently recorded by GPS waypointing but the approximate locations are extracted from the calibration survey data.

Preventative maintenance inspections were conducted at least once a day by all team members, focusing particularly on the tow vehicle and sensor trailer or the MP EM sensor array. Any deficiencies were addressed according to the severity of the deficiency. Parts, tools, and materials for many maintenance scenarios are available in the system spares inventory located on site. Routine tools and supplies, for example spare tires for the tow vehicle and sensor trailer, were carried in the chase vehicle which accompanied the tow vehicle onto the site. Status on break-downs / failures that resulted in long-term delays in surveying was reported to the WAA Project Manager as appropriate.

3.3.2.3 Periods of Operation

The main portion of the demonstration was accomplished from Monday, March 20th through Friday, March 31st, 2006. Operations were conducted as detailed in tabular form in Table 3-10. The MP EM demonstration occurred during the period Sunday, October 1st through Tuesday, October 10th, 2006. Operations were conducted as detailed in tabular form in Table 3-11.

Table 3-10 – Victorville PBRs Y & 15 Survey Demonstration Planning Schedule

Date (2006)	Planned Action
Week of March 6th	Pack 53’ trailer at Blossom Point.
Mon, March 13th	Trailer leaves Blossom Point for Victorville.
Sun, March 19th	Personnel arrive in Yucca Valley.
Mon, March 20th	Receive and unpack 53’ trailer. Receive and set up base camp. Assemble MTADS system. Install and survey calibration items.
Tue, March 21st	Begin ground surveys.
Fri, March 31st	Complete ground surveys.
Fri, March 31st	Pack 53’ trailer. 53’ trailer picked up. Base camp demobilized.
Sat, April 1st	Personnel depart Yucca Valley.
Fri, April 7th	Trailer arrives at Blossom Point.
Week of May 8th	Submit Draft Data Report to ESTCP.

3.3.3 Transect Magnetometer Survey Results

The transect plan provided by PNNL / SNL was based on archive data (CSM) and WAA Pilot Project goals, and designed to interrogate the entire Victorville WAA Demonstration site for the actual positions and footprints of PBRs Y and 15 as noted in the CSM and to locate any additional similar features of interest. The transect plan was designed to traverse precision bombing targets used for dropping 100-lbs practice bombs dropped from high-altitude aircraft and 100-lbs HE-laden demolition bombs dropped from low flying aircraft. 100-lbs practice bombs were also reported to have been dropped on Target 15 during low altitude missions. The design probability of traversing such a 500 ft circular target or feature of interest was set at 100%. The transects were oriented E/W with a 154 m spacing. As an example, a portion of the E/W transect plan is shown in Figure 3-18 along with the COG of the transect data collected on March 21, 2006.

Table 3-11 – Victorville PBRs Y & 15 MP EM Survey Demonstration Field Schedule

Date (2006)	Planned Action
Week of September 18th	Equipment packed at Blossom Point.
Monday, September 25th	Equipment transferred to NRL for shipment.
Tue, September 26th	Equipment left NRL for hold in Palm Springs, CA.
Fri, September 29th	Equipment arrived Palm Springs, CA.
Sun, October 1st	Advance personnel arrived in Palm Springs, CA.
Mon, October 2nd	Advanced personnel received, deployed to site, and unpacked equipment. Remaining team members arrived in Yucca Valley and continued with site preparation.
Tue, October 3rd	Total coverage surveys began
Wed, October 4th	Completed total coverage surveys and began transect surveys.
Sun, October 8th	Completed transect surveys and packed equipment.
Mon, October 9th	Equipment shipped to Blossom Point. Advance personnel departed Palm Springs, CA.
Tue, October 10th	Remaining team members depart Palm Springs, CA
Thu, October 19th	Equipment arrived at Blossom Point.
Week of October 30th	Submitted Draft Data Report to ESTCP.

Five additional areas of interest were identified from the E/W transect data by PNNL / SNL, labeled Additional Transect Request (ATR)-1 through -5. The transect plans were based on 67 m transect separation (132 m for ATR-4) and transect lengths running from 265 to 454 m.

Figure 3-19 shows the results of all transect data collected in the course of this demonstration. The COGs are shown as green lines and each detected anomaly is shown as a filled circle. The total acreage covered by transect surveys was 93 acres, or approximately 1.7% of the total 5,500 acre site. Natural topology (ravines, dense boulder fields, etc.) made it difficult and impractical to complete each transect in a single survey. Therefore each transect was broken into one or more segments in the field. The flexibility of the MTADS Pilot Guidance software allows for this to be done easily and on the fly. The exact details of the area covered by each survey file are given in the Demonstration Data Report [16].

3.3.4 MP EM Transect Survey Results

Transect MP EM data were collected following a transect plan consisted of segments of 35 of the original vehicular East / West transects that could not be completed by the vehicular survey due to surface geology and terrain limitations. Figure 3-20 shows the results of all transect data collected in the course of this demonstration. The COGs are shown as green lines and each detected anomaly is shown as an open circle.

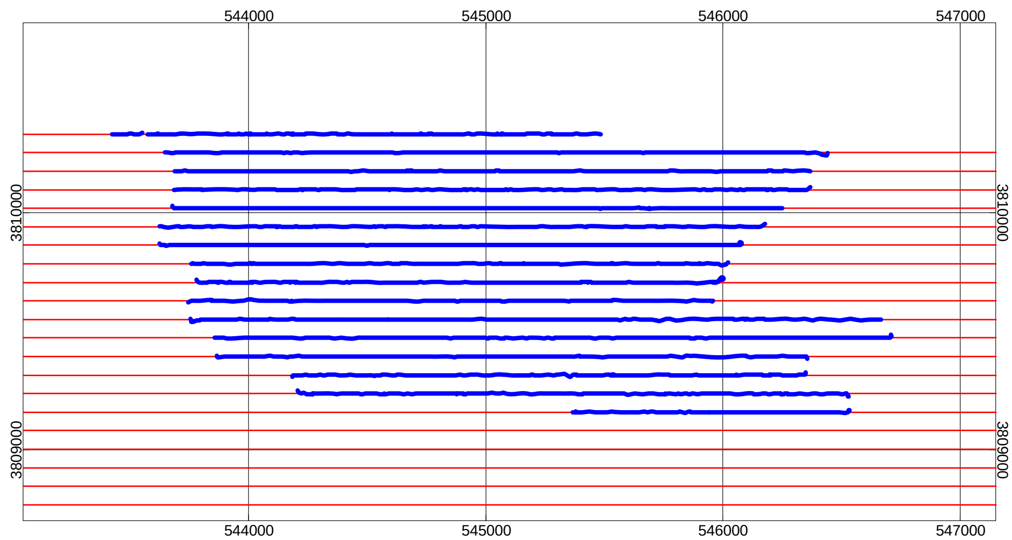

Figure 3-18 – Victorville PBRs Y and 15 transect plan with actual survey COG (blue) for Julian date (06080, March 21, 2006) shown.

The total acreage covered by transect surveys was 14 acres, or approximately 0.25% of the total 5,500 acre site. When combined with the 1.7% site coverage of the vehicular survey, the total site coverage by transects approaches 2%. The combined transect results are shown in Figure 3-21. Transect COGs are shown as green lines for the vehicular magnetometer and blue for the MP EM system. Individual detected anomalies are shown as filled circles, a green fill color for vehicular magnetometer and a blue fill color for MP EM.

Transects were broken into one or more segments in the field to minimize off-transect walking time based on road and trail availability. A transect was surveyed in more than one file when the situation warranted, e.g. if the survey is halted for a GPS outage window. The exact details of the area covered by each survey file are given in the Demonstration Data Report [17]. To allow calibration between the vehicular magnetometer and MP EM surveys, 1-km long portions of Transects 19 and 21 were surveyed by the EM system. Transect 21 crosses over a portion of

PBR #15 and Transect 19 is located 154 m to the south. See Section 4.2.4 for discussion of the comparison.

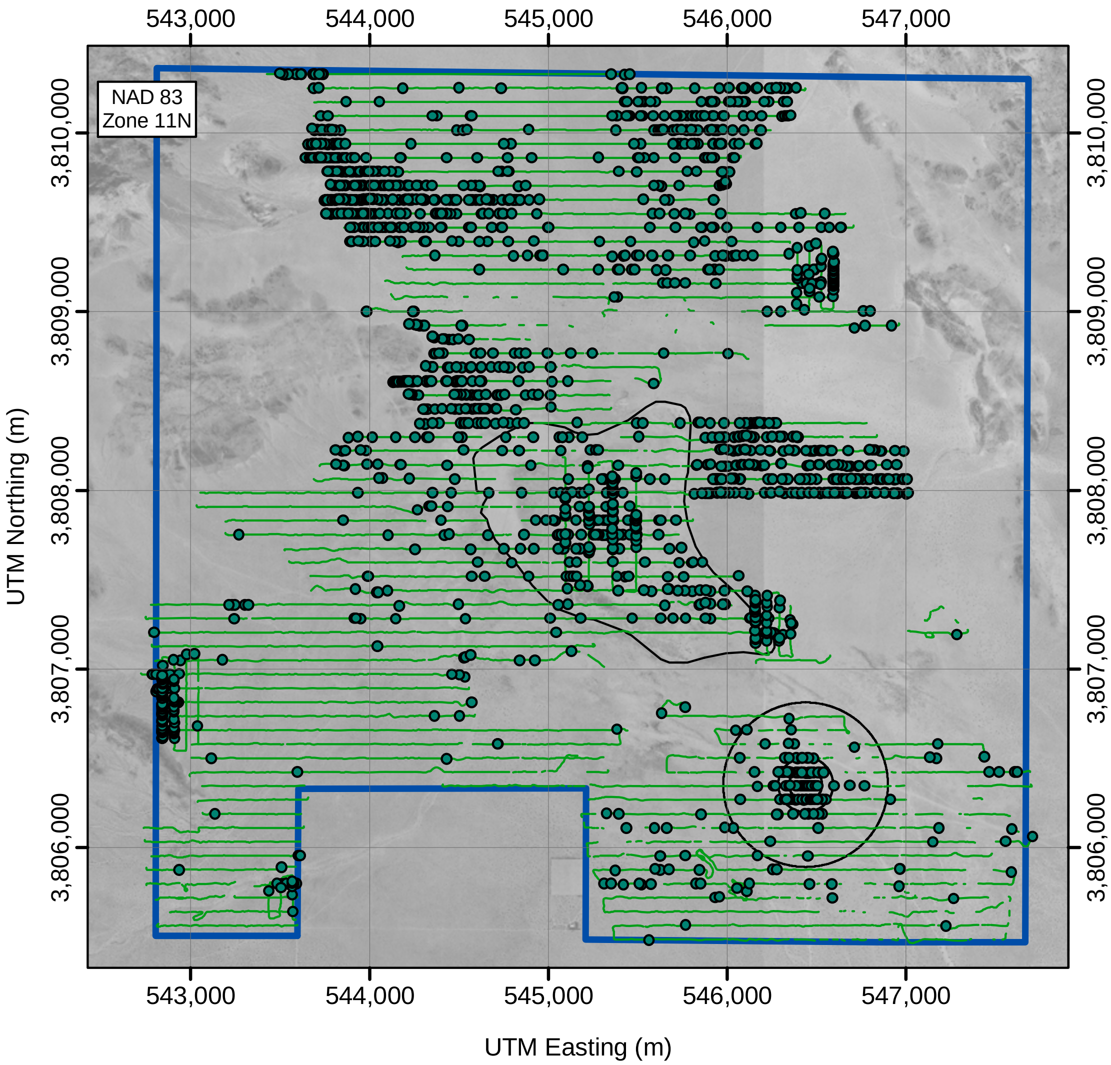

Figure 3-19 – Map showing the magnetometer transect survey results for the Victorville PBRs Y and 15 demonstration. Transect COGs are shown as green lines and individual detected anomalies are shown as filled circles.

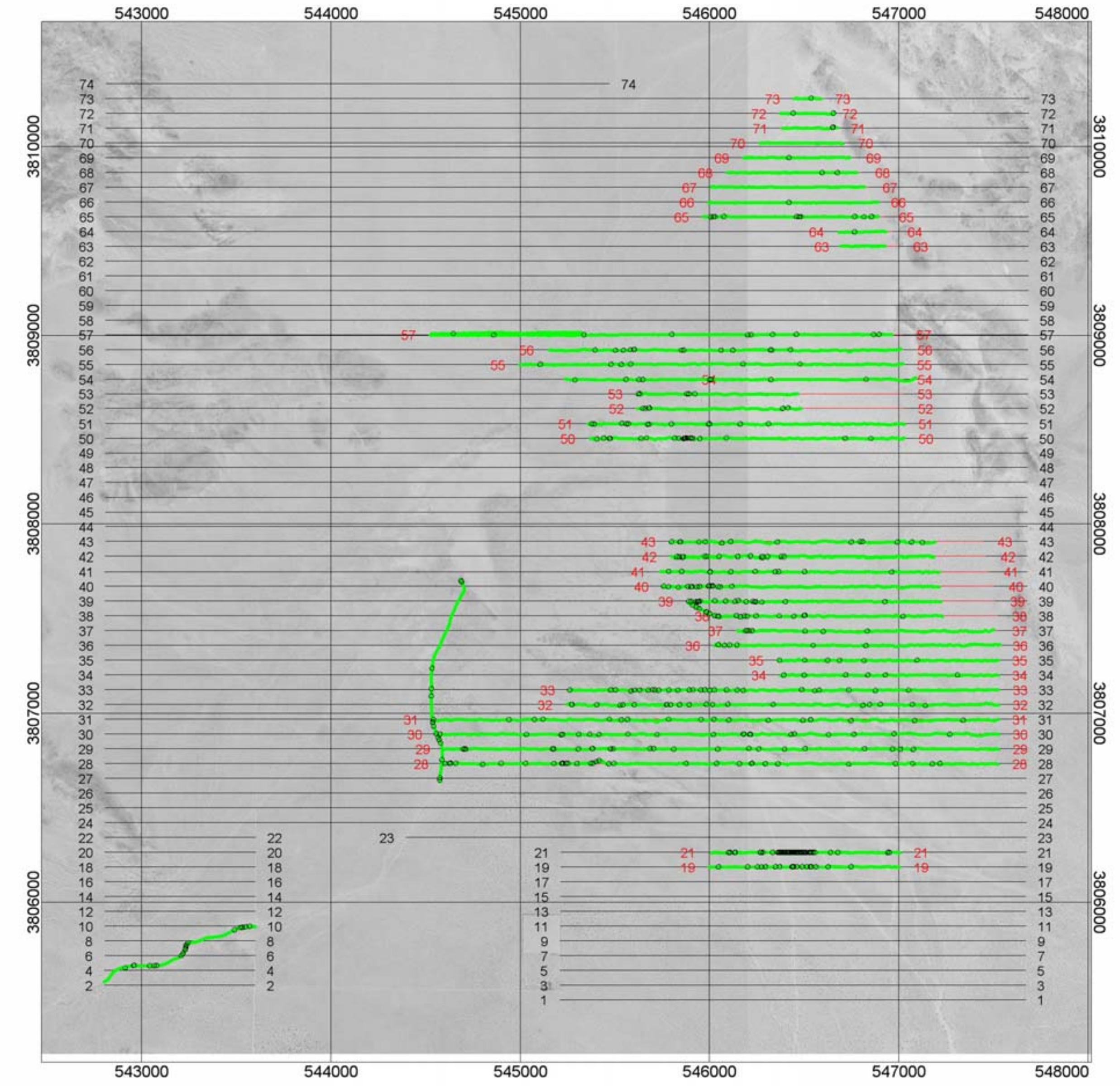

Figure 3-20 – Map showing the transect survey results for the Victorville PBRs Y and 15 MP EM demonstration. Transect COGs are shown as green lines and individual detected anomalies are shown as open circles. The black lines represent the original transect plan and the red lines represent the MP transect plan.

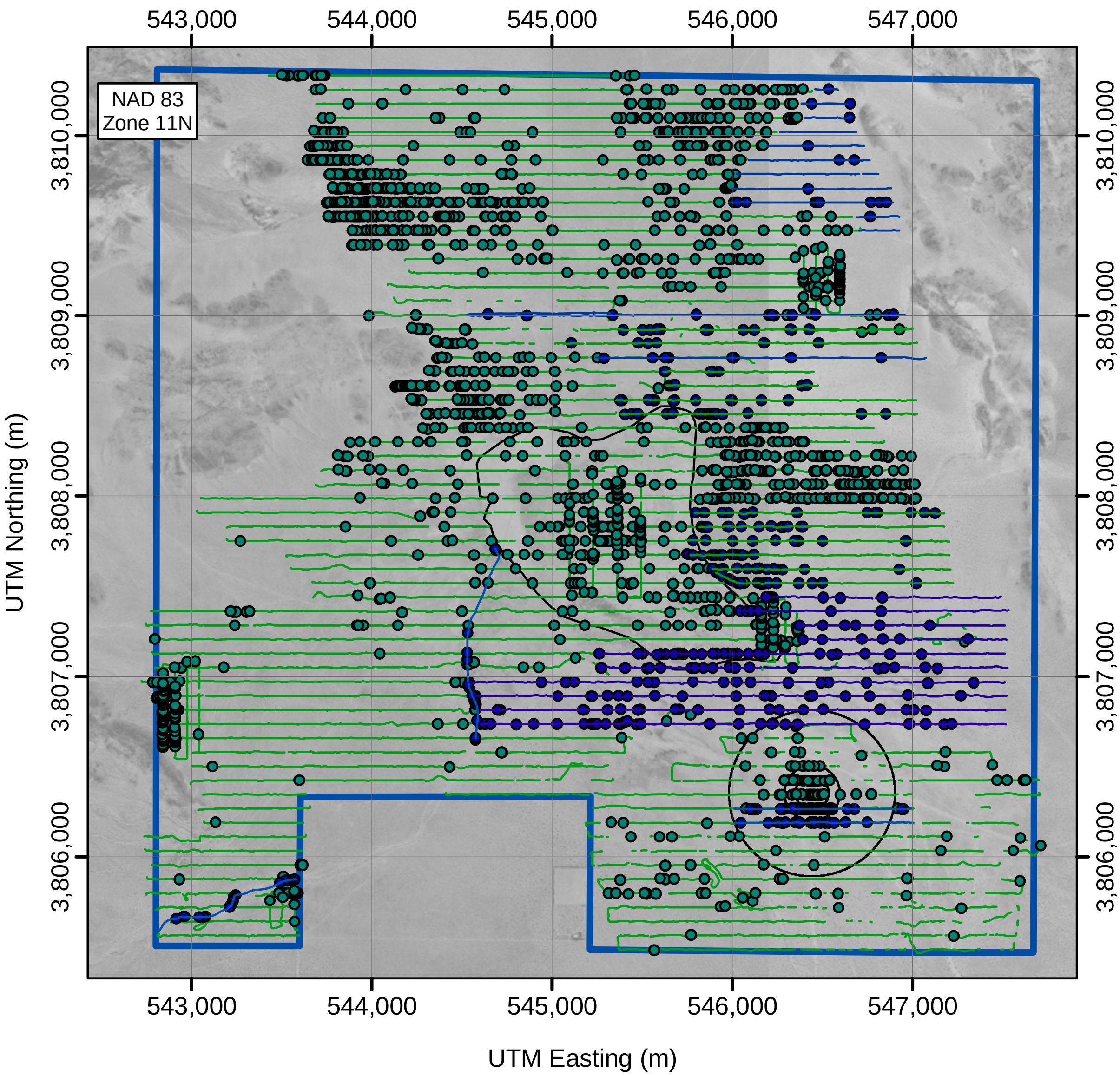

Figure 3-21 – Map showing all transect survey results for the Victorville PBRs Y and 15 demonstrations. Transect COGs are shown as green lines for the vehicular magnetometer and blue for the MP EM system. Individual detected anomalies are shown as filled circles, a green fill color for vehicular magnetometer and a blue fill color for MP EM.

3.3.5 Total Coverage Magnetometer Survey Results

In addition to the transect surveys covering the breadth of the Victorville site, several small areas (6 – 30 acres each) were selected for total coverage magnetometer surveys. Areas were selected in cooperation with the ESTCP Program Office to achieve three objectives: 1) to characterize background anomaly densities in areas found to be quiet (low anomaly density) in the transect survey results, 2) to characterize the falloff behavior of the anomaly density as a function of distance from Target 15 within the demonstration site, and 3) to gather further information on AOIs identified either from the transect data or from other sources. These surveys were conducted as typical MTADS magnetometer surveys with a line spacing of 2.0 m (tire next to tire spacing).

Figure 3-22 shows the total coverage area magnetometer anomaly maps for each survey area superimposed on an aerial photograph of the Victorville WAA demonstration site. Table 3-12 contains a summary of the total coverage survey results. Column two lists the number of anomalies extracted by the operator in the DAS in each area and column four lists the number of those anomalies which could be fit using the resident dipole model to a coherence value of 0.85 or better (typical). Three 30-acre total coverage areas were selected in cooperation with the Program Office and surveyed. The three areas are labeled TCArea 01, 02, and 03. The area dimensions were 350 m in the North / South direction and 300 m in the East / West direction. TCArea 01 is located in the north-central portion of the demonstration area and was selected to represent a "quiet" area, or one with a limited number of anomalies, based on the available transect data at the time of the decision. A magnetometer anomaly map of TCArea 01 is shown in Figure 3-23. As the transect data became available for the southern portion of the site, it became clear that the southern portion of the site exhibits a generally lower background anomaly count than the northern portion of the site. TCArea 02 and 03 were selected to provide magnetometer data for AOIs near the Mean's Dry Lake lakebed and were selected by the Program Office based on the available high airborne data. Figure 3-24 and Figure 3-25 present the magnetometer data anomaly maps for TCArea 02 and 03 respectively. As planned, TCArea 03 was increasing cratered and harder to traverse moving eastward from the western edge. Consequently, we were only able to survey 75 meters into the area from the western edge. After discussion with the Project Manager, an addition 50 meters was surveyed starting at the western edge of the area and moving further west, for a total width of 125 meters.

Table 3-12 – Victorville PBRs Y & 15 Total Coverage Area Result Summary

Area	Number of Anomalies	Anomalies / Acres	Number of Dipole Fits	Acres
TCArea 01	252	8.3	252	30.3
TCArea 02	2453	85.2	2453	28.8
TCArea 03	756	63.5	756	11.9
PBR 15 Radial	1350	45.0	1350	30.0
Hot 1	1695	256.8	705	6.6
Hot 2	1461	251.9	704	5.8
Hot 3	1477	234.4	837	6.3
Hot 4	1534	247.4	990	6.2

Collected and processed magnetometer data were exported from the Oasis montaj environment and loaded into the MTADS DAS software for individual anomaly analysis. The archived magnetometer data and the detailed anomaly lists for each area are provided in the Demonstration Data Report [16].

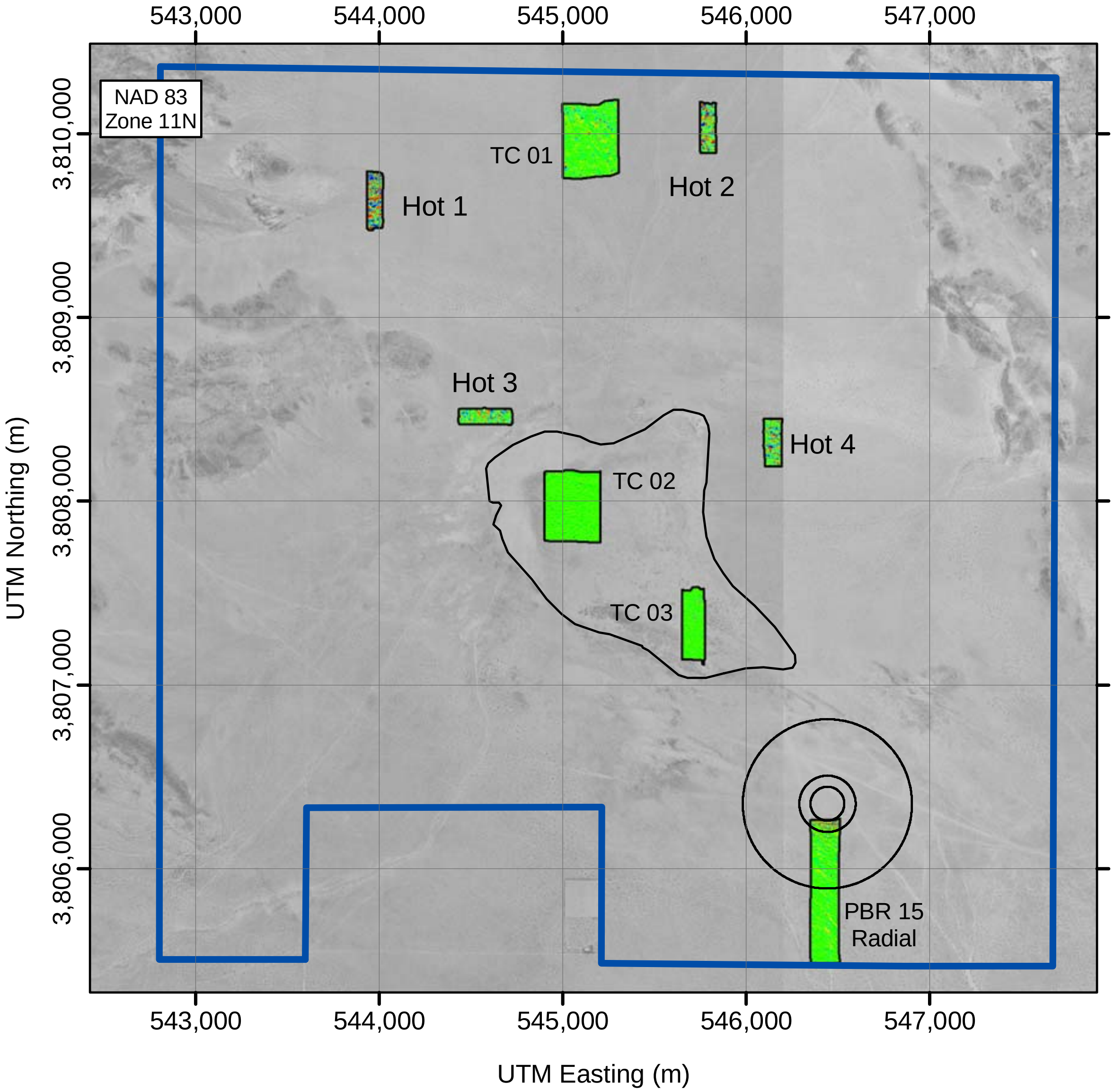

Figure 3-22 – Victorville PBRs Y and 15 Total Coverage Survey Areas

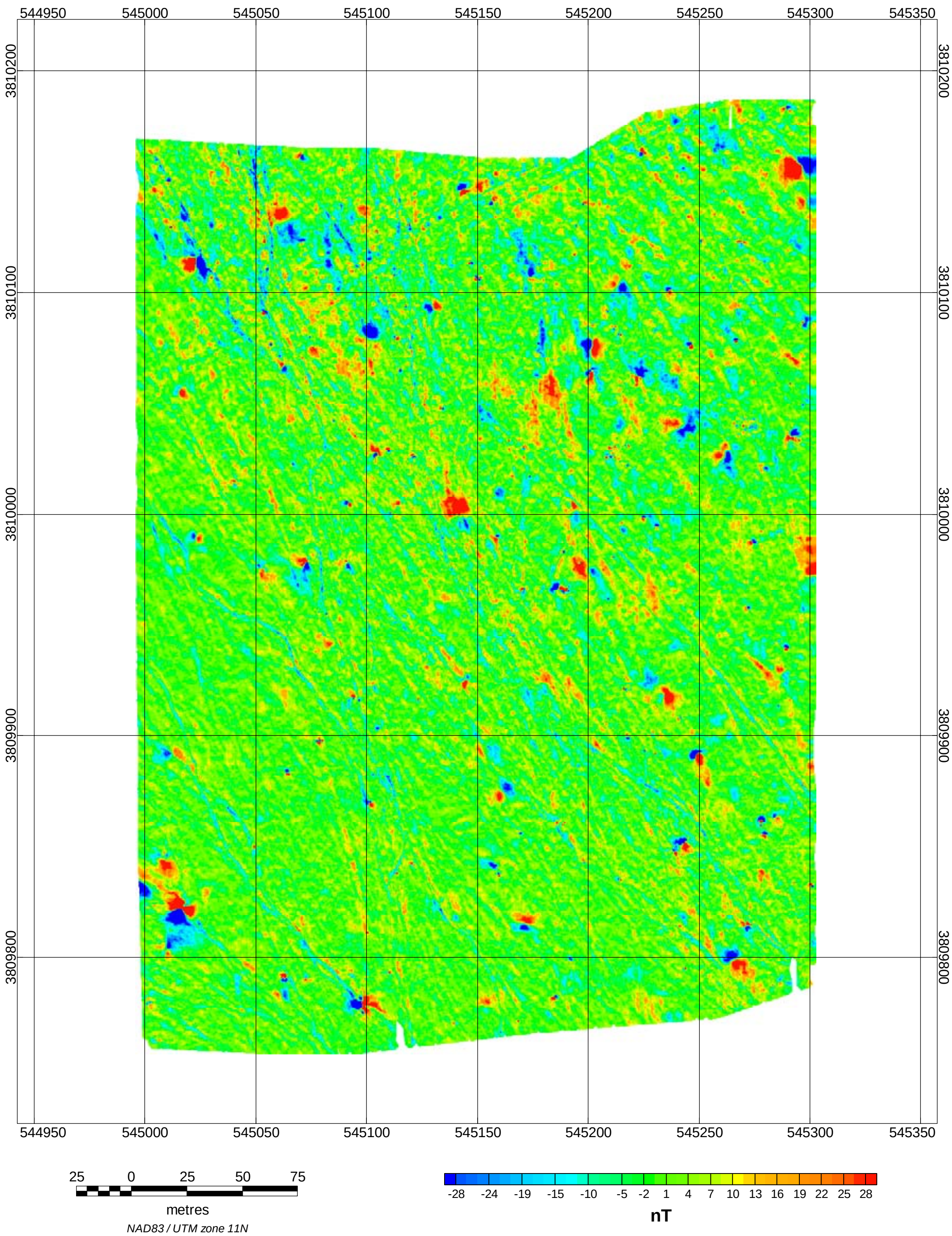

Figure 3-23 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 Total Coverage Area 01

