CONTROLLED RESEARCH UTILIZING GEOPHYSICAL TECHNOLOGIES IN THE SEARCH FOR BURIED FIREARMS AND MISCELLANEOUS WEAPONS

by

MARY MAE REZOS
B.A. University of Central Florida, 2006

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Arts
in the Department of Anthropology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

Spring Term
2009

ABSTRACT

Incorporating geophysical technologies into forensic investigations has become a growing practice. Oftentimes, forensic professionals rely on basic metal detectors to assist their efforts during buried weapons searches, perhaps being used by someone with negligible or limited training, in turn slowing down investigation time and destroying the scene. This has created a need for research in the area of weapons searches, specifically to formulate guidelines for advanced geophysical methods that may be appropriate for locating weapons that have been discarded or buried by criminals attempting to conceal their involvement in a crime.

This research project was the first to demonstrate the utility of geophysical technologies at a crime scene or a suspected weapon burial site by detecting and identifying specific types of buried metal targets, including an array of firearms. Controlled testing of 32 buried targets (including sixteen decommissioned street-level firearms, six pieces of assorted scrap metals, and ten blunt or bladed weapons) was conducted using a basic all-metal detector, an advanced metal detector, and a magnetic locator. Overall, a number of important conclusions were drawn from the research project. All forensic targets included in the project were detected with the basic all-metal detector, but only down to the shallower depths. The magnetic locator provided the deepest detection for the largest firearms, scrap metals, and miscellaneous weapons. However, not all forensic targets included in the project were detected due to the detection capabilities inherent to the magnetic locator (i.e. only detecting ferromagnetic items). The advanced metal detector was best suited for detecting the handguns and was able to detect most of the targets, excluding a number of items comprised of iron, down to deeper depths using the factory presets.

To Greg, for everything. Thank you for supporting my love of knowledge.
I love you.

To Mom and Dad, for their constant love and support.

ACKNOWLEDGMENTS

First and foremost, thank you to my committee members:

Thank you to Dr. Schultz for providing me with an interesting topic.
Your experience, knowledge, patience, and consideration have allowed me to grow
as both a student and a person.

Thank you also to Dr. Dupras, your guidance was invaluable.
You always know just how to make it all sound better.

Finally, thank you to Dr. Jasinski.
Having an outside view on this project was refreshing and greatly appreciated.

Thank you all for your support.

Thank you also to:

Ron Murdock, Steve Smith, Michael Facella, and the rest of the wonderful personnel at the Orange County Sheriff's office and the Lawson Lamar Firearms and Tactical Training Center. This project would not have been possible without the assistance you provided. For decommissioning the firearms, to research site access, to digging those deep holes on hot and humid Florida summer days, I thank you.

My boys - Charles Dionne, Michael Martin, and Dennis Wardlaw. Thank you for your tireless efforts in the field. Sorry for the red ants and the sludge. I think I still owe you guys lunch.

This project was funded through a UCF in-house grant, a Forensic Sciences Foundation, Inc. Lucas Research Grant, and by NIJ Grant #2007-DN-BX-K304.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Forensic evidence searches require a multidisciplinary team of investigators, volunteers, specialists, and additional resources, and can be laborious tasks. Incorporating geophysical technologies into forensic investigations is a growing practice because of the confounding issues inherent to locating buried bodies and evidence (Connor and Scott, 1998; Davenport et al., 1992; Dupras et al., 2006; France et al., 1997; Goddard, 1977; Hunter and Cox, 2005; Isaacson et al., 1999; Killam, 2004; Murray and Tedrow, 1975; Nielsen, 2003; Ruffel and McKinley, 2005; Schultz et al., 2006; Schultz, 2007). Oftentimes, forensic professionals rely on basic equipment to assist in their efforts; for instance, buried weapons searches frequently incorporate metal detectors into the process, perhaps used by someone with negligible or limited training. A high number of false hits that need to be physically checked by digging may then be produced, slowing down investigation time, and destroying the scene. Those limitations have created a need for controlled research in the area of buried weapons searches, specifically to formulate guidelines for advanced geophysical methods that may be appropriate for locating weapons that have been discarded or buried by criminals attempting to conceal their involvement in a crime.

Prior to the following research project, published controlled forensic research involving the use of geophysical technologies to locate and identify buried objects has been mainly limited to replicated archaeological features and buried pig cadavers serving as proxies for human remains (Connor and Scott, 1998; Davenport et al., 1992; France et al., 1997; Isaacson et al., 1999; Rowlands and Sarris, 2007; Schultz et al., 2006; Schultz, 2007; Scott et al., 1989). Controlled settings provide an opportunity to demonstrate the capabilities of utilized technologies, to test innovative geophysical tools or new software, and to improve standard geophysical detection methods. Research methods utilized in the controlled context must be similar to those methods that will be practiced in the field, creating guidelines for replicable results during real-world search scenarios.

Controlled Research Design

The current research project was the first to demonstrate the utility of geophysical technologies at a crime scene or a suspected weapon burial site by detecting and identifying specific types of buried metal objects, including an array of firearms. In addition, the controlled setting of this research allowed for the opportunity to improve standard geophysical detection methods which are used in the search for street-level firearms commonly used in crimes which have been buried for the purpose of concealing or discarding them.

Controlled testing of 32 buried targets (including sixteen decommissioned street-level firearms, six pieces of assorted scrap metals, and ten blunt or bladed weapons) was conducted over two years. The scrap metals and miscellaneous weapons have been included to test the discrimination function of the advanced metal detector and to allow for a wider variety of metals to be tested on all three of the geophysical tools.

As this project utilizes controlled research conditions, a probe was used to locate the target prior to detection, allowing for readings to be confirmed on the target, not an unknown object or iron concretion in the soil. Quality control procedures were also established to account for soil compaction and weather concerns. Soil compaction did not seem to affect target detection, as loose soil and the compact soil of the control graves did not provide any results. However, due to inconsistent results during periods of rain or wet soil, all targets were retested individually with all three geophysical tools, with two additional projects members providing inter-observer confirmation of the author's results. After first testing each hole to be sure there were no metal components that would skew results, targets were tested both in their burial location in the grid, and also in the control hole in both a north/south and east/west direction. Taking into consideration that the research site is a live firearms range, each hole was tested for metallic items such as bullet fragments or ricochets each visit.

Geophysical Tools Tested

Due to their steady use in archaeology and forensics, their accessibility, and their efficiency, many law enforcement agencies will find the tools used for this research project easy to find, relatively inexpensive, and easy to use. The geophysical tools included in this research are designed to detect metallic objects and provide consistent readings, allowing for dependable results which should be replicable during real-world forensic search scenarios. Included in this research project were: (1) a Fisher M-97 basic all-metal detector (2) a Schonstedt GA-72Cd® magnetic locator, which detects differences in the earth's magnetic field (3) and a Minelab Explorer II advanced metal detector, which provides "signature" ferrous and conductivity readings, allowing for metal discrimination. Control readings of detection and signature ranges (if applicable) were taken for each weapon with each geophysical tool prior to their burial. Starting at 20-25 cm, the weapons were subsequently tested at a number of depths.

Utilization of the aforementioned geophysical technologies allowed for the following objectives to be addressed: (1) To test the ease with which these geophysical technologies may be used to detect buried weapons with little operator training; (2) To determine what effects the metallic composition of the weapons have on their detection; (3) To determine which instrument is better at detecting specific weapons; (4) To determine maximum depth at which these objects may be detected with these three tools; (5) To provide guidelines for forensic investigators using geophysical tools so that they are better prepared to search for buried firearms.

Thesis Outline

The following chapters detail results of the controlled research conducted. Chapter two discusses the utilization of both a basic all-metal detector and a magnetic locator, illustrating similarities and differences between the two when searching for buried metallic items. Advantages and disadvantages were found for both technologies, and are discussed at length. Chapter three discusses the abilities of an advanced metal detector to locate and identify suspected metal targets. Information regarding the association of metal composition and “signature” readings has also been gathered from the Explorer II. The final chapter focuses on the project as a whole, discussing guidelines which will assist crime scene officials in determining which geophysical tools should be used at a suspected weapon burial site, depending upon which type of metallic item is being searched for.

LIST OF REFERENCES

Connor M, Scott DD. 1998. Metal detector use in archaeology: an introduction. Historical Archaeology 32(4):76-85.

Davenport GC, France DL, Griffin TJ, Swanburg JG, Lindemann JW, Tranunell V, Armbrust CT, Kondrateiff B, Nelson A, Castellano K, and Hopkins D. 1992. A multidisciplinary approach to the detection of clandestine graves. J Forensic Sci 37(6):1445-1458.

Dupras TL, Schultz JJ, Wheeler SM, Williams LJ. 2006. Forensic recovery of human remains: archaeological approaches. Boca Raton, FL: CRC Press, Taylor and Francis Group.

France DL, Griffin TJ, Swanburg JG, Lindemann JW, Davenport GC, Trammell V, Travis CT, Kondratieff B, Nelson A, Castellano K, Hopkins D, and Adair T. 1997. NecroSearch revisited: further multidisciplinary approaches to the detection of clandestine graves. In: Haglund WD, Sorg MH, editors. Forensic taphonomy: the postmortem fate of human remains. Boca Raton, FL: CRC Press. pp 497-509.

Goddard KW. 1977. Crime scene investigation. Reston, VA: Reston Publishing.

Hunter J and Cox M. 2005. Forensic archaeology: advances in theory and practice. London: Routledge.

Isaacson J, Hollinger RE, Gundrum D, and Baird J. 1999. A controlled test site facility in Illinois: training and research in archaeogeophysics. Journal of Field Archaeology 26(2):227-236.

Killam EW. 2004. The detection of human remains. Springfield, IL: Charles C. Thomas.

Murray RC, Tedrow JCF. 1975. Forensic geology: earth sciences and criminal investigation. New Brunswick, NJ: Rutgers University Press.

Nielsen E. 2003. Metal detectors at the crime scene. Law and Order 51(12):78-81.

Rowlands A, Sarris A. 2007. Detection of exposed and subsurface archaeological remains using multi-sensor remote sensing. Journal of Archaeological Science 34:795-803.

Ruffell A, McKinley J. 2005. Forensic geoscience: applications of geology, geomorphology and geophysics to criminal investigations. Earth-Science Reviews 69:235-247.

Schultz JJ, Collins ME, Falsetti AB. 2006. Sequential monitoring of burials containing large pig cadavers using ground-penetrating radar. J Forensic Sci 51(3):607-616.

Schultz JJ. 2007. Using ground-penetrating radar to locate clandestine graves of homicide victims: forming forensic archaeology partnerships with law enforcement. Homicide Studies 11(11):15-29.

Scott DD, Fox RA, Jr., Connor MA, and Harmon, D. 1989. Archaeological perspectives on the Battle of Little Bighorn. Norman, OK: University of Oklahoma Press.

II. CONTROLLED RESEARCH UTILIZING A BASIC ALL-METAL DETECTOR AND A MAGNETIC LOCATOR

Criminals may go to great lengths to conceal their involvement in a crime by discarding or burying the weapon used in the commission of a crime. Locating discarded or buried metallic weapons, such as firearms, often involves the use of a variety of search methods and technologies. Depending upon the size and composition of the weapon, forensic scene professionals may incorporate advanced search methods to locate or identify the suspected weapon. Search methods or technological instruments appropriate for an investigation depend upon diverse factors, including location, weather, timeframe, object being searched for, and available specialists (Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Nickell and Fischer, 1999; Schultz, 2007). When metallic weapons such as firearms are being searched for, advanced search methods are often required to locate or identify the suspected weapon. Key components in many of these advanced searches are geophysical technologies.

Geophysical methods respond to acoustic, electrical, magnetic or electromagnetic changes in the earth, and are utilized by forensic professionals when searching for victims, weapons, or criminals (Hunter and Cox, 2005; Killam, 2004; Schultz, 2007; Schultz et al., 2006). A large part of archaeological methods, geophysical tools are non-intrusive remote sensing technologies that are used in the location, identification, and recovery of buried objects. The appropriate geophysical tool can be used to recognize anomalies or hot-spots of contrasting properties in the soil (Connor and Scott, 1998; Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Isaacson et al., 1999; Murray and Tedrow, 1975; Rowlands and Sarris, 2007; Ruffell and McKinley, 2005; Schultz et al., 2006; Schultz, 2007). Geophysical technologies provide a measurable advantage in that some types can be utilized when and where other geophysical technologies cannot be; for instance, over concrete or salt water. The greatest advantage of non-intrusive methods lies within their ability to preserve the integrity of the ground surface (Dupras et al., 2006; Schultz et al., 2006; Schultz, 2007).

Non-intrusive methods cause minimal, if any, disturbance to the ground surface, and are used to search for evidence both above and below ground (Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Nickell and Fischer, 1999; Schultz, 2007). Non-intrusive techniques include visual search lines to locate evidence of a burial or surface scatter, cadaver dogs to assist in the location of a grave, and geophysical technologies to locate buried evidence (Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Schultz et al., 2006; Schultz, 2007). Utilization of non-intrusive geophysical technologies not only allows for the location of objects, but also to clear the area in question, disproving allegations of burial and also allowing for searches to be directed elsewhere (Connor and Scott, 1998; Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Nickell and Fischer, 1999; Schultz et al., 2006; Schultz, 2007). Since these technologies vary in what they are able to detect, the fact that one tool does not locate an anomaly does not mean that the area is clear (Hunter and Cox, 2005; Schultz et al., 2006).

However, if an anomaly is detected, it is left up to the operator’s experience and knowledge of the surrounding area whether or not to investigate it. If there is a high amount of metal debris, large tree roots, clay soil, underground utilities, rocky terrain, or other similar situations, many geophysical technologies will be of little use for the detection of weapons, graves, or other buried objects (Hunter and Cox, 2005; Schultz et al., 2006; Schultz, 2007). Intrusive methods cause moderate to severe ground destruction, and are ideally used after the non-intrusive techniques have either been exhausted or have pinpointed an anomaly. If an area warrants further examination, intrusive techniques may be used to locate and recover the object in question (Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Nickell and Fischer, 1999; Schultz, 2007).

Advantages and disadvantages are evident in both non-intrusive and intrusive methods. The greatest advantage of non-intrusive methods lies within their ability to preserve the integrity of the ground surface; however, this limits the ability to identify and recover what has been buried. Basic non-intrusive methods do not require heavy equipment or the need for trained specialists, while advanced non-intrusive techniques, as well as most intrusive methods, often require that the participants be trained specialists in their areas (Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Nickell and Fischer, 1999; Schultz et al., 2006; Schultz, 2007). Disadvantages of intrusive techniques include loss of context or association of evidence, destruction of ground surface, scene, or evidence, and that they may impede the reconstruction of events if not utilized properly (Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Schultz, 2007). From walking a basic visual search line to incorporating advanced geophysical technologies to proper excavation techniques, the location and recovery of evidence is the goal of any forensic search (Connor and Scott, 1998; Davenport, 2001; Dupras et al., 2006; Schultz et al., 2006;).

Geophysical technologies fall into two categories for measuring geologic signals: passive or active. Passive tools simply measure those signals inherent to the earth's physical properties, while active methods transmit human-made signals into the ground and measure any signals received from an object in the ground (Davenport, 2001; Dupras et al., 2006; Killam, 2004). Examples of active geophysical instruments include metal detectors, conductivity meters, resistivity meters, and ground-penetrating radar (GPR), while magnetic locators are passive tools (Connor and Scott, 1998; Davenport, 2001; Dupras et al., 2006; Garrett, 1998; Hunter and Cox, 2005; Isaacson et al., 1999; Murray and Tedrow, 1975; Nelson, 2004; Nielson, 2003; Rowlands and Sarris, 2007; Ruffell and McKinley, 2005; Schultz et al., 2006; Schultz, 2007).

