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Magnetometer Transect Survey of AOI 6 — Dalecarlia Impact Area, American University Experiment Station December 2006

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14. ABSTRACT

In December 2006, the Environmental Security Technology Certification Program (ESTCP) Program Office and the Chemistry Division of the Naval Research Laboratory conducted a transect magnetometer survey of the Federal Property on the western edge of the Spring Valley, DC Formerly Used Defense Site (FUDS). The purpose of this demonstration was to evaluate the use of statistically-guided ground transect methods, previously validated for wide area assessment (WAA), to locate and bound an artillery fan and suspected disposal site associated with the former American University Experiment Station in the Spring Valley neighborhood of Washington, DC. Survey results however, show that the background density on the site is substantially higher than estimated during the planning process. We conclude that it is not reasonable to expect to find a lightly used target on a site with this background density using statistical methods. The high-quality geophysical data collected have been transmitted to the site team for use in planning future investigations on this site.

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List of Acronyms

AAPP	Abbreviated Accident Prevention Plan
ASR	Archive Search Report
CSM	Conceptual Site Model
DoD	Department of Defense
DSB	Defense Science Board
DQO	Data Quality Objectives
EE/CA	Engineering Evaluation/Cost Analysis
EMI	Electromagnetic Induction
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Sites
GIS	Geographic Information System
ha	hectare
LiDAR	Light Detection and Ranging
MRA	Munitions Response Area
MRS	Munitions Response Site
OB/OD	Open Burning/Open Detonation
USACE	US Army Corps of Engineers
UXO	Unexploded Ordnance
VSP	Visual Sample Plan
WAA	Wide Area Assessment

Acknowledgements

This demonstration would not have been possible without the assistance of personnel from the US Army Corps of Engineers. In particular, we acknowledge the assistance of Mike Peterson of the Washington Aqueduct and Andy Schwartz and Ken Shott of the U.S. Army Engineering and Support Center, Huntsville. We acknowledge the survey assistance from Ms. Katherine Kaye, Mr. Jeff Fairbanks, and Mr. Tony Buschur fro HGL, Inc. We thank Sky Research of Ashland, OR for loan of the magnetometer array and Brent Pulsipher and John Hathaway of Pacific Northwest National Laboratory for assistance with the VSP analysis..

Executive Summary

In December 2006, the Environmental Security Technology Certification Program (ESTCP) Program Office and the Chemistry Division of the Naval Research Laboratory conducted a transect magnetometer survey of the Federal Property on the western edge of the Spring Valley, DC Formerly Used Defense Site (FUDS). The purpose of this demonstration was to evaluate the use of statistically-guided ground transects technologies, previously validated for wide area assessment (WAA), to locate and bound an artillery fan and suspected disposal site associated with the former American University Experiment Station in the Spring Valley neighborhood of Washington, DC. These techniques have been successfully demonstrated on aerial bombing targets during the 2005 ESTCP Wide Area Assessment Pilot Program. Specific goals of the demonstration included:

- investigate the suspected range fan on Federal property west of Dalecarlia Parkway,
- search a 1-ha area around a suspected disposal area for any evidence of a concentration of munitions, and
- characterize site conditions for future work - provide information about the Muntitions Response Site (MRS) conditions to support future investigation, prioritization and cost estimation tasks.

A statistical planning tool, Visual Sample Plan (VSP), was used to design transects calculated to give a 100% change of traversing and a high likelihood of detecting a 45-m radius area of concentrated magnetic anomalies. Additional transects were planned for a 1-ha area that may contain a disposal area. The survey was conducted using a 1.5-m wide, four sensor magnetometer array on loan from Sky Research, Inc. Additional characterization surveys were conducted at the Naval Research Laboratory's Ordnance Classification Test Field at Blossom Point, MD.

Using data collected at Blossom Point, we demonstrate that the array and deployment method are capable of detecting the target munitions and fragments. Survey results however, show that the background density on the site is substantially higher than estimated during the planning process. We conclude that it is not reasonable to expect to find a lightly-used target on a site with this background density using statistical methods. From the data we collected, we can conclude with 80% confidence that there is no 45-m radius target with a density of 250 anomalies per acre or greater on this site. These results do not imply that there are no munitions on the site; they do demonstrate that there is not a 45-m radius area of concentrated magnetic anomalies on this site. Similarly, the results from the 1-ha sub-area do not show the large, extended anomaly that would be expected from a disposal area.

During the course of this survey, we collected high-quality geophysical data that will be useful in the planning process for future investigations on this site. These data have been transmitted to the site team.

Magnetometer Transect Survey of AOI 6 – Dalecarlia Impact Area, American University Experiment Station

December 2006

1. Introduction

1.1 Background

Unexploded ordnance (UXO) contamination is a high-priority problem for the Department of Defense (DoD). Over the past ten years, the Environmental Security Technology Certification Program (ESTCP) which is charged with promoting innovative, cost-effective environmental technologies by demonstrating and validating those technologies, has sponsored a number of demonstrations of technologies to detect UXO [1].

In December 2003, a Defense Science Board (DSB) Task Force on Unexploded Ordnance issued a series of recommendations about the UXO problem [2]. In response to the DSB Task Force report and recent Congressional interest, ESTCP sponsored a Wide Area Assessment Pilot Program beginning in FY 2005 to validate the application of a number of recently developed and validated technologies as a comprehensive approach to Wide Area Assessment.

One of the technologies demonstrated as a component of the Wide Area Assessment Pilot Program was statistically-guided ground transect surveys to locate areas of concentrated munitions contamination such as firing points, target rings, burial pits, etc. Although the typical Wide Area Assessment site was thousands of acres, the transect methods are applicable to any size site.

1.2 Objective of the Demonstration

The purpose of this demonstration was to evaluate the use of statistically-guided ground transects technologies, previously validated for wide area assessment (WAA), to locate and bound an artillery fan and suspected burial site associated with the former American University Experiment Station in the Spring Valley neighborhood of Washington, DC. These techniques have been successfully demonstrated on aerial bombing targets during the 2005 ESTCP Wide Area Assessment Pilot Program. Specific goals of the demonstration include:

- confirm the presence of the suspected range fan on Federal property west of Dalecarlia Parkway,
- search a 1-ha area around a suspected disposal area for any evidence of a concentration of munitions, and

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- characterize site conditions for future work - provide information about the MRS conditions to support future investigation, prioritization and cost estimation tasks.

A secondary objective was to develop an understanding of the effects of site specific factors such as terrain, vegetation, proximity to an urban area, and ordnance type that will affect applicability and limitations of the technologies used.

1.3 Regulatory Drivers

The Department of Defense (DoD) is responsible for environmental restoration of properties that were formerly owned by, leased to or otherwise possessed by the United States and under the jurisdiction of the Secretary of Defense. Such properties are known as Formerly Used Defense Sites (FUDS). The Army is the executive agent for the program and the U.S. Army Corps of Engineers is the organization that manages and directs the program's administration. A significant portion of the remediation required at a typical FUDS site involves UXO. As noted above, a task force of the Defense Science Board has recently studied the UXO problem and has issued a series of recommendations for improvements in the assessment process. If proven valuable, these procedures will have a large impact on the FUDS restoration program.

1.4 Stakeholder/End-User Issues

ESTCP plans to use a process that will ensure that the information generated by WAA technologies is useful to a broad stakeholder community (e.g., technical project managers and Federal, State, and local governments, as well as other stakeholders). ESTCP demonstration team personnel presented a preliminary demonstration plan to a regularly-scheduled meeting of the Spring Valley Partners (a working group consisting of Army Corps of Engineers, national and local regulators, and community representatives) for their input and concurrence. Several features in this demonstration plan were added or modified based on feedback obtained during the presentation and a final version of the demonstration plan was published in mid-November 2006. This same group will be briefed in late-February 2007 on the results of the demonstration.

2. Technology Description

The Wide Area Assessment Pilot Program consisted of a number of technologies, each of which contributed to the overall goals of the demonstration. These technologies can be thought of in a layered fashion. The top layer consisted of the various sensors deployed from (relatively) high-flying fixed- or rotary-wing aircraft. These were referred to as "high-airborne" technologies. These sensors include Light Detection and Ranging (LiDAR) sensors for measuring variation in surface elevation and orthorectified photography. These sensors are designed to detect anomalies that can be referred to as "ordnance-related features." These are features such as target rings, craters, and possibly surface metal that can be associated with the presence of UXO.

The next layer was a helicopter-borne magnetometer array. This technology is designed to detect subsurface ferrous metal directly. The magnetometer data can be analyzed to extract either distributions of magnetic anomalies which can be used to locate and bound targets, aim points, and OB/OD sites or individual anomaly parameters (location, depth, rough size, etc.) that can be used in conjunction with target remediation to validate the results of the survey.

The final layer of the Pilot Program was a ground survey of portions of the demonstration site using a vehicular-towed array of magnetometers. These ground surveys were deployed in two modes. The first was in conjunction with statistical transect planning with the goal of defining target locations and bounds. Additional ground surveys were conducted to validate the results of the airborne layers. These validation surveys consisted of 100% coverage of selected areas with emphasis on areas that have been declared to be outside a target by the airborne systems.

Of these technologies, only the ground-based techniques are applicable to this relatively small, heavily-treed site. In fact, the tree coverage is so dense that a vehicular system is not feasible; this demonstration was conducted with a man-portable sensor system. Details of the two components of the demonstration are presented in the following sections.

2.1 Statistical Transect Planning

Visual Sample Plan (VSP) is a statistical sampling software package developed by Pacific Northwest National Laboratory (PNNL) to provide the site investigators a simple to use, statistically-defensible method of gathering and analyzing their data for site characterization. VSP contains a module to aid in transect sampling to identify areas where the likelihood of UXO presence is elevated [3]. For a given set of design parameters, VSP will compute the required spacing of transects to achieve a specified probability of traversing a target area of a specified size and density, calculate the probability of both traversing and detecting the target zone if it exists, display the proposed transects on the site map and output the x,y coordinates of the proposed transects. The user can then conduct a sensitivity analysis by evaluating the effects of varying the input parameters and their required Data Quality Objectives. These methods and tools allow the project team to balance DQO objectives against costs and other site constraints.

After survey data have been collected, VSP's target identification algorithm uses a circular window that systematically moves along each transect surveyed and marks points where the window has a greater anomaly density than expected from background. Because there is often no prior estimate of background anomaly density, VSP provides the capability of examining the distribution of densities found during the survey. The user can then determine an optimum critical value above background density for target detection. The effect of window size on target area detectability can be determined iteratively. With the optimum window size and appropriate background density determined, cells along the transects belonging to potential target areas are identified.

This is shown schematically in Figure 1. Visual Sample Plan has been used to define transect spacing on the site shown outlined in blue. The suspected targets, along with an estimate of their size, were inputs to VSP which calculated the transects shown to meet the user-specified probabilities of traversing the various targets and recognizing that traversal.