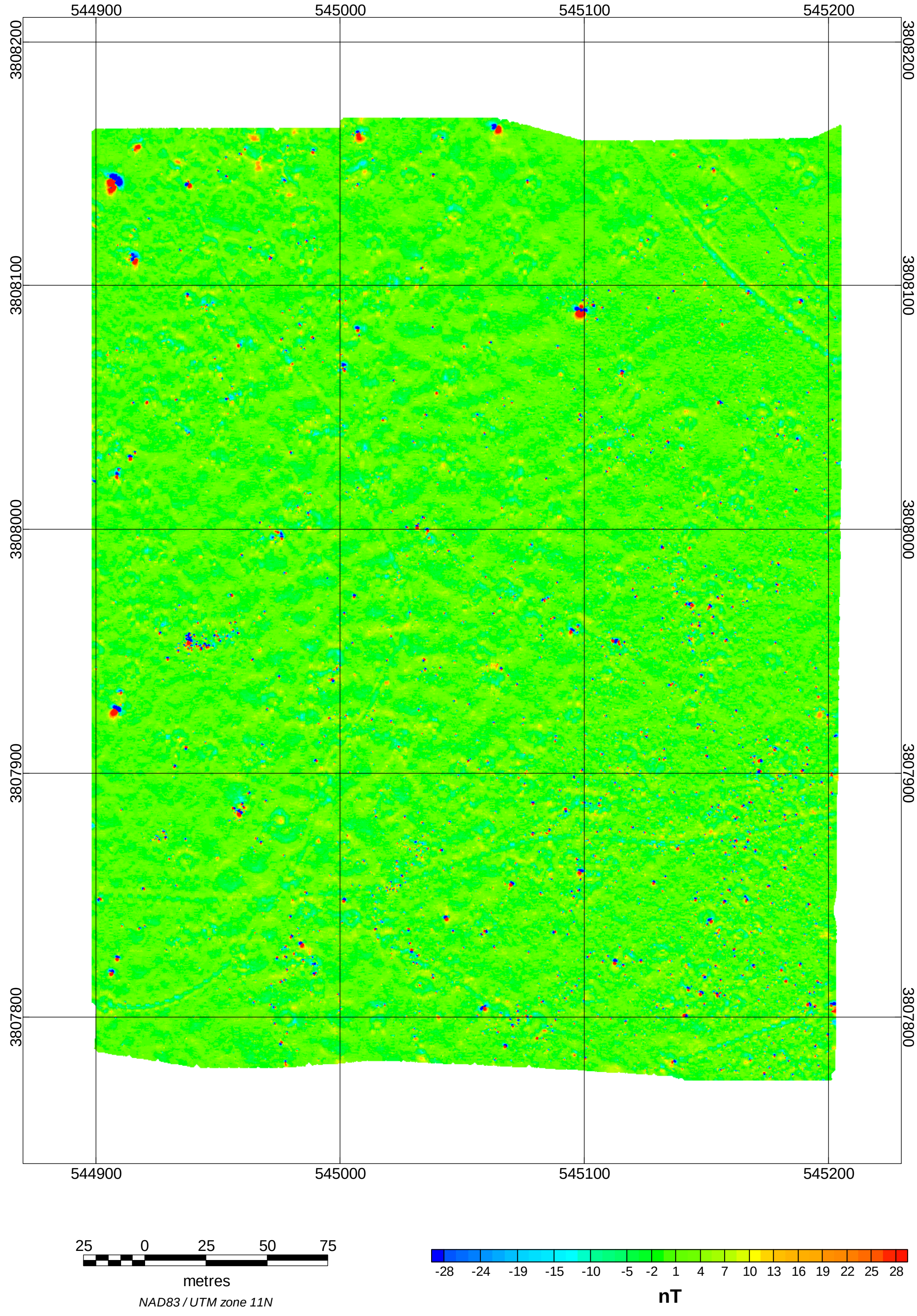

Figure 3-24 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 Total Coverage Area 02

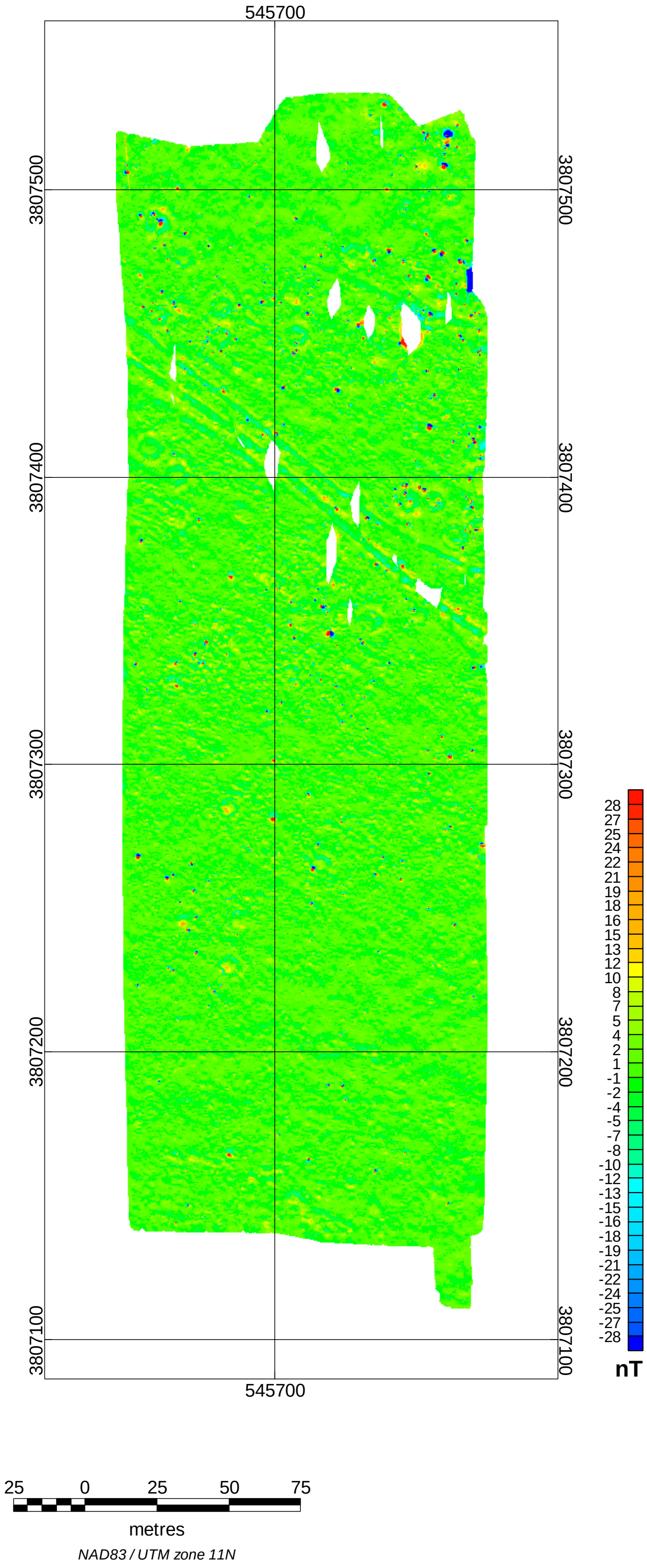

Figure 3-25 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 Total Coverage Area 03

Based on the East / West transect survey results (see Figure 3-19), four additional total coverage areas were selected to explore several regions of high anomaly density. The locations within the demonstration area can be seen in Figure 3-22. These areas were originally designed with dimensions 250 m down-track and 162 m cross-track, or 12 acres in area. After members of the field team visiting each area to evaluate the sites and consulting with the Program Office, the areas were decreased to 81 m cross-track, or 6 acres in area. While visiting the four sites, a possible hypothesis was developed as to the source of the high anomaly counts. The surface of each area was covered with a large number of rocks with sizes ranging from that of a basketball to pebble-sized. Examples are shown in Figure 3-26 and Figure 3-27. Given the potential source of the high anomaly counts, labels TCArea Hot 1 through 4 were assigned to these areas.

Figure 3-26 – Examples of smaller rocks found on the surface of Victorville PBRs Y & 15 TCArea Hot 4. A VHF radio is shown for scale.

Magnetometer anomaly maps for areas TCArea Hot 1 through 4 are presented in Figure 3-28 through Figure 3-31. Notice that area TCArea Hot 3 was rotated from the North / South orientation to the East / West orientation to facilitate the mechanics of conducting the survey by accounting for the local terrain.

The total coverage survey conducted south of the PBR #15 Target center was used to map the anomaly density falloff as a function of radial distance from the Target. The magnetometer anomaly map for this area is shown in Figure 3-32.

Figure 3-27 – An example of the larger rocks found on the surface of Victorville PBRs Y & 15 TCArea Hot 4. A VHF radio is shown for scale.

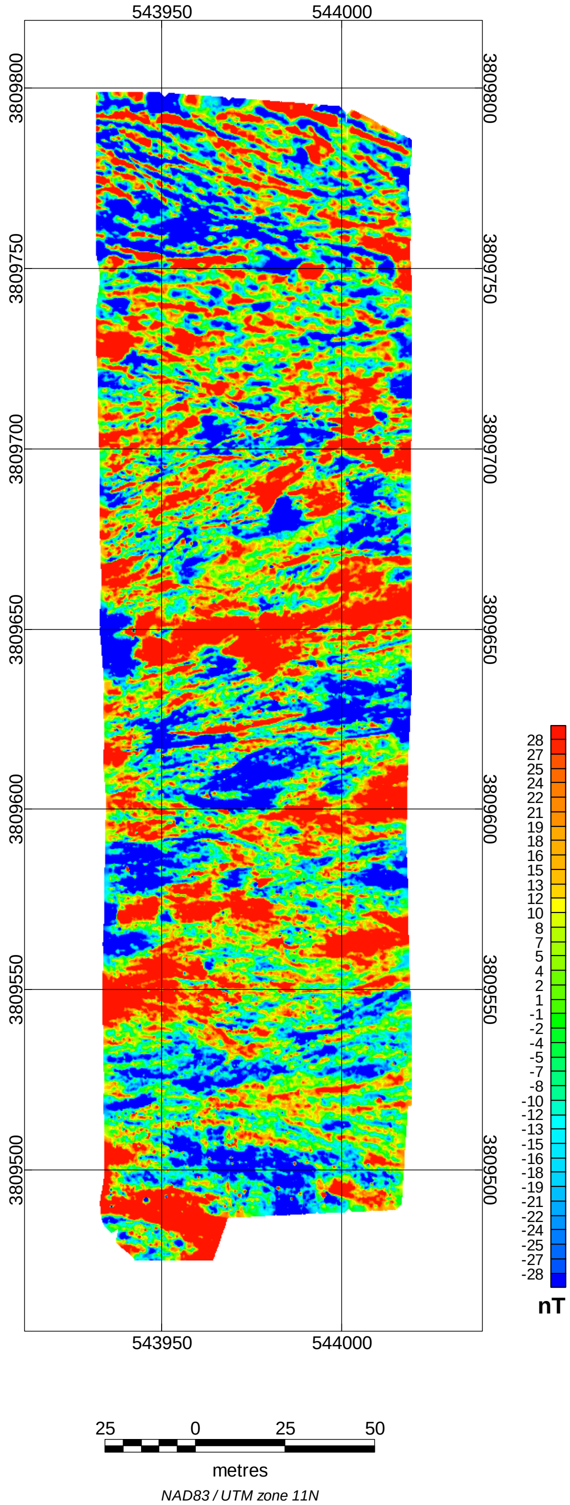

Figure 3-28 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 TCArea Hot 1

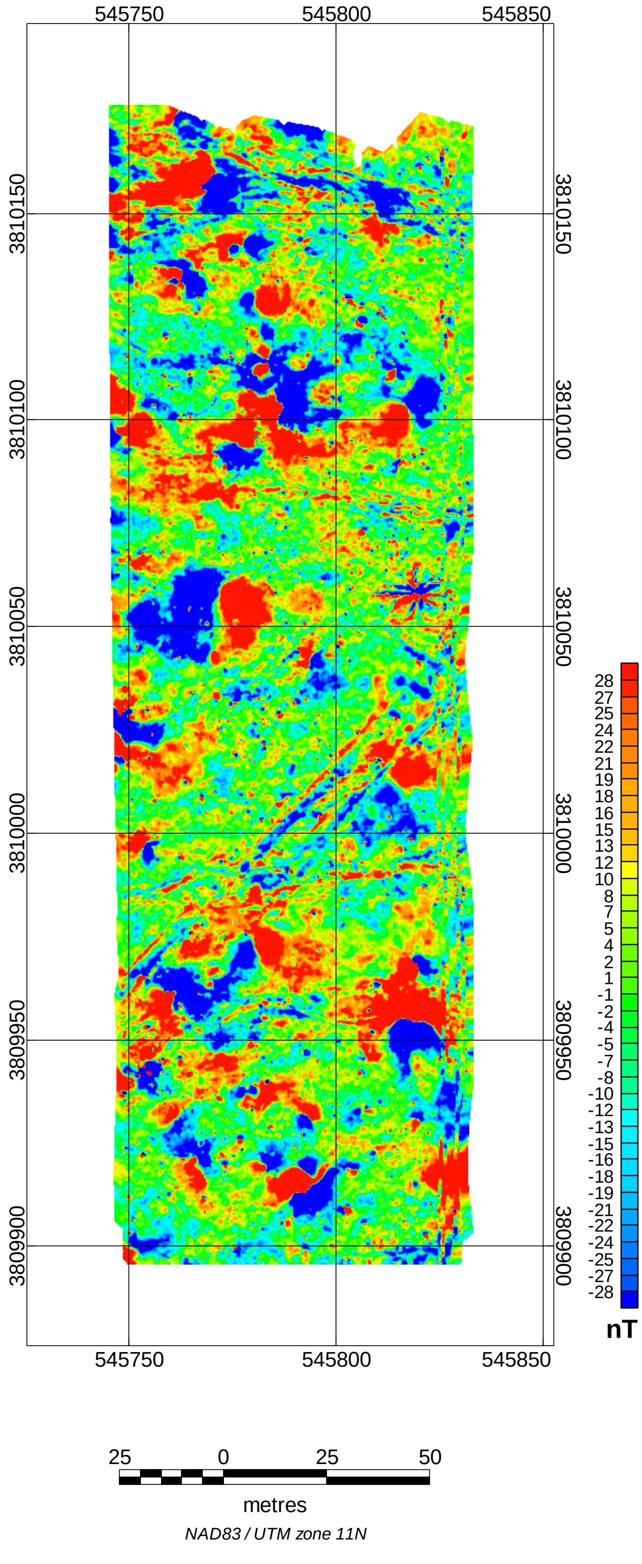

Figure 3-29 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 TCArea Hot 2

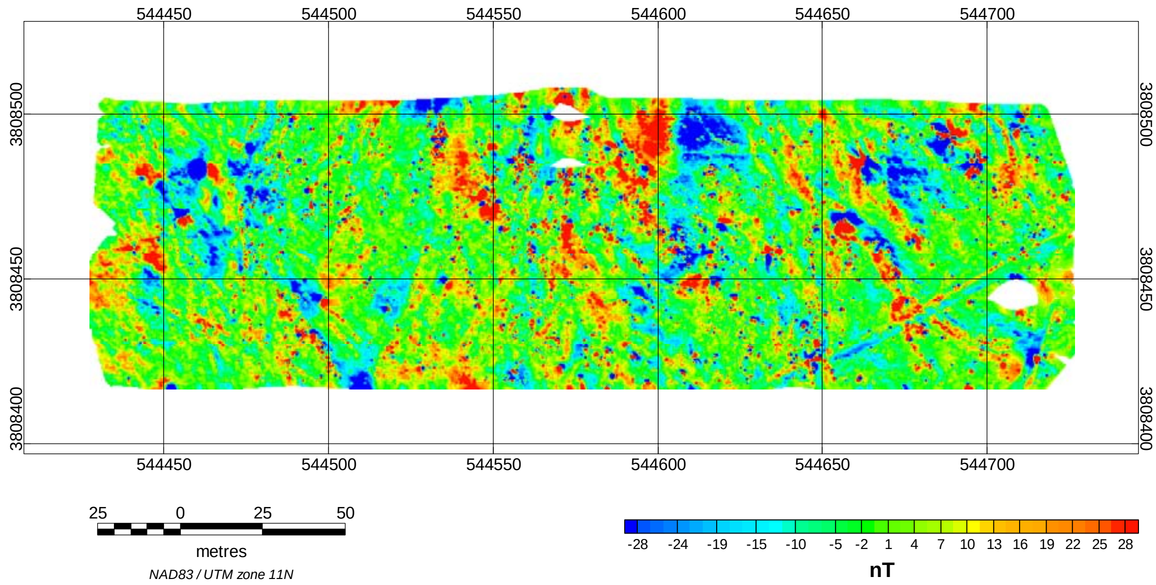

Figure 3-30 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 TCArea Hot 3

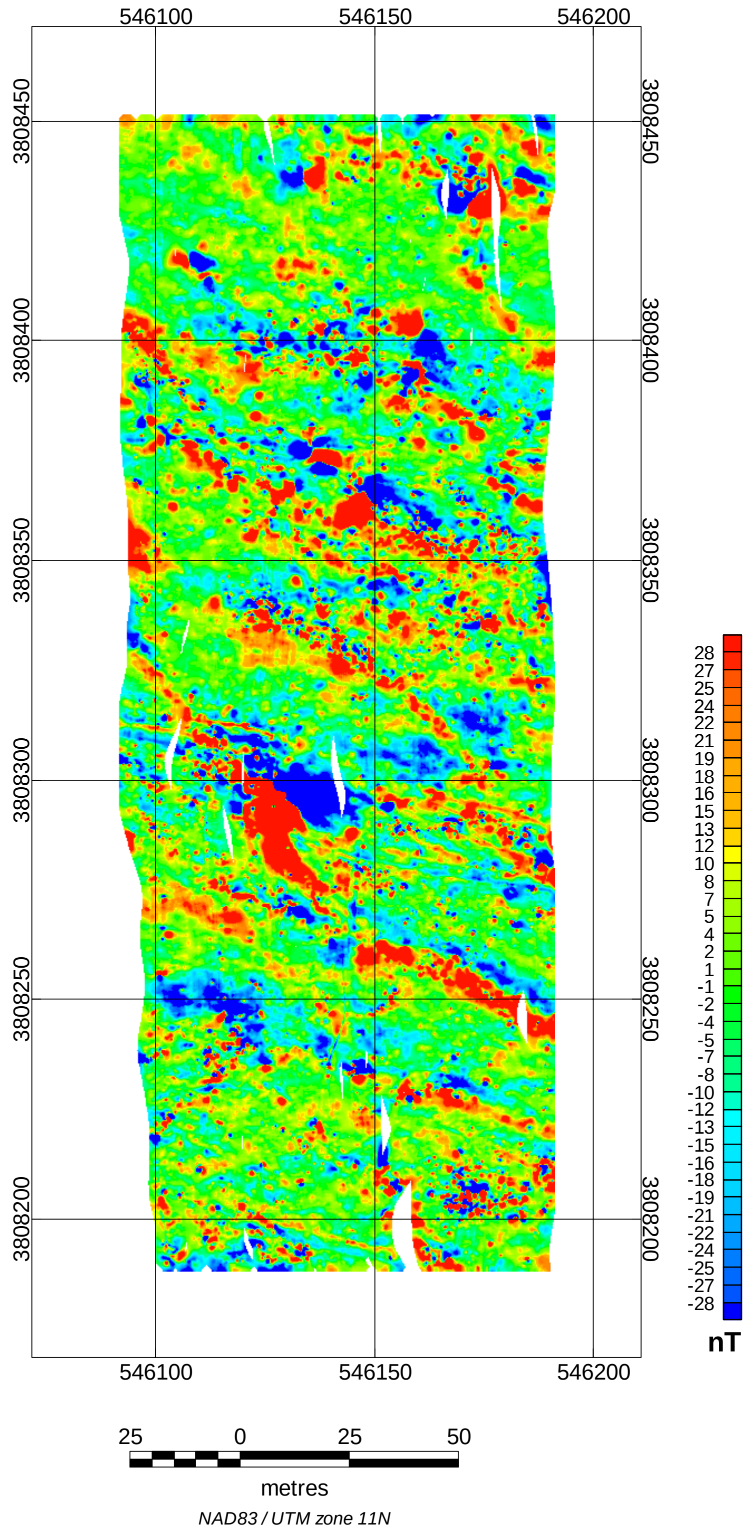

Figure 3-31 – Magnetometer Anomaly Map of Victorville PBRs Y & 15 TCArea Hot 4

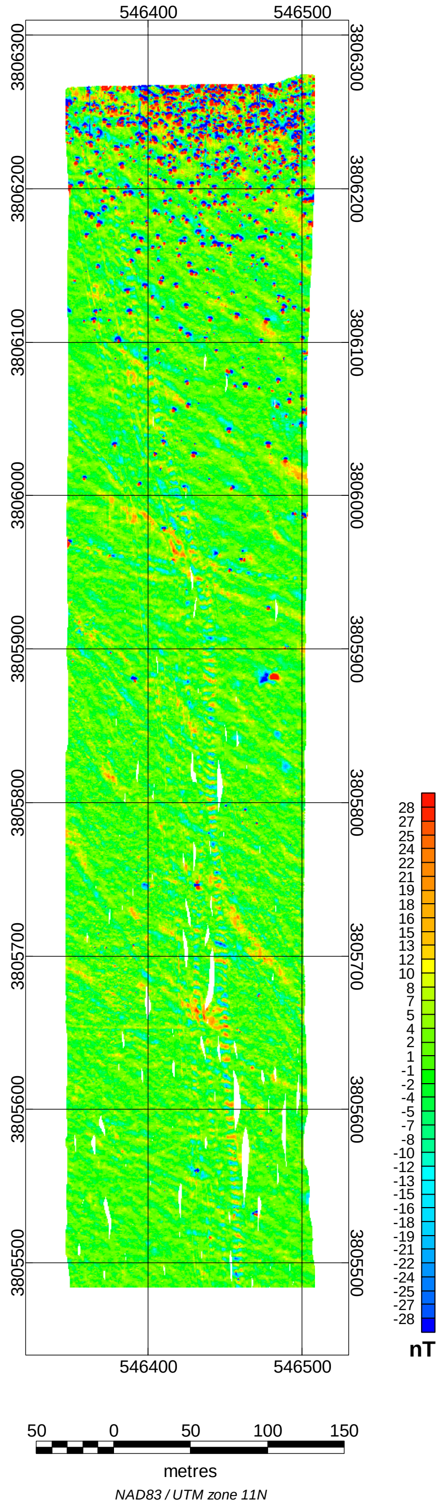

Figure 3-32 – Magnetometer Anomaly Map of the Victorville PBR 15 Radial Total Coverage Area

3.3.6 MP EM Total Coverage Survey Results

The total coverage areas in the northern portion of the Victorville site from the vehicular survey were found to have a much higher magnetic anomaly density, ~250 anomalies/acre, than was seen in the southern portion of the site and had been seen previously at other WAA demonstration sites, 80 anomalies/acre or less. Based on site reconnaissance and considering the geology of the area, the high anomaly density was attributed to magnetically active or 'hot' rocks. To validate the 'hot' rocks assignment of the northern magnetic anomalies, man-portable EMI total coverage surveys were conducted on small subsets (0.75 to 1 acre each) of three vehicular total coverage areas. One area was located in the southern portion of the site within the PBR #15 Radial TC area, an area known to contain munitions-related material as a control. Two others areas were located in the northern portion of the site within the confines of vehicular TCAreas Hot 1 and Hot 2.