Geophysical Technologies in Archaeology and Forensics

Archaeologically, geophysical techniques have run the gamut from finding small metal artifacts to reconstructing features (Connor and Scott, 1998; Isaacson et al., 1999; Murray and Tedrow, 1975; Rowlands and Sarris, 2007; Scott et al., 1989). Forensically, geophysical techniques have proven useful for the identification of buried ordnance (Garrett, 1998; Nelson, 2004; Ruffell and McKinley, 2005), other metallic evidence (Davenport, 2001; Dupras et al., 2006; Garrett, 1998; Nielson, 2003; Ruffell and McKinley, 2005), and the location of buried bodies (Davenport et al., 1992; Davenport, 2001; Dupras et al., 2006; France et al., 1997; Schultz et al., 2006; Schultz, 2007).

The advantages of geophysical technologies in archaeological or forensic investigation include minimal disturbance to ground surfaces, in-field results, and the ability to conduct a search discreetly. Disadvantages of these technologies include time constraints, the need for an experienced handler for some technologies (GPR and resistivity meters), and also the cost (GPR and conductivity meters) (Dupras et al., 2006; Rowlands and Sarris, 2007; Schultz et al., 2006; Schultz, 2007). The non-intrusive characteristic of geophysical search methods is the most beneficial in terms of crime scene investigation where an area needs to be preserved for future reference (Dupras et al., 2006; Hunter and Cox, 2005; Killam, 2004; Schultz, 2007). While these techniques are quite useful at forensic scenes, many law enforcement personnel often view them as too complicated due to a lack of familiarity with the technology (Hunter and Cox, 2005; Schultz et al., 2006).

Metal detectors, in particular, are non-intrusive geophysical technologies that have a long history of use in both archaeological and forensic contexts (Connor and Scott, 1998; Davenport, 2001; Garrett, 1998; Goddard, 1977; Isaacson et al., 1999; Murray and Tedrow, 1975; Nelson, 2004; Nielson, 2003; Nickell and Fischer, 1999). Two interesting historical facts, according to Nelson (2004), are that the first known metal detector was used approximately 200 years ago by a Chinese Emperor in the form of a magnetic door which attracted weapons and other metal objects that visitors were carrying, and that Alexander Graham Bell utilized a metal detector to recover a bullet from President James Garfield following an attempted assassination in 1881. Connor and Scott (1998) detail several archaeological and forensic cases which utilized metal detectors. Both Connor and Scott (1998) and Scott et al. (1989) detail the controlled excavation of Little Bighorn, Montana, which is perhaps the best study of the use of geophysical technologies (specifically metal detectors and GPR) in the location and recovery of metallic archaeological artifacts and evidence.

Metal Detector and Magnetic Locator Properties

Metal detectors transmit electromagnetic fields which penetrate the material surrounding the search coil - be it soil, sand, rock, wood, brick, stone, masonry, water, concrete, vegetable, some mineral sources, or air. If the electromagnetic field interacts with a metal, eddy currents will form, creating a secondary field that transmits a detection signal back to the receiver in the unit (Connor and Scott, 1998; Dupras et al., 2006; Garrett, 1998; Nelson, 2004; Nielson, 2003).

Magnetic locators utilize sensors (one or two, depending upon model) to measure local variations in earth's magnetic field, and are used to detect ferromagnetic objects (Davenport, 2001; Dupras et al., 2006; Hunter and Cox, 2005; Schonstedt Instrument Company, 1998). The use of magnetic profiling requires basic familiarity with the locator, but is relatively easy to learn, and the devices themselves are some of the more inexpensive geophysical tools (Davenport, 2001; Hunter and Cox, 2005).

Purpose

Prior to the current research project, published controlled research involving the use of geophysical technologies to locate and identify buried objects has been limited to replicated archaeological features (Isaacson et al., 1999) and buried pig cadavers serving as proxies for human remains (Davenport et al., 1992; France et al., 1997; Schultz et al., 2006; Schultz, 2007). Controlled settings provide an opportunity not only to demonstrate the capabilities of utilized technologies, but also to test innovative geophysical tools, new software, and methodologies (Isaacson et al., 1999; Schultz et al., 2006). Research methods utilized in the controlled context must be similar to those methods that will be practiced in the field, creating guidelines for replicable results during real-world search scenarios (Schultz et al., 2006). This research is the first to utilize controlled geophysical tools to detect, identify, and map specific types of buried metal objects, including an array of firearms. In addition, the controlled setting of this research allows for the opportunity to improve standard geophysical detection methods which are used in the search for street-level firearms that have been buried for the purpose of concealing or discarding them.

This research is designed to demonstrate the utility of geophysical technologies at a crime scene or a suspected weapon burial site through controlled testing of 32 buried objects, including firearms. Utilizing a basic metal detector and a magnetic locator, the objectives of this research are:

- To test the ease at which these geophysical technologies may be used to detect buried weapons with little operator training
- To determine the effect that burial has on the detection of these objects with each of the geophysical tools
- To determine maximum depth at which these objects may be detected with these two tools
- To determine which instrument is better at detecting specific weapons
- To provide guidelines to forensic investigators using geophysical tools so that they are better prepared to search for buried firearms

Materials and Methods

Research Site

An undeveloped, flat, open section of the Orange County Sheriff's Office (OCSO) Lawson Lamar Firearms and Tactical Training Center in Orlando, Florida was designated as the research site for this project (Figure 1). Centered in the overflow portion for a retention pond, the research area is frequently mowed, but otherwise inactive. Soil in the research area is classified as a spodosol, specifically in the Smyrna series, which consists of poorly drained soils with spodic horizons (dark organic layers which may consist of aluminum, carbon, and/or iron) which have formed in sandy marine sediment (Doolittle and Schellentrager, 1989). However, when the range was developed, extra fill was incorporated into the area to raise the ground surface.

Figure 1: Aerial Photograph of Lawson Lamar Firearms and Tactical Training Center in Orlando, Florida. The Research Site (White Square) is located at 28°25'11.28" N 81°10'25.07" W.

The research area contained a total of 32 buried metallic objects and three control holes (consisting of only backfill) in a grid of seven rows (Figure 2). Each row contains five buried targets, except for rows D and G. Row D contains a total of seven holes, which includes five buried targets and two control holes, and row G contains only two buried targets and one control hole. Rows A and B contain strictly buried firearms (10), rows C and D contained both firearms (3,1) and scrap metal (2,4), rows E and F housed only blunt or edged metal weapons (10), and the final row was added to incorporate two additional firearms and a third control hole. Burial holes were marked with bright orange plastic stakes as metallic flags would have interfered with results.

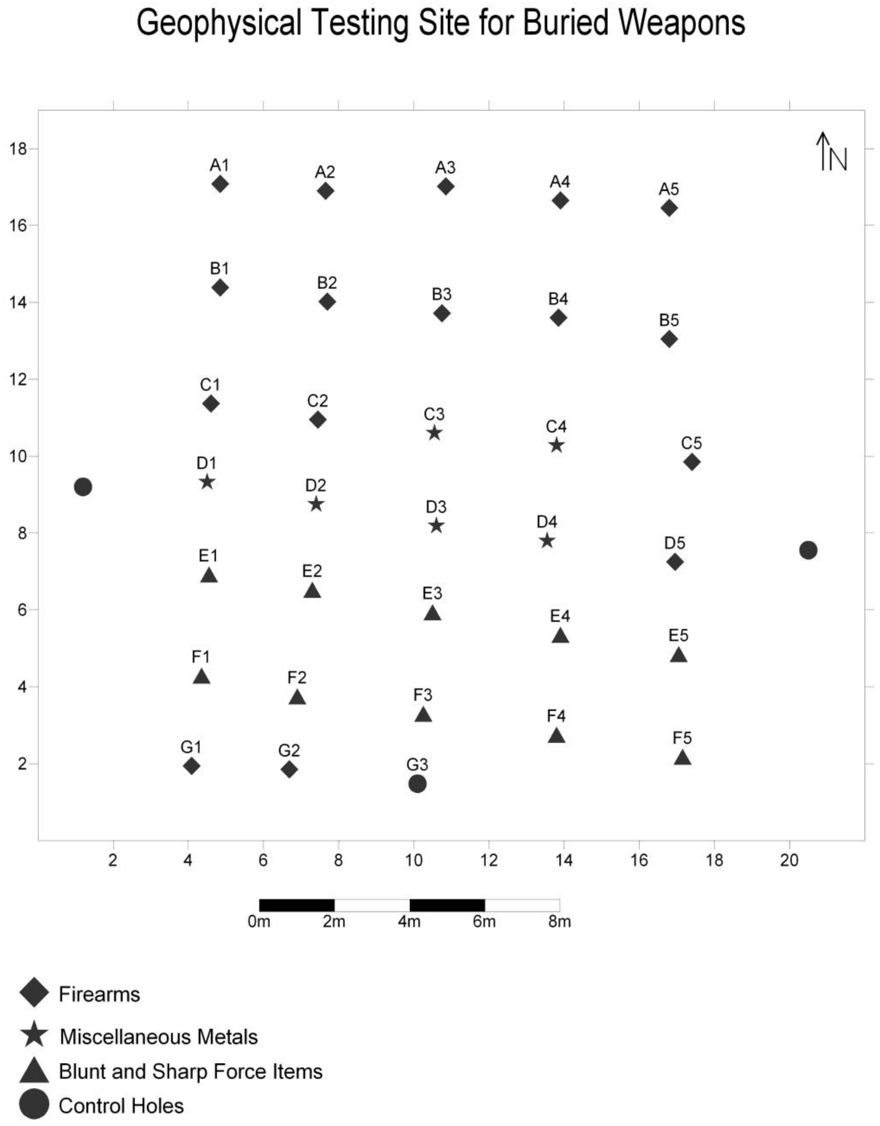

Figure 2: Map of Research Area Containing a Total of Thirty-two Buried Metallic Objects and Three Control Holes. Map Created Using Surfer ® Software.

Forensic Targets

Included in this research were sixteen firearms, six pieces of assorted scrap metals, and ten blunt or edged weapons (Figures 3-5). In order to gain access to the weapons for research, all protocols outlined by the OCSO's security procedures, including the decommissioning of the firearms, were followed. Firearms were decommissioned by removing or filing firing pins and blocking the firing pin channel and barrel with JB Weld® cold-weld liquid epoxy compound. Of note is A5, the Glock 9mm; due to the minimal amount of metal in the polymer frame, the firing pin was removed and welded into the grip, and both the firing pin channel and barrel were blocked.

Firearms

A collection of firearms most commonly associated with street-level crime in Central Florida were provided for this research by the Orange County Sheriff's Office, and consisted of a derringer, eight pistols, four revolvers, two shotguns, and a rifle (Figure 3; Table 1). The firearms selected represent a variety of metallic compositions, finishes, and lengths. The majority of the firearm frame compositions consist of steel, with several utilizing other metals or materials, such as zinc, aluminum, or polymer.

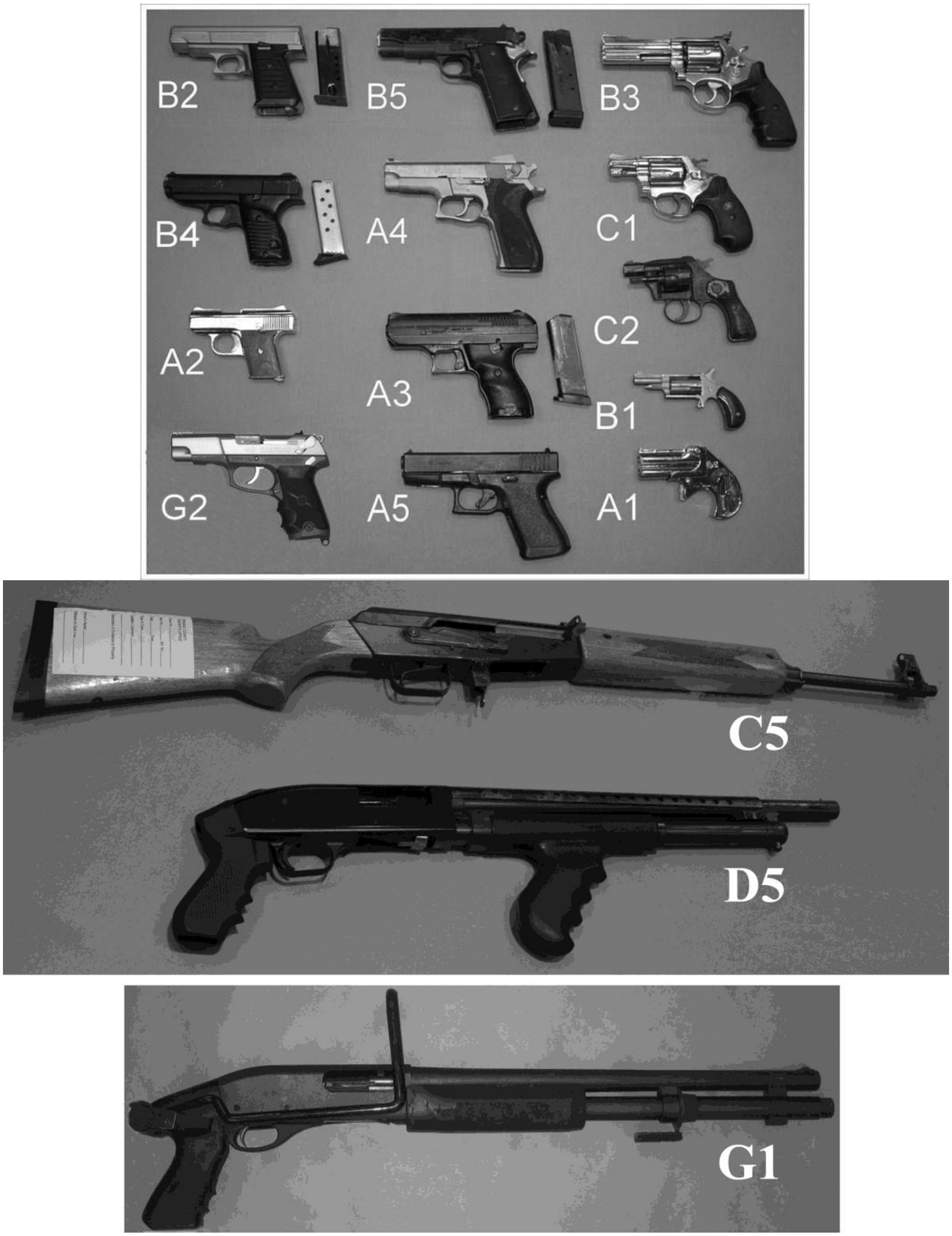

Figure 3: Sixteen Decommissioned Firearms Utilized in the Project. a) Thirteen Handguns, b) Rifle and Two Shotguns

Table 1: Firearms

Grid Location	Firearm	Type	Metal/ Composition	Special Finish	Length (mm)	Unloaded Weight (oz.)
A1	Davis Derringer D9	Derringer/ 9mm	Steel	Chrome-plated	119	12.8
A2	Raven Arms MP25	Pistol/.25	Zinc Alloy/Steel	Chrome-plated	123	14.4
A3	Hi-Point Model C	Pistol/9mm	Steel/Polymer	Blued	178	35
A4	Smith & Wesson 5906	Pistol/9mm	Stainless Steel		190	38.3
A5	Glock Model 19	Pistol/9mm	Polymer Frame/ Steel Slide and Firing Pin	Blued/Tenifer	187	20.6
B1	North American Arms Mini-Magnum	Revolver/ .22 Magnum	Stainless Steel		130	6.4
B2	Jennings Bryco 59	Pistol/9mm	Zinc Alloy/Steel Magazine	Satin Nickel-plated	170	33.6
B3	Smith & Wesson Model 686	Revolver/ .357 Magnum	Stainless Steel		235	37
B4	Lorcin L380	Pistol/ .380	Aluminum Frame, Magazine, Slide/Steel	Blued	171	30.4
B5	Colt Commander	Pistol/ .45 ACP	Steel	Blued	196	27
C1	Smith & Wesson Model 37	Revolver/ .38 Special	Steel	Nickel-plated	167	25
C2	RG Industries RG23	Revolver/ .22 Long rifle	Aluminum Frame/Steel Barrel, Cylinder	Blued	148	14.4
C5	Norinco AK Hunter	Rifle/ 7.62	Steel/Polymer	Blued	1067	125.5 Includes Wooden Stock
D5	Mossberg Model 500A with Knoxx COPStock	Shotgun/ 12 Gauge	Steel/ Polymer	Blued	711	96
G1	Remington 870	Shotgun/ 12 Gauge	Steel	Parkerized	762	120
G2	Ruger P89	Pistol/9mm	Aluminum/ Stainless Steel	Terhune Anticorro	203	32

Scrap Metals and Miscellaneous Weapons

The scrap metals include pieces of copper, aluminum, and iron (including rebar), representing trash metals which are frequently encountered during weapons searches (Figure 4; Table 2). A variety of blunt (mallet, hammer, prybar, baton, brass knuckles) and edged (machete, sword, Buck knife, Philip's head screwdriver, scissors) weapons which have been recovered from OCSO crime scenes were also included, and primarily consist of steel (Figure 5; Table 3).