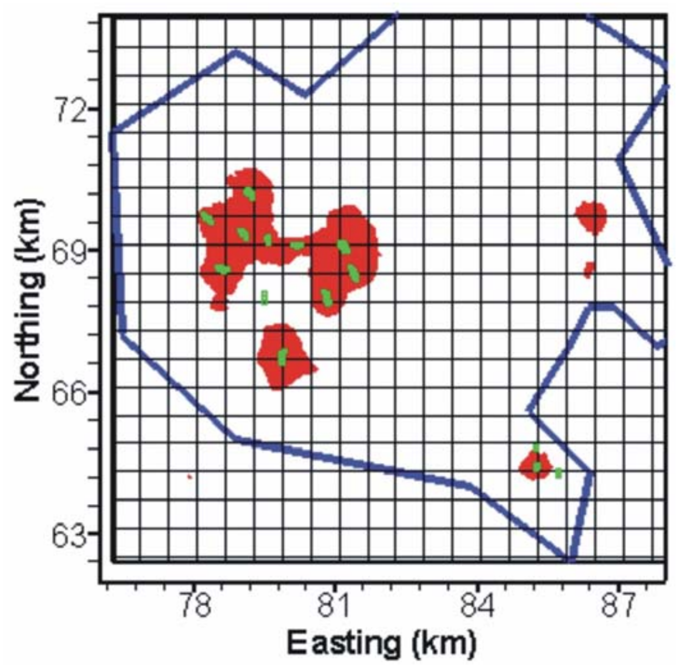

Figure 1 – Example of planned transects resulting from the use of Visual Sample Plan

An example of the application of this process at Pueblo Precision Bombing Range #2, CO is shown in Figures 2 through 4. Figure 2 shows the transects that were planned to characterize the two bombing targets (known from historical records) indicated by the circles and the anomalies detected along those transects. Figure 3 shows the areas flagged by VSP as being above a threshold of 60 anomalies/acre and Figure 4 plots the geostatistical probabilities of exceeding that threshold over the LiDAR data collected on the site. Plots such as this can be used to define the boundaries of areas of concentrated munitions use for remediation.

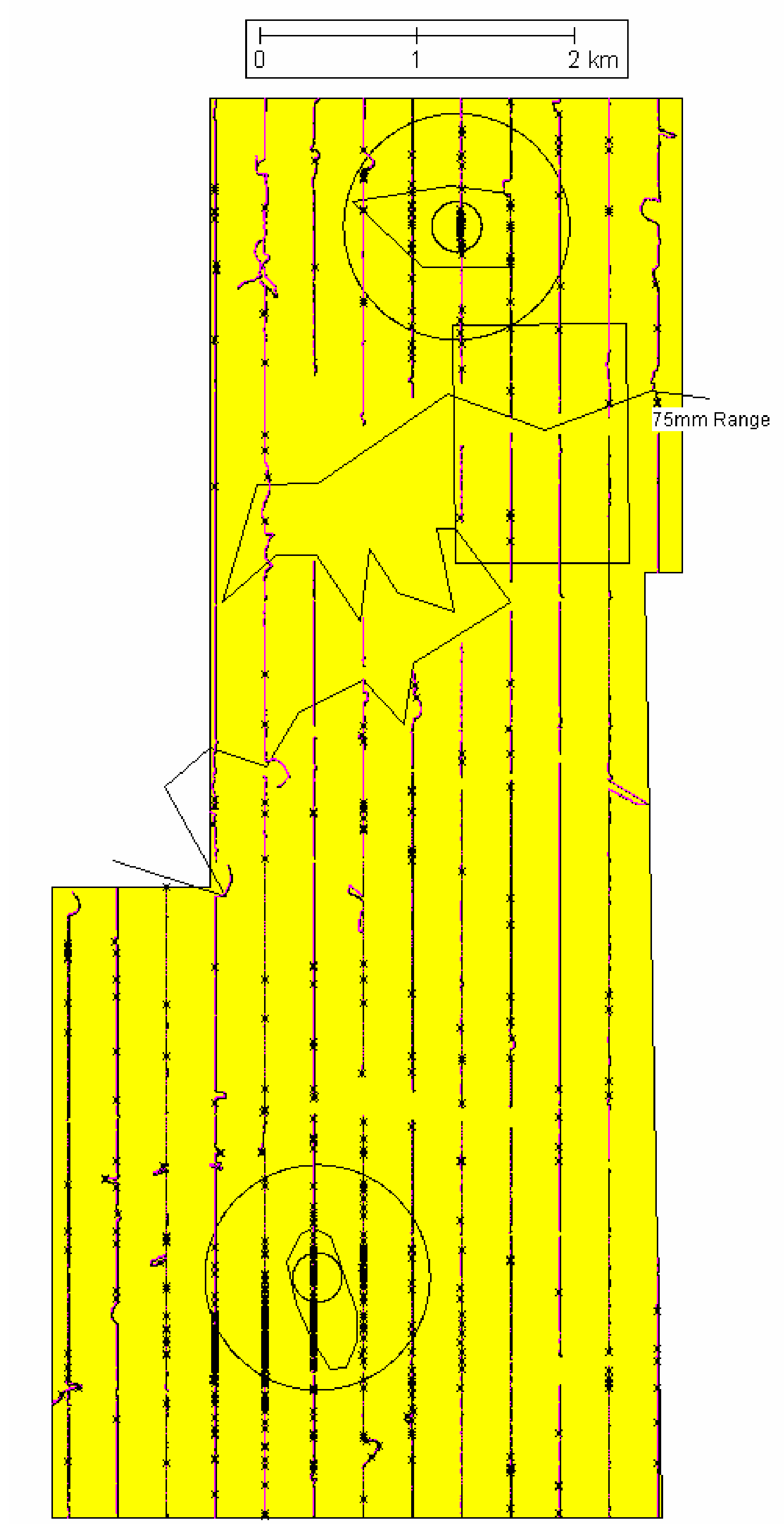

Figure 2 – Transects and detected anomalies from the WAA demonstration at Pueblo Precision Bombing Range #2, La Junta, CO. The two bombing targets known from historical data are indicated by the circles.

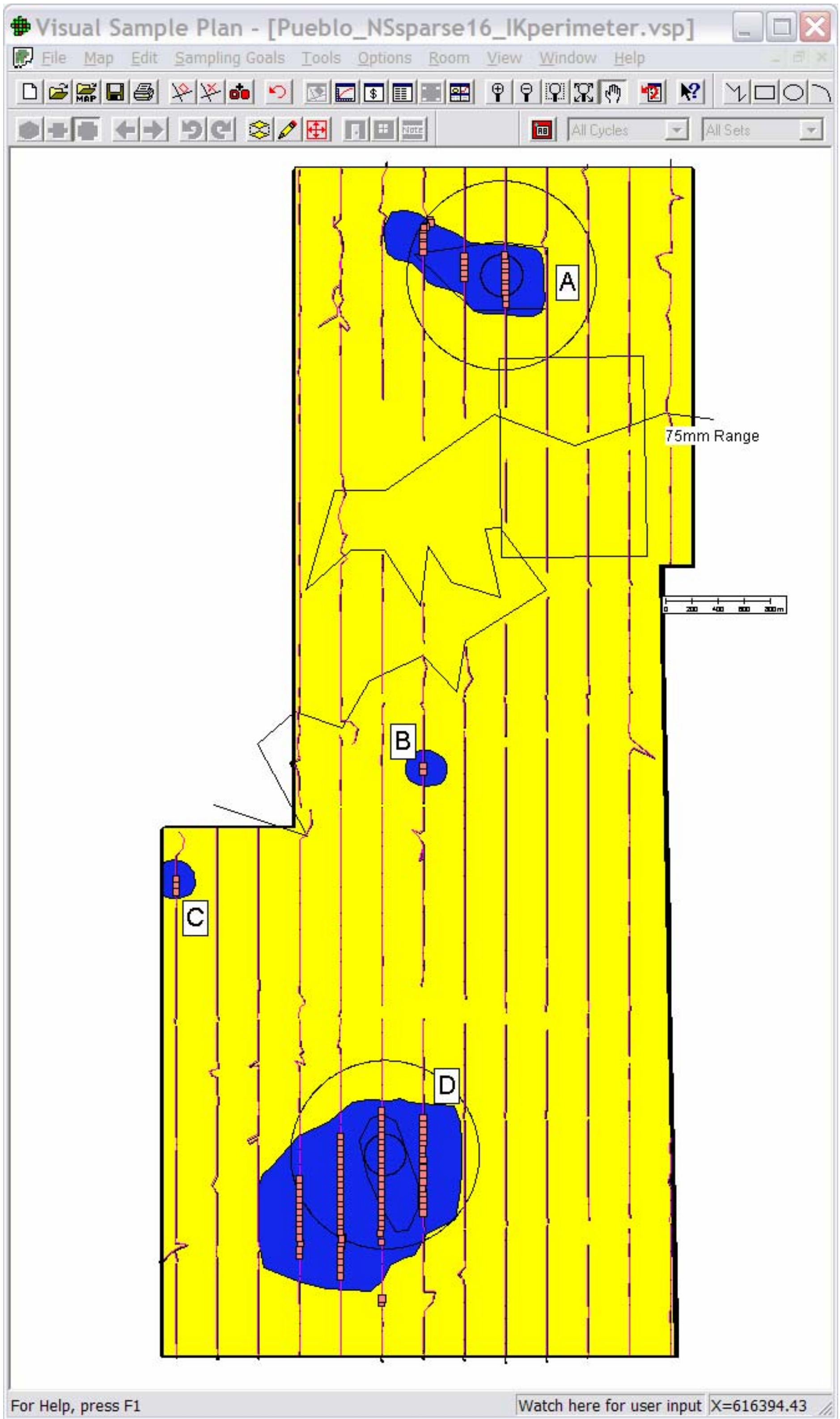

Figure 3 – Screen shot showing the VSP analysis of the data from Figure 2. Note that the two bomb targets are flagged as areas of interest along with two additional areas with elevated anomaly density.