The first area, the PBR #15 Radial MP TC area, is located in the south-east corner of the demonstration site and contains surface-visible fragments of 100-lbs practice bomb and other munitions-related items. This area was chosen as a control for the validation of the vehicular results in the north. Many magnetic anomalies in this area correspond to munitions-related items and should have a corresponding EM signature from the litter-carried system. Figure 3-33 gives a close-up view of the magnetic anomaly map and proposed survey area (Refer to the full magnetic anomaly map in Figure 3-32). All analyzed vehicular anomalies within the proposed area are indicated by unfilled, black circles. The Gate 1 EM anomaly map for the PBR #15 Radial MP TC Area is shown in Figure 3-34. The large amplitude, linear anomaly on the western edge of the survey is a metal chain laid out on the surface as a timing reference for the survey. One hundred and nine (109) anomalies were analyzed and fit parameters determined using both 660 μs time gates (top and bottom) and the UX-Analyze tool. The archived EM data and the detailed anomaly list are provided in the Demonstration Data Report [17].

The second vehicular TC area, TCArea Hot 1, is located in the northwest corner of the WAA demonstration site and contained little or no surface-visible material, cultural or munitions-related. However, the results from the vehicular magnetometer survey identified 1695 anomalies, of which 705 could be fit using the resident dipole model in the MTADS DAS, or 257 anomalies/acre. Given the likelihood of finding volcanic, magnetically active 'hot' rocks in this area, the pattern of anomaly location with respect to the severely weathered hillsides, and surface reconnaissance; the abnormally high anomaly count from the vehicular data in this area has been attributed to 'hot' rocks. If this attribution is correct, the anomaly count should be significantly lower with the EM system and few anomalies should be common between the vehicular and man-portable surveys. A proposed survey area 30m wide x 150m tall was selected containing 245 anomalies, of which 104 can be fit, from the vehicular data which are shown in Figure 3-28. The Gate 1 EM anomaly map for the TCArea Hot 1 MP EM is shown in Figure 3-35. The large amplitude, linear anomaly on the northern edge of the survey is a metal chain laid out on the surface as a timing reference for the survey. No EM anomalies of significant signal strength were found. The archived EM data are provided in the Demonstration Data Report [17].

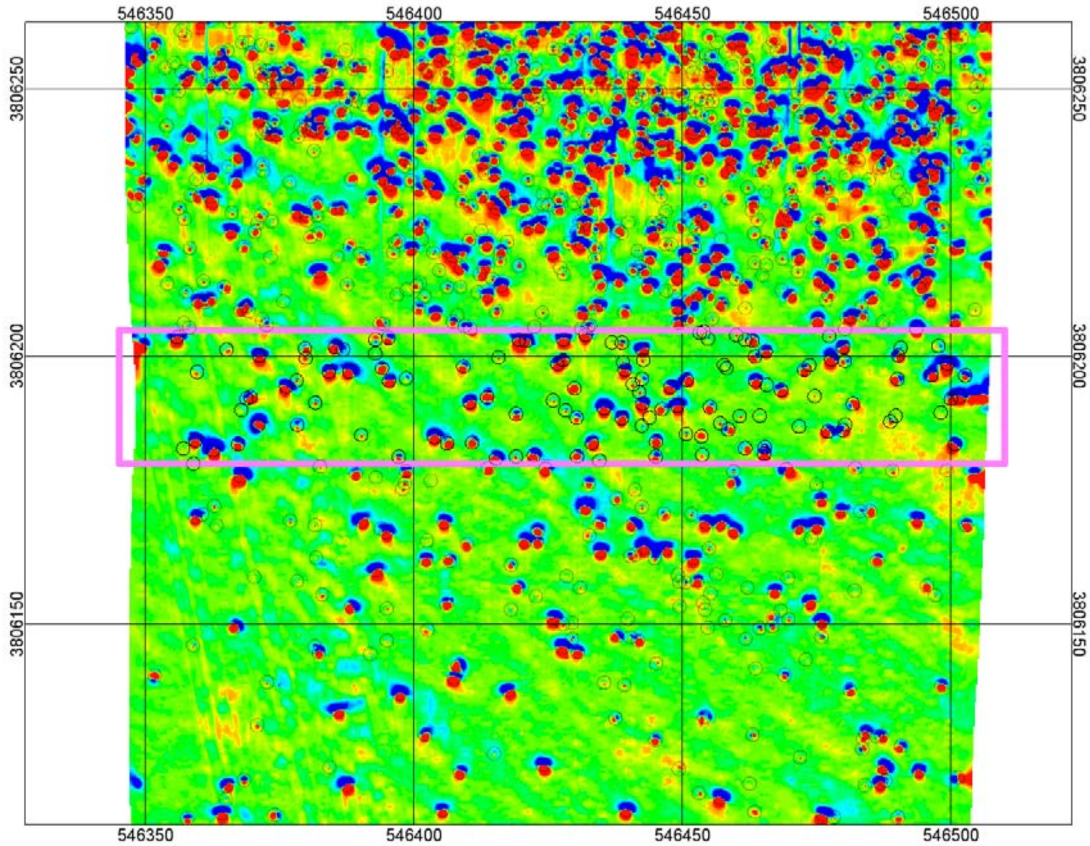

Figure 3-33 – Close up of the Victorville PBR #15 MP EM TCArea

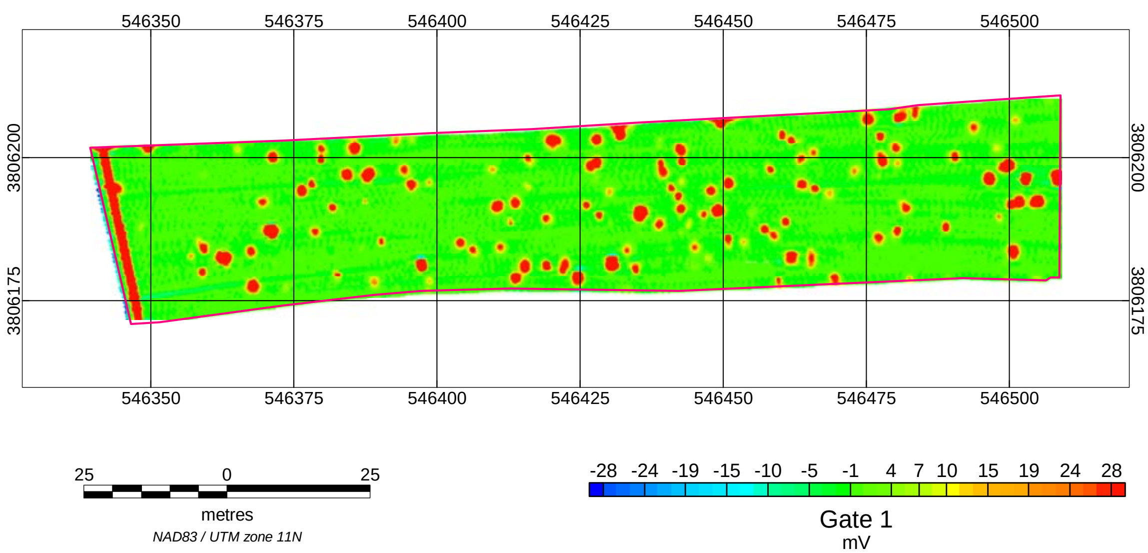

Figure 3-34 – Victorville PBR #15 radial MP EM TCArea anomaly map (time gate 1)

The third vehicular TC area, TCArea Hot 2, is located in the northeast corner of the WAA demonstration site and contained little or no surface-visible material, cultural or munitions-related. However, the results from the vehicular magnetometer survey identified 1461 anomalies, of which 704 could be fit using the resident dipole model in the MTADS DAS, or 252 anomalies/acre. In addition to the 'hot' rocks issue seen for TCArea Hot 1, TCArea Hot 2 also appeared to contain several large, deep magnetic anomalies as seen in Figure 3-29. The TCArea Hot 2 MP EM area was chosen to include several of these large deep anomalies as well. The area was 25m wide x 150m tall and contained 199 anomalies, of which 101 could be fit from the vehicular data. The Gate 1 EM anomaly map for the TCArea Hot 2 MP EM is shown in Figure 3-36. The large amplitude, linear anomaly on the northern edge of the survey is a metal chain laid out on the surface as a timing reference for the survey. One anomaly was analyzed and fit parameters determined using both 660 μs time gates (top and bottom) using the UX-Analyze tool. The archived EM data and the detailed anomaly list are provided in the Demonstration Data Report [17].

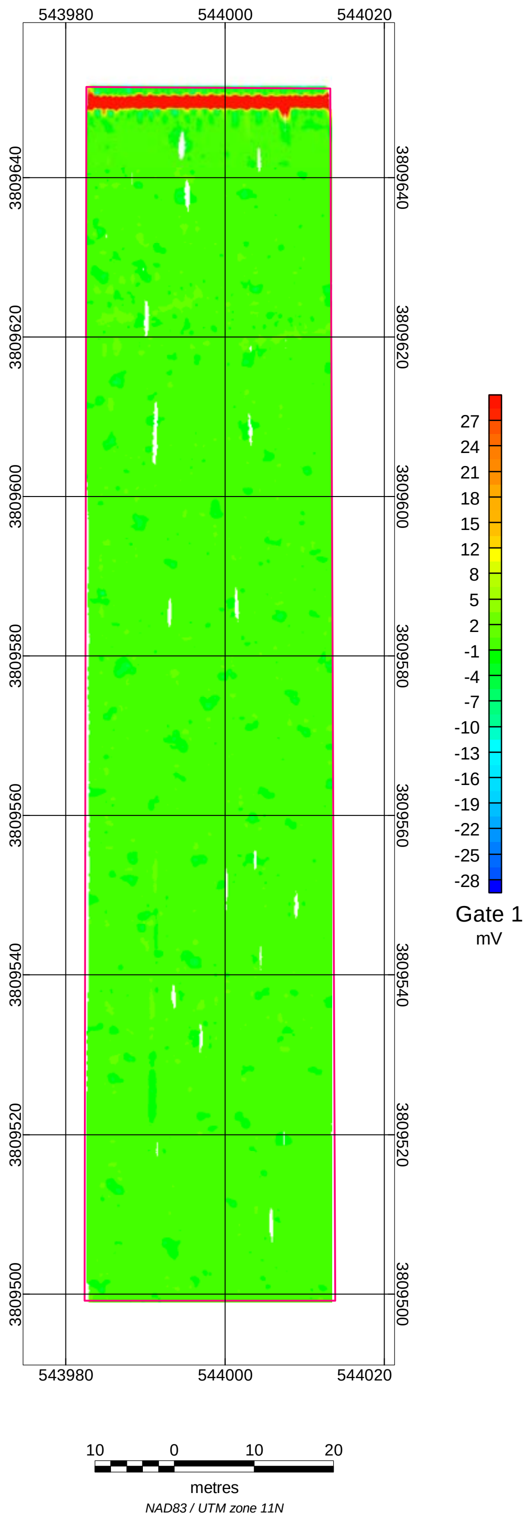

Figure 3-35 – Victorville TCArea Hot 1 MP EM anomaly map (time gate 1)

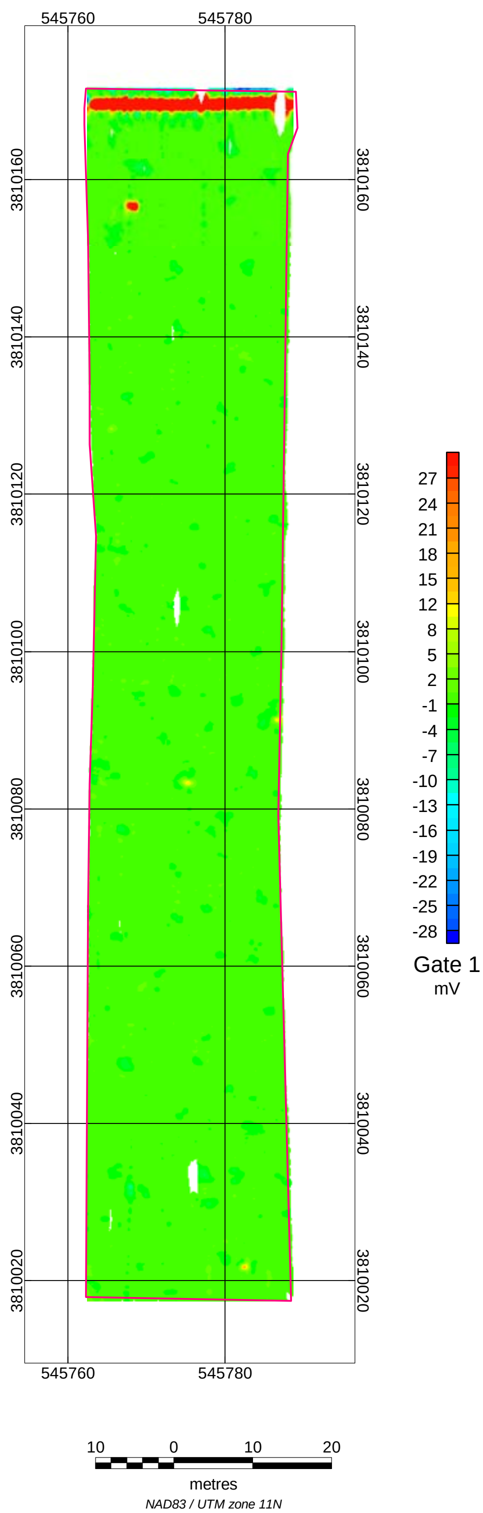

Figure 3-36 – Victorville TCArea Hot 2 MP EM anomaly map (time gate 1)

3.3.7 Calibration Items

As mentioned in Section 3.3.2.1.3, a calibration strip of munitions and munitions stimulants were emplaced near the Base Camp during the vehicular survey. Table 3-9 gives a schedule of the emplaced items and parameters (i.e. depth and orientation). Figure 3-37 shows a magnetometer anomaly map of the calibration strip. The midpoint positions of the emplaced items, as determined by RTK GPS waypointing, are shown as open circles.

This calibration strip was surveyed at the beginning and end of each work day in which transect data were collected. Each field day involving transect surveys commenced with collection of a 5-6 minute static survey after the sensors had been warmed up and RTK GPS was established. After the static survey, the calibration strip was surveyed. At the end of the field day, the calibration lane was surveyed again prior to system shutdown in the same direction. To evaluate the data from the calibration items, the peak positive demedianed magnetometer value for each emplaced item in each survey was determined. A sub-area within the calibration lane identified to be relatively free of anomalies was used for each data set to extract a small area of the magnetometer data. The sub-area data were then used to determine the driving background level for each survey. For the MP EM survey, the limited mobilization did not allow for the emplacement of a full calibration strip. One of our standard calibration objects, a 4” diameter Aluminum sphere was placed on the surface at the beginning and end of each transect work day and data were recorded during several passes across the sphere.

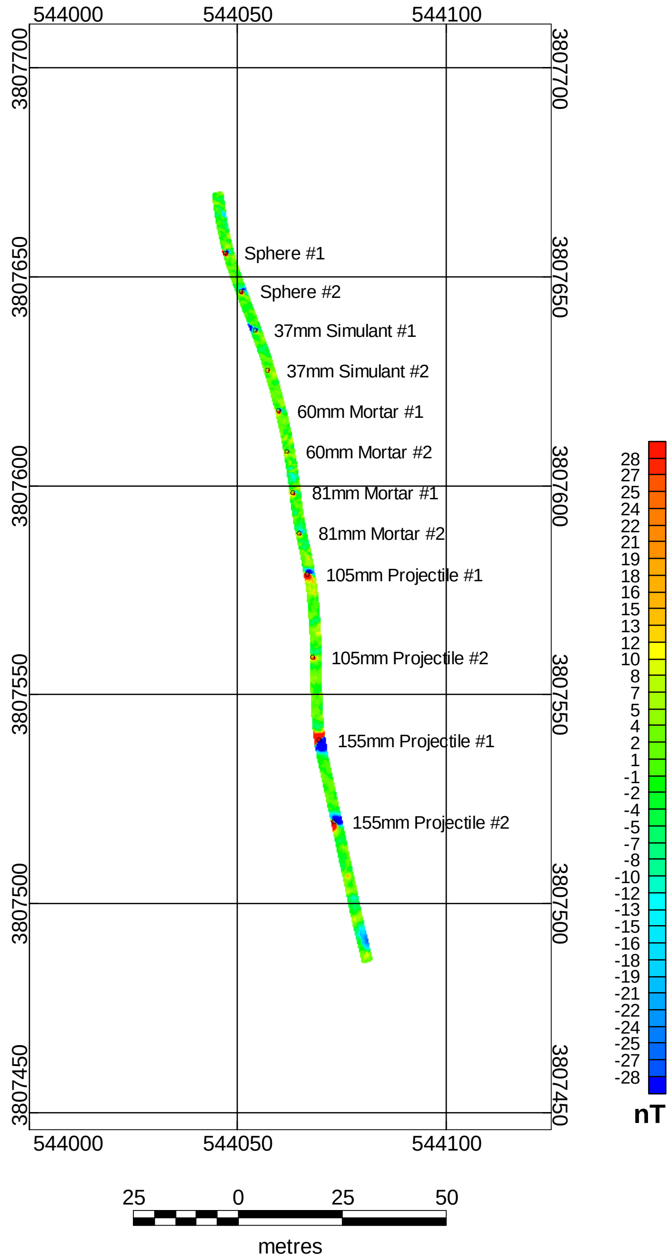

Figure 3-37 – Magnetometer anomaly map of the calibration strip emplaced near the Base Camp at the Victorville PBRs Y and 15 Demonstration site

3.3.8 Demobilization

At the end of vehicular field operations, all equipment, materials, and supplies were repacked on the 53' trailer and secured. Harris Transportation Company, a government contract transportation firm transported the trailer from the site to the MTADS home base at ARL Blossom Point, Welcome, MD. When the survey completion date could be estimated with some confidence, the local vendors were contacted to remove the Base Camp logistics materials. The return date of the 53' trailer to Blossom Point are indicated in Table 3-10. At the end of the MP field operations, all equipment, materials, and supplies was repacked. Two team members delivered the equipment to the FedEx shipping office in Palm Springs prior to departing Palm Springs, CA. The final MP EM demonstration schedule is given in Table 3-11.

3.4 Operational Parameters for the Technology

3.4.1 Magnetometer Array Anomaly Selection Parameters

The precision collection of high SNR magnetometer data using the MTADS platform is a mature technology. The rapid and accurate extraction of anomaly location and a measure of anomaly amplitude (peak analytic signal) from high-volume transect data collection is the novel component of this series of demonstrations. To accomplish this task an automated method of extracting the anomaly locations from the survey data was required. One such method has been developed and is discussed in detail in Appendix A. Briefly, the located magnetic field data (nT) are collected as normal for an MTADS survey. The demedianed total field data are converted to analytic signal (AS, nT/m) where the analytic signal is calculated from the squares of the derivatives in the *x*, *y*, and *z* directions:

$$AS = \sqrt{\left(\frac{d}{dx}\right)^2 + \left(\frac{d}{dy}\right)^2 + \left(\frac{d}{dz}\right)^2}$$

This process involves a gridding step, where real-world data are interpolated onto a fine-scale mesh with a defined grid cell size. The use of a regular grid reduces the complexity of the calculations required for the following steps. The utility of the analytic signal is that anomaly features which are dipolar (have both positive and negative components) in the total field are monopolar in the analytic signal. This facilitates the detection of anomalies.

One can then define the peak cut-off threshold and grid smoothing parameters required to eliminate multiple picks per anomaly and the grid cell size to be used for the analysis. Initial analysis (See Appendix A) has shown that these parameters may be similar for several sites with diverse geology and have the potential to be applied more generally. This assertion was evaluated during the early data collection stages by optimizing the peak threshold cut-off value against the incoming data. The grid cell size used was not varied as initial testing has indicated that processing times become prohibitive at grid cell sizes smaller than 0.25m for transects of any length. There was no indication in the incoming data that the number of smoothing passes required fresh optimization. When the survey results from the calibration strip and several transect data sets from the first day of data collection at each site were available, the data were used to evaluate the anomaly extraction parameters. The RMS variation in the analytic signal from quiet portions of the data was evaluated and the results are tabulated in Table 3-13. The dynamic noise level at the Victorville site was found to be a factor of 2-3x larger than was seen for the Pueblo site.

Table 3-13 – Anomaly selection parameters for the MTADS magnetometer array by site

Site	RMS Dynamic Noise Level (nT/m)	Anomaly Peak Cut-off Threshold (nT/m)
Pueblo PBR #2	2.5	25.0
Victorville PBRs Y & 15	5 – 7	62.5

Once the dynamic noise level was established for each site, the anomaly selection cut-off threshold was determined. Starting with a cutoff level equal to the dynamic noise level, the cut-off threshold was increased in increments of dynamic noise level (i.e. 2.5 nT/m for Pueblo PBR #2) and the anomaly extraction results were determined. For the Pueblo WAA site, 25 nT/m was found to effectively avoid extracting spurious anomalies. At the Victorville WAA site, the range of cut-off values from 50 – 75 nT/m was found to effectively avoid extracting spurious anomalies. A final threshold of 62.5 nT/m was chosen for the anomaly extraction for the transect survey results. The results for an early data set (06080002) are shown in Figure 3-38.

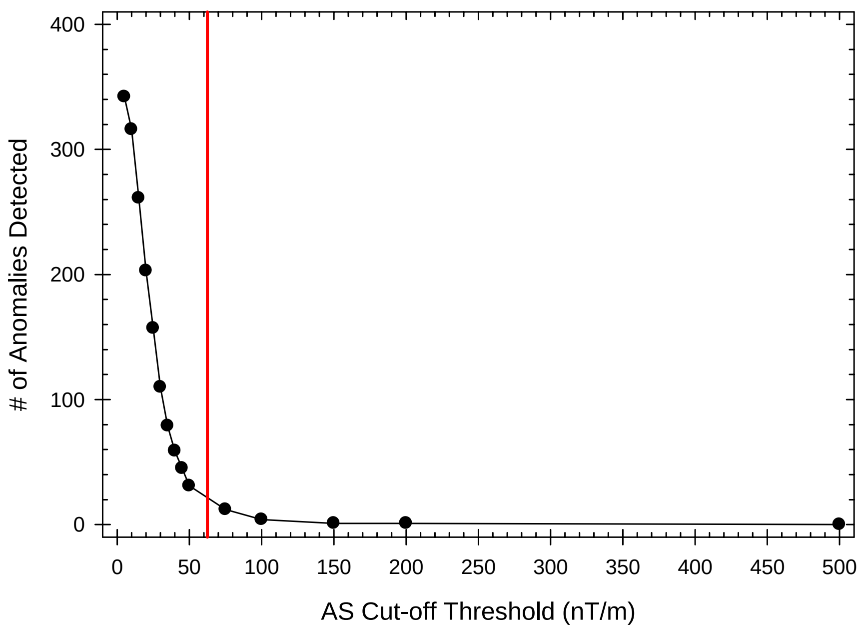

Figure 3-38 – Effect of increasing peak anomaly cut-off threshold value on the 06080002 data set results. The red line indicates the result for the final parameter value, 62.5 nT/m.

The magnetometer anomaly detection cut-off threshold for the Victorville site is more than double that for the Pueblo site. To reduce the number of anomaly detections due to geology (false alarms) in the Victorville data, the cut-off threshold was raised to the listed level based on analysis of early data sets as described above. A trade-off between the detection of small munitions-related fragments is made in favor of reduced false alarms from geology. Give that the success of WAA concept does not require the detection of every individual item present, this trade-off is acceptable.

3.4.2 Man-Portable EM Anomaly Selection Parameters

In the case of the man-portable, EM61 MkII system used for this demonstration, modifications to the anomaly selection methodology were required. The man-portable system is composed of a single sensor with a 0.5m x 1m footprint. With the single-pass, single sensor transect data collection model used, it is neither possible nor necessary to generate a sensor value grid, or mesh, and to calculate the analytic signal values. The lack of cross track sensor data prevents the generation of any signal grid. Additionally, EM61 MkII data are essentially monopolar within a given time gate once the data are properly leveled so the benefit of converting to the analytic signal is not realized like it is for magnetometer data. For MP EM sensor system used for this demonstration, transect sensor data were evaluated as a position-referenced profile of a single time gate using a built-in profile peak picking feature of Oasis montaj (anompick.gx). The profile peak picking feature has only two input parameters, the zero level and the minimum threshold for selected a peak. Time gate 1 data were found to be acceptable for anomaly selection as shown in Figure 3-39. Given that the data are well leveled / demedianed, the zero level parameter is effectively moot and set to 0 mV.

The survey data from several early transect surveys were used to evaluate the minimum peak threshold parameter the Victorville site and the MP EM system. The RMS variation in the sensor data from quiet portions of the data was evaluated and found to be 0.3 – 0.8 mV, or roughly 5 times the static sensor noise levels.

Starting with a minimum peak height threshold of 1 mV and increasing the threshold, a viable minimum peak height threshold was determined for this site / system pair. A minimum peak height threshold value of 4 mV for time gate 1 was found to be the best compromise between sensitivity and spurious anomaly detection and was used for this demonstration. The results for several early data sets are shown in Figure 3-40. The chosen threshold is shown as a vertical red line. Continued review throughout the survey found no need to further refine the minimum peak height threshold value. See Section 4.2.4 for a comparison of the anomaly selection methods for both the magnetometer array and the MP EM system.