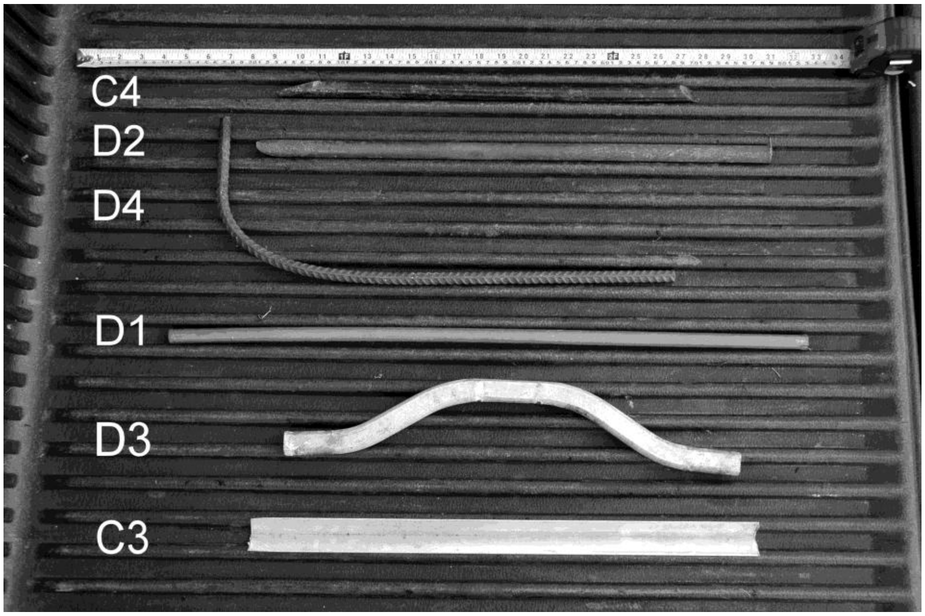

Figure 4: Six Pieces of Assorted Scrap Metals Utilized in the Project

Table 2: Scrap Metals

Burial Grid Location	Type	Metal/Composition	Length (cm)
C3	Aluminum Edging	Aluminum	53
C4	Solid Iron Pipe	Iron	48
D1	Hollow Copper Tube	Copper	68.5
D2	Rusty Iron Pipe	Iron	57
D3	Solid Aluminum Pipe	Aluminum	47.7
D4	Rebar	Iron	66.5

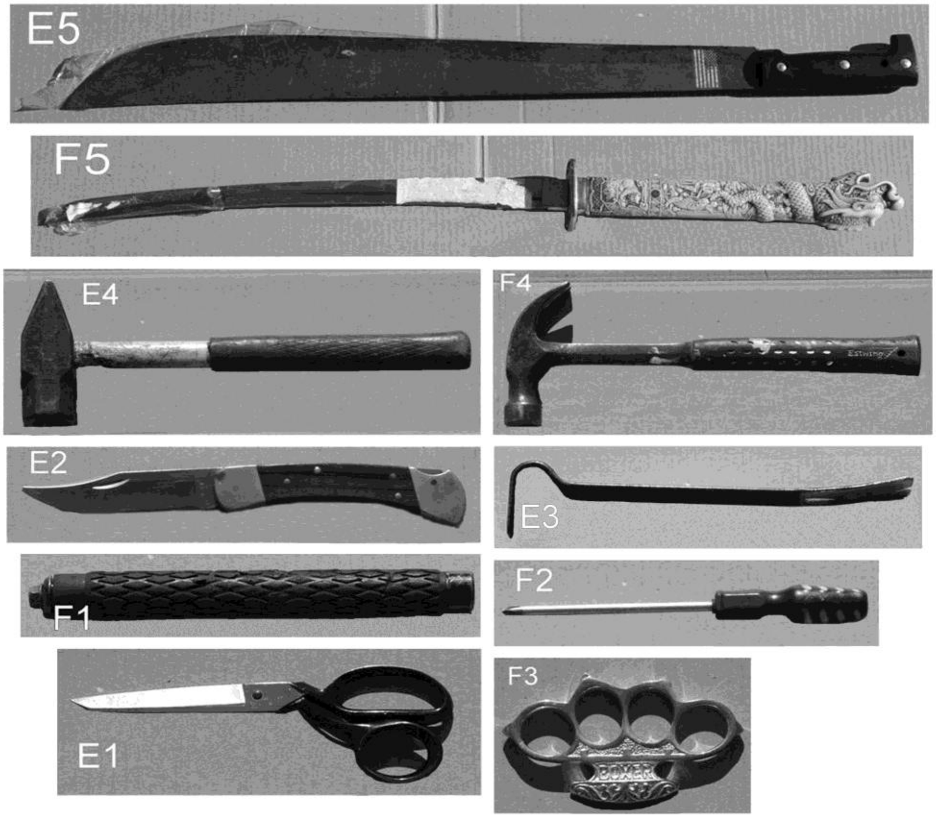

Figure 5: Ten Blunt and Edged Weapons Utilized in the Project

Table 3: Blunt and Edged Miscellaneous Weapons

Burial Grid Location	**Type**	**Metal/Composition**	**Length (cm)**
E1	Scissors	Steel	20
E2	Buck Knife	Stainless Steel	22.2
E3	Prybar	Steel	32.2
E4	Mallet	Steel	38.4
E5	Machete	Steel	68.2
F1	Baton	Steel	25.7
F2	Philip’s Head Screwdriver	Steel	26.2
F3	Brass Knuckles	Brass (Copper and Zinc)	11.6
F4	Claw Hammer	Steel	35
F5	Sword	Steel	81

Geophysical Tools in this Research

The geophysical tools used in this research are designed to detect metallic objects and provide consistent readings, allowing for dependable results which should be replicable during real-world search scenarios (Fisher Research Laboratory, 2006.; Schonstedt Instrument Company, 1998). Chosen due to their accessibility and efficiency, many law enforcement agencies will find these tools easy to purchase, relatively inexpensive, and easy to use. The geophysical tools used in this study are a basic all-metal detector (Fisher M-97) and a magnetic locator (Schonstedt GA-72Cd®) (Figure 6 a,b). Simple detection by the M-97 and the GA-72Cd was tested at various burial depths for each metal target.

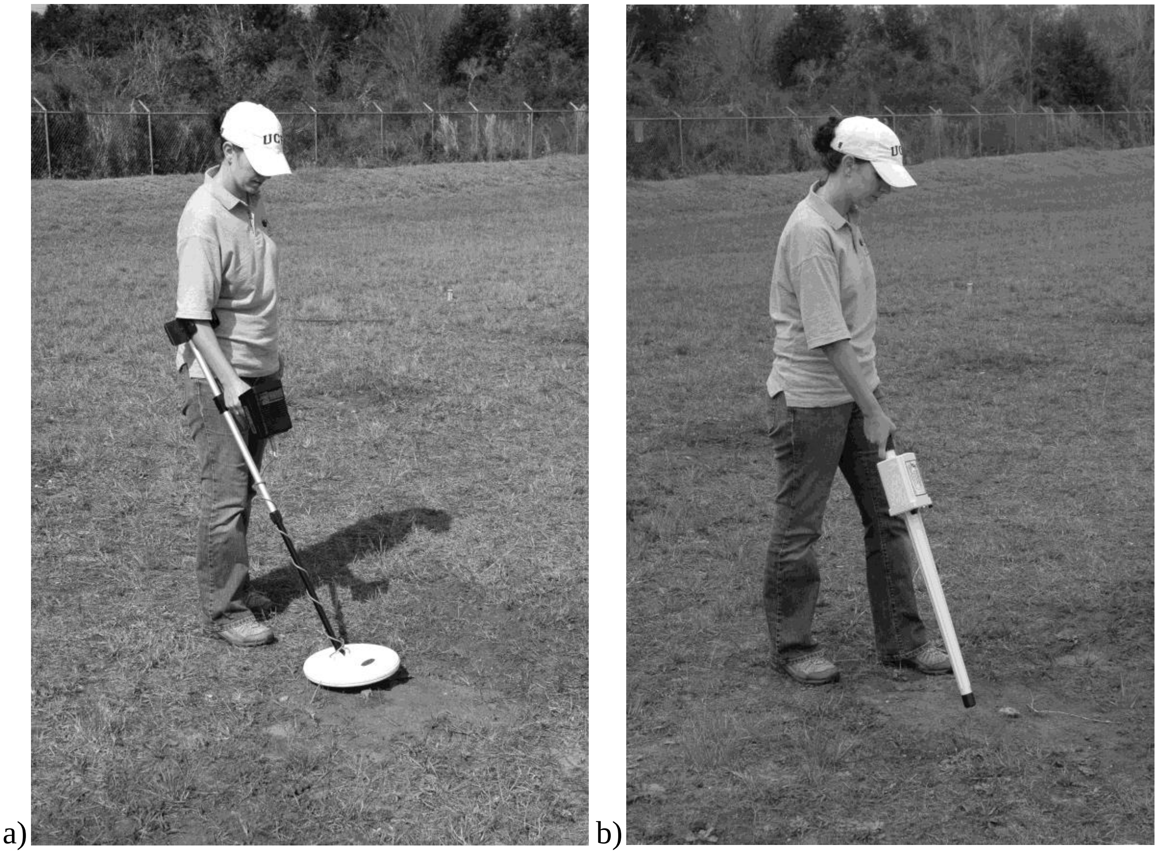

Figure 6:(a) Fisher M-97 Basic All-Metal Detector; (b) Schonstedt GA-72Cd Magnetic LocatorFisher M-97

Fisher M-97

The Fisher M-97 utilized in this project is an affordable, rugged, and simple to use all-metal detector which utilizes a waterproof 11” Double-D search coil to identify metallic objects with both visual and audio responses (Figure 6a). According to the manufacturer, the Fisher M-97 is designed to search for concealed, buried, or paved-over metallic objects, including valves, manhole covers, and boxes (Fisher Research Laboratory, 2006). Detected metals also include iron, lead, brass, and aluminum. The M-97 features high sensitivity, ground effect rejection due to mineralized ground or wet ground foliage, and auto-tune for stabilizing ground interference. The detector has ten ground rejection levels that can be adjusted to compensate for high mineral content in the area being searched. Additional sensitivity settings (Normal and High) further allow the user to customize the detector to the soil conditions (Fisher Research Laboratory, 2006).

Ten ground rejection levels are used to balance the M-97, compensating for the search area’s mineral content. The manufacturer recommends that detection begin by selecting ground balancing level 5, and the Normal sensitivity setting. Generally, these settings do not require much ground rejection adjustment, and provide a “turn on and go” mode. Tuning the machine higher or lower depends upon ground conditions; the machine is tuned when the there is no change in audible hum when the detector is lifted 12-18 inches off of the ground. High setting is recommended for increasing the mineral sensitivity and depth of detection (Fisher Research Laboratory, 2006). Retuning the machine once High is chosen allows the detector to correctly rebalance itself to the ground conditions.

Schonstedt GA-72Cd

The Schonstedt GA-72Cd magnetic locator used in this project is a field sensor that is designed to detect the magnetic field of ferromagnetic (material or substance that is highly magnetic-such as iron) objects while ignoring non-metallic materials such as gold, silver, copper, brass, and aluminum (Schonstedt Instrument Company, 1998). Two sensors located in the shaft, spaced roughly 14 inches apart, respond to the difference in the magnetic field around the locator (Figure 6b). The Schonstedt GA-72Cd magnetic locator includes Low, Medium, High, and Maximum sensitivity settings. According to the manufacturer, the level of sensitivity required for accurate detection differs based upon background interference and depth of object. High sensitivity will allow for deeper detection, but also increases the sensitivity of the machine, producing background noise (Schonstedt Instrument Company, 1998).

Materials which may be located with the Schonstedt GA-72Cd include magnetic markers, stakes, manholes, septic tanks, magnetically detectable nonmetallic duct and cable, well casings, barbed wire, chain link fence, valve boxes, cast-iron pipes, steel drums, magnetized non-metallic duct and cable, weapons, projectiles, hunting knives, and hand guns. According to the manufacturer, the locator can be used over snow or water, and the maximum known burial depths for 55 gallon steel drums, hunting knives, and hand guns are 2.44 meters, 40.64cm of underwater silt, and 30.48cm, respectively (Schonstedt Instrument Company, 1998). Of course, these vary by conditions and depend on vertical or horizontal burial orientation. In addition, the manufacturer (Schonstedt Instrument Company, 1998) asserts that this equipment can aid explosive ordnance disposal technicians and law enforcement officers during area search operations for improvised explosive devices, buried ordnance, and covered weapons.

The digital display and the audible alarm operate very similar to metal detectors; as you move closer to a target, the audible tone and/or digital readout will increase. Digital indications of both signal strength and polarity register in the display unit when a magnetic object is located, and audible tone changes can also be discerned with training and experience. Advanced training and experience allows for simultaneous use of both indications, helping to pinpoint a target and determine its burial orientation. Using the polarity readings, the positive and negative ends of the target can be determined, if the object is buried horizontally. If an object is buried vertically, the audio signal will only sound directly over the object, and can appear either positive or negative.