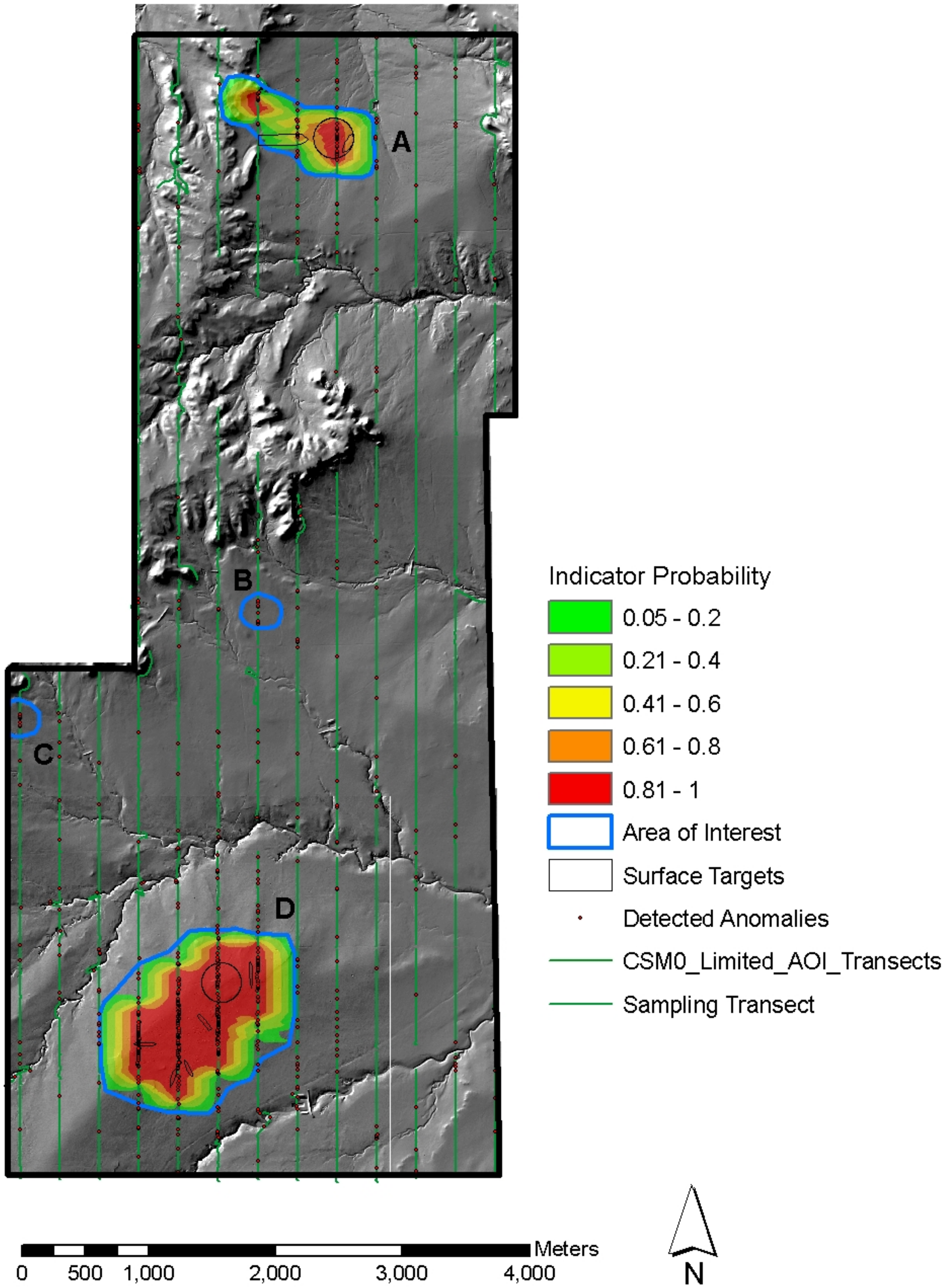

Figure 4 – Results of geostatistical analysis of the flagged areas from Figure 3 showing the probability of a parcel having an anomaly density above a threshold of 60 anomalies/acre and a first cut at defining the extent of the areas of interest. The background is the LiDAR data collected during the demonstration.

2.2 Man-portable Magnetometer Array

The man-portable magnetometer array that was used in the demonstration is shown in Figure 5. It consists of four Cs-vapor, total-field magnetometers arranged as a 1.5-m wide array. The sensor readings are recorded at 10 Hz which, combined with survey speed of 0.5 to1 m/s achieved in this demonstration, results in a down-track sampling interval of ~5 to 10 cm with 50 cm across track.

Figure 5 – Man-portable magnetometer array in use during the demonstration

Use of the array involves two operators, the front operator carries the sensors (in front in the figure) and associated electronics (bottles behind the operator). The second operator trails with the data recording electronics. The sensor array is shown with a low-magnetic signature GPS antenna mounted over the center of the sensor boom for array positioning. We were able to use sub-meter GPS for array positioning in this demonstration.

The sensor array has been used extensively in support of the Montana Air National Guard [4]. Its characteristics and operation are well understood. In conjunction with the work at Spring Valley, we conducted additional calibration and characterization tests of the system at our Test Field in Blossom Point, MD [5]. The results of these characterization tests are presented in Section 3.4.

3. Demonstration Design

3.1 Selecting the Test Site

The site for this demonstration is part of a long-term project of the Corps of Engineers, the American University Experiment Station, or Spring Valley, in Northwest DC. The specific area for the demonstration is referred to as AOI 6, the Dalecarlia Impact Area. It became of interest after the discovery of a Livens Gun Pit in August 2002. A map of the western portion of the FUDS site with the relevant points of interest marked is shown in Figure 6.

3.2 Test Site History

The Spring Valley Formerly Used Defense Site (FUDS) consists of approximately 661 acres in the northwest section of Washington, DC [6]. During the World War I era, the site was known as the American University Experiment Station (AUES), and was used by the U.S. Government for research and testing of chemical agents, equipment and munitions. Today, the Spring Valley neighborhood encompasses approximately 1,200 private homes, including several embassies and foreign properties, as well as the American University and Wesley Seminary.

On January 5, 1993, while digging a utility trench in Spring Valley, a contractor unearthed buried military ordnance. The U.S. Army Technical Escort Unit initiated an emergency response. This response was completed on February 2, 1993, and resulted in the removal of 141 ordnance items (43 suspect chemical items) from a past burial pit.

On February 3, 1993, the U.S. Army Corps of Engineers, Baltimore District, began a remedial investigation of the site. Using historical documentation-reports, maps and photos, the Corps focused its investigation on specific sites that were determined to have the greatest potential for contamination. These sites were referred to as Points of Interest or POIs.

During the extensive, two-year investigation that followed, geophysical surveys were done at POIs considered to be potential ordnance burial locations, plus a selection of approximately 10 percent of all properties outside of the POIs. These additional properties served as a check on the historical information that had been gathered. A total of 492 properties were surveyed. Most were surveyed with state-of-the-art electromagnetic device called an EM-31. This device is useful in identifying large metallic objects under the ground, such as ordnance burial pits. Some properties had a magnetometer survey due to the difficult terrain or other limiting conditions.

In the years since 1995 there have been a number of investigations performed at this site. A full history of this work is available at the Spring Valley web site [6].

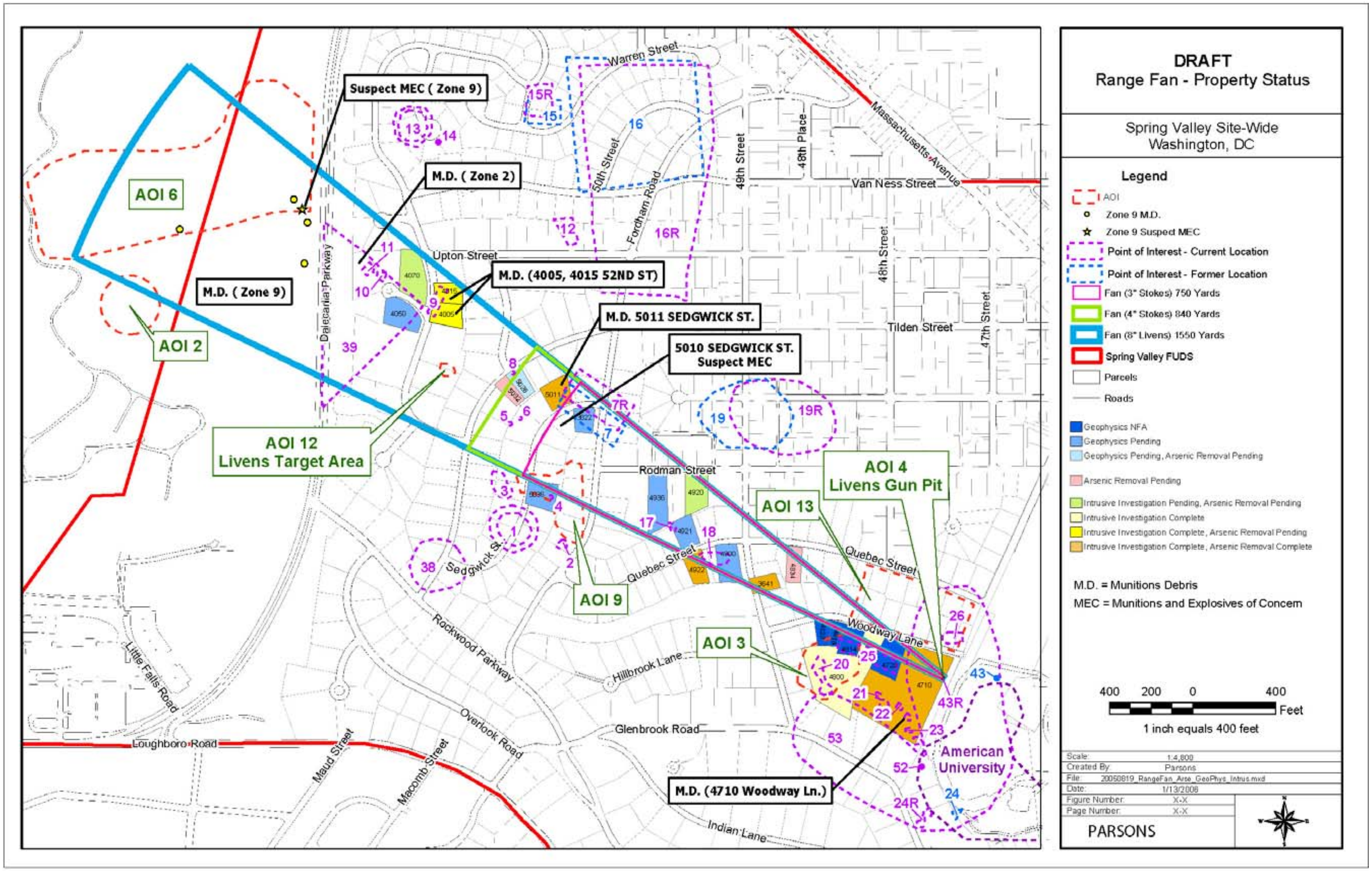

Figure 6 – Map of the western portion of the Spring Valley FUDS site with the relevant areas of interest for this demonstration marked

The precipitating event for this demonstration was the discovery of a Livens Gun Pit in August 2002 on Woodway Lane. After discovery of the gun pit, Corps of Engineers personnel were able to determine the exact direction of fire. This direction of fire confirms other historical evidence about the use of this range. Based on historic maps and aerial photos it is believed that there were only three impact areas associated with this range. Two of these, POI 18 and AOI 12, are located east of Dalecarlia Parkway. The possible impact area west of Dalecarlia Parkway has been designated "AOI 6 - Dalecarlia Impact Area". Confirming this assumption, munitions debris has been previously identified in this area west of Dalecarlia Parkway on the Federal Property.

According to historical evidence, it is thought that only 3" Stokes, 4" Stokes, and Livens Projectors were ballistically fired on this range. Based on the maximum range of these munitions, we would only expect to find Livens west of Dalecarlia Parkway.

3.3 Site Characteristics

The demonstration site is primarily gently rolling hills with some steep banks at the edge of streams. There is moderate tree cover on the site but aerial photos show that there is substantial sky view after leaf drop, Figure 7.

Figure 7 – Screen shot from Google Earth© showing the sky view available at the demonstration site after leaf drop

3.3.1 Climate Data

Climate data for a reporting station on the Federal Property in NW DC is given in Table 3-1. The demonstration was conducted during the first week in December so that the trees would be bare while still having moderate daytime temperatures for the field work. The actual conditions on the days of the demonstration were somewhat colder than average with daily highs in the lower 40s.

Table 3-1. Climate Data for NW Washington, DC

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (in degrees Fahrenheit)													
Avg. Temperature	32.9	36.0	45.5	54.9	64.8	73.0	77.2	75.7	69.1	57.4	47.3	37.4	55.9
Avg. Max. Temperature	43.0	46.8	57.6	67.6	77.2	84.9	88.2	86.7	80.2	69.4	58.5	47.3	67.3
Avg. Min. Temperature	23.0	25.5	33.4	41.9	52.2	61.2	65.8	64.8	57.7	45.0	36.0	27.3	44.4
Precipitation													
Precipitation (inches)	2.9	3.0	3.8	3.6	4.2	3.9	4.5	4.1	3.9	3.5	3.5	3.4	44.3

Source: Data from http://www.worldclimate.com/ for Washington, DC.

3.3.2 Present Use

The demonstration area is unused at present.

3.4 Pre-Demonstration Testing and Analysis

Each of the individual technologies to be demonstrated as part of this Wide Area Assessment demonstration has been previously demonstrated and validated. The details of this prior testing can be found in recent publications by the technology developers [3, 4].