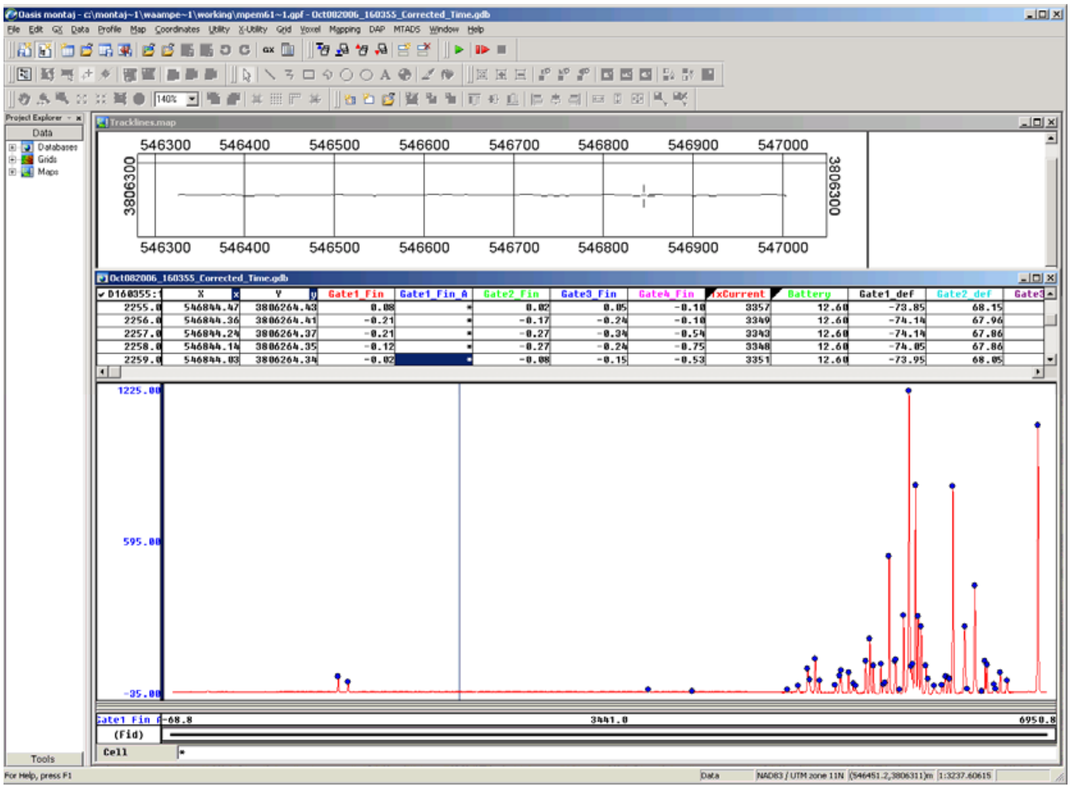

Figure 3-39 – Screenshot from Oasis montaj displaying a profile for time gate 1 and the selected anomalies from the transect using the final minimum peak threshold value

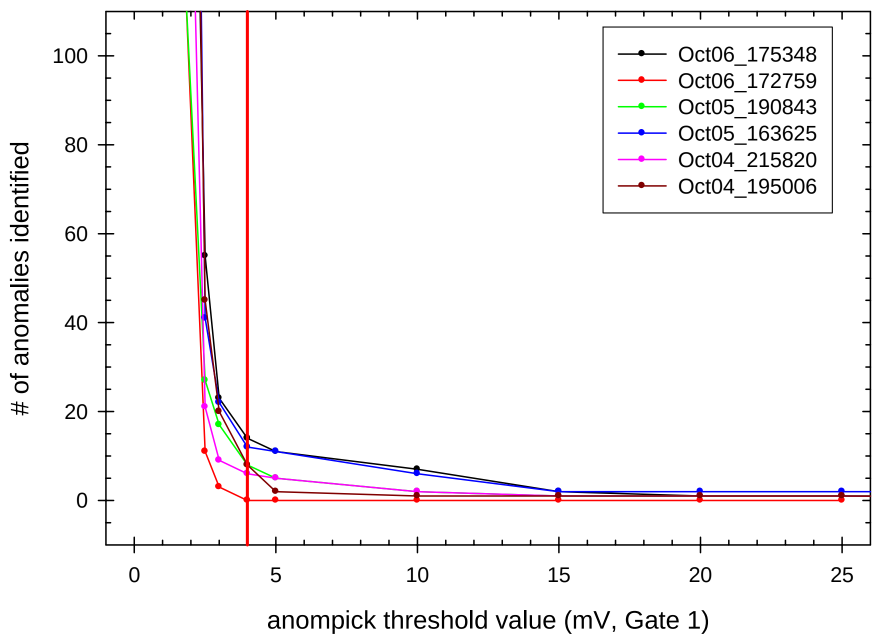

Figure 3-40 – Effect of increasing minimum peak height threshold value for early MP EM data set results. The red line indicates the result for the final parameter value.

4. Performance Assessment

4.1 Performance Criteria and Confirmation Methods

The Performance Criteria for the demonstration were introduced in combination with the Performance Objectives in Table 3-1 and Table 3-2 in Section 3.1 of this document. Table 3-1 and Table 3-2 are reproduced here as Table 4-1 and Table 4-4. Modification to some Performance Objectives and Metrics was required due to the evolution of the Project goals during and after the demonstrations. Refer to Table 3-1 and Table 3-2 for the original Performance Objectives and Metrics.

Table 4-1 – Primary Transect Performance Objectives/Metrics and Confirmation Methods

Type of Performance Objective	Performance Criteria	Expected Performance (Metric)	Performance Confirmation Method	Actual Performance Objective Met?
Primary Metrics (Relating to Detection of Target Areas and Target-free Areas)				
Qualitative	*Reliability and Robustness*	*General Observations*	*Operator feedback and recording of system downtime (length and cause)*	*Yes*
	Terrain / Vegetation Restrictions	*General Observations*	*Correlation of areas not surveyed to available data (topographical maps, etc.)*	*Yes*
Quantitative	*Survey Rate*	*15 acres / day*	*Calculated from survey results*	*See Below*
	Data throughput	*All data from day x processed for anomalies and submitted by end of day x+1*	*Analysis of records kept / log files generated while in the field*	*Yes*
	Percentage of Assigned Coverage Completed	*>95% as allowed by topography*	*Calculated from survey results*	*Yes*
	Transect Location	*95% within 2 meters of requested transects*	*Calculated from survey results*	*No*

4.1.1 Primary Qualitative Performance Objectives

Reliability and Robustness: The MTADS tow vehicle and magnetometer array are designed for off-road operations in rugged terrain with demonstrated operational success in a variety of desert [11] and plains / grasslands environments [3]. Having said this, participation in the WAA Pilot Project has called for continuous operations for several weeks at a time traversing long distances across large areas. This differs from the past method of operations where total coverage surveys have been conducted focusing on completing smaller areas and then moving to another area.

The accumulated punishment of the transect style of surveying was non-trivial. Brief stops were required 2-3 times a day to thoroughly clean the vehicle engine air intake and filters. A portion of each deployed Sunday was spent removing field debris from the tow vehicle systems, tensioning all fasteners (nuts and bolts) including within computers and power supplies, replacing the missing fasteners, and other maintenance items that had accumulated during the week that could be deferred until then. Additionally, several of the vehicle systems entered unanticipated major maintenance cycles during these demonstrations. First, the magnetometer sensors, which are all approximately the same age, contained optical components that the vendor has since learned deteriorate in damp environments, necessitating replacement. Several of our magnetometers required repair during the Pueblo PBR #2 demonstration. The first three-week portion of the Pueblo PBR #2 demonstration depleted the reserve of spare magnetometers. Additional sensors requiring repair were identified during the second and third portions of the demonstration. An intermittent problem with one of the magnetometer counters developed during the third portion of the survey. A part was required to troubleshoot / repair this issue that is not typically kept in the spares collection. The part arrived on October 21 and the problem did not manifest itself again. The tow vehicle engine required a major maintenance on October 7th which delayed operations for a week while the repairs were made. The boom arm on the magnetometer array trailer which connects the trailer to the tow vehicle is made of aluminum and developed a series of fractures during the first portion of the demonstration. A local welding vendor repaired the boom arm overnight resulting in the loss of less than a day of useful field work. Unfortunately, this problem reoccurred during the Victorville demonstration where the boom arm failed completely, separating into two pieces. This failure also damaged the magnetometer electronics when the full weight of the trailer settled on the connecting cables. Again, a local welding vendor was employed to temporarily repair the boom arm while the field team made temporary repairs to the magnetometers. The system was operational again within 24 hours and completed the demonstration. The boom arm was then determined to have exceeded its useful lifespan and was replaced. Additional cable bulkheads were installed to further protect the magnetometers better against any future failures.

In each of these cases, the issue was rapidly assessed and repairs made from the systems spares when possible. When the repair was beyond the scope of the team's expertise, local vendors were brought in to make the necessary repairs as quickly as possible. Only in the case of the engine repair did operations cease for more than 24 hours and did the field team demobilize. Had the engine repair not occurred just prior to a holiday weekend, even that repair may have been made more quickly. In each case, upon the return of the system to Blossom Point, all system components were thoroughly serviced or replaced and tested before redeployment. Any identified changes or upgrades were also made, such as the addition of more cable bulkhead interfaces to protect against failures.

Terrain / Vegetation Restrictions: On large open ranges the vehicular MTADS provides an efficient survey technology. Surveys with the magnetometer array often exceed production rates of 20 acres per day. The presence of certain non-navigable terrain features such as ravines without good crossing points, concentrated boulder fields, and other non-navigable features such as the combination of steep rises with loose, sandy soils limited the areas that could be surveyed. The presence of fence lines with limited access between areas can also limit efficiency by breaking survey lines into smaller portions which are inherently less efficient as more and more time is spend driving between transects and not collecting data. A lesson learned from the

Pueblo PBR #2 demonstration was the value of a 2-3 day site reconnaissance visit by the field team prior to the survey to investigate the site to evaluate these issues. Such a site visit was conducted prior to the Victorville demonstration and greatly aided in the efficient survey of the site in terms of knowledge about hazards to navigation, site conditions, and access routes. Even with this knowledge, there can still be surprises. For example, based on the site visit to Victorville, a map was generated indicating what portions of the site were thought to be accessible to the tow vehicle, Figure 4-1. Compare this figure to Figure 3-19 which shows the actual transect coverage. Portions of the site proved to be too sandy to allow the tow vehicle to pull the magnetometer array at survey speed without getting stuck in the sand repeatedly. The presence of sandy or other similar soils will have to be more carefully included in future site visit analyses.

4.1.2 Primary Quantitative Performance Objectives

Survey Rate: Another lesson learned from the Pueblo demonstration was that the original performance metric for that demonstration, 30 acres/day, for this performance object was unrealistic for a towed array system on this site. Table 4-2 gives the average daily survey rate for the vehicular towed array at Pueblo PBR #2 site. Eleven acres per day, on average, falls well below the 30 acre/day metric. Many survey days were cut short by afternoon lightening storms and/or maintenance requirements. If the calculation is restricted to only those days which were full survey days, the average survey rate rises to 11.8 ± 5.0 acres/day. Based on this experience, the metric was revised to 15 acres/day for the towed array demonstration at the Victorville site. Due to the investment in maintenance items after the Pueblo PBR #2 demonstration, the Victorville demonstration ran without incident until the complete failure of the sensor boom discussed previously. The average survey rate reflects this as shown in Table 4-2. At the Victorville site, the performance metric was met with an average survey rate of 20.5 ± 2.5 acres/day. The MP EM system has a much lower rate of advance and the expected survey rate was set at 10 lane km/day, or 2.5 acres/day. The average survey rate for the three full days of transect surveys was above the metric at 15 lane km/day, corresponding to 3.7 acres/day. When comparing the MP EM survey rate to the vehicular survey rate, recall that the MP EM array is 1m wide versus the vehicular array's 2m width. Some transect data (4-6 lane km/day) were collected on two other days but was excluded from this calculation since neither comprised a full day's effort.

Table 4-2 – Survey Rate by Demonstration Site and System

	Avg. Lane (km/day)	Avg. Area (acre/day)
Vehicular		
Pueblo PBR #2	22.1 ± 11.2	10.9 ± 5.5
Victorville PBRs Y & 15	41.8 ± 5.0	20.5 ± 2.5
Man-Portable		
Victorville PBRs Y & 15	15.1 ± 3.6	3.7 ± 0.9

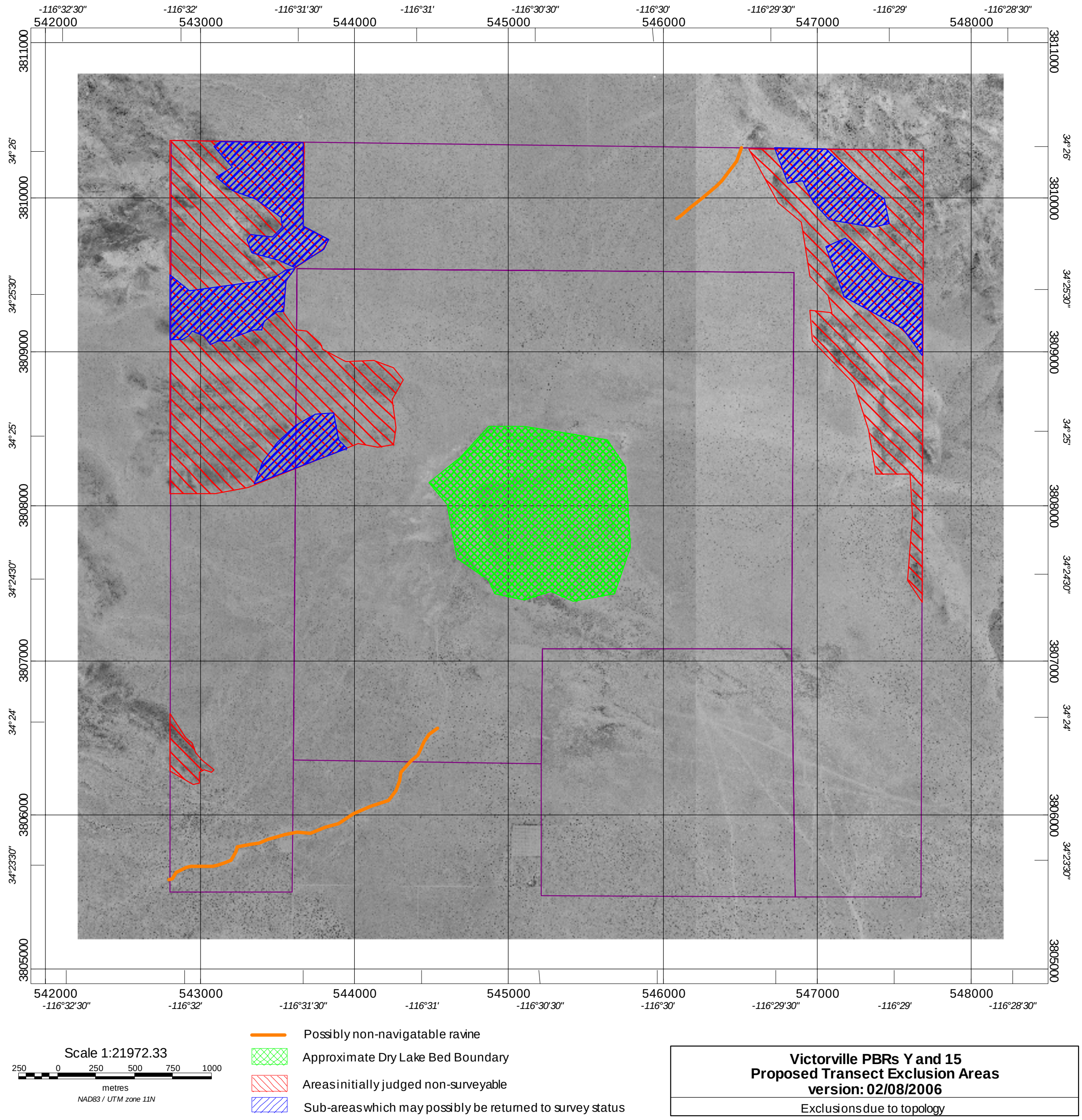

Figure 4-1 – Post-site visit recommendation of potential terrain exclusions from survey

Data throughput: This performance metric, simply stated, required that all transect results be transmitted to the Program Office, PNNL, and SNL within 24 hours of data collection for the vehicular survey. This was accomplished. For the MP EM survey, the need for real-time feedback was relaxed and all transects results were submitted after the field team returned home. The transect results were delivered on October 12th, 2006, two days after the team returned from the field, satisfying the criterion. Demonstration Data Reports were provided to the Program

Office within the Periods of Operations listed in Section 3.3.2.3 to archive all field data and analysis results from the individual demonstrations.

Percentage of Assigned Coverage Completed: The performance metric for this objective was "*>95% as allowed by topography.*" Every transect from every transect plan was attempted in its entirety, in some cases in multiple sections and from multiple directions. This corresponds to 100% coverage, as allowed by topography. As can be seen from Figure 3-4, Figure 3-19, and Figure 3-20, it was not always possible to complete each transect due to limitations from the topography of the sites.

Transect Location: To determine the performance of the demonstrations with respect to this metric, the .COG files provided as part of the daily deliverables were used as the data set. The .COG files are the location of the center of each array down sampled to provide a point every 6-10m down-track during data collection. Only the .COG files corresponding to the main transect plans were evaluated and not any of the additional transects. Each .COG file was then paired with the corresponding planned transect and the position difference calculated for each reported position. No attempt was made to remove reported points which corresponded to off-track maneuvering due to the difficulty of doing so in an unbiased manner. Therefore the results in this section represent an upper bound on the cross track position error (lower bound on "*%'age within 2m*"). Data collection is started and stopped near the transect ends but may include some off-track recording to reach a safe starting or stopping point. Additionally, if a topographic feature required avoidance, these segments were not removed. The percentages, reported in Table 4-3, clearly do not meet the "*95% within 2m metric*." Another approach is to look at the cross-track statistics and determine what the cross-track error would be to contain 95% (3σ) of the location measurement. The final column in Table 4-3 lists the average cross-track offset and the 1σ standard deviation. To encompass 95% of the location points at the Pueblo PBR #2 site, a width of 20.4m would have to be used. Remembering that the transect spacing for the North/South transects at the Pueblo PBR #2 site was 310m for the sparse transect plan and 155m for the conservative transect plan, 95% of the measurement locations were made within 7 or 13% of the transect spacing of the planned location, respectively. At the Victorville PBRs Y&15 site, the MP EM system exhibited a similar percentage within the 2m bound, but the cross track variation was much lower, 1.8 m (1σ). Similarly, 95% of the measurement positions were made within 5.4m of the planned transects.

Implicit in reaching this conclusion is the assumption that the cross-track variation follows a normal error distribution. To test the appropriateness of this assumption, a histogram of the cross-track deviation for all of the data points in the COG files collected during the Victorville Man-Portable demonstration was generated and then fit to a Gaussian distribution. The results are shown in Figure 4-2. The fit result parameters, x_0 = 0.5 m and σ = 1.9 m, well reproduce the values quoted in Table 4-3, supporting the validity of the above conclusions regarding possible alternate metrics for evaluating the success of following a planned transect.

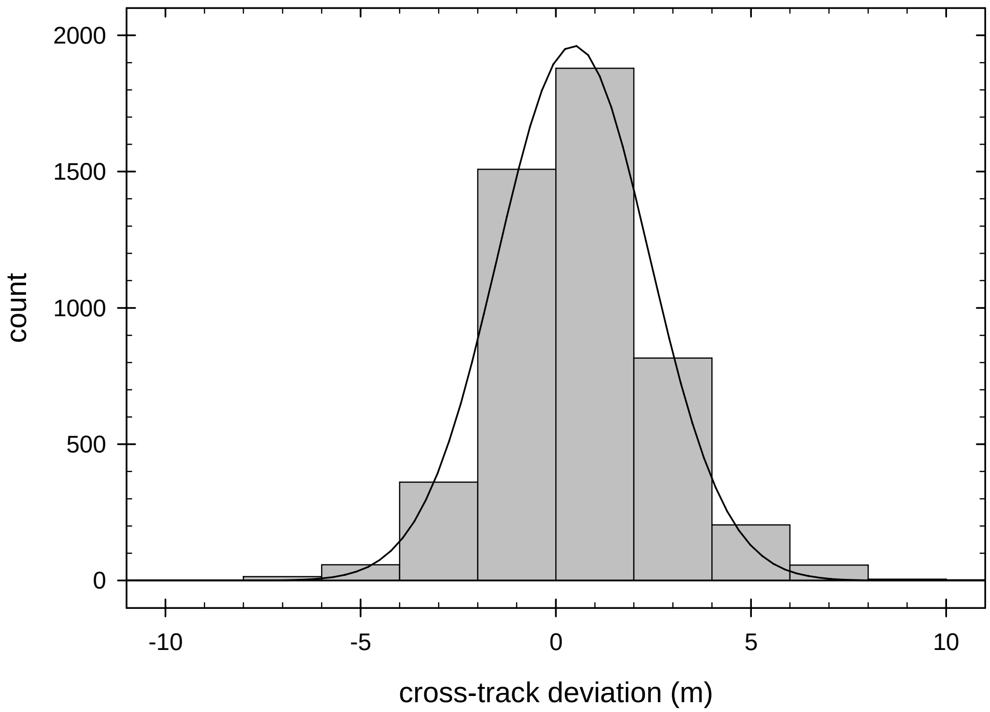

Figure 4-2 – Histogram of cross-track deviation for the Victorville MP EM Demonstration. The solid line represents a Gaussian fit to the histogram results.

This is an impressive feat considering the navigation for the MP EM system was provided by a meter-level WAAS GPS receiver (See Section 2.1.2). When viewed on the coarse scales of Figure 3-4, Figure 3-19, and Figure 3-20, the transect data collection was centered on the planned track and reasonably reproduced the planned transect with respect to the transect spacing distance. To efficiently conduct transect surveys across areas with complicated terrain and vegetation issues, these types of systems will generate deviations on the order of 10m from the transect plan. With transect spacing of 200m, these deviations have proven to be tolerable transect analysis process conducted by PNNL and SNL.

Table 4-3 – Transect Location Statistics by Demonstration Site and System

	%'age within 2m of transect	**Average Cross-Track Offset (m) and Std. Dev. (1σ)**
Vehicular		
Pueblo PBR #2	79.6	0.3 ± 6.8
Victorville PBRs Y & 15	76.4	-0.1 ± 4.5
Man-Portable		
Victorville PBRs Y & 15	68.8	0.4 ± 1.8

4.2 Secondary Performance Objectives

Table 4-4 – Secondary Transect Performance Objectives/Metrics and Confirmation Methods

Type of Performance Objective	Performance Criteria	Expected Performance (Metric)	Performance Confirmation Method	Actual Performance Objective Met?
Secondary Metrics (Relating to Characterization of Target Areas)				
Qualitative	*Ability of Analyst to Visualize Targets from Survey Data*	*All targets in survey area identified*	*Data Analyst feedback and comparison to total-coverage data / other demonstrators results*	*Yes*
Quantitative	*Depth of Inverted Anomalies*	*< 30% for depths ≥ 30 cm, < ±10 cm for depths < 30 cm*	*Validation Sampling (100% survey) and/or Remediation Sampling (digging)*	*Yes*
	Probability of False Alarm	*<5% of identified anomalies correspond to no ferrous metal source*	*Validation Sampling (100% survey) and/or Remediation Sampling (digging)*	*N/A*
	Signal to Noise Ratio (SNR) for Calibration Items	*+/- 10% of expected from Standardized UXO Technology Demonstration Site Performance*	*Comparison of Calibration Item results to documented Standardized UXO Technology Demonstration Site performance*	*See Below*
	Data Density	*> 60 pts / m^2*	*Calculated from survey results*	*Yes*

4.2.1 Secondary Qualitative Performance Objectives

Ability of Analyst to Visualize Targets from Survey Data: Visual comparison of the AMTADS data collected by Sky Research, Inc. in overlapping areas with the MTADS total coverage areas did not indicate that any anomalies in the AMTADS data that were not seen in the MTADS data also. Similarly, a visual comparison of MTADS and AMTADS anomaly picks did not show any significant disagreement. When using any anomaly selection technique, there will be some metric for determining what is an anomaly for analysis and what is not. This will lead to different sets of selected and analyzed anomaly lists. In the AMTADS case, several techniques were used including manual selection and automated selection techniques. For the MTADS total coverage areas, all magnetic anomalies which could be visually identified by the Analyst using a 30m x 30m data window and a vertical scale of ±30 nT were extracted and submitted to the physics-based models resident within the MTADS DAS for analysis. In general, anomalies with a fit coherence of 0.85 or greater are added to the anomaly lists included in each corresponding Demonstration Data Report along with the anomaly fit parameters. Individual anomalies with a fit coherence lower than 0.85 may be selected by the Analyst if the Analyst judged the anomaly fit to correspond to a real anomaly. These anomaly results will typically include an explanatory comment. Anomalies with fits deemed unacceptable by the Analyst are either discarded (i.e. not added to the anomaly list) or entered as a location (easting, northing) only for archiving purposes. Two analysts were involved in the data analysis and the decision to report the positions of poorly fit anomalies was made on an area-by-area basis. For the MP EM survey at the Victorville PBRs Y & 15 site, UX-Analyze, which is based in part on the MTADS DAS, was used for the analysis. Total coverage areas with the location-only anomalies excluded are Areas 2A, 3B, 3B, and the Simmons Area from the Pueblo PBR #2 site, and the PBR #15 Radial and TCArea 01, 02. 03, Hot 2 MP, and PBR #15 Radial MP from the Victorville PBRs Y & 15 site. The analyses from the remaining areas include some number of location-only anomalies for reference. Anomalies selected using automated techniques are typically screened for QC purposes and similar criteria could be applied at this point to exclude anomalies or not, depending on the analyst's judgment and the project objectives. Again, as the Project requirements evolved, there was a focus placed on recording the location of all anomalies possible for the future evaluation of the source of background anomalies detected in transect surveys and not necessarily focusing on the selection of compact, metallic anomalies alone.

4.2.2 Secondary Quantitative Performance Objectives

Depth of Inverted Anomalies: No anomalies from the Victorville site have been subject to remediation to date, so the discussion of this performance objective will focus on the Pueblo site. A dig list comprised of items of interest from all available data sets was prepared by the ESTCP Program Office and 621 items were intrusively investigated during the late Summer / early Fall of 2006. The subset of anomalies generated by the MTADS system were selected and sorted by fit quality. Of the MTADS-related anomalies that were investigated, 213 had fit quality values of 0.9 or higher and had a complete, unambiguous dig report to allow further analysis. The actual horizontal location of the remediated items was not recorded, so no comparison of horizontal location performance can be performed. The anomalies were partitioned into two categories for analysis, those with predicted depths of 30 cm or greater and those with depths of less than 30 cm. This separation allows the comparison between fit and actual depths for the shallower targets to be expressed in a meaningful fashion, in cm, while allowing a fractional comparison for the deeper anomalies. The average depth difference (Predicted – Actual Depth) for the 157 deep anomalies as determined from the dig list results is 0.22 ± 0.27 (1σ) m. This immediately points to a communication problem. The MTADS DAS software reports the depth on an anomaly below the sensor, not the depth below the surface, for an anomaly fit. After the anomaly list is exported from the MTADS DAS, the sensor height (0.25m) needs to be subtracted by an Analyst. In the case of the Pueblo MTADS anomaly lists, this was accidentally not done prior to transmitting the anomaly lists. Removing the sensor height basis, 59 anomalies remain in the deep category with an average depth difference of -0.02 ± 0.31 (1σ) m. The average fractional difference, (Predicted – Actual Depth) / Predicted Depth is -0.10 or the predicted depths are on average 10% shallow. For the shallow anomalies, the criterion was the absolute depth difference. For the 154 shallow anomalies, the average depth difference was -0.01 ± 0.15 (1σ) m.

Probability of False Alarm: The metric for this performance objective is stated as "*<5% of identified anomalies correspond to no ferrous metal source.*" During the period of operation for the Pueblo demonstration, the requirements for analyzing individual anomalies were changed to reporting all anomalies that could be identified by the analyst for possible remediation during the various validation phases of the WAA Pilot Project to characterize what the sources of the anomalies in the background areas were. As such, the concept of false alarms loses meaning and this performance objective is not addressed.

Signal to Noise Ratio (SNR) for Calibration Items: For the vehicular demonstrations, the emplaced lanes of calibration items described in Sections 3.2.2.1.3 and 3.3.2.1.3 were surveyed at the beginning and end of each field day that transect survey data were collected. To evaluate the calibration item data, the peak positive demedianed magnetometer value for each emplaced item from each sortie was determined. A finer grid (0.05m versus the 0.25m used for anomaly detection) was used to match the down-track data spacing and limit any smoothing effects from decreasing the peak magnitudes. Since the extents of the calibration lane data were smaller than that of a typical transect, the finer mesh could be used without suffering a processing time penalty. A sub-area in between two of the calibration items was identified to be relatively free of anomalies, and was used for each data set to extract a background value. The standard deviation (1σ) was then calculated for the sub-area and that value was reported as the driving background value for each survey. For the Pueblo PBR #2 demonstration, the area between 105mm projectile #2 and 60mm mortar #2 was selected. For the Victorville PBRs Y&15 demonstration the area between the two 155mm projectiles was selected. These values are presented in Table 4-5 and Table 4-6, respectively.