Data Collection Parameters

Controlled readings of simple detection were taken for each object with each geophysical tool prior to their burial**.** Over the course of two years, the weapons were first buried at depths of 20-25cm, and depths were then increased by 5cm each re-burial visit until detection by the two geophysical tools was no longer possible. Target detection was achieved by walking the grid in both north/south and east/west patterns. As this project utilizes controlled research conditions, a probe was used to locate the target if the marked burial produced a detection reading. Doing so allowed for readings to be confirmed on the target, not an unknown object or iron concretion in the soil.

It is important to note that a number of quality control procedures were also established to account for soil compaction and weather concerns. Control holes (two outside the grid and one inside the grid – G3, see Figure 2) were tested during data collection. The disturbed soil of the control holes did not produce any audible responses for the various depths when tested with either geophysical tool. Soil compaction differences also did not seem to affect target detection, as loose soil and the compact soil of the control graves did not provide any detection results.

However, due to inconsistent results following periods of rain or wet soil, all targets were retested individually with all three geophysical tools, with two other projects members providing inter-observer confirmation of the author's results. After first testing each hole to be sure there were no metal components that would skew results, targets were tested both in their burial location in the grid, and also in the control hole. Taking into consideration that the research site is a live firearms range, each hole was tested for metallic items such as bullet fragments or ricochets each visit.

Fisher M-97

The M-97 all-metal detector was initially tested in the manufacturer's recommended "turn on and go" (Normal sensitivity, level 5) setting, which provided the correct ground balancing for the research area. Swinging the detector side-to-side, low and even to the ground, the sound of the detector's hum increased and the readings on the display meter changed when a metallic object was encountered. Once deeper depths were reached, some of the targets were sampled on High when Normal did not produce a notable audible response, as the High setting increases the depth capabilities of the machine.

Schonstedt GA-72Cd

The GA-72Cd magnetic locator was used very much like a metal detector in that it was slowly waived in front of the operator, pointing at the ground. When the audio and visual readings become stronger, an object may be located by running the locator in an “x” type fashion over the area. The point of strongest readings is most likely a magnetic object. The lowest sensitivity setting did not adequately detect the targets, and the maximum setting reflected too much background interference. Medium setting was first utilized in detection for this reason; if no audible response was noted, the High setting was then used.

Using factory presets and/or Medium settings on the geophysical technologies allowed for detection and readings at multiple depths. Detection was categorized into “No”, “Slight”, and “Strong”. *Slight* detection readings meant that a change in the detector’s hum was audible, but may not have been noticeable enough in real-world searches involving areas that are littered with trash metals and/or have a high mineral content, include large groups searching in the area, or have other background noise or distractions to qualify as a *Strong*. For the magnetic locator, *slight* may also have included a noticeable change in the polarity readings on the display; enough change to determine orientation of the target. This was only useful at deeper depths, and after much operator experience. Any *no* or *slight* readings were checked on High settings to determine if the High settings proved more useful at deeper depths.

Results

Fisher M-97

Firearms

Data collection on the buried firearms with the all-metal detector on Normal setting shows that all 16 firearms produce *strong* audible responses, although at varying depths (Figure 7). One shotgun, the larger Remington 870 (G1), produced a *strong* audible response down to a maximum depth of 30-35cm. The Norinco AK rifle (C5), the Mossberg 500A shotgun (D5), and the Colt Commander (B5) produced *strong* audible responses down to a maximum depth of 25-30cm. Three of the largest handguns, the Smith & Wesson 686 (B3), the Ruger P89 (G2), and the Smith & Wesson 5906 (A4) produced *strong* audible responses down to a maximum depth of 20-25cm. Seven medium-to-small handguns produced *strong* audible responses down to a maximum depth of 15-20cm: the Glock Model 19 (A5), the Hi-Point Model C (A3), the Lorcin L380 (B4), the Jennings Bryco 59 (B2), the Smith & Wesson Model 37 (C1), the RG Industries RG23 (C2), and the Raven Arms MP25 (A2). Finally, two of the three smallest handguns, the North American Arms Mini-Revolver (B1) and the Davis Derringer (A1), produced *strong* audible responses down to a maximum depth of only 10-15cm.

Data collection on the buried firearms with the all-metal detector on High setting showed that all 16 firearms produced *strong* audible responses, although at varying depths (Figure 8). The Remington 870 (G1) produced a *strong* audible response down to a maximum depth of 50-55cm. The Norinco AK rifle (C5) was detected as a *strong* audible response down to a maximum depth of 45-50cm. The Mossberg 500A (D5) produced a *strong* audible response down to a maximum depth of 40-45cm. Six large-to-medium handguns produced strong audible responses down to a depth of 35-40cm: Smith & Wesson 686 (B3), the Ruger P89 (G2), the Colt Commander (B5), the Smith & Wesson 5906 (A4), the Hi-Point Model C (A3), and the Jennings Bryco 59 (B2). Four firearms, representing medium to small handguns, produced *strong* audible responses down to a maximum depth of 30-35cm: the Lorcin L380 (B4), the Smith & Wesson Model 37 (C1), the RG Industries RG23 (C2), and the Glock Model 19 (A5). Finally, three firearms produced only *strong* audible responses down to a maximum depth of 25-30cm: the North American Arms Mini-Revolver (B1), the Raven Arms MP25 (A2), and the Davis Derringer (A1).

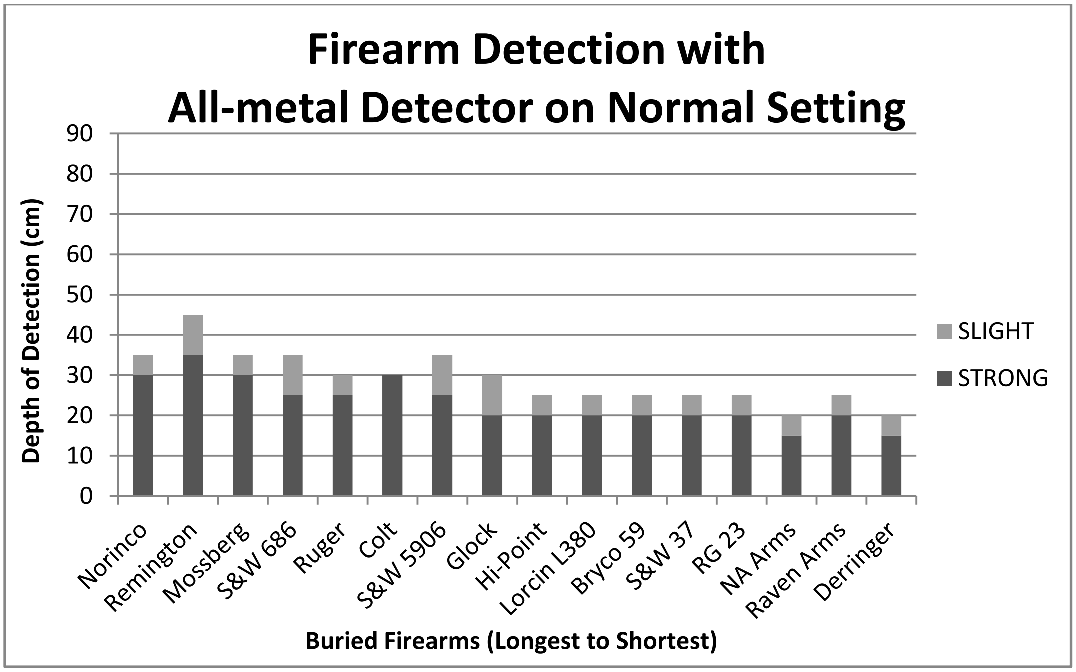

Figure 7: Results from Firearm Detection with M-97 on Normal Setting

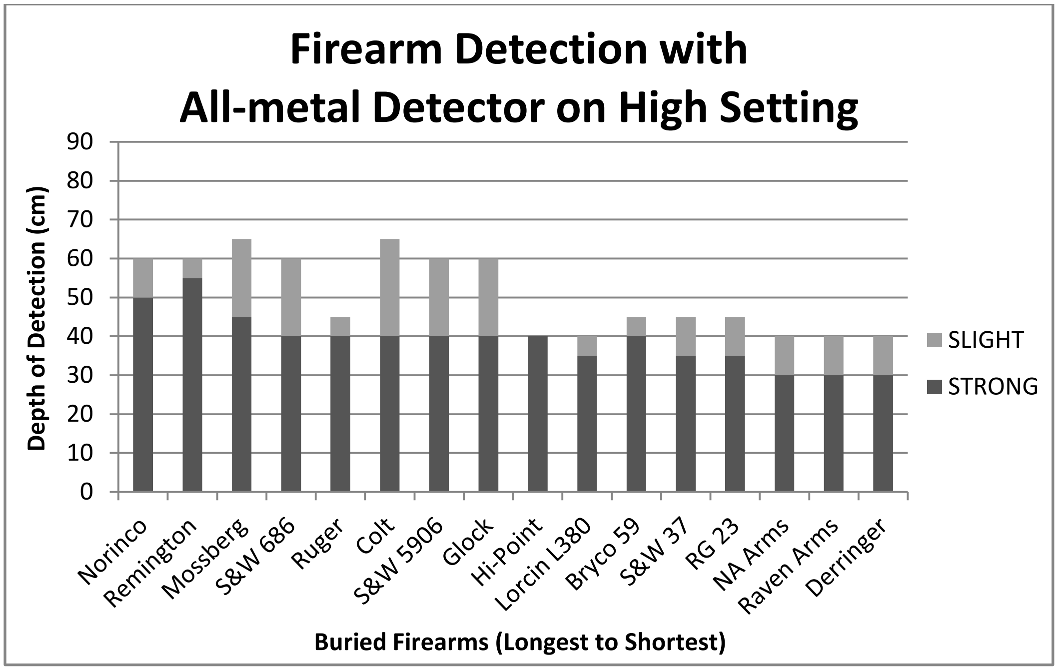

Figure 8: Results from Firearm Detection with M-97 on High Setting

Scrap Metals

Data collection on the buried scrap metals with the all-metal detector on Normal setting shows that all six scrap metals produced *strong* audible responses, although at varying depths (Figure 9). Two scrap metal targets produced a *strong* audible response down to a maximum depth of 25-30cm: the rusty iron pipe (D2), and the solid iron pipe (C4). The rebar (D4) and the aluminum edging (C3) produced *strong* audible responses down to a maximum depth of 15-20cm. Finally, two scrap metal targets, the hollow copper tube (D1) and solid aluminum pipe (C4), produced a *strong* audible response down to a maximum depth of 10-15cm.

Data collection on the buried scrap metals with the all-metal detector on High setting shows that all six scrap metals produced *strong* audible responses, although at varying depths (Figure 10). Two scrap metal targets produced a *strong* audible response down to a maximum depth of 40-45cm: the rusty iron pipe (D2), and the solid iron pipe (C4). The rebar (D4) and the aluminum edging (C3) produced *strong* audible responses down to a maximum depth of 30-35cm. Finally, the hollow copper tube (D1) produced a *strong* audible response down to a maximum depth of 25-30cm, while the solid aluminum pipe (C4), produced a *strong* audible response down to a maximum depth of 20-25cm.

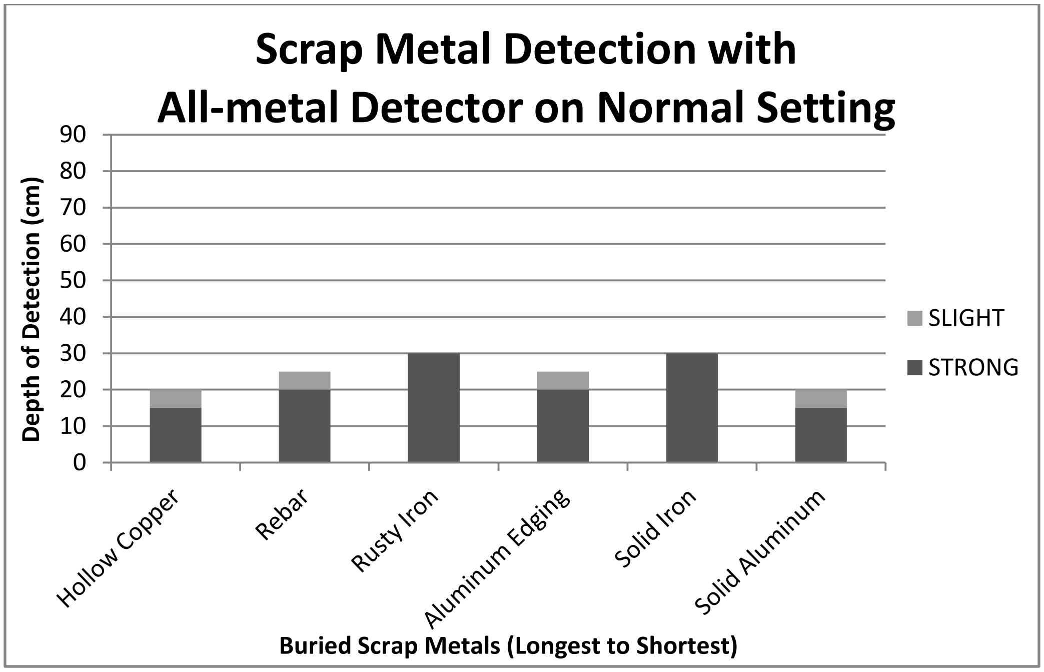

Figure 9: Results from Scrap Metal Detection with M-97 on Normal Setting

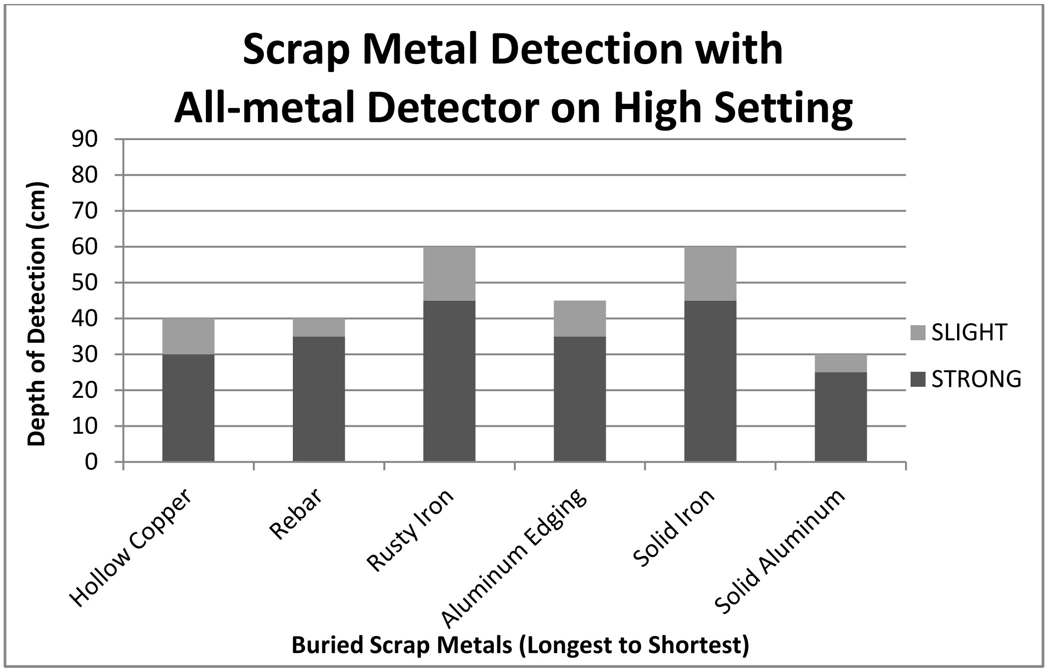

Figure 10: Results from Scrap Metal Detection with M-97 on High Setting

Miscellaneous Weapons

Data collection on the buried miscellaneous weapons with the all-metal detector on Normal setting shows that all ten miscellaneous weapons produced a *strong* audible response, although at varying depths (Figure 11). The claw hammer (F4) produced a *strong* audible response down to a maximum depth of 25-30cm. Four miscellaneous weapons, representing large, medium, and small targets, produced a *strong* audible response down to a maximum depth of 20-25cm: the sword (F5), the machete (E5), the mallet (E4), and the baton (F1). The prybar (E3) produced a *strong* audible response down to a maximum depth of 15-20cm, while the buck knife (E2), the scissors (E1), and the brass knuckles (F3) all produced *strong* audible responses down to a maximum depth of 10-15cm. Finally, the Philip's head screwdriver (F2) produced a *strong* audible response down to a maximum depth of 5-10cm.