3.4.1 Demonstration Set-Up and Start-up

There were two major components of demonstration set-up. The first was to plan the transects that will be surveyed. This task consumed the majority of the pre-demonstration effort and will be discussed in detail in the following section. The second was the additional characterization of the magnetometer array at our Test Field in Blossom Point, MD

Transect Planning: At this site, the direction of the firing fan has been establish from historical data and the discovery of the firing point (Figure 6) so there is little uncertainty on this point. Figure 8 shows the firing fan plotted over an aerial photo of the western portion of the Spring Valley FUDS site with the demonstration area outlined in black. This area encompasses all of the Federal Property west of Dalecarlia Parkway. As can be seen in the figure, the demonstration area included a large buffer area on either side of the historic range in case the historical information is in error.

Figure 8 – Historic firing fan (white) and proposed survey area (black) for this demonstration

The first step in planning transects is to establish the parameters of the target area to be located. We have been told that an aiming error of ± 2° is reasonable to expect for a Livens Projector. It is approximately 1325 m from the firing point to the middle of the survey area. Coupled with the ± 2° aiming area this translates to a target area approximately 90-m wide. A notional area of this size, assuming we know nothing about the down-range aim point, is shown in Figure 9.

There are two steps in the transect planning process using Visual Sample Plan, calculating the probability of traversing the target area and the separate probability of detecting the target area if you traverse it. For this demonstration, we require a 100% probability of traversing the target area with our 1.5-m wide array as shown in Figure 10. We then make some reasonable assumptions about the background anomaly density at this site and the instrument false negative rate (also highlighted in Figure 11). In this context, the background anomaly density is the anomaly density expected to be found on the parts of the site outside any target. We have chosen a value of 10 anomalies per acre for a background based on results obtained at a number of the WAA sites. The instrument false negative rate (fraction of anomalies missed) is set to a conservative 5%. This leads us to a nine-transect survey for which the probability of detecting the target area as a function of anomaly density is shown in Figure 11. Also plotted in the figure is an equivalent calculation for the case of a well-defined down-range distance that results in a 45-m radius circular target area.

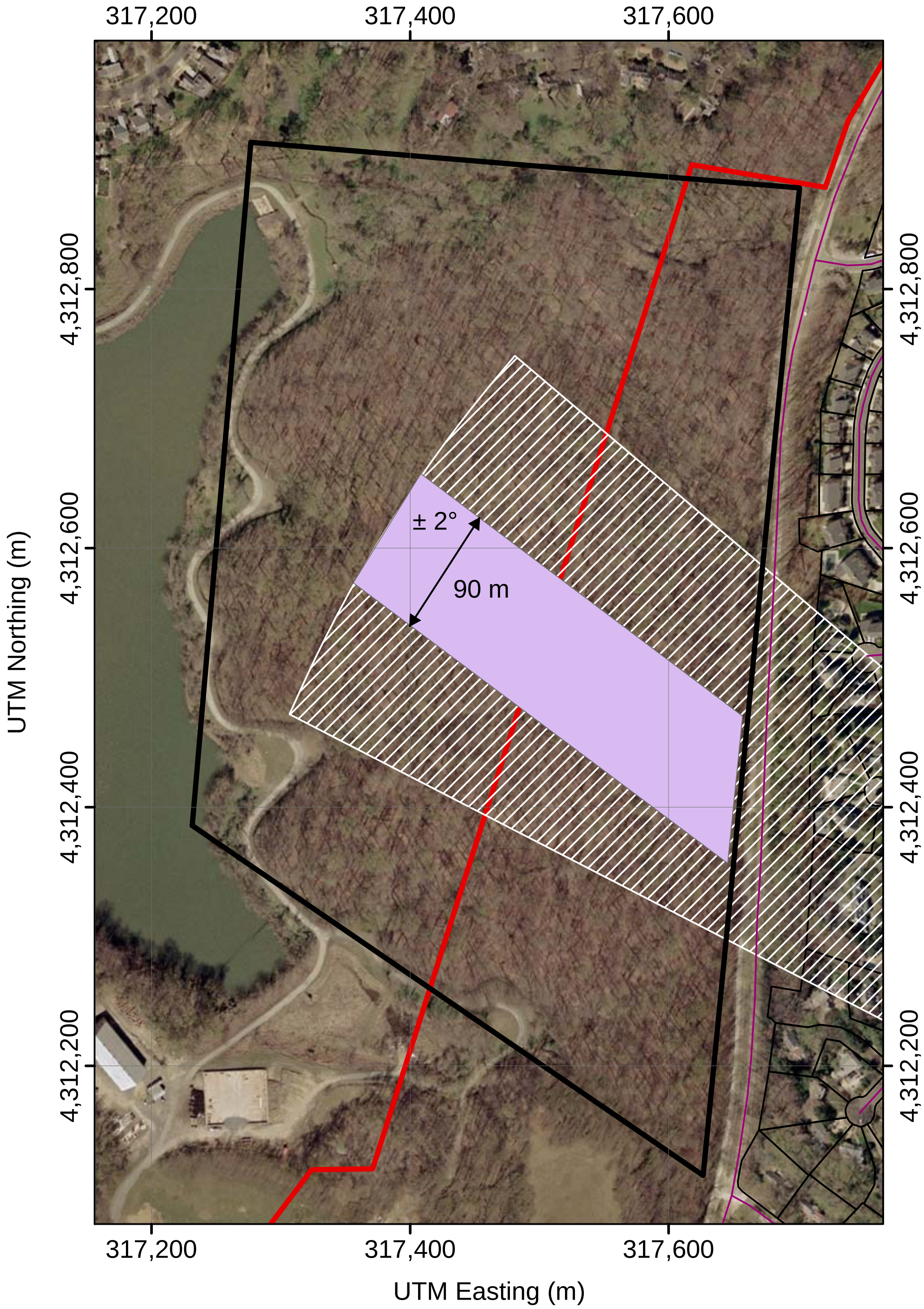

Figure 9 – Detail of demonstration area with notional target area highlighted as discussed in the text

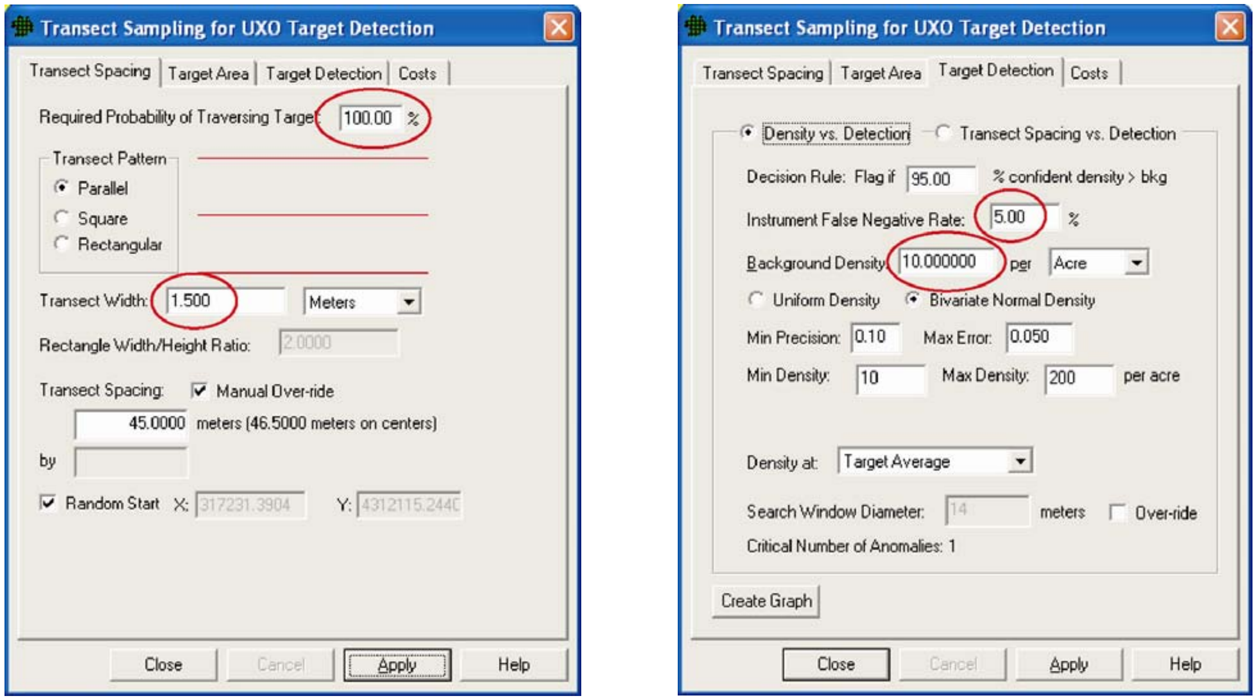

Figure 10 – Screen shots from Visual Sample Plan showing the input parameters discussed in the text

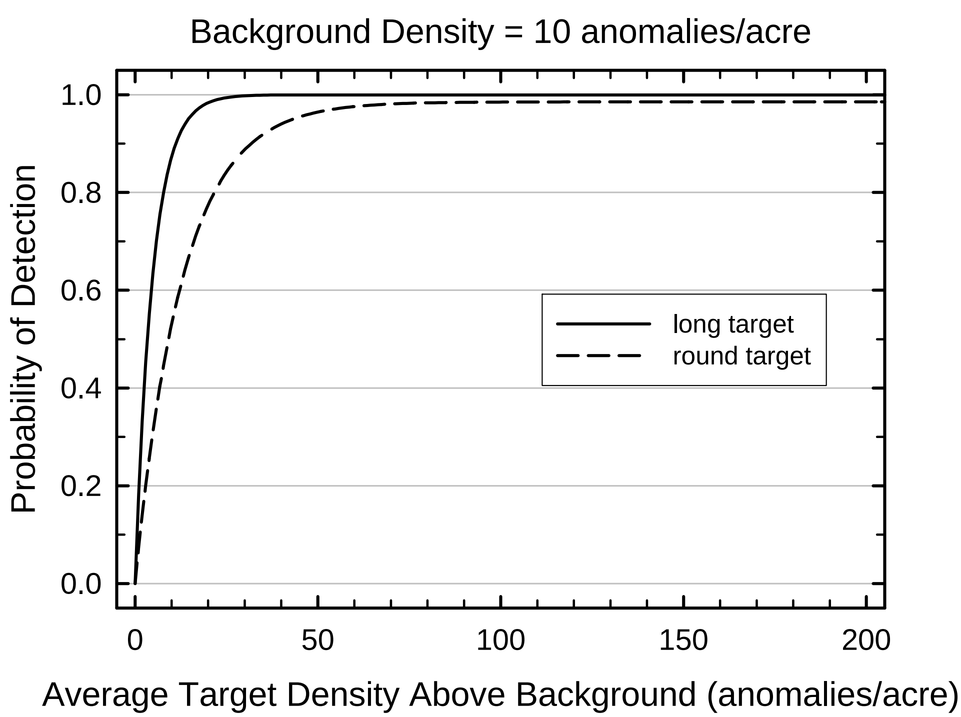

Figure 11 – Probability of detecting a 90 m x 200 m target area or a 45-m radius circular target area as a function of anomaly density

As can be seen in Figure 11, even for the worst case assumption of a 45-m radius circular target area, the probability of detection approaches 100% for target densities above 50 anomalies per acre. The transects that result from this analysis are shown in Figure 12.