For each calibration item emplaced in the calibration strip at the Pueblo PBR #2 site, the aggregate peak positive values for all sorties (average and standard deviation (1σ) are tabulated in Table 4-5. Figure 4-3 and Figure 4-4 plot the measured anomaly peak positive values for 155mm Projectile #2 and 60mm Mortar #1 for all sorties in a time series as examples of the day-to-day variations in the measurements. The 155mm Projectile #2 had the largest measured signal values. The measured values for 60mm Mortar #1 were approximately 1/10 those for 155mm Projectile #2 and represent the smallest values measured. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope. It is likely that the variation shown in Figure 4-3 and Figure 4-4 more represents the difficulty in navigating the sensor array over the exact same path every sortie than any variability in the sensor response to the emplaced items.

Similarly, for each calibration item emplaced in the calibration strip at the Victorville PBRs Y & 15 site, the aggregate peak positive values for all sorties (average and standard deviation (1σ) are tabulated in Table 4-6.

Figure 4-5 and Figure 4-6 plot the measured anomaly peak positive values for 155mm Projectile #1 and 37mm Simulant #1 for all data sets in a time series as examples of the day-to-day variations in the measurements. The 155mm Projectile #1 had the largest peak positive values. The 37mm Simulant #1 values were approximately 1/10 the 155mm values and represent the range of the smallest values measured. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope.

Table 4-5 – Peak Positive Aggregate Demedianed Magnetometer Values for Pueblo PBR #2 Calibration Strip Emplaced Items

ID	Easting (UTM, m)	Northing (UTM,m)	Depth (cm)	Orientation (deg., from North)	Avg. Signal (nT)	Std. Dev (nT, 1σ)
Driving Background (1σ)					1.04	0.78
Sphere #1 (Driver Side)	616,434.500	4,178,732.403	0	N/A	694.42	95.20
Sphere #2 (Passenger Side)	616,435.459	4,178,732.109	0	N/A	417.68	47.26
155mm Projectile #2	616,441.180	4,178,749.703	35	35	2068.51	123.18
60 mm Mortar #2	616,447.267	4,178,768.742	30	46	17.37	1.04
105mm Projectile #2	616,453.828	4,178,787.621	60	44	71.12	2.51
105mm Projectile #1	616,459.639	4,178,806.967	45	178	213.43	12.57
81mm Mortar #2	616,465.341	4,178,825.771	43	69	47.98	2.00
81mm Mortar #1	616,469.792	4,178,839.941	25	20	105.28	8.18
155mm Projectile #1	616,474.350	4,178,854.198	50	46	467.96	18.69
60 mm Mortar #1	616,478.260	4,178,868.186	10	148	116.32	13.50
37mm Sim #2	616,481.220	4,178,877.825	10	57	129.54	11.80
37mm Sim #1	616,484.096	4,178,887.419	5	160	188.85	28.81

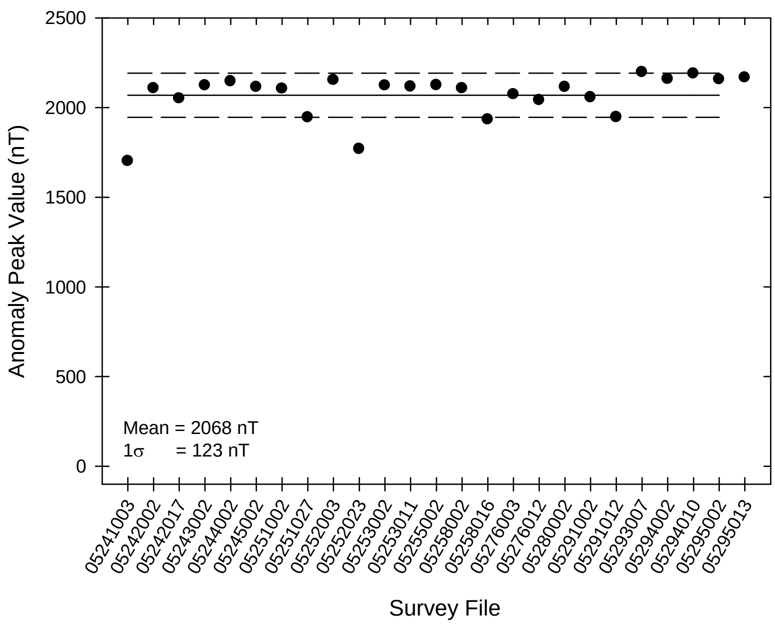

Figure 4-3 – Peak positive values from each survey for 155mm Projectile #2 at Pueblo. The result for each data set is shown in order of acquisition. The horizontal axis is survey file number. The solid line represents the aggregate average analytic signal and the dashed lines represent a 1σ envelope.

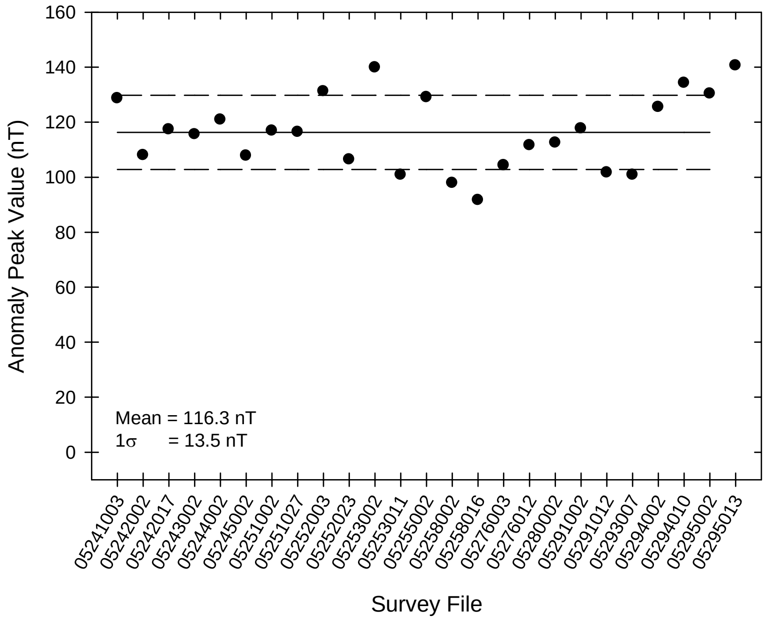

Figure 4-4 – Peak positive values from each survey for 60mm Mortar #1 at Pueblo. The result for each data set is shown in order of acquisition. The horizontal axis is survey file number. The solid line represents the aggregate average analytic signal and the dashed lines represent a 1σ envelope.

Table 4-6 – Peak Positive Aggregate Demedianed Magnetometer Values for Victorville PBRs Y & 15 Calibration Strip Emplaced Items

Item	Northing (m)	Easting (m)	HAE (m)	Depth (cm)	Orientation (deg)	Length (m)	Avg. Signal (nT)	Std. Dev (nT, 1σ)
Driving Background (1σ)							1.52	0.15
155mm Projectile #2	3,807,519.543	544,073.033	756.726	100.00	058	0.884	117.44	3.56
155mm Projectile #1	3,807,539.148	544,069.439	756.787	50.00	105	0.935	825.86	23.08
105mm Projectile #2	3,807,558.965	544,067.969	756.398	66.00	091	0.655	39.52	2.80
105mm Projectile #1	3,807,578.848	544,066.653	756.711	40.00	015	0.694	126.71	7.58
81mm Mortar #2	3,807,588.621	544,064.728	756.529	42.00	048	0.539	37.39	1.95
81mm Mortar #1	3,807,598.330	544,063.191	756.875	25.00	090	0.525	58.79	4.10
60mm Mortar #2	3,807,608.162	544,061.711	756.738	28.00	068	0.276	30.45	2.04
60mm Mortar #1	3,807,617.963	544,059.760	756.819	10.00	010	0.279	101.64	6.99
37mm Simulant #2	3,807,627.643	544,057.143	756.741	30.50	N/A	N/A	37.45	2.92
37mm Simulant #1	3,807,637.192	544,054.115	756.908	10.00	010	0.158	52.21	8.63
Sphere #2	3,807,646.516	544,050.775	756.997	25.00	N/A	N/A	133.24	9.06
Sphere #1	3,807,655.664	544,047.007	757.221	10.00	N/A	N/A	336.58	48.97

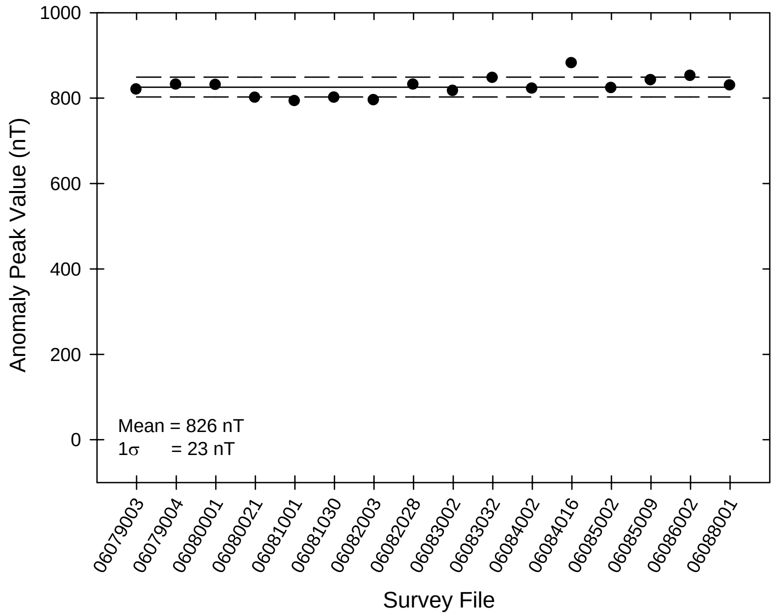

Figure 4-5 – Peak positive values from each survey for the 155mm Projectile #1 at Victorville. The result for each data set is shown in order of acquisition. The horizontal axis is survey file number. The solid line represents the aggregate average peak positive value and the dashed lines represent a 1σ envelope.

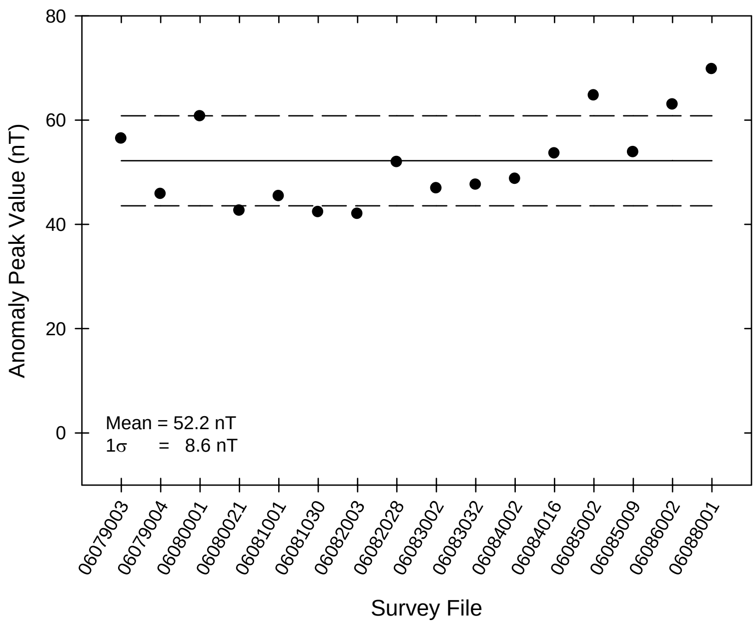

Figure 4-6 – Peak positive values for the 37mm Simulant #1 for each data run at Victorville. The result for each data set is shown in order of acquisition. The horizontal axis is survey file number. The solid line represents the aggregate average peak positive value and the dashed lines represent a 1σ envelope.

To investigate the correspondence between the data collected for the calibration lanes at the Pueblo and Victorville sites and similar items from the Standardized UXO Technology Demonstration Site, direct comparison is not a viable mechanism due to the marked differences in depth and orientation of the available ground truth items from the Standardized UXO Technology Demonstration Site and the items emplaced in the WAA calibration lanes. Instead, theoretical curves representing the peak positive response due to a prolate-shaped object that best represents the UXO in question are used. An example is given in Figure 4-7 for the MTADS magnetometer system and the 105mm projectile. The upper curve represents the sensor response (blue, in nT) for the most favorable orientation of the projectile with respect to the exciting field (the Earth's magnetic field) as a function of depth below the surface. The magnetometers travel an additional 25 cm above the surface. The lower curve (red) represents the response for the least favorable orientation. Peak positive values from actual field measurements of 105mm projectiles from the APG Standardized UXO Technology Demonstration Site are shown as black circles. Representative noise levels from the APG Standardized UXO Technology Demonstration Site and both WAA demonstration sites are shown as dashed lines (see figure legend for details). The aggregate average responses from the 105mm projectiles emplaced in the WAA calibration lanes are shown as triangles (up for Pueblo and down for Victorville). The 105mm projectiles emplaced at Victorville fall near but below the least favorable orientation prediction.

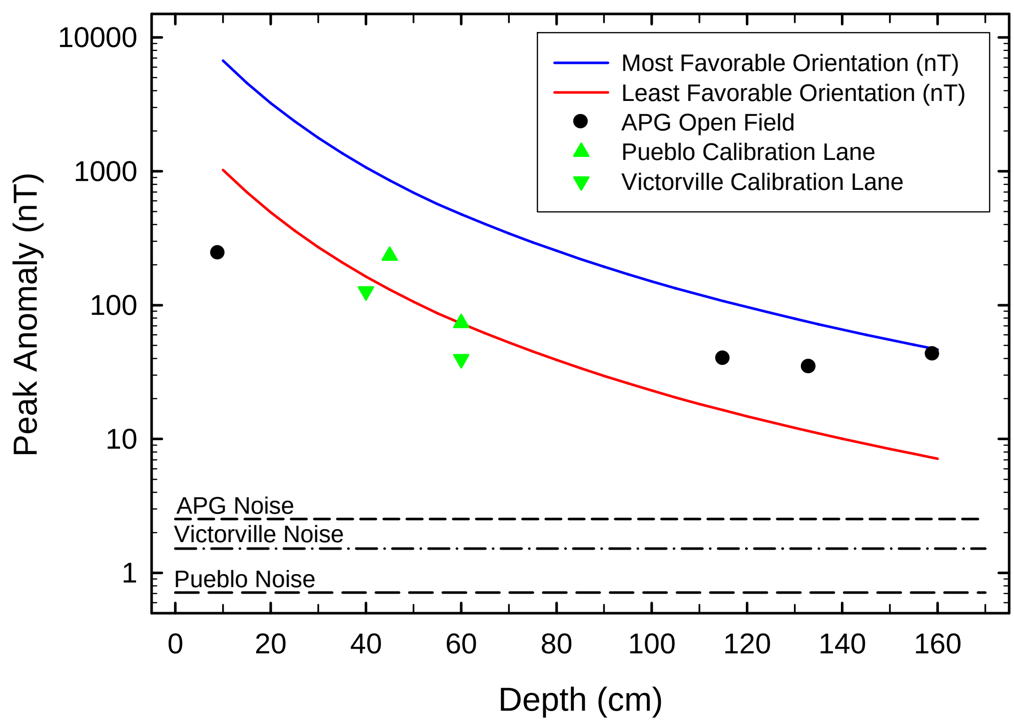

Figure 4-7 – Predicted magnetometer peak anomaly response for a 105mm projectile versus depth for most and least favorable orientations

Possible differences here are two-fold. First, the APG 105mm projectiles are of the M60 variety, while those at Kirtland and Pueblo are of the HEAT variety. The M60 has a nice prolate shape and was the model used to generate the curves in Figure 4-7. The HEAT markedly deviates from a regular prolate shape and has a smaller effective volume. A smaller volume will push the response curves downward. In addition, as a large object gets close to the sensor – such as the APG 105mm projectile buried less then 10cm – the sensor essentially "sees" only part of the object, also resulting in a smaller effective volume and correspondingly smaller response.

As mentioned in Section 3.3.2.1.3, a calibration strip of munitions and munitions stimulants was not available for the MP EM demonstration at the Victorville PBRs Y & 15 site. In lieu of such, one of our standard calibration objects, a 4" Aluminum (Al) sphere was placed on a visually-identified clear area and used as an ad hoc calibration object to test system response at the beginning and end of each day. The exact location of the sphere at each measurement was not independently recorded by GPS waypointing but the approximate locations can be extracted from the calibration survey data.

After the daily sensor warm-up period each day that transect surveys were conducted, a calibration survey consisting of three round trips over the Al sphere was conducted following a roughly North – South or East – West path as dictated by the local environment. At the end of the field day, the Al sphere was again placed in a visually clear spot and a calibration survey was conducted prior to system shutdown at the current location of the survey team. To evaluate the data from the 4" Al sphere, the peak demedianed sensor value for each time gate was determined for each pass (6 measurements total per sortie). The peak positive value was extracted using the same anomaly extraction technique as for the transect surveys. The standard deviation (1σ) was then calculated for each survey. The results for each survey of the 4" Al sphere (average and standard deviation (1σ)) are tabulated in Table 4-7.

Table 4-7 – Position Deviation and Peak Demedianed EM Values for 4" Al Calibration Sphere

Date Code	Position		Gate1		Gate2		Gate3		Gate4	
	Distance from Average (m)	Std. Dev (m, 1σ)	Average Peak Signal (mV)	Std. Dev (mV, 1σ)	Average Peak Signal (mV)	Std. Dev (mV, 1σ)	Average Peak Signal (mV)	Std. Dev (mV, 1σ)	Average Peak Signal (mV)	Std. Dev (mV, 1σ)
Oct042006_145030	0.07	0.04	109.30	4.40	81.59	3.31	51.82	1.42	61.10	1.71
Oct042006_221928	0.05	0.02	93.60	7.71	70.04	5.74	44.86	3.54	53.35	3.80
Oct052006_144638	0.06	0.03	226.88	18.80	169.73	14.12	108.01	8.30	119.00	8.51
Oct052006_223226	0.09	0.03	126.93	7.17	95.58	5.50	60.84	3.41	70.45	3.81
Oct062006_145601	0.08	0.03	158.44	10.86	118.30	7.92	74.81	4.62	85.67	4.92
Oct062006_223315	0.07	0.04	100.48	12.05	75.55	9.23	47.93	5.68	56.68	6.68
Oct072006_151412	0.06	0.01	82.53	5.43	61.52	4.06	38.88	2.55	47.42	3.01
Oct072006_212314	0.06	0.04	76.54	3.13	57.36	2.24	36.58	1.17	44.76	1.08
Oct082006_151006	0.06	0.04	166.02	9.36	123.85	6.86	77.94	4.38	89.73	4.48
Oct082006_180106	0.09	0.06	105.28	11.22	78.79	8.51	49.66	5.02	58.92	5.68

Figure 4-8 plots the peak EM61 MkII time gate 1 sensor values for all of the calibration data sets in a time series. The solid line indicates the aggregate average and the dashed lines indicate a 1σ envelope. Figure 4-9 plots the position deviations for the calibration data sets in a time series. As indicated previously, the exact location of the Al sphere was different for each survey and was not independently recorded, so the values reported are for variation from the average of all six measurements comprising each survey.

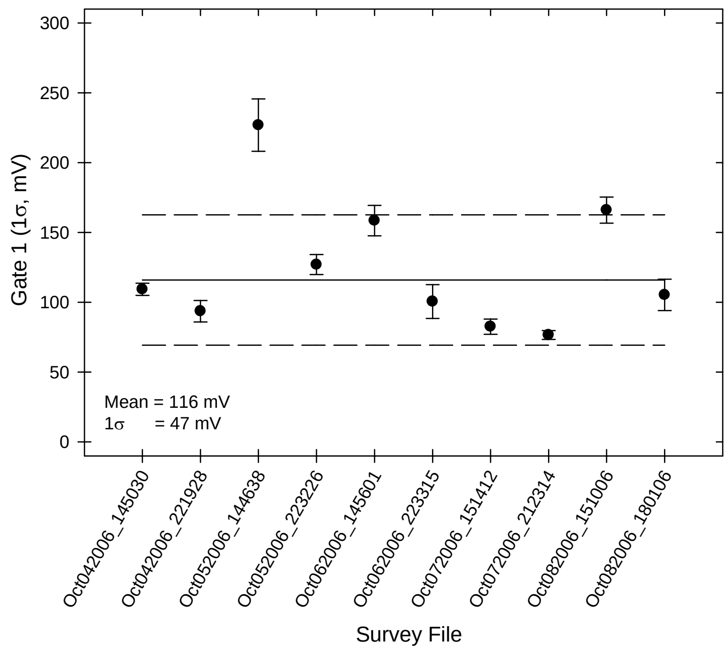

Figure 4-8 – EM61 MkII gate 1 peak values from each Al sphere calibration survey at Victorville. The result for each data set is shown in order of acquisition. The solid line represents the aggregate average peak positive value and the dashed lines represent a 1σ envelope.

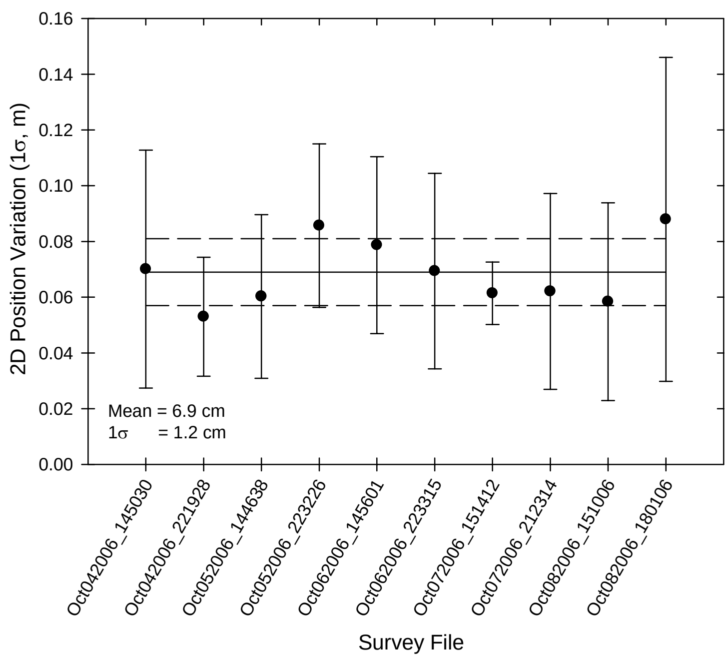

Figure 4-9 – 2D location variation for the Al sphere for each Al sphere calibration survey at Victorville. The result for each data set is shown in order of acquisition. The solid line represents the aggregate average position variation and the dashed lines represent a 1σ envelope.

The sensor system noise floors were also evaluated using the series of static data sets collected each morning. The field day began with a period for system warm up of approximately 15 minutes for the magnetometer array and thirty minutes for the MP EM system. During this time walk-around preventative maintenance inspections were conducted and the RTK GPS network was established. Static tests of the sensor platform performance were then conducted. A data set was collected for at least 5-6 minutes while the vehicle was kept stationary and engine turned off. Every effort was made to minimize the movement of personnel and equipment in the vicinity of the MTADS. The 2-D positioning variation was evaluated by computing the standard deviation of both the northing and easting components of the position data for the entire period and combining them as the square root of the sum of the squares. The standard deviation for the demedianed magnetometer data from each sensor was computed and the arithmetic mean was computed for each data set. In occasional cases, an obvious artifact was present in the data (e.g. a vehicle pulls up along side the tow vehicle unannounced) and distorts a portion of the static run. In these cases, only the unperturbed data were used. The aggregate average and standard deviation (1σ) of both the positioning and sensor data for all data sets were then computed.

The results of the static tests at the Pueblo PBR #2 site are shown as time series in Figure 4-10 and Figure 4-11. The results of a similar analysis for the data sets collected near the Auxiliary Base Camp are available in the Demonstration Data Report [15]. Table 4-8 summarizes the static test data results from the Pueblo site.

Table 4-8 – Static Test Data Results for the Vehicular Survey at the Pueblo PBR #2 site

Calibration Area	Result Type	Value
North	2-D Position	0.42 ± 0.14 cm
	Magnetometer	0.89 ± 0.97 nT
South	2-D Position	0.44 ± 0.10 cm
	Magnetometer	0.67 ± 0.72 nT

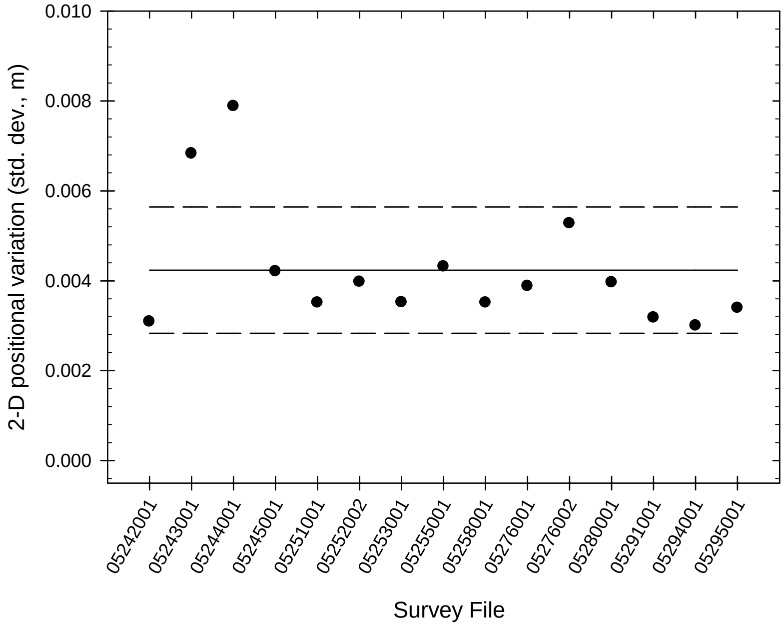

Figure 4-10 – Positional variation data runs for static data collected at the Pueblo calibration strip. The horizontal axis is survey file number. The solid line represents the aggregate average positional variation and the dashed lines represent a 1σ envelope.

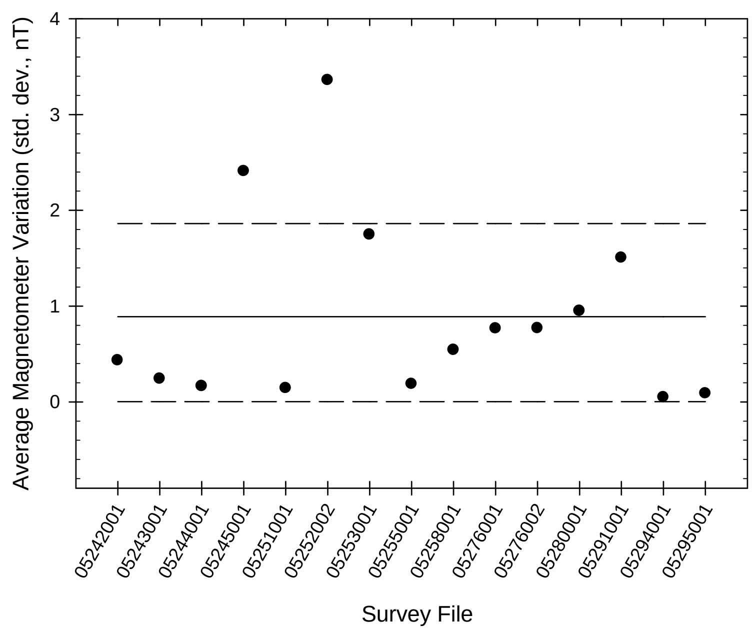

Figure 4-11 – Overall magnetometer (all sensors) variation data runs for static data collected at the Pueblo calibration strip. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope.