Data collection on the buried miscellaneous weapons with the all-metal detector on High setting shows that all miscellaneous weapons produced a *strong* audible response, although at varying depths (Figure 12). The claw hammer (F4) produced a *strong* audible response down to a maximum depth of 40-45cm. Three miscellaneous weapons, representing large targets, produced a *strong* audible response down to a maximum depth of 35-40cm: the sword (F5), the machete (E5), and the mallet (E4). The prybar (E3) and the baton (F1) produced a *strong* audible response down to a maximum depth of 30-35cm, while the buck knife (E2), the scissors (E1), and the brass knuckles (F3) all produced *strong* audible responses down to a maximum depth of 25-30cm. Finally, the Philip's head screwdriver (F2) produced a *strong* audible response down to a maximum depth of 15-20cm.

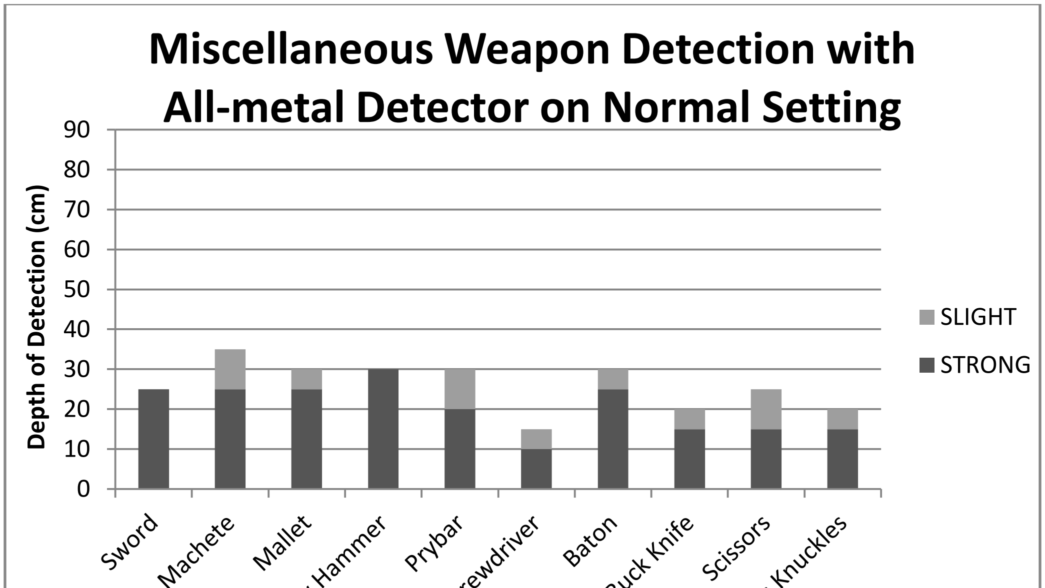

Figure 11: Results from Miscellaneous Weapon Detection with M-97 on Normal Setting

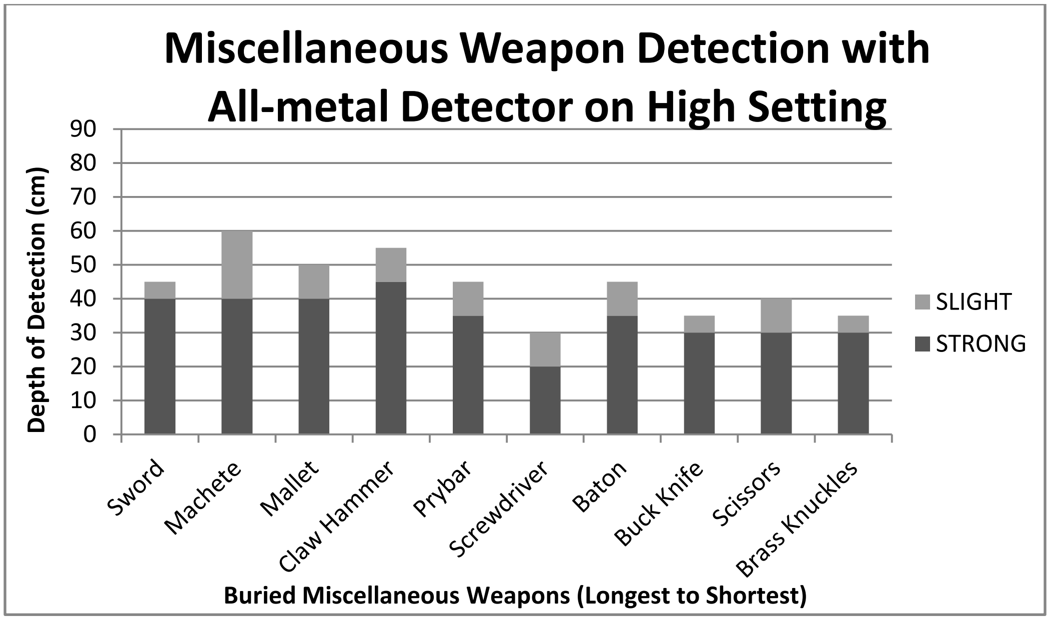

Figure 12: Results from Miscellaneous Weapon Detection with M-97 on High Setting

Schonstedt GA-72Cd

Firearms

Data collection on the buried firearms with the magnetic locator on Medium setting (Figure 13) shows that all but two firearms (14 of 16; 87.5%) produced *strong* audible responses, although at varying depths. Both the Lorcin L380 (B4) and the Raven Arms MP-25 (A2) were only detected as *slight*. Four of the six largest firearms produced *strong* audible responses deepest, the Remington 870 (G1) was *strong* down to a maximum depth of 50-55cm, the Norinco rifle (C5) was *strong* down to a maximum depth of 45-50cm, the Colt Commander (B5) was *strong* down to a maximum depth of 40-45cm, and the Mossberg 500A shotgun (D5) was *strong* down to 25-30cm. Two of the medium-sized handguns, the Smith & Wesson 5906 (A4) and the Smith & Wesson 37 (C1), were detected with a *strong* audible response down to a maximum depth of 20-25cm. Five of the handguns representing large, medium, and small sizes were detected with a *strong* audible response down to a maximum depth of 15-20cm: Smith & Wesson Model 686 (B3), Ruger P89 (G2), Glock Model 19 (A5), Hi-Point Model C (A3), and the North American Arms Mini-Revolver (B1). The Jennings Bryco 59 (B2) was detected with a *strong* audible response down to a maximum depth of 10-15cm. The smallest handgun, the Davis Derringer (A1), was only detected with a *strong* audible response down to a maximum depth of 5-10cm, while the RG Industries RG23 (C2) was only detected with a *strong* audible response down to a maximum depth of 0-5cm.

Data collection on the buried firearms with the magnetic locator on High setting (Figure 14) shows that all 16 firearms produced *strong* audible responses, although at varying depths. The two largest firearms, the Norinco AK rifle (C5) and the Remington 870 (G1) shotgun, produced *strong* audible responses down to a maximum depth of 70-75cm. Two firearms, the Mossberg 500A (D5) shotgun and the large Colt Commander (B5) handgun produced *strong* audible responses down to a maximum depth of 55-60cm. The second largest handgun, the Ruger P89 (G2), produced a *strong* audible response down to a maximum depth of 40-45cm. The Smith & Wesson 5906 (A4), a larger handgun, produced a *strong* audible response down to a maximum depth of 35-40cm. The largest handgun and three medium handguns produced a *strong* audible response down to a maximum depth of 30-35cm: the Smith & Wesson Model 686 (B3), the Glock 19 (A5), the Jennings Bryco 59 (B2), and the Smith & Wesson Model 37 (C1). Two medium-to-small handguns, the Hi-Point Model C (A3) and the North American Arms Mini-Revolver (B1) produced *strong* audible responses down to a maximum depth of 25-30cm. The smallest handgun, the Davis Derringer (A1), was detected with a *strong* audible response down to a maximum depth of 20-25cm. The RG Industries RG-23 (C2) only produced a *strong* audible response down to a maximum depth of 10-15cm. Finally, the Lorcin L380 (B4) and the Raven Arms MP-25 (A2) only produced a *strong* audible response down to a maximum depth of 5-10cm.

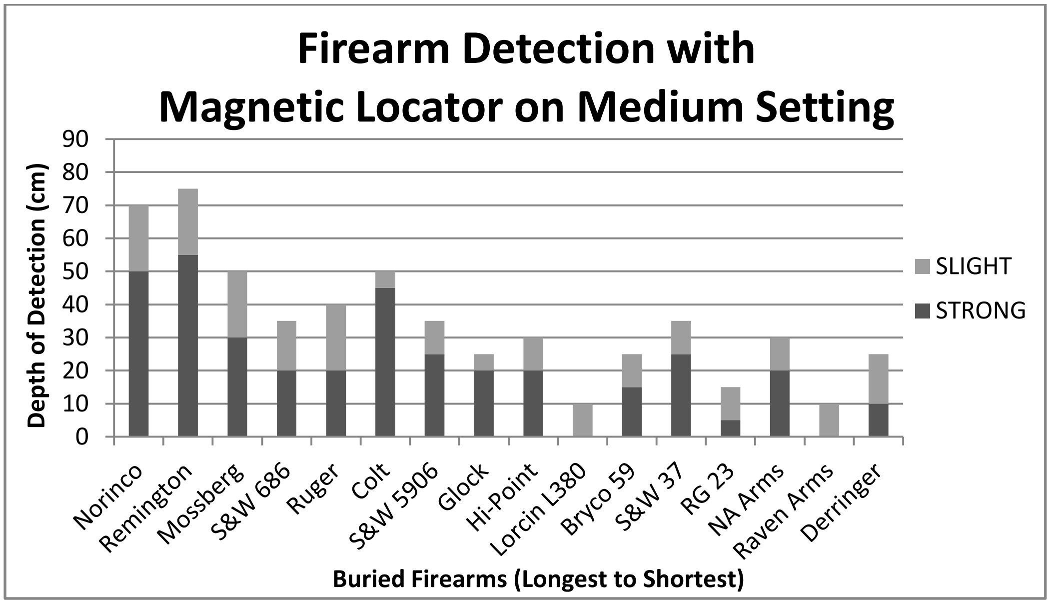

Figure 13: Results from Firearm Detection with GA-72Cd on Normal Setting

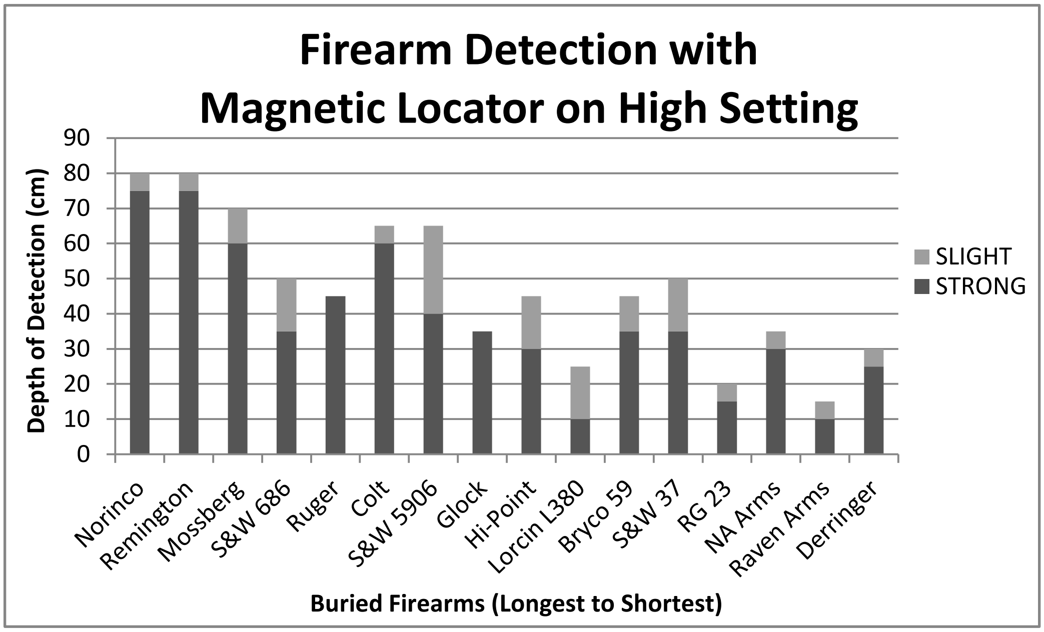

Figure 14: Results from Firearm Detection with GA-72Cd on High Setting

Scrap Metals

Data collection on the scrap metals with the magnetic locator on Medium setting (Figure 15) shows that only three of the scrap metal targets (50%), the rebar (D4), the solid iron pipe (C4), and the rusty iron pipe (D2) produced *strong* audible responses prior to burial; the hollow copper tube (D1), aluminum edging (C3), and solid aluminum pipe (D3) did not produce any audible responses prior to their burial. Once buried, the rusty iron pipe (D2) produced a *strong* audible response down to a maximum depth of 55-60cm, the solid iron pipe (C4) produced a *strong* audible response down to a maximum depth of 40-45cm, and the rebar (D4) produced a *strong* audible response down to a maximum depth of 15-20cm.

Data collection on the buried scrap metals with the magnetic locator on High setting (Figure 16) shows that the rebar (D4), rusty iron pipe (D2), and the solid iron pipe (C4) are still the only scrap metals detected, all producing *strong* audible responses down to maximum depths of 65-70cm , 55-60cm, and 25-30cm, respectively.