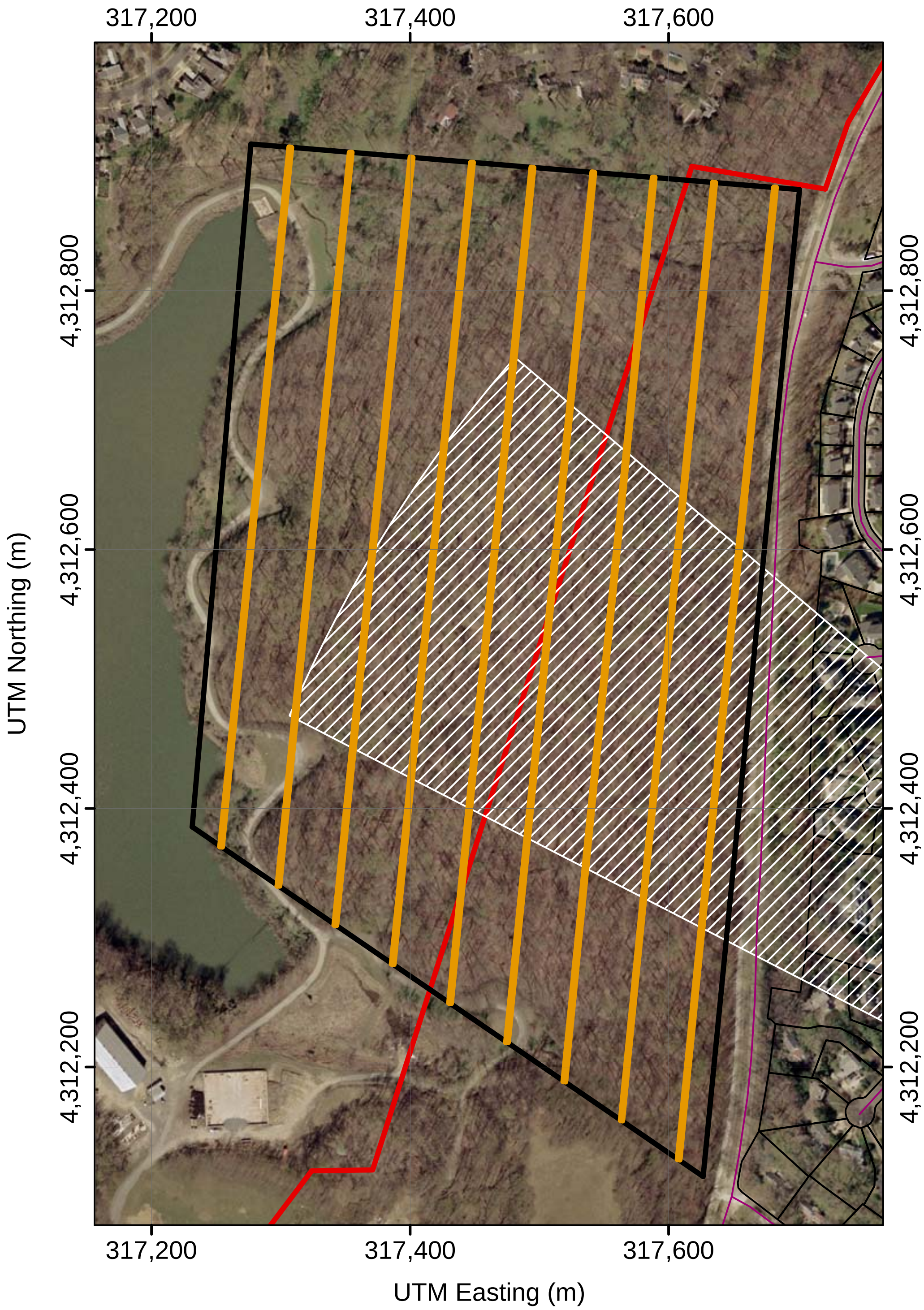

Figure 12 – Nominal transects surveyed in this demonstration

The second objective of this demonstration was to search for a possible burial site marked AOI 2 in Figure 6. To accomplish this, we surveyed a 1 ha (100 m x 100 m) area around the presumed location of the burial site using a 10-m transect spacing. To maximize our probability of detecting the suspect disposal area if it exists, the transects were perpendicular to the main transects as shown in Figure 13.

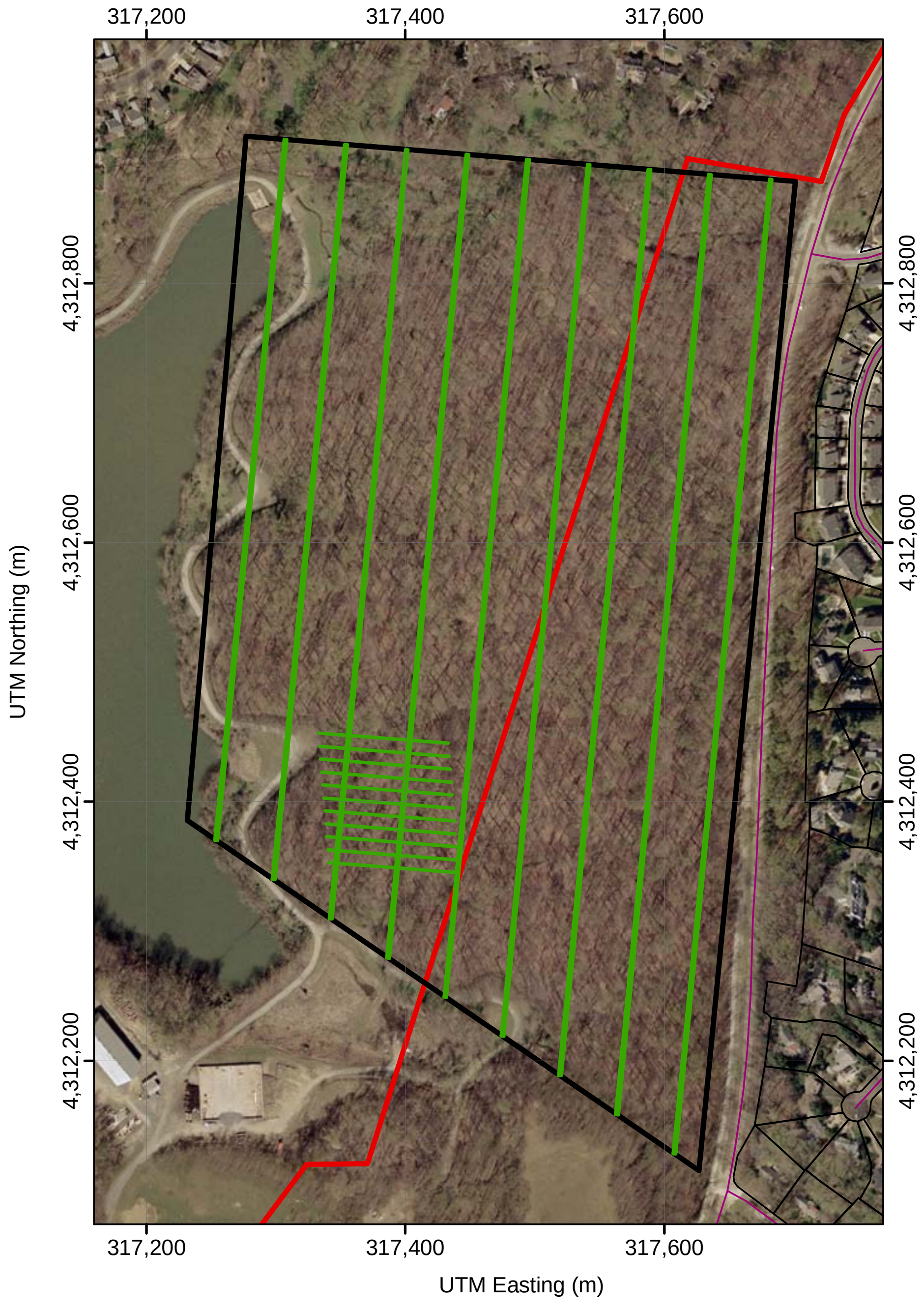

Figure 13 – One hectare disposal area search area transects shown over the main target search transects

Magnetometer Array Characterization: As part of the demonstration, we undertook to characterize the magnetometer array at our Test Field at Blossom Point. Figure 14 shows the magnetometer data collected as we walked transects over the five original lines [5] of emplaced targets at the site. A more quantitative presentation of the data will be given in the next Section.

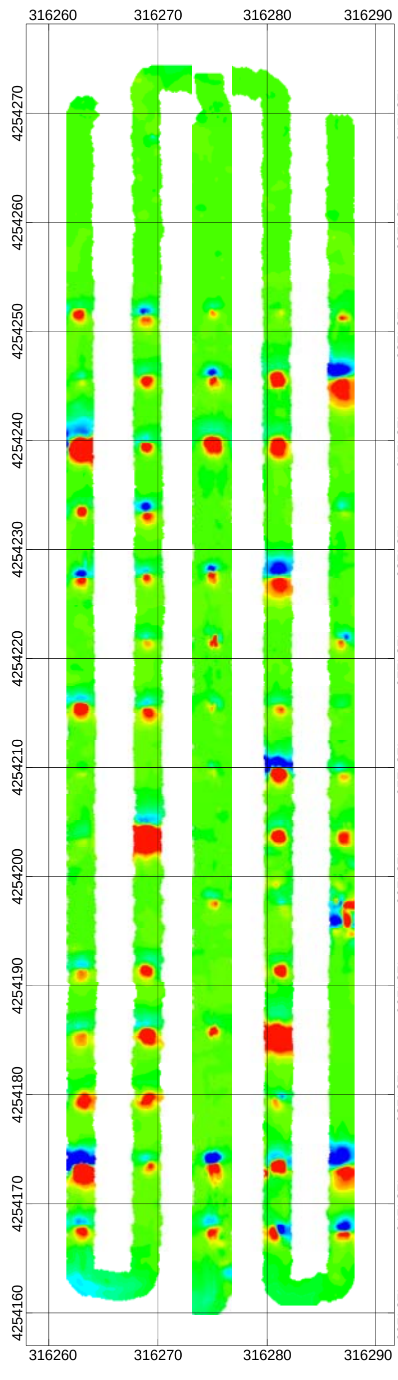

Figure 14 – Demedianed magnetometer data collected on our Blossom Point Test Field

Initial Field Activities: One week prior to the start of the field work, we made a visit to the demonstration site to locate the survey monuments we would use and make a quick traversal of the demonstration area to confirm that the sub-meter GPS system was appropriate for use after the trees had undergone leaf drop. We had originally planned to use one of a pair of survey monuments which we had installed in 2001 in conjunction with a vehicular survey of a portion of the Federal Property [7]. These monuments were no longer available so we used a Corps of Engineers monument, details of which are given in Table 3-2.

Table 3-2. Control Point Used For This Demonstration

Station	Latitude	Longitude	HAE
P3, 2004	38° 56' 15.75534" N	77° 06' 22.64438" W	36.872 m

The survey equipment and all spares were deployed to the site in the vehicles of the survey team. The equipment was stored each evening in the conference room of the site trailer and the various batteries were charged in the trailer.

The first order-of-business after arriving at the site was to lay out rough transect lines using light string. The ends of each transect, located using the sub-meter GPS system, were marked by driving a wooden stake into the ground and our best approximation of the desired line was marked with string. An example of this process is shown in Figure 15. After the transect lines were laid out, we walked the lines and performed light brush and obstacle removal to facilitate passage of the 1.5-m wide array. This process is shown in Figure 16.