The results of the daily static tests at the Victorville site are shown as time series in Figure 4-12 and Figure 4-13. The magnetometer values shown in Figure 4-13 indicate a significant increase in the overall average magnetometer sensor noise level for Julian dates 06085 and 06086. The diesel generator that supplied power to the Base Camp began to fail during this period and presumably provided insufficient overnight charging to the system batteries. The vendor was contacted as soon as the problem was evident and a replacement was delivered and installed during Julian date 06086. Table 4-9 summarizes the static test data results from the Victorville site.

Table 4-9 – Static Test Data Results for the Vehicular Survey at the Victorville PBRs Y & 15 site

Result Type	Value
2-D Position	0.60 ± 0.24 cm
Demedianed Magnetometer	0.26 ± 0.17 nT

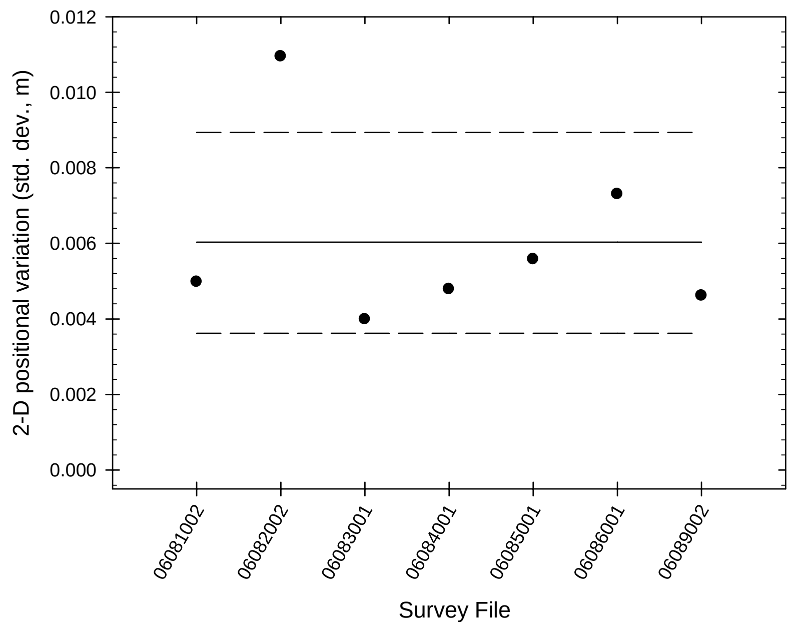

Figure 4-12 – Positional variation data runs for static data collected at the Victorville calibration strip. The horizontal axis is survey file number. The solid line represents the aggregate average positional variation and the dashed lines represent a 1σ envelope.

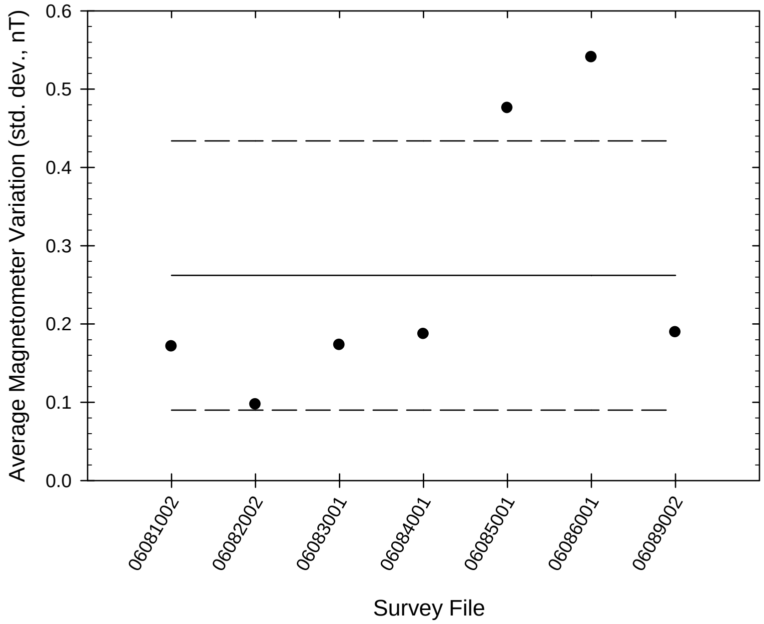

Figure 4-13 – Overall magnetometer (all sensors) variation data runs for static data collected at the Victorville calibration strip. The horizontal axis is survey file number. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope.

For the MP EM demonstration at the Victorville site, static tests of the sensor platform were conducted each survey day involving transect data collection. Generally, during a period of high GPS PDOP (Positional Dilution of Precision) at approximately 9:00 am each day, a static survey was collected to monitor the static sensor levels for the EM61 MkII. GPS data were collected during this survey but they suffer from the reduced accuracy of the high PDOP event. Since the primary goal of the static data collection was to evaluate the EM61 MkII sensor and not the positioning which has been evaluated previously [15,16], this compromise was authorized by the Quality Assurance Officer to enhance productivity. The 2-D positioning variation was evaluated by computing the standard deviation of both the northing and easting components of the position data for the entire period and combining them as the square root of the sum of the squares. The standard deviation for the demedianed EM61 MkII data from each time gate was computed and the arithmetic mean was computed for each data set. Results are reported for a) all time gates and b) only bottom coil time gates. The aggregate average and standard deviation (1σ) of both the positioning and sensor data for all data sets were computed. The results are shown in the following pseudo-time series figures. Figure 4-14 and Figure 4-15 show the positioning and EM61 MkII variations for the static tests. Table 4-10 summarizes the static test data results for the MP EM system at Victorville.

Table 4-10 – Static Test Data Results for the MP EM system at Victorville

Result Type	Value
2-D Position	0.50 ± 0.21 cm
Demedianed EM61 MkII (bottom gates)	0.082 ± 0.002 mV
Demedianed EM61 MkII (all gates)	0.096 ± 0.002 mV

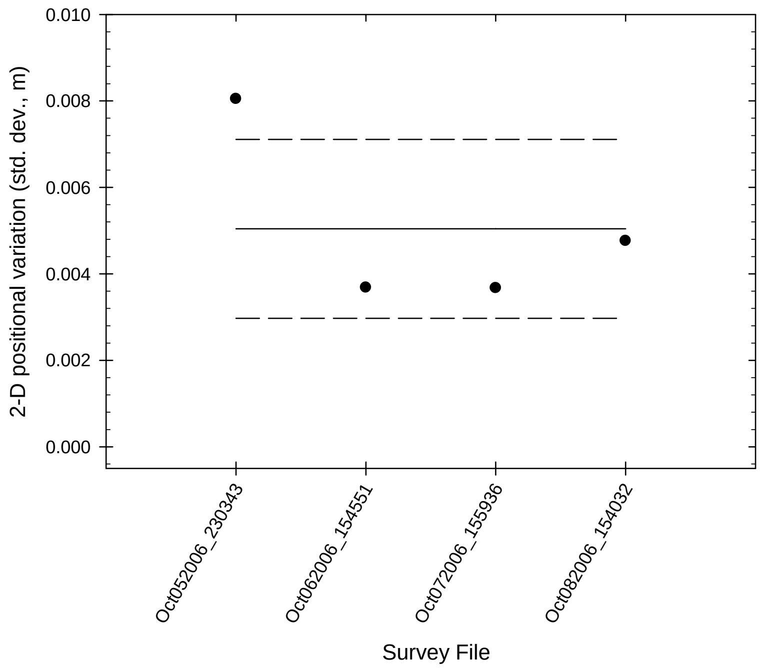

Figure 4-14 – Positional variation data runs for static data collected with the MP EM system at Victorville. The horizontal axis is survey date code. The solid line represents the aggregate average positional variation and the dashed lines represent a 1σ envelope.

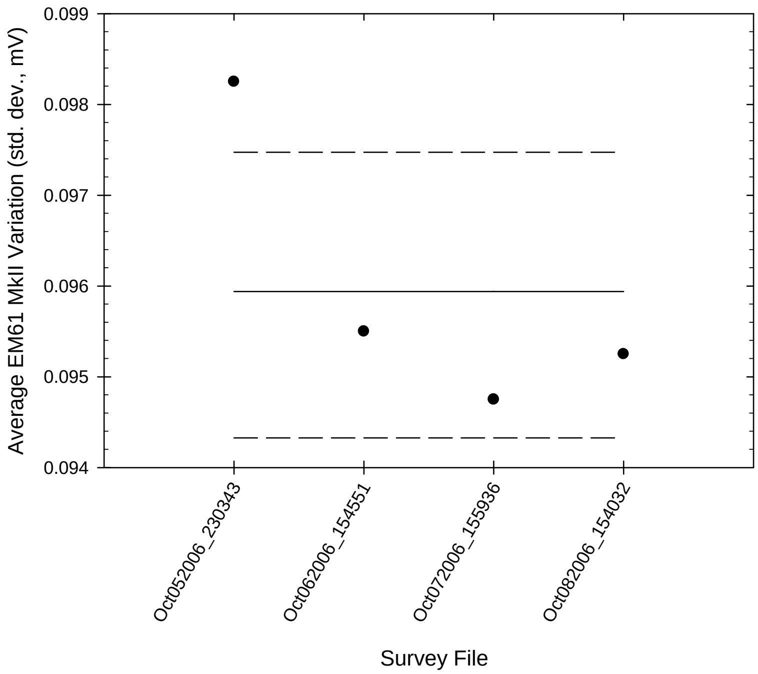

Figure 4-15 – Overall EM61 MkII (all time gates) variation for static data collected with the MP EM system at Victorville. The horizontal axis is survey date code. The solid line represents the aggregate average sensor variation and the dashed lines represent a 1σ envelope.

Data Density: As an example of the system performance for this Objective, the analyses of one transect survey from each vehicular demonstration are presented in Table 4-11. A sensor array width of 2m was assumed and only data which met the MTADS QC requirements were considered. Similar performance can be seen for the entire data archive.

Table 4-11 – Example Vehicular Data Density Results

	Pueblo PBR #2	Victorville PBRs Y&15
Sortie Number	05256009	06081019
Survey Length (m)	3,650	4,000
# of data points	501,304	499,512
Data Density (pts/m^2)	68	62

The MP EM system has a data rate of 10 Hz and a rate of advance of approximately 1 m/s, corresponding to an approximate data density of 10 pts/m^2. No specific performance metric was set in the Demonstration Plan Addendum covering the first-time demonstration of this system, but the example presented in Table 4-12 demonstrates that 10 pts/m^2 is practical in the field.

Table 4-12 – Example MP EM Data Density Results

	Victorville PBRs Y&15
Sortie Number	Oct062006_214531
Survey Length (m)	1,700
# of data points	16,970
Data Density (pts/m^2)	10

4.2.3 Anomaly Density Falloff Analysis for Known Targets

One intention of the total coverage surveys conducted as part of these demonstrations was to map the anomaly density falloff as a function of distance from the known Targets. Once the total coverage data have been collected and analyzed in the MTADS DAS, the data were divided into cells in a radial leading away from the center of each target. Figure 4-16 depicts the total coverage plan for Area 3 (Target 3) at the Pueblo site. The red diamond indicates the CSM v0 center of the Target 3 target circle. The red line indicates the path of the 30m x 30m cells used for the analysis. The blue rectangles represent the planned locations of the total coverage areas. Some modification to the area locations were made in the field and the small mismatch between the red line and blue rectangles reflects this. The number of anomalies in each cell was counted and is shown in Figure 4-17. Assuming that the anomaly density around a target falls off according to a normal distribution, the results can be fit to a normal distribution with a persistent background value. The functional form used was:

$$y = y_0 + ae^{-\frac{1}{2}\left(\frac{r}{b}\right)^2}$$

Such a fit is shown in Figure 4-17 as a solid line. If the center of the distribution is fixed at the center of the CSM v0 target circle, the resulting background value is 1.8 anomalies per cell, or 8.1 per acre. Allowing the center to float yields the same background value and displaces the center position to -38m along the radial.

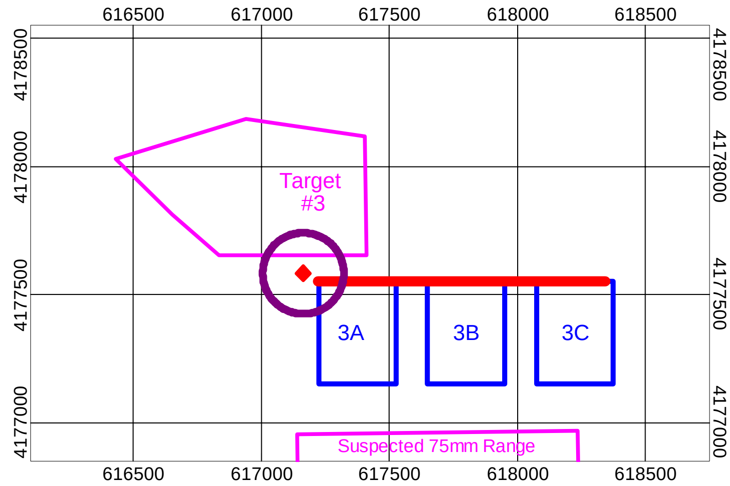

Figure 4-16 – Total Coverage Plan for Pueblo Area 3 (Target 3). The planned total coverage survey areas are shown in blue, the Target 3 target circle from CSM v0 is shown in dark purple and the ASR target outlines are shown in pink. The red diamond indicates the center of the Target 3 target circle. The red line indicates the swath selected for the radial analysis.

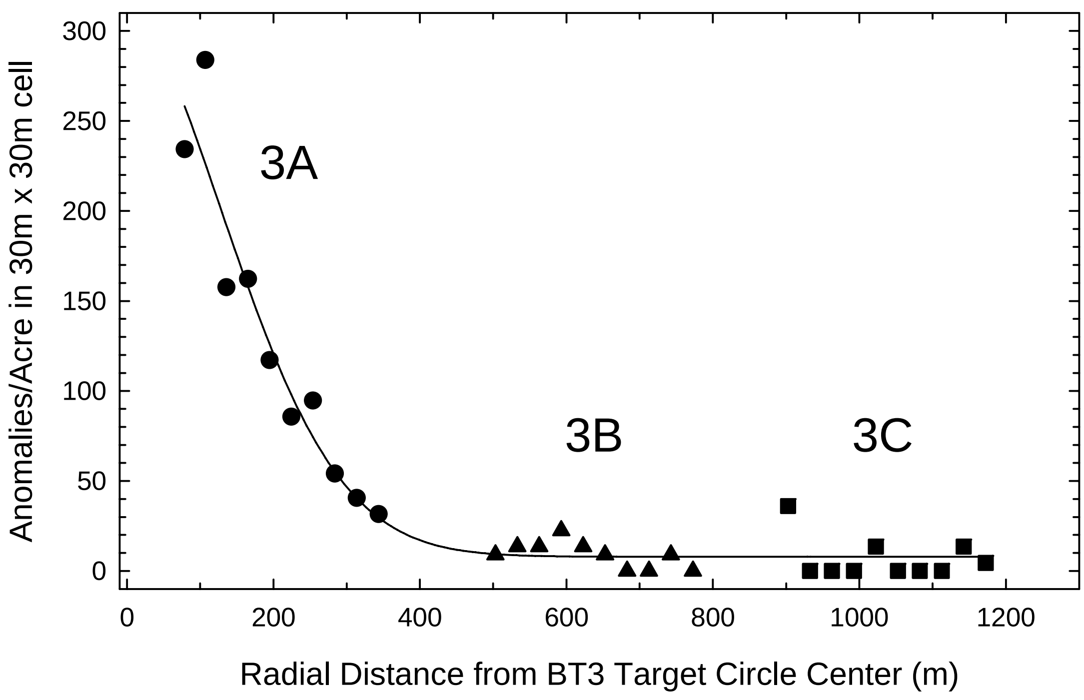

Figure 4-17 – Number of anomalies per acre in each analysis cell as a function of radial distance from the CSM v0 T3 target circle center at Pueblo. The solid line is the results of a fit to a normal distribution with a persistent background value of 8.1 anomalies / acre.

Figure 4-18 depicts the total coverage plan for Pueblo Area 1 (Target 4). The red diamond indicates the center of Target 4 as determined by the AMTADS magnetometer survey conducted by Sky Research as part of the WAA Pilot Project. The red line indicates the swath of the 30m x 30m cells used in the analysis. The blue rectangles represent the planned locations of the total coverage areas. Some modification to the area locations were made in the field and the small mismatch between the red line and blue rectangles reflects this. The number of anomalies in each cell was counted and is shown in Figure 4-19. The results of a fit to a normal distribution with a persistent background value is shown in Figure 4-19. If the center of the distribution is fixed at the center of the AMTADS survey, the resulting background value is 6.2 anomalies per cell. Table 4-13 tabulates these results along with the overall anomaly densities for the Area 2 (Suspected 75mm Range) and the Simmons Area for comparison. The background anomaly density 1200 – 2000 m from the center of the two Targets remains higher than any other area subjected to a total coverage survey at the Pueblo Site.

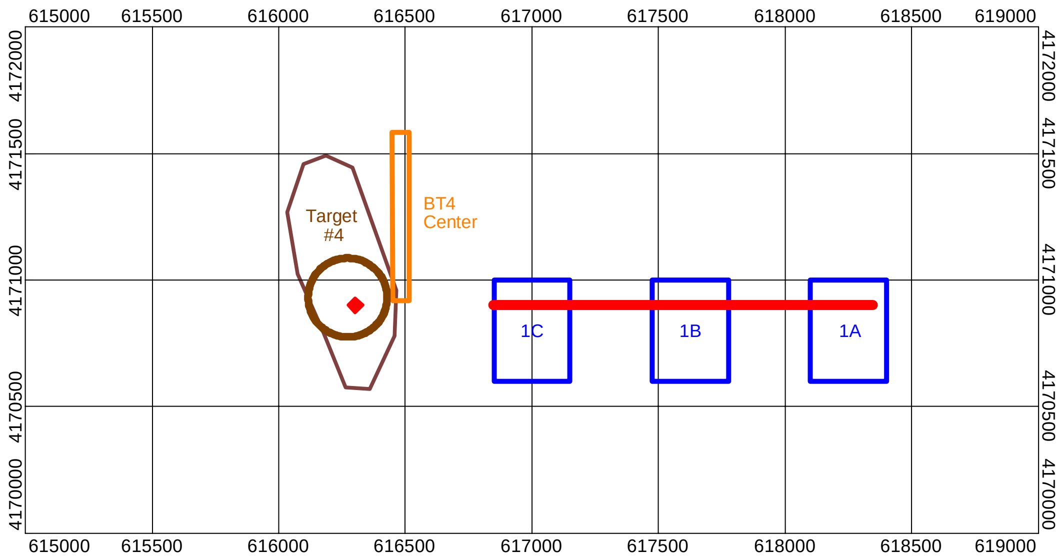

Figure 4-18 – Total Coverage Plan for Pueblo Target 4. The planned total coverage survey areas are shown in blue, the Target 4 target circle from CSM v0 and the ASR target outline are shown in dark brown. The red diamond indicates the center of Target 4 as reported from the AMTADS magnetometer data collected by Sky Research. The red line indicates the swath selected for the radial analysis.

Table 4-13 – Background Anomaly Densities for Pueblo Total Coverage Areas 1, 2, 3, and the Simmons Area

Area	Anomalies / acre
Area 1 (Target 4)	6.2
Area 2A (Suspected 75mm Range)	4.9
Area 2B (Suspected 75mm Range)	2.2
Area 3 (Target 3)	8.1
Simmons Area	0.4

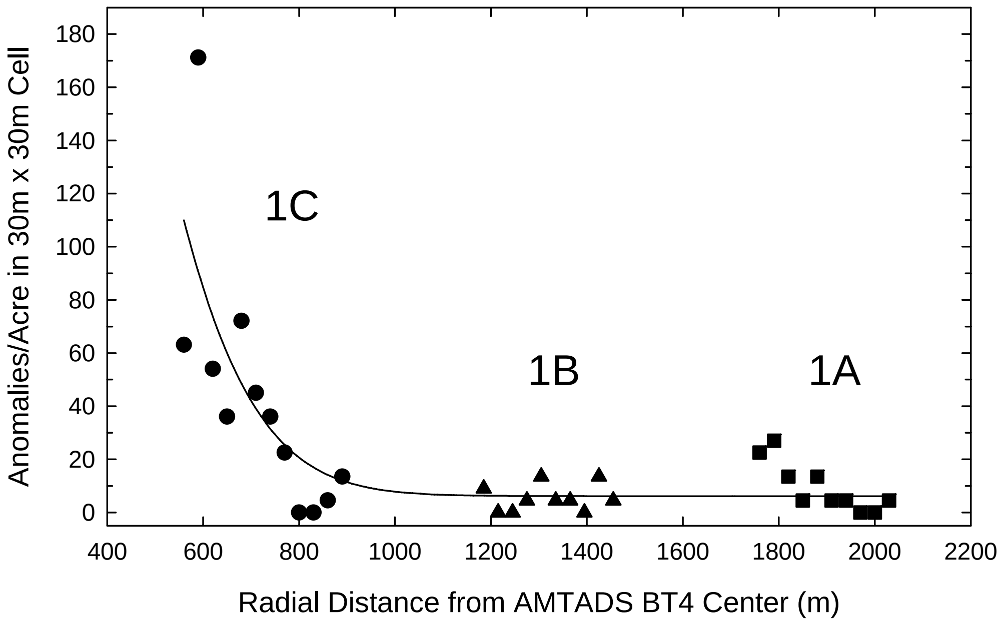

Figure 4-19 – Number of anomalies per 30m x 30m cell as a function of radial distance from the AMTADS T4 center at Pueblo. The solid line is the results of a fit to a normal distribution with a persistent background value of 6.2 anomalies / acre.

A similar analysis was conducted for Victorville PBR #15 Target. Once the total coverage data have been collected and analyzed in the MTADS DAS, the data were divided into non-overlapping bands 30m thick (in radial distance) and with increasing radial distance from the center of the PBR #15 Target oriented to the South. The number of anomalies in each band was counted and is shown in Figure 4-20. The Target center was determined during a site visit in January by the Project team using WAAS-level GPS and the coordinates are given in Table 4-14.

Such a fit is shown in Figure 4-20 as a solid line. If the center of the distribution is fixed at the GPS-located center of the target, the resulting persistent background value is 12.2 anomalies per acre. There does appear to be a small feature that rises above background at a radial distance of approximately 590m. The fit parameters and those for Targets BT3 and BT4 at the Pueblo PBR #2 demonstration site are given in Table 4-15. The persistent component y_0, or background value, is 12.2 for the PBR #15 radial, a similar value that seen at Pueblo PBR #2. The coefficient b, which accounts for the falloff, is 2-4 times smaller for the PBR #15 Target than those values seen at Pueblo PBR #2.

Table 4-14 – Victorville PBR #15 Target center location (WAAS GPS)

UTM (Zone 11N) Coordinate	meters
Northing	3,806,343
Easting	546,417

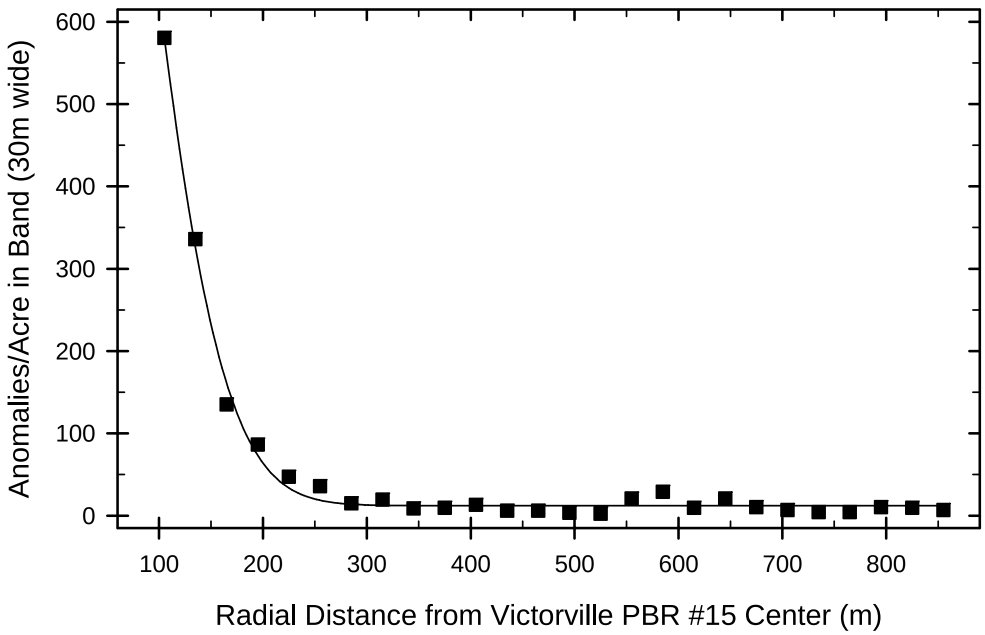

Figure 4-20 – Number of anomalies per acre as a function of radial distance from the Victorville PBR #15 Target center as located via GPS on site. Bands with increasing radial distance and 30 meter width (radial distance) were used to bin the anomalies. The solid line is the results of a fit to a normal distribution with a persistent background value of 12.2 anomalies / acre.

Table 4-15 – Fit Parameters for Victorville PBR #15 and Pueblo PBR #2 Targets

Fit Parameter	PBR #15	Pueblo PBR#2 BT3	Pueblo PBR#2 BT4
a	1417	63	152
b	78	148	288
y_0	12.2	8.2	6.2

4.2.4 Comparison of EM and Magnetometer Anomaly Selection Methodologies

The vehicular magnetometer survey surveyed approximately 1.7% of the total Victorville WAA demonstration site with magnetometer array transects. A man-portable EM system was fielded to augment the transect coverage by expanding operations into areas inaccessible to the tow vehicle. Additionally, the EM instrument is less sensitive to the local geology identified in the northern portion of the site during the vehicular demonstration. To maximize the utility of these additional data, it is necessary to understand the relationship between results from the two systems and to be able to combine the two data sets into a coherent whole. How to compare results from the two different sensor systems which operate on different principles is not immediately obvious.

Two transect lines were identified from the southern portion of the vehicular survey for inter-system comparison. One kilometer long segments of Lines 19 and 21 were selected for being free of geological interference and for spanning a range of densities of known compact metallic targets. These two lines traversing the area south of Target PBR #15 with Line 21 crossing one of the Target's outer pavement circles and Line 19 further to the south. The vehicular data indicated a large number of anomalies along the selected portion of Line 21 (29 anomalies) and a smaller but non-zero number along the selected portion of Line 19 (8 anomalies). Man-portable EM transect surveys were conducted for the same 1-km long sections of Lines 19 and 21.