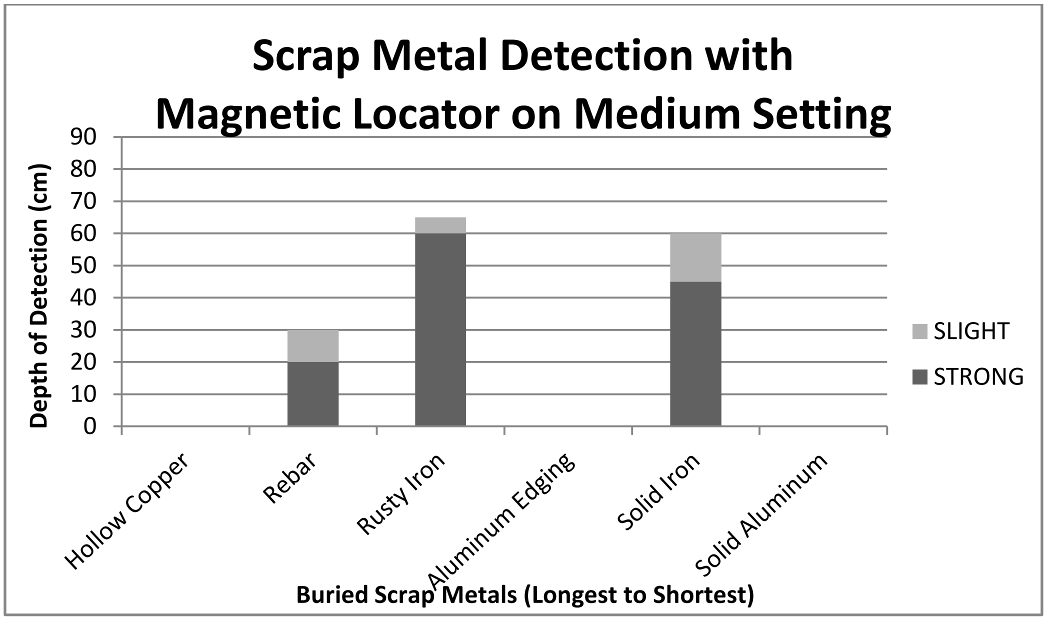

Figure 15: Results from Scrap Metal Detection with GA-72Cd on Normal Setting

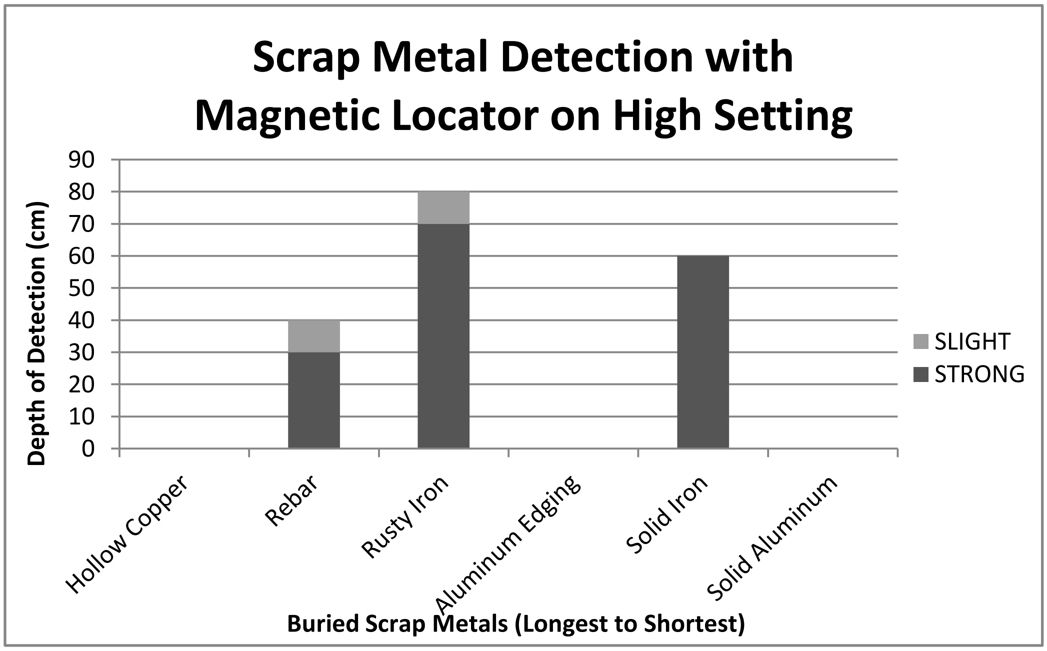

Figure 16: Results from Scrap Metal Detection with GA-72Cd on High Setting

Miscellaneous Weapons

Data collection on the buried miscellaneous weapons with the magnetic locator on Medium setting shows that nine out of ten miscellaneous weapons (90%) produced *strong* audible responses (Figure 17). Only the brass knuckles (F3) did not produce any audible response once buried, and were found to have only produced a *slight* audible response pre-burial. The weapon detected most strongly was the Philip's head screwdriver (F2) which produced a *strong* audible response down to a maximum depth of 70-75cm. Two weapons, the claw hammer (F4) and the scissors (E1), produced *strong* audible responses down to a maximum depth of 60-65cm, while the buck knife (E2) produced a *strong* audible response down to a depth of 25-30cm. The sword (F5), mallet (E4), the prybar (E3), and the baton (F1) produced *strong* audible responses down to a maximum depth of 15-20cm. Finally, the machete (E5) only produced a *strong* audible response down to a depth of 0-5cm.

Data collection on the buried miscellaneous weapons with the magnetic locator on High setting (Figure 18) shows that the Philip's head screwdriver (F2) produced a *strong* audible response down to a maximum depth of 80-85cm. The claw hammer (F4) and the scissors (E1) produced *strong* audible responses down to a maximum depth of 60-65cm. The sword (F5) produced a *strong* audible response down to a maximum depth of 40-45cm, while the Buck knife (E2) produced a *strong* audible response down to a maximum depth of 35-40cm. Three targets produced *strong* audible responses down to a maximum depth of 25-30cm: the machete (E5), prybar (E3), and baton (F1). Finally, the mallet (E4) produced a *strong* audible response only down to a maximum depth of 20-25cm. The brass knuckles (F3) only produced a *slight* audible response, down to a maximum depth of 0-5cm.

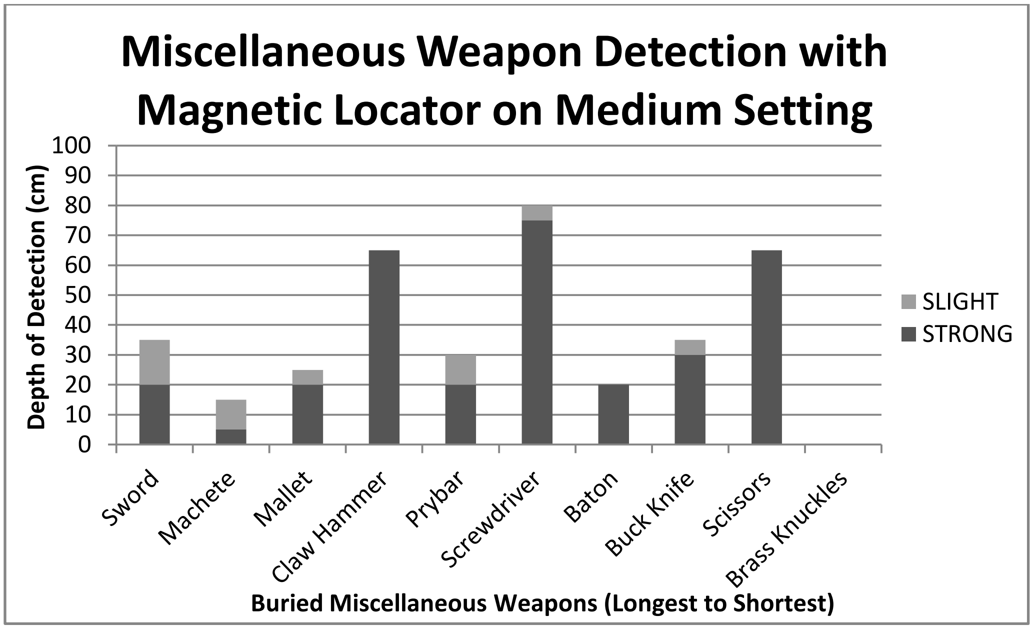

Figure 17: Results from Miscellaneous Weapon Detection with GA-72Cd on Normal Setting

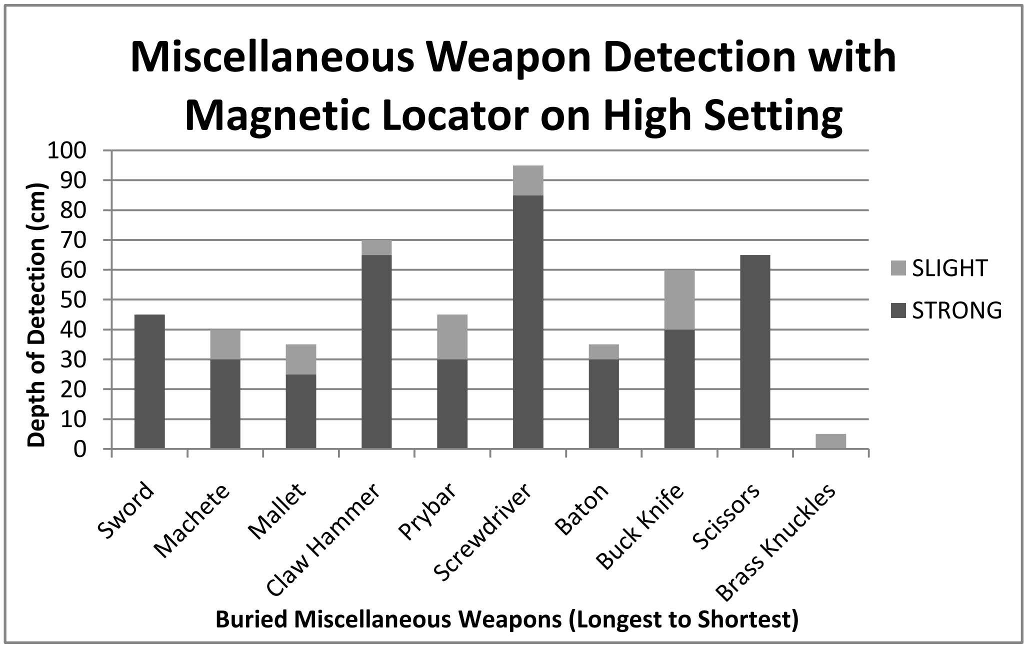

Figure 18: Results from Miscellaneous Weapon Detection with GA-72Cd on High Setting

Discussion

Both geophysical tools selected for this project proved to be easy for the author to use with little training; however, this does not mean to say that dependable, reproducible results will be achieved without proper training, simply that the machines are not difficult to operate. Owner's manuals (Fisher Research Laboratory, 2006; Schonstedt Instrument Company, 1998) provided answers to any questions that arose, and in-field adjustment was simple. A basic metal detector and/or a magnetic locator would therefore be suitable for law enforcement officials and forensic investigators with little or no prior experience with geophysical technologies.

Discussed below are only those results which concern the audible response of *strong*, as it is the most easily discernable response. *Slight* audible responses take more in-depth operator experience to tune one's ear to, as do the High settings, and should be interpreted with caution.

Data collection performed over the past two years utilizing the aforementioned geophysical technologies has yielded both expected and unexpected results. For both the all-metal detector and the magnetic locator, Normal/Medium and High levels allowed for detection and readings at multiple depths. As expected, the all-metal detector was able to detect each target, and the magnetic locator was able to detect ferric targets made of iron and steel and not those of non-ferric copper or aluminum composition (Fisher Research Laboratory, 2006; Schonstedt Instrument Company, 1998). Once deeper depths were reached, higher settings on both tools generally proved to be more helpful in *strong* detection of the targets.

As the purpose of this research entailed determining the maximum depth of detection for these selected targets, the concentration of discussion must therefore be on which factors aided or hindered detection. Several aspects of the research design affected detection: metal and size of the forensic targets, and detector settings.

Depth

When examining the effect of depth on the detection of forensic targets, there are several patterns which became apparent. On Normal/Medium settings, the all-metal detector did indeed detect all of metallic targets; however, many maximum depths of detection were shallower than those achieved by the magnetic locator. Once High settings were incorporated, the array of items detected for both tools were roughly the same as on Normal/Medium; however, the magnetic locator was still able to detect more targets down to deeper depths.

On Normal/Medium settings, the magnetic locator was more useful when *strongly* detecting the firearms at deeper depths, as three more firearms were detected past the 30-35cm benchmark of the metal detector, with two of those being *strongly* detected down to 45-50cm and 50-55cm, respectively (Tables 4-5; Figures 19-20). As suggested by the manufacturer, the magnetic locator was able to locate firearms down to 30.48cm, with 62% (8 of 13) being detected either *strongly* or *slightly* on Normal down to at least 30-35cm (Schonstedt Instrument Company, 1998).

On High settings, the all-metal detector and magnetic locator detected all 16 firearms s*trongly*, although to varying depths. The all-metal detector provided more consistent readings, and the shallowest detection was on the smallest three handguns at a maximum depth of 25-30cm. The magnetic locator detected the larger firearms deeper than the all-metal detector; however, the handguns were detected deeper with the all-metal detector as seven out of the 13 handguns (54%) were not detected as deeply with the magnetic locator as they were with the all-metal detector.

Table 4: Maximum Depth of Detection (in cm) for Firearms Comparing the All-metal Detector and Magnetic Locator on Normal/Medium Setting When Only Audible Responses Classified as Strong are Considered

Firearms	**All-Metal Detector (cm)**	**Magnetic Locator (cm)**
Norinco (C5)	25-30	45-50
Remington (G1)	30-35	50-55
Mossberg (D5)	25-30	25-30
S&W 686 (B3)	20-25	15-20
Ruger (G2)	20-25	15-20
Colt (B5)	25-30	40-45
S&W 5906 (A4)	20-25	20-25
Glock (A5)	15-20	15-20
Hi-Point (A3)	15-20	15-20
Lorcin L380 (B4)	15-20	Not Detected
Bryco 59 (B2)	15-20	10-15
S&W 37 (C1)	15-20	20-25
RG 23 (C2)	15-20	0-5
NA Arms (B1)	10-15	15-20
Raven Arms (A2)	15-20	Not Detected
Derringer (A1)	10-15	5-10

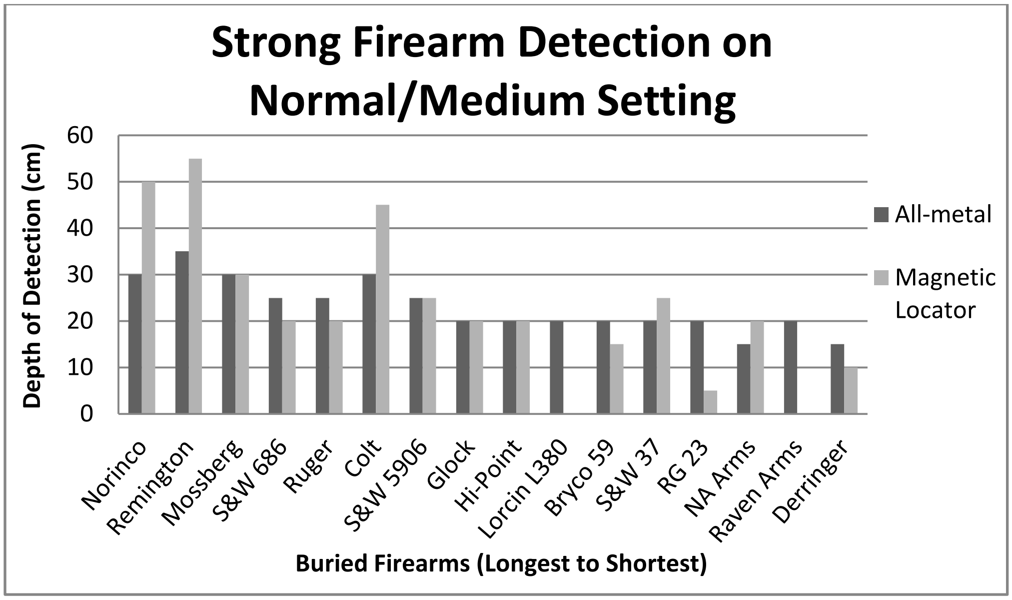

Figure 19: Comparison of Strong Detection of Firearms with All-metal Detector and Magnetic Locator on Normal and Medium Settings