Figure 15 – The transect path is marked by running light string from the two surveyed ends of the transects

Figure 16 – Light brush and obstacles were removed to facilitate the passage of the magnetometer array

3.4.2 Period of Operation

The performance schedule for the demonstration is given in Table 3-3

Table 3-3. Performance Schedule for the Demonstration at Spring Valley

Date	**Activity**
22 August 2006	Initial Site Visit by ESTCP Team
3 October 2006	ESTCP Program Office briefing to Spring Valley partners
3 November 2006	Draft Demonstration Plan submitted for comment
17 November 2006	Final Version of the Demonstration Plan published
27 November 2006	Site visit to confirm applicability of sub-meter GPS system
29 November 2006	Obtain magnetometer array from Sky Research
4 December 2006	Initial transect survey begins
6 December 2006	Initial transect survey ends
18 December 2006	Characterization of magnetometer array at Blossom Point
20 December 2006	Second collection on transect 5. Remove stakes and strings.
8 February 2007	Draft demonstration report submitted for comment
22 February 2007	Brief Spring Valley Partners on demonstration results
30 April 2007	Final Report Submitted

3.4.3 Scope of Demonstration

The overall demonstration area was ~27.5 ha or 68 acres. This was a detection survey only, no targets were remediated.

3.4.4 Health and Safety Plan

An Abbreviated Accident Prevention Plan (AAPP) for this demonstration was prepared with the assistance of personnel from US Army Corps of Engineers, Huntsville. All activities at the site were conducted in accordance with procedures in that plan. Mr. Glenn Harbaugh, of Nova Research, a UXO Tech III (former Army EOD Tech) with 5 years supervisory experience served as Site Safety Officer for this demonstration. He and Mr. Ken Shott of the Army Corps of Engineers conducted daily tailgate briefings before the start of work. Cellular telephone service was good on the site; in case of emergency all personnel were directed to dial 911. Sibley Hospital is adjacent to the Federal property and was available for emergency medical attention. George Washington University (GWU) Hospital was the dedicated facility for chemical response. Maps and directions to GWU were maintained in each vehicle on the site.

3.5 Management and Staffing

On-site supervision duties were shared by Dr. Anne Andrews of the ESTCP Program Office and Dr. Herb Nelson of the Naval Research Laboratory. Mr. Glenn Harbaugh of Nova Research served as Site Safety Officer. Dr. Dan Steinhurst, also of Nova Research, served as Quality Assurance Officer. Contact information for all survey personnel can be found in Section 8.

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4. Results and Data Analysis

4.1 Geophysical Data Collection

The actual survey course-over-ground is shown in Figure 17. Compare these results with the planned transects from Figure 13. As can be seen from the figure, the middle transect of the main survey, Line 5, was laid out incorrectly for the original deployment (note the large bulge to

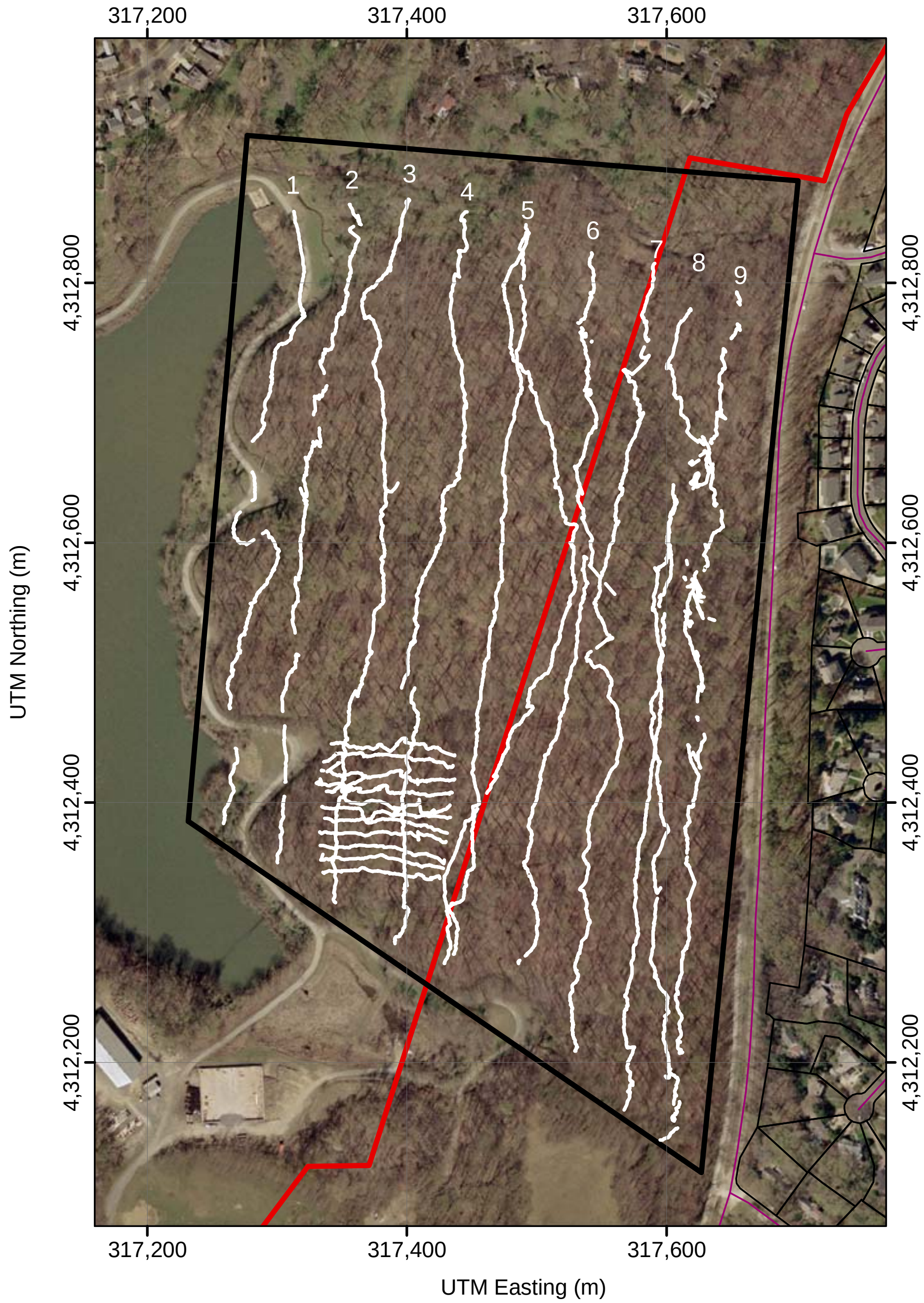

Figure 17 – Actual survey course-over-ground for this demonstration with the main survey transects numbered

the east) and was repeated on our follow-up deployment. The survey lines are less straight than in the characterization survey at Blossom Point due to the presence of obstacles and rough terrain in places during this survey. The range of conditions at this site is illustrated in Figure 18.

Figure 18 – The conditions at this site ranged from steep slopes (upper photo) to relatively mild inclines (bottom photo)

4.2 Data Analysis and Interpretation
Individual data sets are collected using a custom software package developed at NRL. The raw data, which are comprised of several files, each containing the data from a single system device with unique data rates, are processed on site for quality assurance purposes using standard

MTADS procedures and checks. 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 19. As part of the import process any data corresponding to a sensor outage, a GPS outage, or a COG stop / reverse, is defaulted or marked so as not to be processed further. 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).

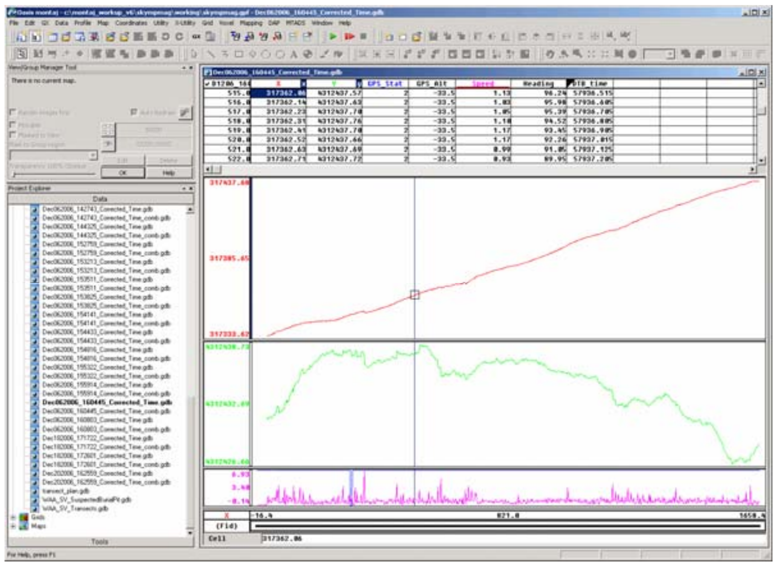

Figure 19 – Screenshot of the working view using Oasis montaj

Magnetometer data anomaly features exhibit a dipolar response having both positive and negative peaks. It is difficult to robustly pick anomaly locations from this type of data as the anomaly location is best described by the zero crossing between the negative and positive peaks. We have previously demonstrated [8,9] a technique for WAA applications where the demedianed magnetometer data are converted to the analytic signal where a dipolar magnetometer anomaly is represented by a single positive peak. Due to the degraded positioning under the tree cover using sub-meter GPS rather than full RTK GPS, the results using this technique were not satisfactory. An alternate method was adapted from our man-portable EM61 survey at the WAA Victorville site [10] where anomaly selection was done using the down-track EM data profiles. A one-dimensional function similar to the definition of the analytic signal was used to convert the dipolar magnetometer data into a form more easily used for anomaly selection. The Peak Extraction function is defined as

$$PE = \sqrt{\left(\frac{d}{dx}\right)^2}$$

where d/dx represents the horizontal derivative down-track along the profile. Then a built-in feature of Oasis montaj was used to extract peaks above a given threshold from the PE profile data from each sensor. The detected anomalies from all sensors were then clustered together using a custom piece of software and a 1.5-m selection radius to eliminate duplicate selections among all four sensors. The detected anomaly locations along with the PE amplitude at the peak of the anomaly were provided as a deliverable. The down-sampled transect COG (every tenth sample, approximately 2m separation) was also provided.

The application of this analysis to a portion of the Blossom Point characterization data is illustrated in Figure 20. The bottom panel shows the demedianed total field magnetometer data from one sensor as the array traverses the middle, or "C", line of the test field. The upper panel shows the Peak Extraction function for these data along with an indication (+) of the targets detected using a threshold of 25 nT/m. Details of the emplaced items on the "C" line are given in Table 4-1. The only seed item missed (×) was the Al plate in position 3 which, of course, should not be detected by a magnetometer system.

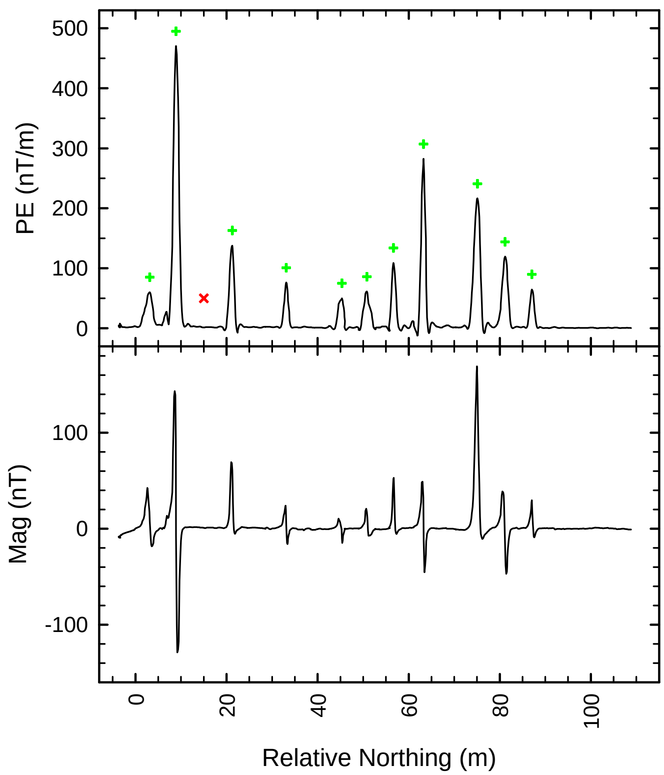

Figure 20 – Demedianed total-field magnetometer data (lower panel) collected over the "C" line at Blossom Point and the Peak Extraction function calculated from these measurements (upper panel). The emplace items detected using threshold of 25 nT/m (+) and the Al plate not detected (×) are marked.