To compare the anomaly selection methods for the magnetometer and EM systems, a similar method to that used to establish the site-specific anomaly selection thresholds for each system was used. Anomalies were selected from each transect segment for each sensor at various threshold values. As expected, the number of anomalies selected decreases rapidly as the threshold is increased above the sensor noise floor until reaching a 'knee' or curvature change beyond which the rate of anomalies selected slows dramatically. This region presumably corresponds to well-defined anomalies well above the noise floor. The final site-specific threshold value used during the demonstrations is chosen to fall in this 'knee' region. For the magnetometer survey, the threshold was chosen conservatively or placed in the higher threshold portion of the 'knee' region at 62.5 nT/m for Victorville. Based on repeated feedback asking for lower threshold results to evaluate their potential utility, the threshold of the EM survey was chosen less conservatively at 4 mV (see Figure 3-40) while maintaining an acceptable rejection level for spurious anomalies. Linear scaling factors were evaluated for the co-registration of EM anomaly selection results with the existing magnetometer results. A scaling factor of 10 for the EM cut-off threshold was found to give good agreement with the magnetometer data. For example, an EM cut-off threshold of 4 mV corresponds to a magnetometer cut-off threshold of 40 nT/m. For anomaly densities, a scaling factor of 0.67 was found to give good agreement between the EM and magnetometer results. The number of anomalies selected per kilometer, a measure of anomaly density, is 50% larger for the EM system than for the magnetometer system for the two transect segments used in this evaluation. These results are shown in Figure 4-21 for Line 19 and Figure 4-22 for Line 21. A small linear offset was required to achieve good co-registration of the anomaly counts (vertical axis in Figure 4-22, -5) for the Line 21 results at high cut-off threshold values. A review of the COGs for the two systems showed less overlap ($\overline{\Delta Northing} = -2.7 \pm 1.2\ \mathrm{m}$) than was achieved for Line 19 ($\overline{\Delta Northing} = 1.3 \pm 1.1\ \mathrm{m}$). Considering the anomaly rich nature of this portion of the PBR #15 target circle, the required offset is attributed to the differences in actual items surveyed by each system and is not thought to be part of the general trend.

Based on these results, the final recommendation for comparing EM transect anomalies to anomalies from the vehicular system is to scale the EM selection threshold to be one-tenth (0.1x) the magnetometer selection threshold and to scale EM anomaly densities by a factor of approximately two-thirds (0.67).

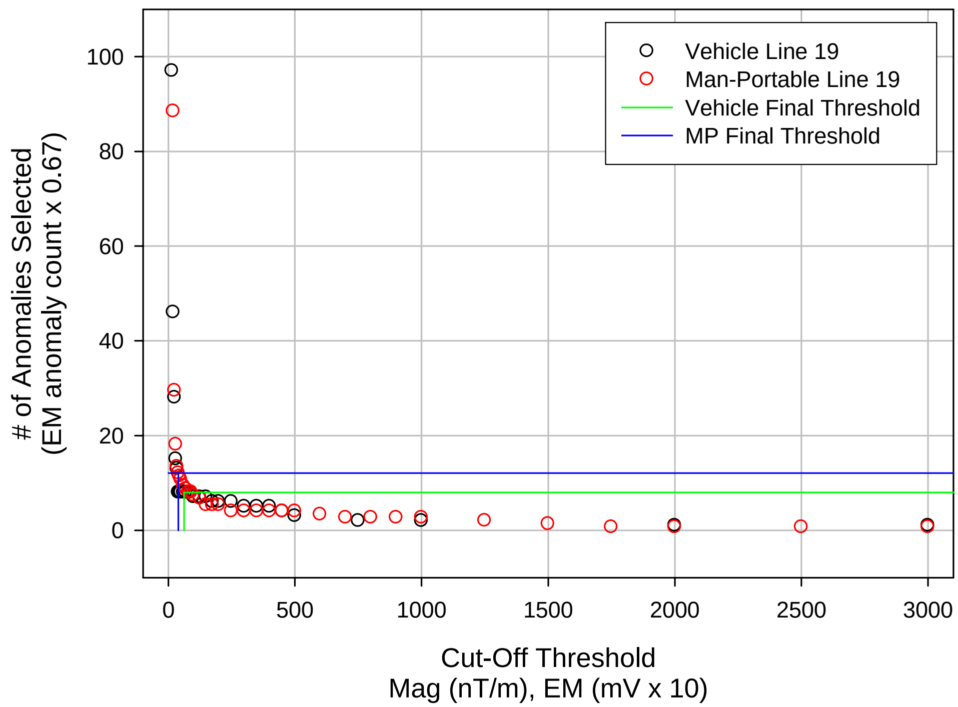

Figure 4-21 – Victorville Transect Line 19 cut-off threshold evaluation results

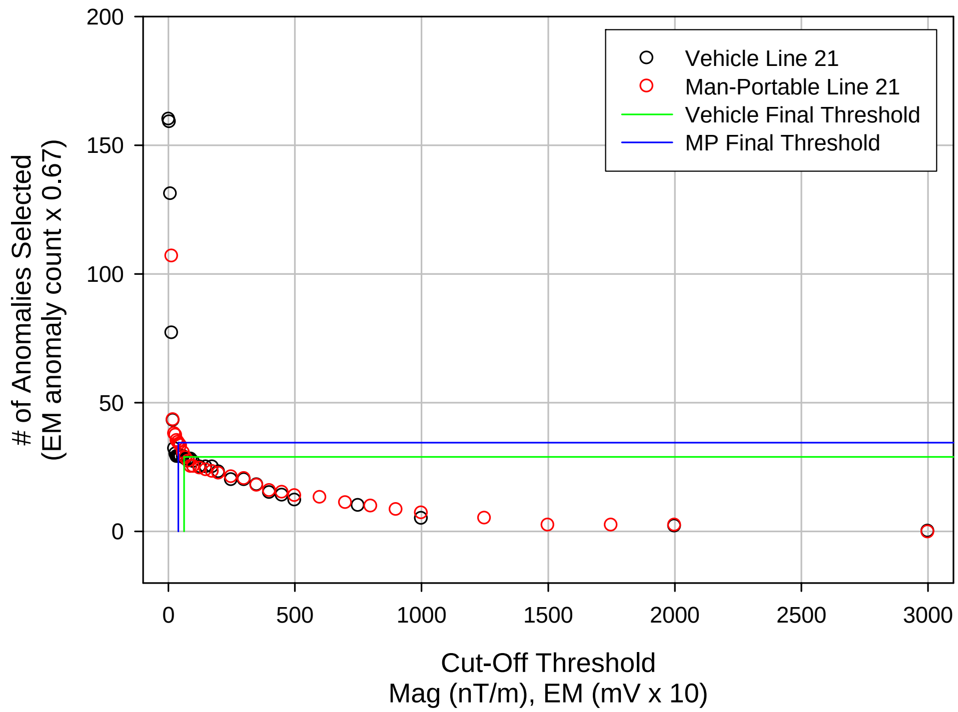

Figure 4-22 – Victorville Transect Line 21 cut-off threshold evaluation results

5. Cost Assessment

5.1 Cost Reporting

Cost categories for this demonstration are mobilization, field survey, data analysis, demobilization, and reporting. Table 5-1 details the costs of mobilization, demobilization, and reporting for both vehicular demonstrations. Additionally, the costs for the field work and associated data analysis have been aggregated and are presented on a 'per week of field work' basis. This presentation is used to facilitate comparison between the two sites and for future cost estimate purposes. A Cost and Performance analysis will be carried out and reported as an ESTCP Cost and Performance Report covering this Demonstration at the conclusion of the project.

5.2 Cost Analysis

5.2.1 Cost Comparison

Baseline alternative technologies to be used as a reference for this site are TBD in cooperation with the ESTCP Program office and the WAA Project Manager. Further information will be provided in the Cost and Performance Report.

5.2.2 Cost Basis

The anticipated cost basis for this technology demonstration is the number of lane kilometers or acres per day which can be surveyed and the collected data analyzed by the end of the following day. The production results for the individual demonstrations were given in Section 4.1.2. In Table 5-2, the cost data provided in Table 5-1 are combined with the results of Section 4.1.2 to generate the final costs in terms of fixed costs and per-week field costs. The fixed costs include mobilization to the site, demobilization, and ESTCP report generation through the Demonstration Data Report. Logistics items are included as a separate item as these costs can vary widely based on what facilities are available on site. The field work and associated data analysis item is self explanatory. This format is chosen to not only provide a basis for evaluating these demonstrations but to serve as a planning tool for future efforts of similar design. While the costs for total coverage survey are not called out explicitly, the costs per week of field work is the same and production rates are consistently 20 acres/day or more. Table 5-3 details the costs associated with the MP EM survey conducted at the Victorville PBRs Y & 15 demonstration site. 56 lane km (14 acres) of transect surveys were conducted over 5 days and 3.3 acres of total coverage surveys were conducted over two days during a 9 day deployment.

5.2.3 Cost Drivers

Two factors were expected to be strong drivers of cost for these technologies as demonstrated. The first is the acreage which can be surveyed per day. The second is the data analysis rate. For the first, actual acreage covered sets the amount of data collected per day. Higher productivity in data collection equates to more total acreage covered for a given period of time in the field. With the emphasis on rapid turn-around in the initial data products (anomaly location (x,y), anomaly strength (peak AS)), the data analysis rate must be able to keep pace with the data collection rate over an extended period of time. For the overall effort, the effective throughput of the system will be dependent upon which driver represents the rate-limiting criteria.

Table 5-1 – Aggregate Costs for Pueblo and Victorville Vehicular Surveys

		Victorville		**Pueblo**	
		Item Cost ($)	**Sub-Total ($)**	**Item Cost ($)**	**Sub-Total ($)**
Mobilization			**38815**		**32354**
	53' Trailer Rental / Amortization	810		810	
	Trailer Tranporation	9180		6480	
	Office Trailer Delivery	475		391	
	Base Camp Connex Delivery	135		216	
	Aux Base Camp Connex Delivery	0		216	
	Generator Delivery and hook up	648		859	
	Facilities Delivery	54		54	
	Emplacement of Calibration Lane	2549		216	
	Team Travel to Site	3240		2430	
	Analyst / Supervisor Preparation	10206		10206	
	Site Visit	3888		3888	
	Equipment Preparation & Packing	7630		6588	
Field Work			**39698**		**35010**
	Week in Field is 5, 8 hr survey days, 7 days in field				
	53' Trailer Rental / Amortization	405		405	
	Base Camp Site Rental	0		540	
	Office Trailer Rental	122		46	
	Base Camp Connex Rental	34		43	
	Aux Base Camp Connex Rental	0		43	
	Generator Rental	716		729	
	Facilities Rental	50		151	
	Generator Fuel	0		563	
	Materials & Consumables	1080		1080	
	Supervisor	4649		4649	
	Field Technician	4050		4050	
	Local Temp Labor	0		2052	
	Vehicular Operator	3294		3294	
	Data Analyst	5103		4860	
	Site Security	4169		0	
	On-site Vehicle Maintenance	1080		0	
	Per Diem for Team	4082		2245	
	SUV Rental Vehicles	2225		1620	
	Magnetometer Repair / Replacement	8640		8640	
Demobilization			**21328**		**18913**
	53' Trailer Rental / Amortization	810		810	
	Trailer Tranporation	9180		6480	
	Office Trailer Pick Up	673		391	
	Base Camp Connex Pick Up	135		216	
	Aux Base Camp Connex Pick Up	0		216	
	Generator Pick Up and Disconnect	648		162	
	Facilities Pick Up	54		0	
	Unpackinging of Trailer / Cleanup	6588		6588	
	Team Travel from Site	3240		4050	
Reporting			**23981**		**23981**
	Site Planning Meeting	4649		4649	
	Travel and Per Diem for 2nd Planning Meeting	1620		1620	
	Demonstration Plan Preparation	8856		8856	
	Demonstration Report Preparation	8856		8856	
		Grand Total	**123823**	**Grand Total**	**110258**

During the course of the individual demonstrations, the data analysis process was not a limiting step as discussed in Section 4.1.2. The refinement of the survey rate performance metric after the demonstration at Pueblo PBR #2 more accurately reflected a sustainable production rate for these types of surveys.

Table 5-2 – Summary Costs of a WAA Transect Survey

	Min	Average	Max
Fixed Costs	**$70,000.00**		**$80,000.00**
Mobilization			
Demobilization			
"Std." WAA Reporting			
Field Work (1 wk)		**$40,000.00**	
Logistics, If required	**$0.00**		**$8,000.00**
Transect Coverage (km/wk)	**110.5**	**159.8**	**209.0**
Transect Coverage (acres/wk)	**54.5**	**78.8**	**103.0**

Table 5-3 – Costs for Victorville PBRs Y & 15 MP EM Survey

		Item Cost ($)	Sub-Total ($)
Mobilization			**10206**
	Equipment Preparation and Packing	3294	
	Shipping of Equipment	2160	
	Facilities Delivery	54	
	Generator Purchase	648	
	Team Travel to Site	4050	
Field Work			**50876**
	Generator Fuel	162	
	Facilities Rental	81	
	Materials & Consumables	1620	
	Supervisor	6974	
	Operator	4941	
	Field Technicians	22113	
	On-site System Maintenance	1620	
	Per Deim for Team	8505	
	SUV Rental Vehicles	4860	
Data Reduction / Analysis			**0**
	QC / Locating of Raw Data	0	
Demobilization			**9558**
	Facilities Pick Up	54	
	Shipping of Equipment	2160	
	Equiipment Unpackinging and Maintenance	3294	
	Team Travel from Site	4050	
Reporting			**13948**
	Finalization of Data Analysis & Methods	4649	
	Demonstration Plan Preparation	4649	
	Demonstration Data Report	4649	
Development			**10913**
	Supervisor	4649	
	Operator	3294	
	Equipment Purchases	2970	
		Grand Total	**95502**

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7. Points of Contact

ESTCP		
Anne Andrews	Program Manager, MM	Tel: 703-696-3826 Fax: 703-696-2114 anne.andrews@osd.mil
Katherine Kaye	Program Assistant, MM	Tel: 410-884-4447 Fax: 703-471-4180 kkaye@hgl.com
NRL		
H. H. Nelson	Project Manager, WAA	Tel: 202-767-3686 Fax: 202-404-8119 Cell: 202-215-4844 herb.nelson@nrl.navy.mil
Nova Research		
Dan Steinhurst	Principal Investigator	Tel: 202-767-3556 Fax: 202-404-8119 Cell: 703-850-5217 dan.steinhurst@nrl.navy.mil
Glenn Harbaugh	Site Safety Officer	Tel: 301-392-1702 Fax: 301-392-1702 Cell: 804-761-5904 roo749@yahoo.com
Russell Jeffries	Logistics Support	Tel: 703-360-3900 Fax: 703-360-3911 Cell: 703-244-1245 rjeffries@novaresearchonline.com
SAIC		
Nagi Khadr	Data Analyst	Tel: 703-413-0500 Fax: 703-413-0505 nagi.khadr@saic.com
NAEVA Geophysics		
Mark Howard	Field Operations Support	Tel: 434-978-3187 Fax: 434-973-9791 Cell: 434-825-4405
Hotel Accommodations		
La Junta, CO Holiday Inn Express	27994 US Highway 50 Frontage Road La Junta, CO 81050	Tel: 719-384-2900
Yucca Valley, CA Americas Best Value Inn and Suites	56377 29 Palms Highway Yucca Valley, CA 92284	Tel: 760-365-6321 Fax: 760-365-9592

Appendix A. Analytical Methods to Support the Experimental Design

To facilitate the scope and tempo of the WAA pilot project, the typical MTADS man-in-the-loop analysis of total field magnetometer data was not going to provide the necessary overall data throughput required. The process is too time consuming and provides far richer results than is initially required by the planning elements of the project on a daily time scale. An alternate approach was required. Briefly, the located total magnetic field data (nT) are collected as normal for an MTADS survey. The demedianed total field data are converted to analytic signal (AS, nT/m) where the analytic signal is calculated from the squares of the derivatives in the *x*, *y*, and *z* directions:

$$AS = \sqrt{\left(\frac{d}{dx}\right)^2 + \left(\frac{d}{dy}\right)^2 + \left(\frac{d}{dz}\right)^2}$$

The *z* derivatives can be estimated from the total field 2-D data using either FFT or convolution methods. For this work, the FFT method was used. All processing work was done in the commercial geophysics software package Oasis montaj and requires the advanced 1-D filters available as part of the Geophysics add-on package (and others). A data grid is calculated for the demedianed total field data and this involves interpolating the actual data to a regularly spaced grid of a given cell size. The algorithms which compute the AS require a regularly spaced input data grid to work efficiently and output an AS data grid. The GRIDPEAK GX is then used to extract all peaks in the AS grid which are above a given threshold. This Appendix describes initial evaluation work done on existing data sets to validate this method and provide initial estimates of the optimized parameters required.

Demedianed total field magnetometer and AS grids were calculated from an existing data set collected using the MTADS platform at our home base in Blossom Point, MD at 0.125, 0.25, 0.50, and 1.00 m grid cell sizes. The GRIDPEAK.GX was then run using a set of Cut-Off threshold values (required peak amplitude to be counted as a peak) and a fixed number of smoothing filter passes (six) on each AS grid. Six passes was found to be the minimum to get reasonable results. Using fewer passes result in multiple picks for the same actual peak in the grid. The following four graphs (Figure A-1 through Figure A-4) show the # of peaks picked for a given Cut-Off value for each AS grid cell size. The red line indicates the number of emplaced targets (all types) in the BP test field (61).

Each curve shows a 'knee', below which one picks up non-emplaced anomalies faster than emplaced items. The 0.25m studies captured 51 to 57 of the 61 emplaced items with a range of non-emplaced anomalies picked. A majority of the undetected emplaced items were in the Clutter category and the exclusion of these objects is not necessarily a failing of the method.

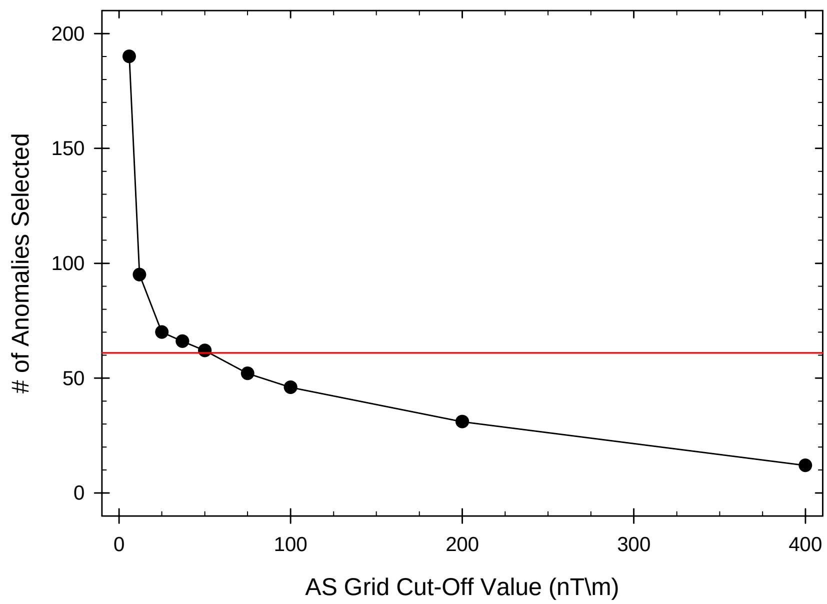

Figure A-1 - Blossom Point GRIDPEAK Results for a 0.125m grid cell size

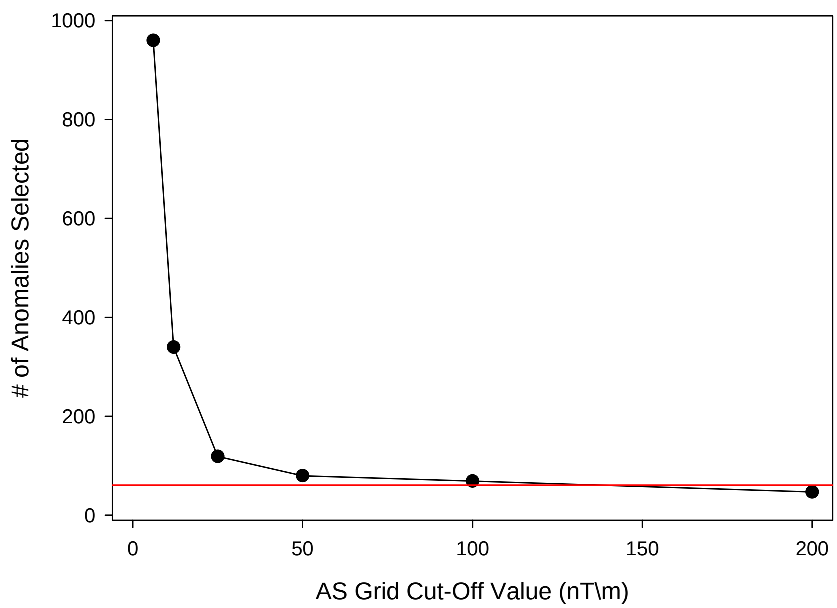

Figure A-2 - Blossom Point GRIDPEAK Results for a 0.25m grid cell size

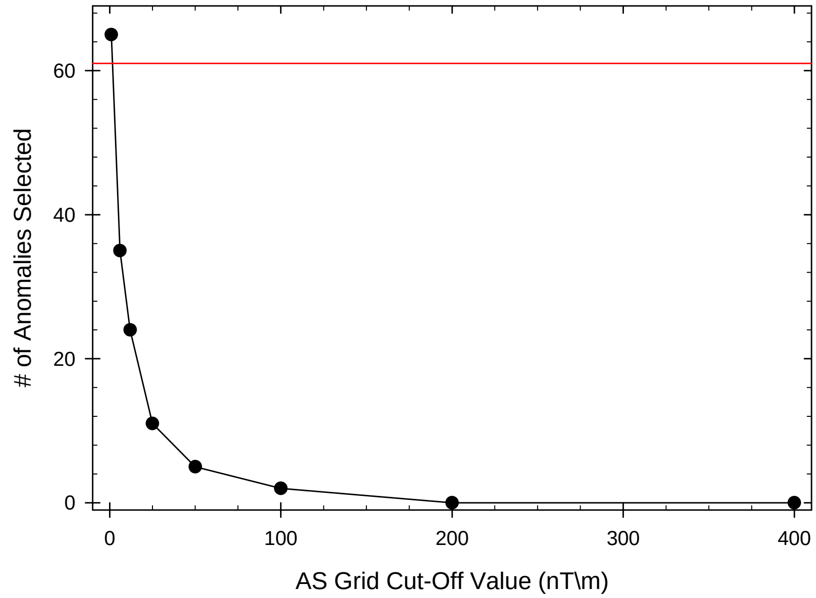

Figure A-3 - Blossom Point GRIDPEAK Results for a 0.50m grid cell size

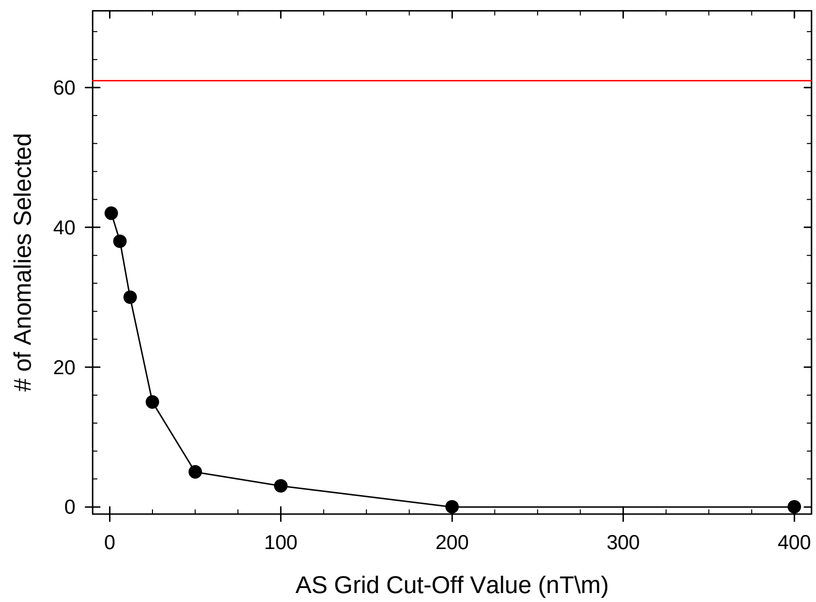

Figure A-4 - Blossom Point GRIDPEAK Results for a 1.00m grid cell size

For eight points from the above studies (predominately from the 0.25m grid cell size results), the picked anomalies were matched to an emplaced item. If the pick was not clearly associated with an emplaced item, it was marked as a False Alarm (FA) since the Blossom Point Test Field is relatively clean after repeated clearances and should have no non-emplaced items. Based on these results, values for probability of detection (P_d), false alarm rate (FAR, FA's / hectare), average miss distance, and the standard deviation of the miss distance were calculated. Table

A-1 gives the results. A ROC curve was constructed and is shown as Figure A-5 for all analyzed cases with the 0.25m cases plotted in red.

Table A-1 – Results for emplaced items at Blossom Point for various parameters

Grid Cell Size (m)	CutOff Threshold (nT\m)	# of Anomalies Picked	# of Emplaced Items Picked	Pd	# of Anomalies Picked Not Emplaced Items	FAR (# FA/ Hectare)	Average Miss Distance (m)	Std. Dev (1σ) (m)
0.125	25	120	57	0.934	63	223	0.119	0.079
0.125	50	80	57	0.934	23	82	0.119	0.079
0.250	25	70	57	0.934	13	46	0.132	0.080
0.250	37	66	56	0.918	10	35	0.133	0.081
0.250	50	62	55	0.902	7	25	0.131	0.080
0.250	75	52	51	0.836	1	4	0.136	0.082
0.500	25	11	11	0.180	0	0	0.419	0.396
0.500	50	5	5	0.080	0	0	0.370	0.289

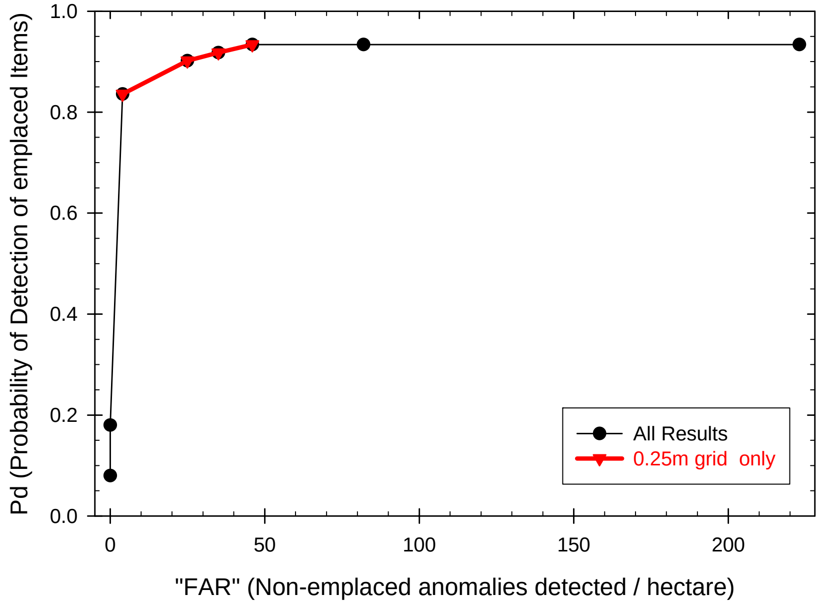

Figure A-5 – ROC curve for emplaced item comparisons

As stated above, the BP Test Field is a relatively small site with a limited number of emplaced items and is relatively clean. To further test the developed method, existing MTADS magnetometer data collected at the Standardized UXO Technology Demonstration Sites located at the Aberdeen and Yuma Proving Grounds were considered. Using 0.25m grid spacing and the same range of Cut-Off threshold values, the # of picks vs. Cut-Off Threshold value for these two sites were determined. Plots are included showing ATC (Figure A-6) and YTC (Figure A-7) separately and then together with the BP results for 0.25 m (Figure A-8) are shown. Notice the strong similarity between the ATC and YTC results. The similarity to the BP is also good considering how much smaller/cleaner the BP field is. These results support the general applicability of the BP analysis to ATC and YTC (if no further). No count of the actual number of emplaced items is available for these sites, so no reference lines are plotted.