Table 5: Maximum Depth of Detection (in cm) for Firearms Comparing the All-metal Detector and Magnetic Locator on High Setting When Only Audible Responses Classified as Strong are Considered

Firearms	**All-Metal Detector (cm)**	**Magnetic Locator (cm)**
Norinco (C5)	45-50	70-75
Remington (G1)	50-55	70-75
Mossberg (D5)	40-45	55-60
S&W 686 (B3)	35-40	30-35
Ruger (G2)	35-40	40-45
Colt (B5)	35-40	55-60
S&W 5906 (A4)	35-40	35-40
Glock (A5)	30-35	30-35
Hi-Point (A3)	35-40	25-30
Lorcin L380 (B4)	30-35	5-10
Bryco 59 (B2)	35-40	30-35
S&W 37 (C1)	30-35	30-35
RG 23 (C2)	30-35	10-15
NA Arms (B1)	25-30	25-30
Raven Arms (A2)	25-30	5-10
Derringer (A1)	25-30	20-25

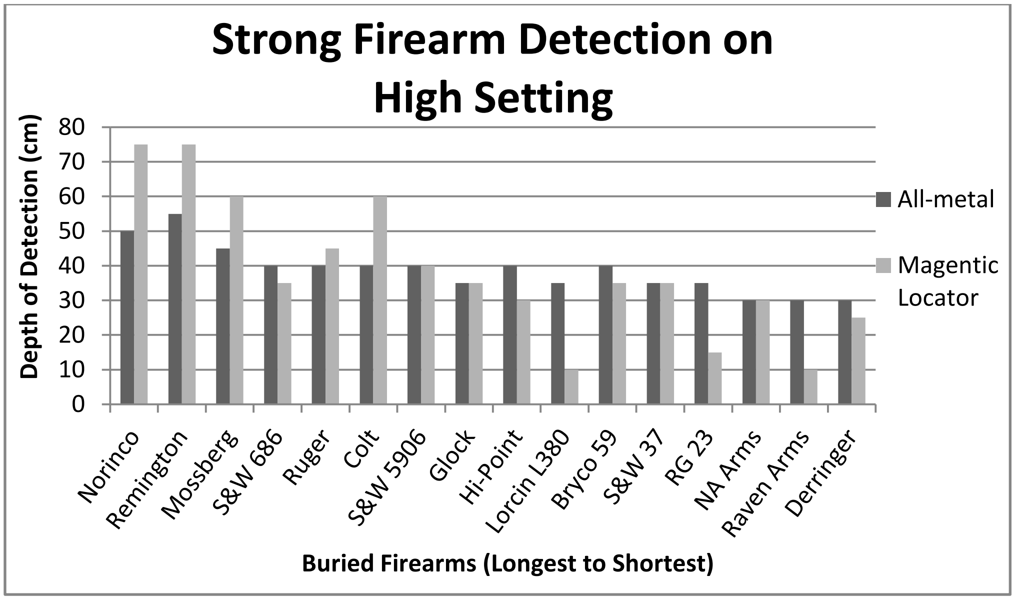

Figure 20: Comparison of Strong Detection of Firearms with All-metal Detector and Magnetic Locator on High Setting

The magnetic locator detected scrap metal targets deeper than the all-metal detector on both the Normal/Medium and High settings; however, as it is not designed to locate targets of a non-ferromagnetic nature, not all scrap metal targets were detected due to their metallic compositions (Tables 6-7; Figures 21-22). With the all-metal detector, two scrap metal targets produced *strong* responses down to a maximum depth of 25-30cm on Normal. On High, two scrap metal targets produced *strong* responses through the 40-45cm data collection. On Medium, the magnetic locator *strongly* detected only three scrap metal targets, down to 15-20cm, 55-60cm, and 40-45cm respectively. The scrap metal targets were then *strongly* detected with the magnetic locator on High, down to 25-30cm, 65-70cm and 55-60cm.

Table 6: Maximum Depth of Detection (in cm) for Scrap Metals Comparing the All-metal Detector and Magnetic Locator on Normal/Medium Setting When Only Audible Responses Classified as Strong are Considered

Scrap Metals	All-Metal Detector (cm)	Magnetic Locator (cm)
Hollow Copper (D1)	10-15	Not Detected
Rebar (D4)	15-20	15-20
Rusty Iron (D2)	25-30	55-60
Aluminum Edging (C3)	15-20	Not Detected
Solid Iron (C4)	25-30	40-45
Solid Aluminum (D3)	10-15	Not Detected

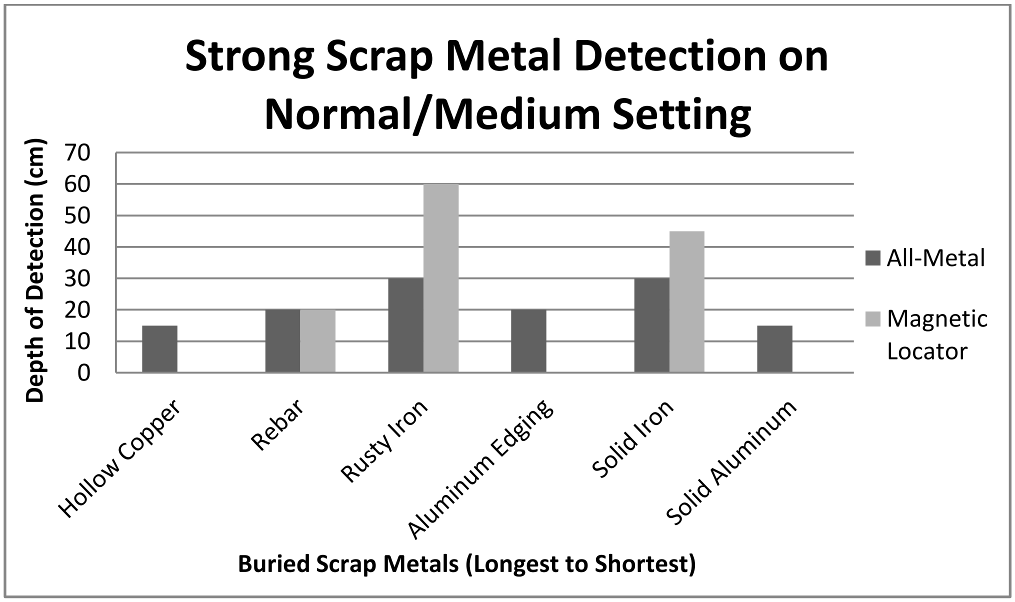

Figure 21: Comparison of Strong Detection of Scrap Metals with All-metal Detector and Magnetic Locator on Normal and Medium Settings

Table 7: Maximum Depth of Detection (in cm) for Scrap Metals Comparing the All-metal Detector and Magnetic Locator on High Setting When Only Audible Responses Classified as Strong are Considered.

Scrap Metals	All-Metal Detector (cm)	Magnetic Locator (cm)
Hollow Copper (D1)	25-30	Not Detected
Rebar (D4)	30-35	25-30
Rusty Iron (D2)	40-45	65-70
Aluminum Edging (C3)	30-35	Not Detected
Solid Iron (C4)	40-45	55-60
Solid Aluminum (D3)	20-25	Not Detected

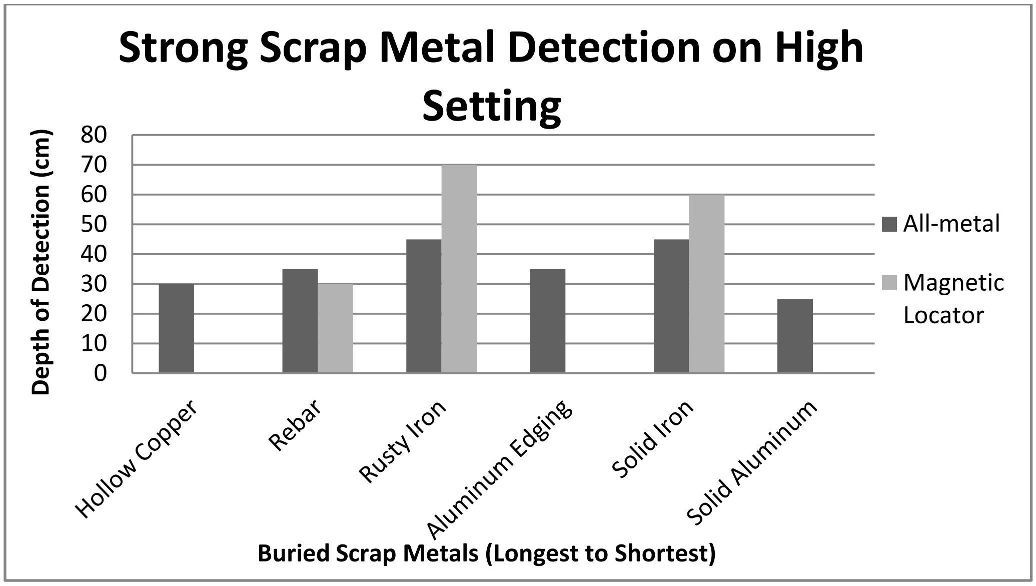

Figure 22: Comparison of Strong Detection of Scrap Metals with All-metal Detector and Magnetic Locator on High Settings

On Normal/Medium settings, the all-metal detector was better at detecting *strong* responses for the miscellaneous weapons, as the magnetic locator is not designed to detect the brass knuckles (Tables 8-9; Figures 23-24). However, three miscellaneous weapons produced *strong* responses deeper (70-75cm to 25-30cm) with the magnetic locator than with the all-metal detector. The same was noted for the High setting, as three miscellaneous weapons produced *strong* responses deeper with the magnetic locator than with the all-metal detector (80-85cm to 40-45cm).

Table 8: Maximum Depth of Detection (in cm) for Miscellaneous Weapons Comparing the All-metal Detector and Magnetic Locator on Normal/Medium Setting When Only Audible Responses Classified as Strong are Considered

Miscellaneous Weapons	**All-Metal Detector (cm)**	**Magnetic Locator (cm)**
Sword (F5)	20-25	15-20
Machete (E5)	20-25	0-5
Mallet (E4)	20-25	15-20
Claw Hammer (F4)	25-30	60-65
Prybar (E3)	15-20	15-20
Screwdriver (F2)	5-10	70-75
Baton (F1)	20-25	15-20
Buck Knife (E2)	10-15	25-30
Scissors (E1)	10-15	60-65
Brass Knuckles (F3)	10-15	

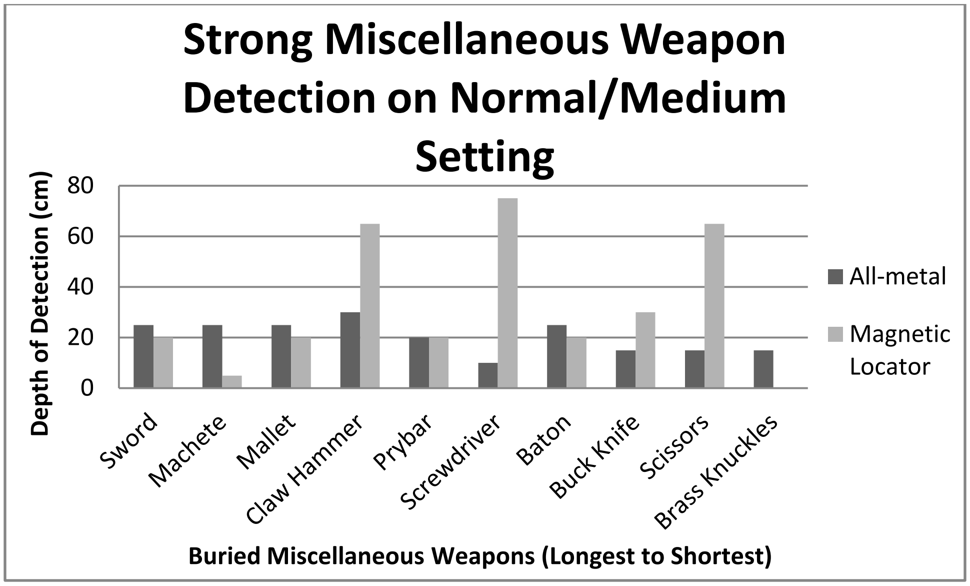

Figure 23: Comparison of Strong Detection of Miscellaneous Weapons with All-metal Detector and Magnetic Locator on Normal and Medium Settings

Table 9: Maximum Depth of Detection (in cm) for Miscellaneous Weapons Comparing the All-metal Detector and Magnetic Locator on High Setting When Only Audible Responses Classified as Strong are Considered

Miscellaneous Weapons	All-Metal Detector (cm)	Magnetic Locator (cm)
Sword (F5)	35-40	40-45
Machete (E5)	35-40	25-30
Mallet (E4)	35-40	20-25
Claw Hammer (F4)	40-45	60-65
Prybar (E3)	30-35	25-30
Screwdriver (F2)	15-20	80-85
Baton (F1)	30-35	25-30
Buck Knife (E2)	25-30	35-40
Scissors (E1)	25-30	60-65
Brass Knuckles (F3)	25-30	

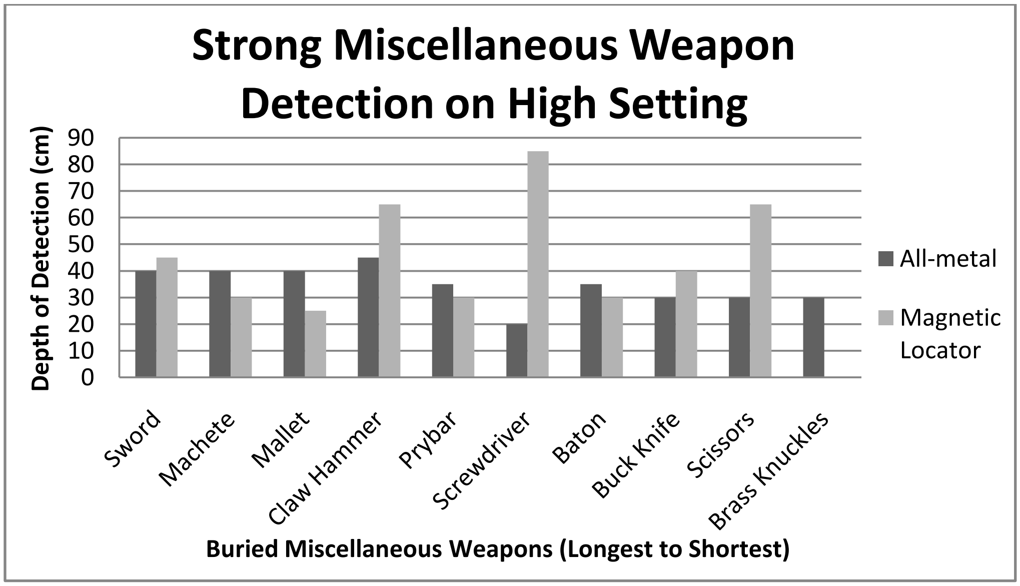

Figure 24: Comparison of Strong Detection of Miscellaneous Weapons with All-metal Detector and Magnetic Locator on Normal and Medium Settings

Metal

It was noted in a number of instances that metallic composition has an effect on detection. As expected, metal composition was an issue using the magnetic locator. The magnetic locator is designed to detect ferromagnetic metals and ignore non-ferromagnetic metals. Not only was metallic composition a factor in the obvious cases of the copper and aluminum targets not being detected with the magnetic locator, but also other instances where the magnetic locator did not detect a target as strongly as the all-metal detector.