Table 4-1. Details of some of the emplaced items in the Blossom Point Test Field

Position	Relative Northing (m)	Description	Depth (cm)	Azimuth (°)	Inclination (°)
C1	3	3" x 12" steel cylinder	50	0	0
C2	9	clump of barbed wire	10	0	0
C3	15	4" x 4" x ¼" Al plate	5	0	0
C4	21	1½" x 6" steel cylinder	20	0	90
C5	27	blank			
C6	33	1½" x 6" steel cylinder	10	0	0
C7	39	blank			
C8	45	1½" x 6" x ¼" steel plate	5	90	0
C9	51	horse shoe	5	0	0
C10	57	4" x 4" x ¼" steel plate	5	0	90
C11	63	banding material	10	0	0
C12	69	blank			
C13	75	3" x 12" steel cylinder	5	0	90
C14	81	8" x 8" x ¼" steel plate	25	45	0
C15	87	1½" x 6" steel cylinder	20	0	0

The average background level was higher at the demonstration site than at Blossom Point (2.5 to 5.5 nT/m at the Federal Property vs. 1.6 nT/m at Blossom Point). The levels at both places are far below the 25 nT/m used as a threshold in the characterization tests. For that reason, we chose to use the same threshold for the Federal Property data.

Primary Range Fan: A map of the magnetic anomalies encountered during the survey of the nine primary NS transects is shown in Figure 21. Most of the anomalies detected fall into the smallest size bin. A number of the larger anomalies result from easily identifiable features such as manhole covers, monitoring wells, etc. There is no obvious concentration of anomalies evident in Figure 21. Reference to Figure 20 shows that a majority of the items the size of intact munitions falls between 100 and 250 in the Peak Extraction Function. Figure 22 shows only this subset of anomalies plotted. As in the case of all anomalies, there is no obvious area of concentrated anomalies present in this image.

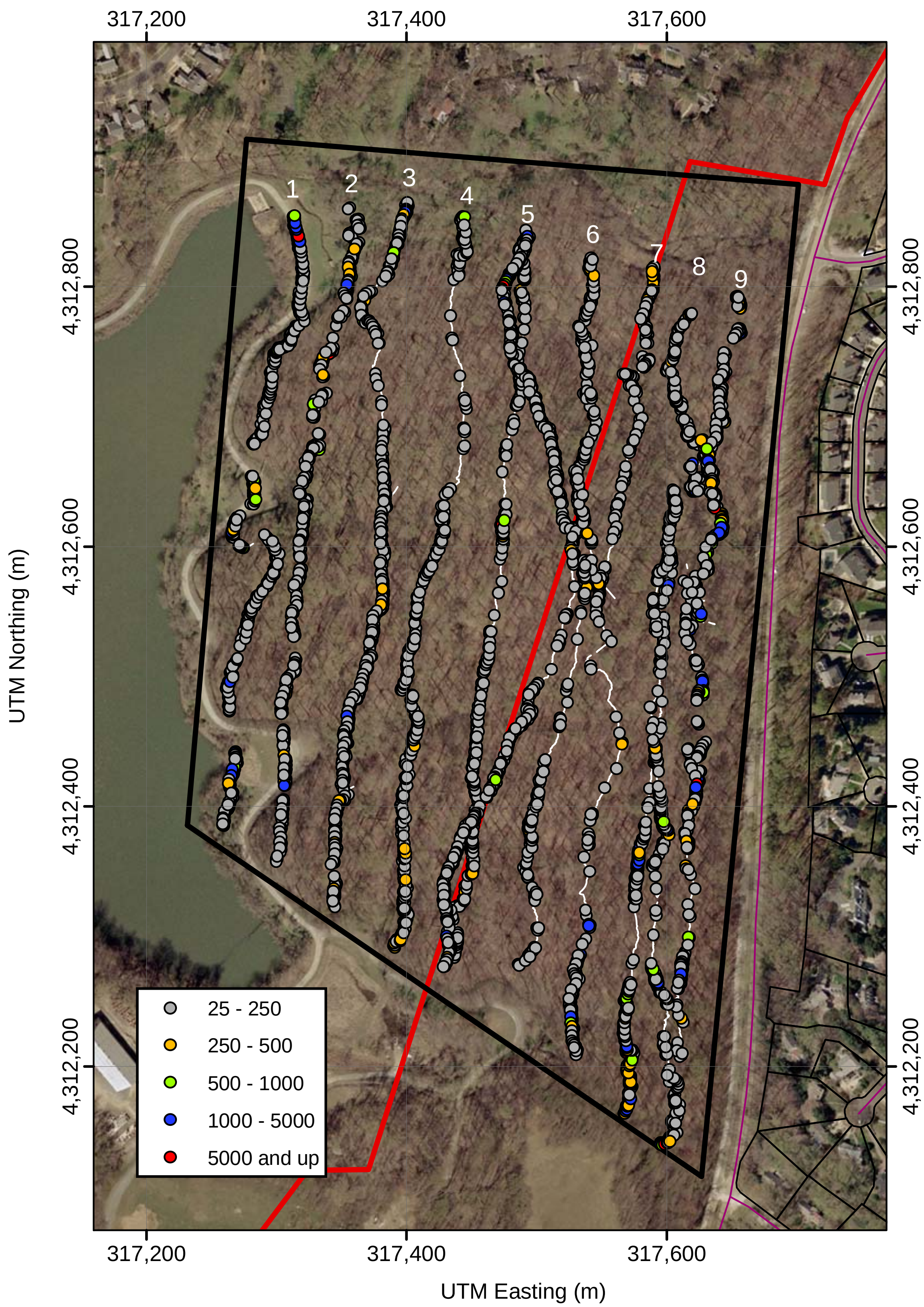

Figure 21 – Magnetic anomalies detected during the primary survey at the Federal Property. Anomalies are color coded by peak amplitude of the Peak Extraction function discussed in the text.

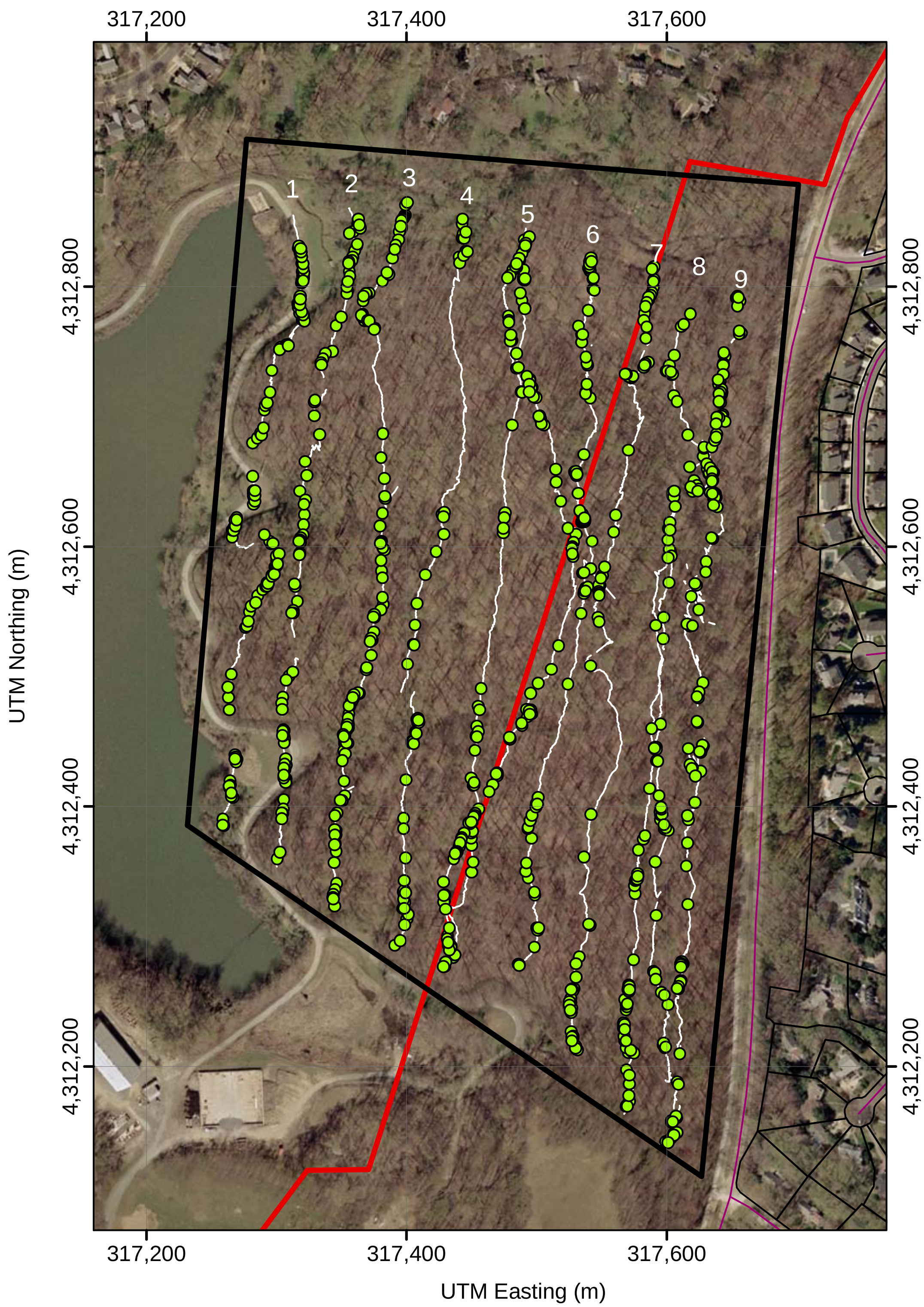

Figure 22 – Subset of anomalies from Figure 21 having maximum Peak Extraction function values between 100 and 250

Potential Disposal Area: Plots analogous to Figures 21 and 22 for the area around the potential disposal area are shown in Figures 23 and 24. If there were a disposal area present, we would expect to observe a small number of large, extended anomalies. Although there is a concentration of anomalies in the lower three or four transects there do not appear to be any large, extended anomalies so we conclude there is no disposal area at this location.