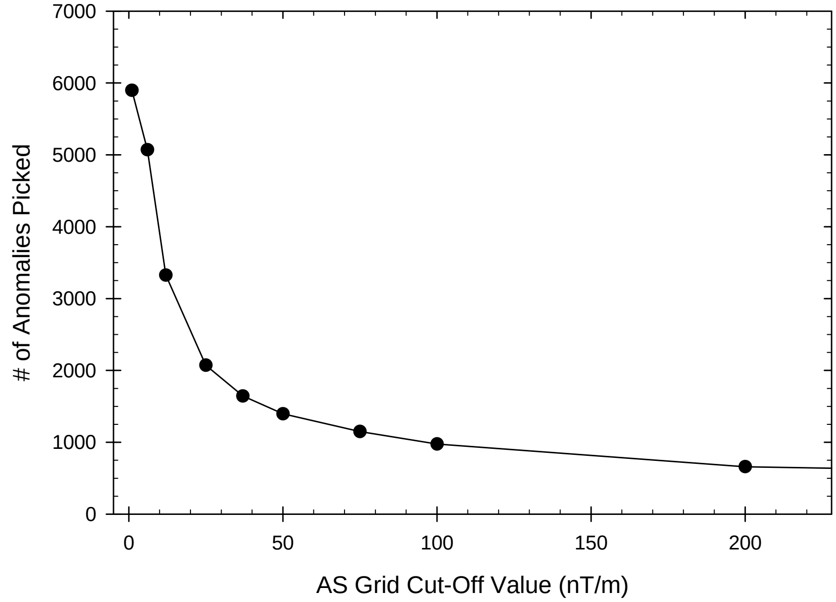

Figure A-6 – ATC GRIDPEAK Results for a 0.25m grid cell size

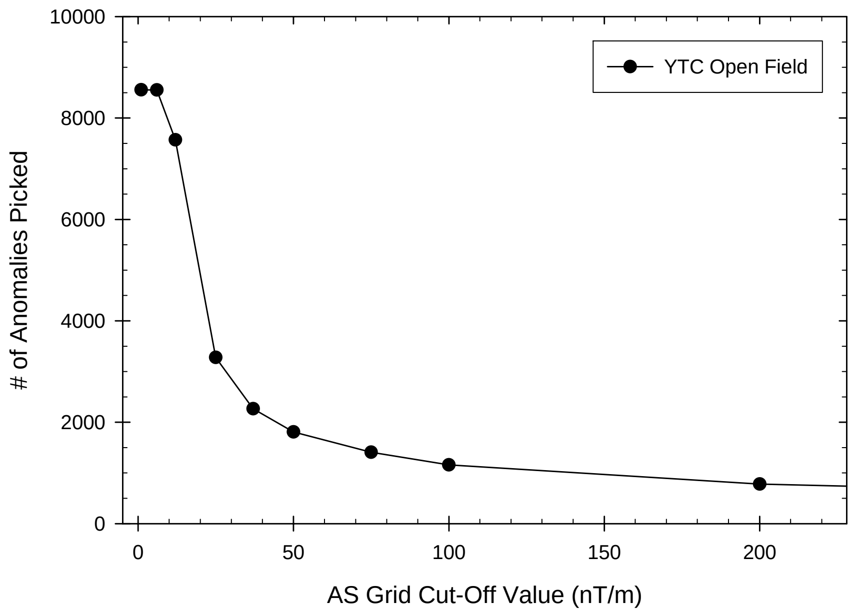

Figure A-7 – YTC GRIDPEAK Results for a 0.25m grid cell size

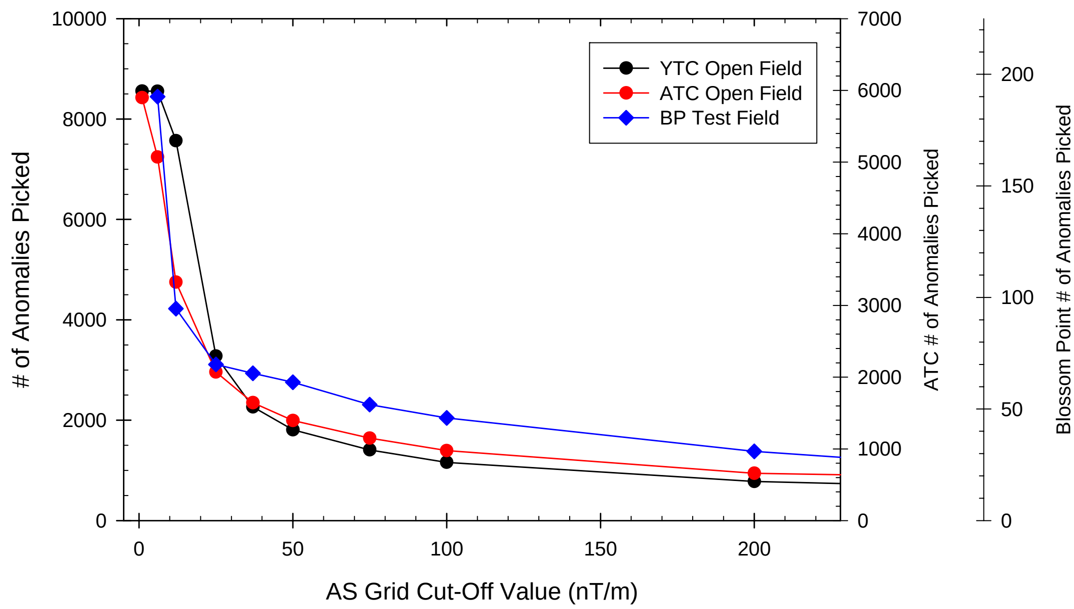

Figure A-8 – YTC, ATC, and BP GRIDPEAK Results for a 0.25m grid cell size

The 0.25m grid cell size appears to be a promising combination of sensitivity (from this work) and computational speed. Timed trials conducted on a large data set found that the typical grid cell sized used in total coverage surveys (0.125 m) is computationally impractical for transect style data with long (~6 km) down track distances and narrow cross track width (2 m). If the computations were completed, the time required was on the order of 4 hours per one hour of survey.

In conclusion, the following three points can be drawn:

1) The 0.25m grid cell size appears to be a promising combination of sensitivity and computational speed.

2) A generally applicable guideline of 25 to 100 nT/m for the AS cut-off threshold value is beginning to appear and holds on three sites.

3) The choice of AS cut-off threshold value will be driven by the relative tolerance for detection of smaller clutter items versus desired sensitivity.

Ongoing efforts which will feed directly into this project include the analysis of other data sets and further exploration of the available parameter space. One other data set from the MTADS BBR 2002 vehicular survey exists. This data set represents a plains-like geology which may be relevant to the PBR#2 site. The large positional errors reported for the 0.5 and 1.0 m grid cell sizes leave room for improvement. Alternate smoothing filter settings may prove more effective for the larger grid cell sizes. This will be an area of continued effort.

Appendix B. Quality Assurance Project Plan (QAPP)

B.1 Purpose and Scope of the Plan

The collection and archiving of high quality survey data in auditable and defensible manner are critical to insure the credibility of the data collected and to support decisions based in part or in total on these data. This Appendix outlines the standard process used in the NRL MTADS program to collect survey data, conduct quality checks to insure the quality of the data, and then process and archive the data.

B.2 Quality Assurance Responsibilities

The team as a whole is involved in insuring the quality of collected data. The MTADS has been designed to provide a series of visual indicators to the operator regarding the status of the individual subsystems that comprise the MTADS. The operator is responsible for monitoring these indicators and halting data collection immediately if any problems are indicated. The issue will be resolved prior to resuming operations. All team members are involved in visual walk-around inspections of the system at least daily. For each survey file set, the data preprocessing tasks are logging receipt of the file set, archiving the file set, verifying that all files within the file set are valid, and verifying that each sensor channel contains valid data with sufficient SNR (where appropriate). Any section of data which is found lacking is flagged accordingly and not processed any further. The section will be logged for future re-acquisition if necessary. After these checks are completed, the resultant located survey data are submitted to the automated anomaly picking routines for analysis and anomaly report generation. The data analyst is responsible for the data preprocessing and processing tasks with the site / project manager's assistance as available. Dr. Daniel Steinhurst will serve as the Quality Assurance Officer for this project.

B.3 Data Quality Parameters

Incoming survey data will be evaluated for: completeness of the data set, locational quality for the data set, and for proper operation of the magnetometer sensors. The following section details in an example how the data quality issues are addressed throughout the survey.

B.4 Calibration Procedures, Quality Control Checks, and Corrective Action

The following procedure constitutes a typical startup for the MTADS system for both initial startup and as daily system evaluations. The RTK GPS base station receiver and radio link will be established on one of the established control points. The validity of the control point location will be verified using the MTADS man-portable RTK GPS rover receiver to occupy one or more of the established control points using the control point occupied by the GPS base station as a reference as required by the Quality Assurance Officer. The magnetometer trailer will be connected to the tow vehicle if disconnected and the system will be powered up. The connectivity of the magnetometers to the DAQ computer (if required) and the establishment of normal SNR performance will be verified along with the operational state of the vehicle RTK system. A period (typically 5 - 10 minutes) of quiet, static data will be collected and submitted to the Data Analyst for validation. A survey of the emplaced calibration lane/object (one or more passes) will be conducted and repeated at the beginning and end of each work day, and as required by the Quality Assurance Officer. The data will be submitted to the Data Analyst for analysis of SNR and locational accuracy. When all system checks are completed to the satisfaction of the Quality Assurance Officer, the main survey will commence.

Preventative maintenance inspections will be conducted at least once a day by all team members, focusing particularly on the tow vehicle and sensor trailer. Any deficiencies will be addressed according to the severity of the deficiency. Parts, tools, and materials for many maintenance scenarios are available in the system spares inventory which will be on site. Status on any break-downs / failures which will result in long-term delays in surveying will be immediately reported to the WAA Project Manager.

MTADS survey raw data generally fall into two categories, location and magnetometer sensor measurements. The data set is comprised of ten separate files, each containing the data from a single system device. Each device has a unique data rate. A software package written by NRL examines each file and compares the number of entries to the product (total survey time * data rate). Any discrepancies are flagged for the data analyst to address. For magnetometer sensor data, operational values are typically on the order of 50,000 nT and have noise levels of ~0.5 nT peak-to-peak (PP) static and 3-5 nT PP in motion. Sensor "drop-outs" can occur if the sensor is tilted out of the operation zone with respect to the earth's magnetic field. If a sensor cable is severed or damaged while in motion, the sensor output value will drop below 20,000 nT and/or become very noisy (1,000's of nT PP). All magnetometer sensor channels (8 total) are examined in each survey file set for these conditions and any data which are deemed unsatisfactory is flagged and not processed further. For location data, the RTK GPS receivers present a Fix Quality value that relates to the quality / precision of the reported position. A Fix Quality (FQ) value of 3 (RTK Fixed) is the best accuracy (typically 3-5 cm or better). A FQ value of 2 (RTK Float) indicates that the highest level of RTK has not be reached yet and locational accuracy can be degraded to as poor as ~1 m. FQ 1 & 4 are Autonomous and DGPS respectively. Data collected under FQ 3 and FQ 2 (at the discretion of the data analyst) are retained. Any other data are deemed unsatisfactory, flagged and not processed further. Survey sections containing flagged data will be logged for future re-acquisition if required. Data which meet these standards are of the quality typical of the MTADS system.

B.5 Demonstration Procedures

See Section B.4. The same discussion applies to this section.

B.6 Calculation of Data Quality Indicators

There are no specialized equations required. The methods are outlined in Section B.4.

B.7 Performance and System Audits

See Section B.4. The same discussion applies to this section.

B.8 Quality Assurance Reports

The results of the daily system checkout runs for the static survey and the dynamic survey of the emplaced targets will be reported to the Quality Assurance Officer daily. The Data Analyst will report any transect sections requiring reacquisition to the site / project manager for a given day by the start of work the following morning.

B.9 Data Formats

B.9.1 Vehicular Magnetometer System Data Formats

Each survey file set contains 10 files which constitute the 'raw data'. The file name structure is YYDDDFFF.DeviceType.DeviceAlias; where YY is the 2-digit year, DDD is the "Julian" day, or day in the year, and FFF is the flight number starting with 001. In the following example, the data were taken on the 210th day of 2002, flight number 4.

02210004.Survey.822A.822A_1
02210004.Survey.822A. 822A_2
02210004.Survey.GPS.NMEA
02210004.Survey.SerialDevice.UTC
02210004.Survey.PpsDevice.PPS
02210004.Survey.TriggerDevice.Trigger
02210004.Survey.LineNumber
02210004.Survey
02210004.Survey.page
02210004.Survey.loginfo1.txt

Each data line is time stamped with the PC system clock to allow syncronization between files

YYDDDFFF.Survey.LineNumber - start and stop time of each line in survey, typically only one line / file
YYDDDFFF.Survey.822A.822A_1 - Output from Counter 1 (4 magnetometers), in nT x 10^5, 50 Hz.
YYDDDFFF.Survey.822A.822A_2 - Output from Counter 2 (4 magnetometers), in nT x 10^5, 50 Hz.
YYDDDFFF.Survey.PpsDevice.PPS - pulse per second (PPS) from GPS receiver, 1 Hz.
YYDDDFFF.Survey.GPS.NMEA - GPS output, Trimble PTNL,GGK sentence at 5 Hz (position).
YYDDDFFF.Survey.TriggerDevice.Trigger - trigger pulse to magnetometers, 50 Hz.
YYDDDFFF.Survey.SerialDevice.UTC - UTC time tag from GPS receiver, "The time will be" message for next PPS, 1 Hz.

The .Survey, .Survey.page, and .Survey.loginfo*.txt files are setup information recorded by the data collection program and contain no data of use to the user.

.Survey.LineNumber files:

```
START LINE 0  12/21/04 12:45:39.523
STOP  LINE 0   12/21/04 12:59:21.072
```

Magnetometer (.822A) files:

```
d15289543808d25289567673d35289555967d45289802122  10/10/02 14:17:00.508
```

```
d15289545560d25289568728d35289557064d45289803821  10/10/02 14:17:00.528
d15289547878d25289569235d35289557743d45289805162  10/10/02 14:17:00.548
d15289547468d25289568538d35289557255d45289804417  10/10/02 14:17:00.568
d15289546204d25289567936d35289556456d45289802950  10/10/02 14:17:00.588
d15289545018d25289566714d35289556217d45289801466  10/10/02 14:17:00.608
```

First line:
d1 - Sensor 1 ok - two characters of status code / marker - other two character codes are possible to indicate error conditions
`5289543808 - 52895.43808 gamma or nT`
d2 - Sensor 2 ok
`5289567673 - 52895.67673 nT`
d3 - Sensor 2 ok
`5289555967 - 52895.55967 nT`
d4 - Sensor 2 ok
`5289802122 - 52898.02122 nT`

`10/10/02` - computer date stamp for receipt of string at computer.
`14:17:00.508` - computer time stamp for receipt of string at computer.

.Survey.PpsDevice.PPS files:

```
PPS   12/21/04 12:45:40.433
PPS   12/21/04 12:45:41.433
PPS   12/21/04 12:45:42.433
```

.Survey.GPS.NMEA files:

```
$PTNL,GGK,175017.00,122104,3825.06336634,N,07706.26656042,W,3,07,2.8,EHT-
25.694,M*7C  12/21/04 12:45:39.470
```

Table B-1 – PTNL,GGK Message Fields

Field	**Meaning**[a]
1	UTC of position fix
2	Date
3	Latitude
4	Direction of Latitude (N = North, S = South)
5	Longitude
6	Direction of Longitude (E = East, W = West)
7	GPS Fix Quality (0 = Invalid,1,2,3,4)
8	Number of Satellites in fix
9	DOP of fix
10	Ellipsoidal height of fix
11	M: ellipsoidal height is measured in meters

[a] For further information, refer to the Trimble MS Series Operation Manual

.Survey.SerialDevice.UTC files:

```
UTC 04.12.21 17:50:18 57  12/21/04 12:45:39.645
```

```
UTC 04.12.21 17:50:19 57  12/21/04 12:45:40.646
```

Located data archives are ASCII files of the format:

For located, demedianed magnetometer data:

```
X (UTM Zone X, NAD83, m) Easting
Y (UTM Zone X, NAD83, m) Northing
Z Height Above Ellipsoid (HAE, WGS84, m)
S Signal in nT
```

where X is the appropriate UTM zone (11N for Victorville, CA)

for the analytic signal data, the Analytic Signal is reported in nT/m.

Anomaly Report (.Anomaly) Files:
Anomaly Reports from Transect data will be ASCII files of the format:

```
ID Fiducial ID of the anomaly
X  (UTM Zone X, NAD83, m) Easting
Y  (UTM Zone X, NAD83, m) Northing
S  Analytic Signal in nT\m
```

where X is the appropriate UTM zone (11N for Victorville, CA)

Course over Ground (.COG) files:
Corresponding Course-Over-Ground (COG) Reports for Transect data will be ASCII files of the format:

```
X       (UTM Zone X, NAD83, m) Easting
Y       (UTM Zone X, NAD83, m) Northing
GPSTime UTC Time in seconds past midnight
```

where X is the appropriate UTM zone (11N for Victorville, CA)

Static Survey Archive (_static.xyz) files:
Daily static calibration run data will be archived as Geosoft .XYZ files of the format:

```
X       (UTM Zone X, NAD83, m) Easting for GPS antenna
Y       (UTM Zone X, NAD83, m) Northing for GPS antenna
HAE     (WGS84, m) Height above Ellipsoid for GPS antenna
Mag1    (nT) Demedianed magnetometer data for sensor 1
Mag2    (nT) Demedianed magnetometer data for sensor 2
Mag3    (nT) Demedianed magnetometer data for sensor 3
Mag4    (nT) Demedianed magnetometer data for sensor 4
Mag5    (nT) Demedianed magnetometer data for sensor 5
Mag6    (nT) Demedianed magnetometer data for sensor 6
Mag7    (nT) Demedianed magnetometer data for sensor 7
Mag8    (nT) Demedianed magnetometer data for sensor 8
```

where X is the appropriate UTM zone (11N for Victorville, CA)

MTADS DAS Target List Example

The example is given in ASCII text file format. Actual delivery will be in Excel Spreadsheet format.

```
MTADS TARGET REPORT
###################
Mon Oct 31 14:00:47 2005
PROJECT: PBR2
SITE: Area_2A
SENSOR: mag
SURVEY: Survey
PRIMARY COORDINATES: UTM=13, nad83
###################
###################
###################
###################
ID,UTM X (m),UTM Y (m),Depth (m),Size (m),Moment (Amps-
m2),Inclination,Azimuth,Goodness of Fit,Comments
1,617608.50,4176876.99,0.331,0.028,0.0121,26.70,30.32,0.9714,
2,617793.59,4176877.94,0.931,0.168,2.5717,57.71,10.09,0.9362,
3,617799.14,4176867.65,0.844,0.125,1.0476,55.00,24.48,0.9964,
```

B.9.2 Man-Portable EM System Data Formats

Each survey file set contains 4 files which constitute the 'raw data'. The file name structure is MMMDDYYYY_HHMMSS.DeviceType; where MMM is the 3-letter abbreviation of the month, DD is the date, YYYY is the 4-digit year, HH is the file start time hour in 24-hour format, and MM and SS are the start time minutes and seconds. In the following example, the data were taken on October 8th, 2006 starting at 15:21:49. The PC clock is synced to UTC at program entry.

Oct082006_152149.pps
Oct082006_152149.mark
Oct082006_152149.mkii
Oct082006_152149.nmea

Each data line is time stamped with the PC system clock to allow synchronization between files

MMMDDYYYY_HHMMSS.mkii -	Output from Geonics EM61 MkII (Mode, Scale Factor, 4 channels, Tx current, battery voltage), 10 Hz.
MMMDDYYYY_HHMMSS.pps -	pulse per second (PPS) from GPS receiver, 1 Hz.
MMMDDYYYY_HHMMSS.nmea -	GPS output, Trimble PTNL,GGK sentence at 10 Hz (position) and UTC time tag from GPS receiver, "The time will be" message for next PPS, 1 Hz..
MMMDDYYYY_HHMMSS.mark -	Fiducial markers recorded by operator, if used.

EM61 MkII (.mkii) files:

```
D  FF       -980        697        631        1976      3420   12.75  55309.000  55309.050
D  FF       -980        698        631        1977      3423   12.75  55309.100  55309.150
D  FF       -979        698        629        1976      3414   12.75  55309.200  55309.250
D  FF       -980        698        629        1976      3408   12.75  55309.300  55309.350
D  FF       -980        698        629        1976      3412   12.75  55309.400  55309.450
```

First line:

D – Sensor Mode, 'D' is differential (3 gates on bottom coil, 1 gate on top coil), 'T' mode has 4 time gates on bottom coil
FF – Scale factor. Hexidecimal representation of range factors for 4 time gates. 'FF' corresponds to the highest range (100x) for all four time gates.
Channel 1
`-980 - -980 counts`
Channel 2
`697 - 697 counts`
Channel 3
`631 - 631 counts`
Channel T
`1976 - 1976 counts`
Tx Current
`3420 - 3420 counts`
Battery Voltage
`12.75 – 12.75 VDC`

`55309.000` – PC Time stamp for transmission of trigger character.
`55309.050` - PC Time stamp for receipt of data packet.

.PPS files:

```
55309.990
55310.990
55311.990
```

.NMEA files:

```
$PTNL,GGK,152149.00,100806,3423.76458565,N,11629.97525670,W,3,08,1.8,EHT766.6
92,M*6B  55309.040
$PTNL,GGK,152149.10,100806,3423.76458579,N,11629.97525721,W,3,08,1.8,EHT766.6
97,M*67  55309.130
UTC 06.10.08 15:21:50 58  55309.200
$PTNL,GGK,152149.20,100806,3423.76458753,N,11629.97525562,W,3,08,1.8,EHT766.6
96,M*6A  55309.230
```

.mark files:

Unused in this demonstration but follows the file format of the .PPS file.

Located data archives are ASCII files of the format:

For located, (demedianed) EM61 MkII data:

```
PC_Time (UTC, seconds since midnight)
X (UTM Zone X, NAD83, m) Easting
Y (UTM Zone X, NAD83, m) Northing
Z Height Above Ellipsoid (HAE, WGS84, m)
Heading (Referenced to Grid North, degrees)
Gate1_Fin (demedianed, mV)
```

```
Gate2_Fin (demedianed, mV)
Gate3_Fin (demedianed, mV)
Gate4_Fin (demedianed, mV)
Gate1_def (not demedianed, mV)
Gate2_def (not demedianed, mV)
Gate3_def (not demedianed, mV)
Gate4_def (not demedianed, mV)
```
where X is the appropriate UTM zone (11N for Victorville, CA)

Course over Ground (.COG) files:
Corresponding Course-Over-Ground (COG) Reports for Transect data will be ASCII files of the format:

```
X       (UTM Zone X, NAD83, m) Easting
Y       (UTM Zone X, NAD83, m) Northing
```
where X is the appropriate UTM zone (11N for Victorville, CA)

Static Survey Archive (.xyz) files:
Daily static calibration run data will be archived as Geosoft .XYZ files of the format:

```
PC_Time (UTC, seconds since midnight)
X       (UTM Zone X, NAD83, m) Easting for GPS antenna
Y       (UTM Zone X, NAD83, m) Northing for GPS antenna
HAE     (WGS84, m) Height above Ellipsoid for GPS antenna
Gate1_Fin (demedianed, mV)
Gate2_Fin (demedianed, mV)
Gate3_Fin (demedianed, mV)
Gate4_Fin (demedianed, mV)
```
where X is the appropriate UTM zone (11N for Victorville, CA)

UX-Analyze Target List Example

The example is given in ASCII text file format. Actual delivery will be in Excel Spreadsheet format.

```
/ ---------------------------------------------------------------------------
---
/ CSV EXPORT [10/18/2006]
/ DATABASE   [c:\montaj~1\waapro~1\waavvm~1\PBR15_Anomalies.gdb]
/ ---------------------------------------------------------------------------
---
/
/fid,Fit_X,Fit_Y,Latitude,Longitude,Fit_Depth,Fit_Size,Fit_Coh,Fit_b1,Fit_b2,
Fit_b3,Fit_theta,Fit_phi,Fit_psi,Fit_chi2,Fit_Error,Comments,Comments_2
Line DAnomalies
0,546367.83,3806177.80,34.395976453,-
116.495551050,1.096,0.081,0.928,3.643,0.542,0.000,83.86,74.77,8.76,0.727,0,""
,""
1,546388.83,3806178.25,34.395979030,-
116.495321551,0.651,0.034,0.658,0.205,0.113,0.000,-
19.93,10.18,72.45,0.428,0,"",""
2,546459.59,3806178.67,34.395975854,-
116.494552376,0.265,0.024,0.921,0.105,0.003,0.000,75.40,48.51,-
7.77,0.550,0,"Partial Anomaly on Edge of Data.",""
```

```
3,546413.58,3806179.04,34.395984953,-
116.495049535,0.770,0.061,0.970,1.808,0.021,0.005,81.41,310.50,130.26,1.022,0
,"",""
```

B.10 Data Storage and Archiving Procedures

Data are stored electronically during collection to hard drives located in the MTADS vehicle DAS computer or the MP EM system laptop. Approximately every two survey hours, the collected data are copied onto removable media (Iomega ZIP 250 disks, USB memory keys, etc.) and transferred to the data analyst. The data are moved onto the data analyst's computer and the media is recycled. Raw data and analysis results are backed up from the data analyst's computer to optical media (CD-R or DVD-R) or magnetic media (external HHD) daily. These results are archived on an internal file server at NRL after the completion of field work. All field notes / activity logs are written in ink and stored in archival laboratory notebooks. These notebooks are archived at NRL. Relevant sections are reproduced in the individual demonstration data reports. Dr. Daniel Steinhurst is the POC for obtaining data and other information. His contact information is provided in Section 7 of this report.