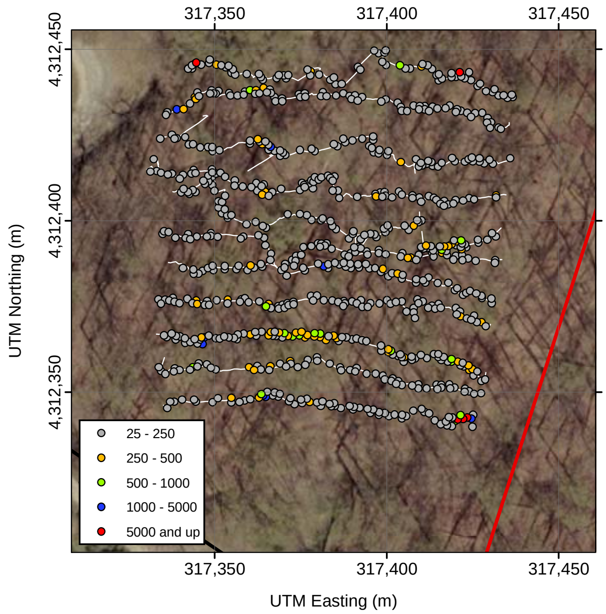

Figure 23 – Magnetic anomalies detected during the search for a potential disposal area color coded by peak amplitude of the Peak Extraction function

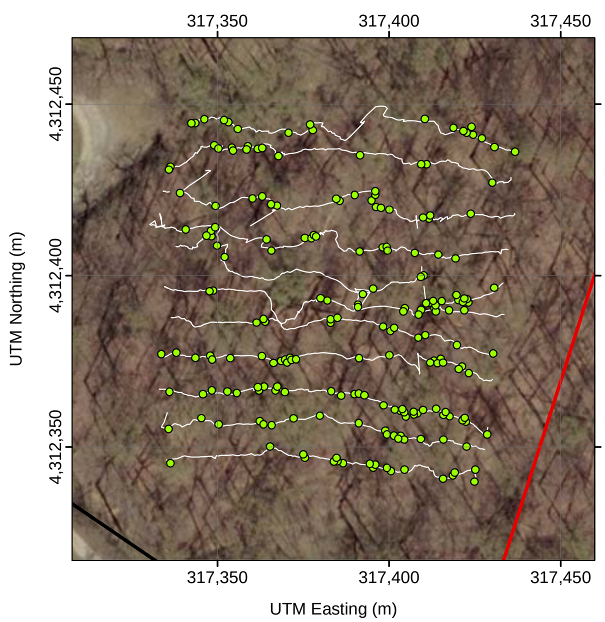

Figure 24 – Subset of anomalies from Figure 23 with maximum Peak Extraction function values between 100 and 250

4.3 Conclusions from the Data

It is evident from the magnetic anomaly map in Figure 21 that the anomaly density throughout this site is substantially higher than the background value assumed in the transect planning process. This likely indicates that the cultural background at this urban site is higher than we have observed at the isolated bombing targets we have previously surveyed. We are not, however, able to use the data collected here to eliminate the unlikely possibility that the target of interest covers the entire site surveyed.

The moving window analysis function in VSP described above was used to develop a histogram of the number of cells with a specified anomaly density which is shown in Figure 25. The densities plotted were calculated using a 75-m window. If a target were present, one would expect an inflection pint in the plot where the cells with densities above background (corresponding to the target) rise above the falling background distribution. There is no obvious break in Figure 25 between background density and potential target density although one might hypothesize a subtle inflection around 1700-1800 anomalies per acre with a background of 1300 per acre (compare to the value of 10 assumed during transect planning).

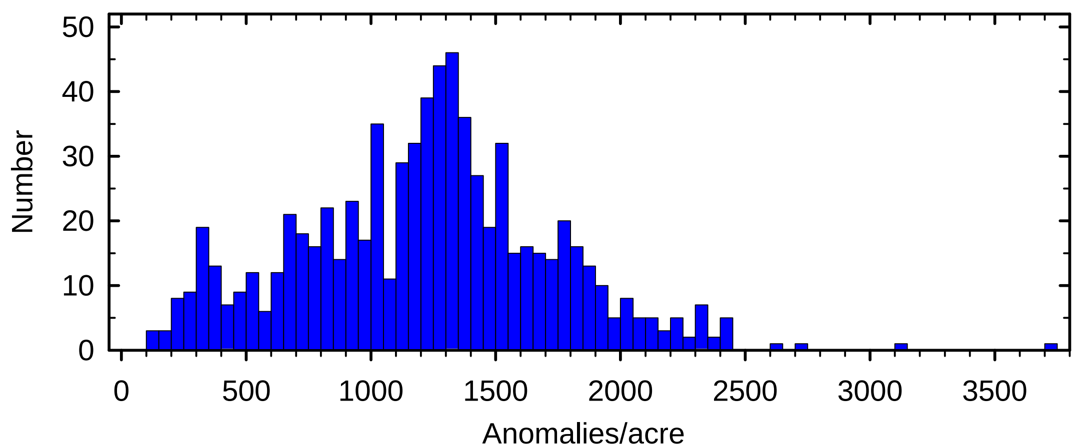

Figure 25 – Histogram of anomaly density over the site calculated using a 75-m window in VSP

The analysis module of VSP was run to search for areas of the site with an anomaly density of 1800 per acre. The areas marked as exceeding this critical density are highlighted in Figure 26. With the exception of one small area in the interior of the site, all the areas marked in Figure 26 are on the periphery of the site and likely result from an old fence (north and east sides) or the magnetically active rocks lining the road and stream (south and west sides).

A revised probability of detection curve calculated using the measured site background density and three transect spacings is shown in Figure 27. From these results, we can conclude that there is an 80% probability that we would detect a 45-m radius target area with an anomaly density of 250 anomalies per acre above a background of 1300 anomalies per acre. Of course, it is straightforward to translate the results of this survey to such hypothetical quantitative examples. However, because little is known about the potential target size and density, it is difficult to draw firm conclusions about the presence of a real target area. We do see from Figure 27 that

Figure 26 – Areas marked by the analysis module of VSP as exceeding a critical anomaly density of 1800 anomalies per acre

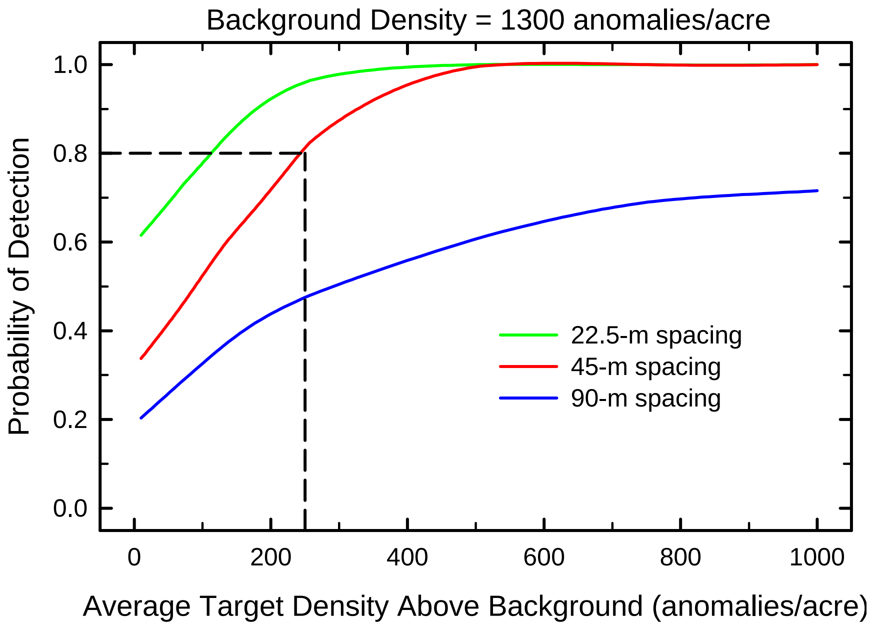

Figure 27 – Probability of detecting a 45-m radius circular target area as a function of anomaly density above a background of 1300 anomalies per acre

doubling the number of transects (22.5-m spacing) would not add significantly to our confidence that no target is present at this site but halving the number (90-m spacing) would have significantly reduced our ability to draw conclusions from these data.

From the discussion above, we can draw several conclusions about this site:

- one should not expect to detect a lightly-used target (100 to 200 anomalies per acre) on a site with background anomaly density similar to that shown in Figure 25,
- from the data measured during this demonstration, we can conclude with 80% confidence that there is no 45-m radius target with a density of 250 anomalies per acre or greater on this site although, as discussed above, the applicability of this to a real target is difficult to judge, and
- it is unlikely that there is a significant disposal site in the area searched for AOI 2 (although there is a concentration of small anomalies near the reported position of the AOI).

The conclusion above regarding a 45-m radius target does not imply that there are not individual items on the site. From the site walkover, we know that muntions fragments exist in the study area. However, the transect method is designed to traverse and detect localized areas of anomaly density above background. Since the transects only cover a small fraction of the total site, it is possible to have a number of items distributed throughout the site that are missed by the transect survey. Although we have not been able to identify an area of concentrated munitions use on this site, we have acquired high-quality geophysical data over the site which will be valuable for planning future stages of the characterization of this site. These data have been transmitted to the site team.

5. Implementation Issues

5.1 Regulatory and End-user Issues

The ESTCP Program Office has established a Wide Area Assessment Pilot Program Advisory Group to facilitate interactions with the regulatory community and potential end-users of this technology. Members of the Advisory Group include representatives of the US EPA, State regulators, Corps of Engineers officials, and representatives from the services. ESTCP staff have worked with the Advisory Group to define goals for the Pilot Program and develop Project Quality Objectives.

This demonstration site represented a number of unique challenges for the WAA technology. Results from this demonstration will be of great interest to the members of the Advisory Group and will play an important role in determining the acceptability of the use of these methods to the regulatory community.

5.2 Stakeholder Issues

There are a large number of identified stakeholders for this demonstration site. Although the specific demonstration site is entirely Federal property, it is part of the larger Spring Valley FUDS. The Corps of Engineers has established a site working group with representatives of national and District of Columbia, regulators, project contractors, Corps representatives, and local elected officials. Personnel from the ESTCP Program Office briefed this group on our initial plans on October 3rd, 2006 and returned to this group with our results in late February 2007. There is an established Restoration Advisory Board for this site. Corps of Engineers personnel have briefed the RAB on our proposed demonstration and the results of this demonstration will be communicated to the RAB

6. References

1. ESTCP Munitions Management and Wide Area Assessment Projects http://www.estcp.org/Technology/MM-Wide-Area-Assessment.cfm.

2. "Report of the Defense Science Board Task Force on Unexploded Ordnance," December 2003, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Washington, D.C. 20301-3140, http://www.acq.osd.mil/dsb/uxo.pdf.

3. "Statistical Methods and Tools for UXO Characterization," Pulsipher, B. A., et al. http://docs.serdp-estcp.org/viewfile.cfm?Doc=MM%2D1199%2DFR%2Epdf.

4. "Experiences with Unexploded Ordnance Discrimination at a Live-site in Montana," Billings, S. D. and Youmans, C., Journal of Applied Geophysics, 2006 (in press).

5. "Design And Construction Of The NRL Baseline Ordnance Classification Test Site At Blossom Point," H. H. Nelson, J. R. McDonald, and R. Robertson, NRL/MR/6110--00-8437, March 20, 2000.

6. "Spring Valley, Washington, DC, Project Overview," http://www.nab.usace.army.mil/projects/WashingtonDC/springvalley/overview.htm.

7. "MTADS Geophysical Survey of Potential Prove-out Sites at the Army Corps of Engineers Federal Property, Washington, DC," H.H. Nelson, B. Puc, and N. Khadr, NRL/MR/6110--01-8587, October 31, 2001.

8. "Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys, Pueblo Precision Bombing and Pattern Gunnery Range #2, Demonstration Data Report," G.R. Harbaugh, D.A. Steinhurst, N. Khadr, Nova Technical Report NOVA-2031-TR-0001, October 3, 2006.

9. "Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys, Victorville Precision Bombing Ranges Y and 15, Demonstration Data Report," G.R. Harbaugh, D.A. Steinhurst, N. Khadr, Nova Technical Report NOVA-2031-TR-0002, October 3, 2006.

10. "Wide Area UXO Contamination Evaluation by Transect Magnetometer Surveys, Man-Portable EM Demonstration Data Report, Victorville Precision Bombing Ranges Y and 15," G.R. Harbaugh, and D.A. Steinhurst, Accepted by ESTCP on December 12, 2006.

7. Points of Contact

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