The most striking instances where metal composition was a factor with detection of firearms using the magnetic locator included the Lorcin L380 (B4), and Raven Arms MP-25 (A2). Both of these weapons were only detected down to 5-10cm using the High setting. Although these are two of the smallest weapons, it is not surprising that there was shallow detection based on the metallic materials comprising the weapons. The Lorcin L380 (B4) is comprised of an aluminum frame and magazine. The Raven Arms MP-25 (A2) is primarily comprised of a zinc alloy with an aluminum clip. Zinc is classified as a diamagnetic alloy that weakly repels magnetic fields, and aluminum objects are not supposed to be detected by the magnetic locator. Conversely, the Jennings Bryco 59 (B2), which is also comprised of a zinc alloy, was detected much deeper than the Raven Arms MP-25 (A2) at 30-35cm because the clip is made out of steel. In addition, the second largest handgun, the Ruger P89 (G2), was detected at a shallower depth with the magnetic locator than the all-metal detector using the Medium/Normal setting and was not detected any deeper using the high setting. This detection limit is not surprising considering that the Ruger P89 (G2) is comprised of aluminum and stainless steel. Also, while the frame for the RG Industries RG23 (C2) is comprised of aluminum, the weapons were detected deeper than the Lorcin L380 (B4) and the Raven Arms MP-25 (A2) at 30-35cm because the barrel and cylinder are comprised of steel. The NA Arms Mini-Magnum (B1) also stands out as being detected to a deep maximum depth with the magnetic locator. As it is the third smallest handgun, the fact that it was detected past 20cm on Medium leads the author to believe that the iron content in the steel composition is high.

The reduced detection of items comprised of non-ferrous materials is further demonstrated by a number of other items that were tested. For example, the two pieces of aluminum scrap metal (C3 and D3) and the hollow copper pipe (D1) were not detected with the magnetic locator on either the Medium or High settings. Furthermore, the brass knuckles (F3) were not detected with a *strong* hit using either the Medium or High settings.

On Normal/Medium setting, the all-metal detector proved better at detecting the scrap metals, as all six scrap metal targets could be detected with *strong* hits. As expected, the magnetic locator was able to detect those scrap metal targets which have ferrous content (solid iron pipe (C4), rusty iron pipe (D2), and rebar (D4)) and not those of copper or aluminum composition (the hollow copper tube (D1), solid aluminum pipe (D3), and aluminum edging (C3)). This would actually make the magnetic locator a more efficient tool in forensic weapons searches; even though items of similar metallic composition may be detected, false hits on scrap metals would be limited when searching for a potential firearm.

Miscellaneous weapon detection produced better results on the all-metal detector; however, only the brass knuckles failed to produce a *strong* response on Normal/Medium and High. As brass is composed of copper and zinc, making it less magnetic than the steel used for the remaining weapons included in this project, it is clear why the magnetic locator would not locate the brass knuckles as strongly as the other weapons (Schonstedt Instrument Company, 1998). The screwdriver seems to be an anomaly, as it is a smaller target, but detected the deepest out of every other target with either the all-metal or magnetic locator. Maximum *strong* depth of detection for the screwdriver with the magnetic locator is 70-75cm on Medium and 80-85cm on High. After speaking with a representative from the manufacturer (pers. Comm. Mark Pugh, Jan. 28, 2009), the suspicion by the author that the iron content in the steel composition of the screwdriver may be high, and that the screwdriver was most likely magnetized were confirmed. Since the magnetic locator is designed to detect objects that can be magnetized, it would make sense that an object that is already magnetized would be detected deeper than an object which is not.

Size

Size was also a factor affecting detection of the weapons; as targets were buried on their sides to increase surface area, size is referring only to overall length. As expected, the all-metal detector follows a pattern of detecting larger items deeper than smaller targets. The magnetic locator, however, seems to detect ferric items deeper, regardless of size. As the magnetic locator is designed to locate ferric items, those results are expected (Schonstedt Instrument Company, 1998).

Conclusions

Controlled research using geophysical technologies has proven that they are beneficial tools in the search for buried metallic weapons, including firearms. Objectives constructed for this research were all answered, and provide valuable information regarding the utility of basic all-metal detectors and magnetic locators in the search for buried metallic weapons. Both the all-metal detector and the magnetic locator proved easy to use in their recommended capacities with little operator training, the effects of burial on target detection and maximum depth of detection for each target with both tools have been explained above, as has the difference between each tool in specific target detection. Although tools acquired by law enforcement agencies may not be the exact models utilized for this research, it was basic metal detector and magnetic locator properties that were tested, and results may be extrapolated to other models.

Data collection performed over the past two years utilizing the aforementioned geophysical technologies has yielded both expected and unexpected results. For the all-metal detector and the magnetic locator, medium/normal levels allowed for detection and readings at multiple depths. The all-metal detector was able to detect each metallic target in the project, although to varying depths. As expected, and for both pre-burial and buried objects, the magnetic locator was able to detect ferric objects made of iron and steel and not those of copper or aluminum composition. Once deeper depths were reached, higher settings proved to be more helpful in detecting the targets.

Overall, the all-metal detector provides a greater range of detected targets than the magnetic locator (32 to 28); however, this includes a greater detection of scrap metals with the all-metal detector. The magnetic locator is a very useful tool as it limits the amount of scrap metal detection, saving time and energy by eliminating many false targets. The magnetic locator has also demonstrated a greater depth range on the firearms, and is most appropriate when searching for targets with suspected or known ferrous content.

LIST OF REFERENCES

Brady NC, Weil RR. 2002. The nature and properties of soil. Upper Saddle, River, NJ: Prentice Hall.

Connor M, Scott DD. 1998. Metal detector use in archaeology: an introduction. Historical Archaeology 32(4):76-85.

Davenport GC, France DL, Griffin TJ, Swanburg JG, Lindemann JW, Tranunell V, Armbrust CT, Kondrateiff B, Nelson A, Castellano K, and Hopkins D. 1992. A multidisciplinary approach to the detection of clandestine graves. J Forensic Sci 37(6):1445-1458.

Davenport GC. 2001. Remote sensing applications in forensic investigations. Historical Archaeology 35(1):87-100.

Doolittle JA, Schellentrager G. 1989. Soil survey of Orange County, FL. United States Department of Agriculture, National Cooperative Soil Survey.

Dupras TL, Schultz JJ, Wheeler SM, Williams LJ. 2006. Forensic recovery of human remains: archaeological approaches. Boca Raton, FL: CRC Press, Taylor and Francis Group.

Fisher Research Laboratory. n.d. Fisher m-scope M-97 valve, pedestal, and box locator: operating manual. Los Banos, CA: Fisher Research Laboratory.

France DL, Griffin TJ, Swanburg JG, Lindemann JW, Davenport GC, Trammell V, Travis CT, Kondratieff B, Nelson A, Castellano K, Hopkins D, and Adair T. 1997. NecroSearch revisited: further multidisciplinary approaches to the detection of clandestine graves. In: Haglund WD, Sorg MH, editors. Forensic taphonomy: the postmortem fate of human remains. Boca Raton, FL: CRC Press. pp 497-509.

Garrett CL. 1998. Modern metal detectors. Dallas: Ram Publishing.

Goddard KW. 1977. Crime scene investigation. Reston, VA: Reston Publishing.

Hunter J and Cox M. 2005. Forensic archaeology: advances in theory and practice. London: Routledge.

Isaacson J, Hollinger RE, Gundrum D, and Baird J. 1999. A controlled test site facility in Illinois: training and research in archaeogeophysics. Journal of Field Archaeology 26(2):227-236.

Killam EW. 2004. The detection of human remains. Springfield, IL: Charles C. Thomas.

Murray RC, Tedrow JCF. 1975. Forensic geology: earth sciences and criminal investigation. New Brunswick, NJ: Rutgers University Press.

Nelson CV. 2004. Metal detection and classification technologies. Johns Hopkins APL Technical Digest 25(1):62-67.

Nickell J and Fischer JF. 1999. Crime scene methods of forensic detection. Lexington: The University Press of Kentucky.

Nielsen E. 2003. Metal detectors at the crime scene. Law and Order 51(12):78-81.

Rowlands A, Sarris A. 2007. Detection of exposed and subsurface archaeological remains using multi-sensor remote sensing. Journal of Archaeological Science 34:795-803.

Ruffell A, McKinley J. 2005. Forensic geoscience: applications of geology, geomorphology and geophysics to criminal investigations. Earth-Science Reviews 69:235-247.

Schonstedt Instrument Company. 1998. Instruction manual: model GA-72Cd magnetic locator. Kearneysville, WV: Schonstedt Instrument Company.

Schultz JJ, Collins ME, Falsetti AB. 2006. Sequential monitoring of burials containing large pig cadavers using ground-penetrating radar. J Forensic Sci 51(3):607-616.

Schultz JJ. 2007. Using ground-penetrating radar to locate clandestine graves of homicide victims: forming forensic archaeology partnerships with law enforcement. Homicide Studies 11(11):15-29.

Scott DD, Fox RA, Jr., Connor MA, and Harmon, D. 1989. Archaeological perspectives on the Battle of Little Bighorn. Norman, OK: University of Oklahoma Press.

III. CONTROLLED RESEARCH UTILIZING AN ADVANCED METAL DETECTOR

With technologies utilized in forensics and death investigations advancing in general, it is no surprise that geophysical technologies that are incorporated into forensic searches are becoming more advanced as well. Whether being used to search for buried bodies (ground penetrating radar (GPR), conductivity meters) or metallic evidence (metal detectors, magnetic locators), geophysical methods are generally used to locate small anomalies near the ground surface (Davenport et al., 1992; Davenport, 2001; Dupras et al., 2006; Fisher Research Laboratory, n.d.; France et al., 1997; Garrett, 1998; Goddard, 1977; Hunter and Cox, 2005; Isaacson et al., 1999; Killam, 2004; Minelab Electronics Pty Ltd, n.d.; Murray and Tedrow, 1975; Nelson, 2004; Nickell and Fischer, 1999; Nielsen, 2003; Rowlands and Sarris, 2007; Ruffell and McKinley, 2005; Schonstedt Instrument Company, 1998; Schultz et al., 2006; Schultz, 2007; Scott et al., 1989).

Many sources support the use of geophysical tools for the search and recovery of buried metallic evidence (Connor and Scott, 1998; Davenport, 2001; Dupras et al., 2006; Garrett, 1998; Goddard, 1977; Hunter and Cox, 2005; Isaacson et al., 1999; Nelson, 2004; Nickell and Fischer, 1999; Nielson, 2003; Scott et al., 1989); however, there have been no published controlled geophysical research studies that have tested the utility of locating buried firearms and weapons using geophysical technologies, specifically advanced metal detectors. Only a few references (Murray and Tedrow, 1975; Nielsen, 2003; Schonstedt Instrument Company, 1998) briefly discuss locating weapons using a metal detector or magnetic locator, although no information is provided for size or metallic composition.

Metal detectors, in particular, are non-intrusive geophysical technologies that have a long history of use in forensic contexts (Davenport, 2001; Dupras et al., 2006; Garrett, 1998; Goddard, 1977; Isaacson et al., 1999; Murray and Tedrow, 1975; Nelson, 2004; Nickell and Fischer, 1999 Nielson, 2003). Metal detectors are generally used to locate small objects at shallow depths and large objects at deeper depths (Connor and Scott, 1998; Garrett, 1998; Nelson, 2004; Nielsen, 2003; Scott et al., 1989). Basic all-metal detectors are used by prospectors, treasure hunters, relic seekers, and novices along the beach (Garrett, 1998), while new, computerized advanced metal detectors are mostly used by people looking to control what they detect and do not detect through the use of metal discrimination (Brockett, 1990; Garrett, 1998; Minelab Electronics Pty Ltd, n.d.; Nelson, 2004;). Metal discrimination allows advanced detectors to recognize the user's identified target, blocking signals from all other materials and providing a great advantage over a basic all-metal detector. This allows for select targets to be ignored, making detection of the sought after objects quicker and easier (Brockett, 1990; Fisher Research Laboratory, n.d.; Garrett, 1998; Minelab Electronics Pty Ltd, n.d.; Nelson, 2004; Nielsen, 2003). However, due to its multiple features and ability to be programmed by the user, therefore increasing user error, the advanced metal detector requires more operator training and efficiency to reach its maximum effectiveness (Garrett, 1998).

A second component of metal detectors is that many different types of search coils are available to meet the needs of the user. Smaller coils (<6") are generally used to locate small items at shallow depths, while larger coils (>10") are generally used when searching deeper depths for larger targets, providing a wide range of options so that a user may choose a coil to suit their investigative needs (Connor and Scott, 1998; Dupras et al., 2006; Garrett, 1998; Hunter and Cox, 2005; Nielsen, 2003). Considering that the weapons utilized in the current research are larger than most items hobbyists commonly search for, it may be inferred that larger coils would be more beneficial when detecting such weapons, especially at greater depths.

Purpose

The paucity of published controlled research focusing on locating buried firearms and miscellaneous weapons using advanced metal detectors, and the impact of search coil size on such searches, led to the construction of the following research study. In order to test the utility of an advanced metal detector at a crime scene or a suspected weapon burial site, controlled testing of 32 buried objects, including firearms, was performed. The advanced metal detector was incorporated in order to determine whether or not the unique attributes of metal discrimination and specialized target programming features would make the more expensive advanced metal detector a necessity for law enforcement agencies. The objectives of this research were:

- To determine what effects the metallic composition of the weapons have on signature readings and their detection
- To determine maximum depth at which these targets may be detected with the advanced metal detector
- To determine if larger search coils provide better depth results than medium coils
- To provide guidelines to forensic investigators using advanced metal detectors so that they are better prepared to search for buried firearms

Materials and Methods

Research Site

An undeveloped, flat, open section of the Orange County Sheriff's Office (OCSO) Lawson Lamar Firearms and Tactical Training Center in Orlando, Florida was designated as the research site for this project (Figure 25). Centered in the overflow portion for a retention pond, the research area is frequently mowed, but otherwise inactive. Soil in the research area is classified as a spodosol, specifically in the Smyrna series, which consists of poorly drained soils with spodic horizons (dark organic layers which may consist of aluminum, carbon, and/or iron) which have formed in sandy marine sediment (Doolittle and Schellentrager, 1989). However, when the range was developed, extra fill was incorporated into the area to raise the ground surface.

Figure 25: Aerial Photograph of Lawson Lamar Firearms and Tactical Training Center in Orlando, Florida. The Research Site (White Square) is located at 28°25'11.28" N 81°10'25.07" W.

The research area contained a total of 32 buried metallic objects and three control holes (consisting of only backfill) in a grid of seven rows (Figure 26). Each row contains five buried targets, except for rows D and G. Row D contains a total of seven holes, which includes five buried targets and two control holes, and row G contains only two buried targets and one control hole. Rows A and B contain strictly buried firearms (10), rows C and D contained both firearms (3,1) and scrap metal (2,4), rows E and F housed only blunt or edged metal weapons (10), and the final row was added to incorporate two additional firearms and a third control hole. Burial holes were marked with bright orange plastic stakes as metallic flags would have interfered with results.

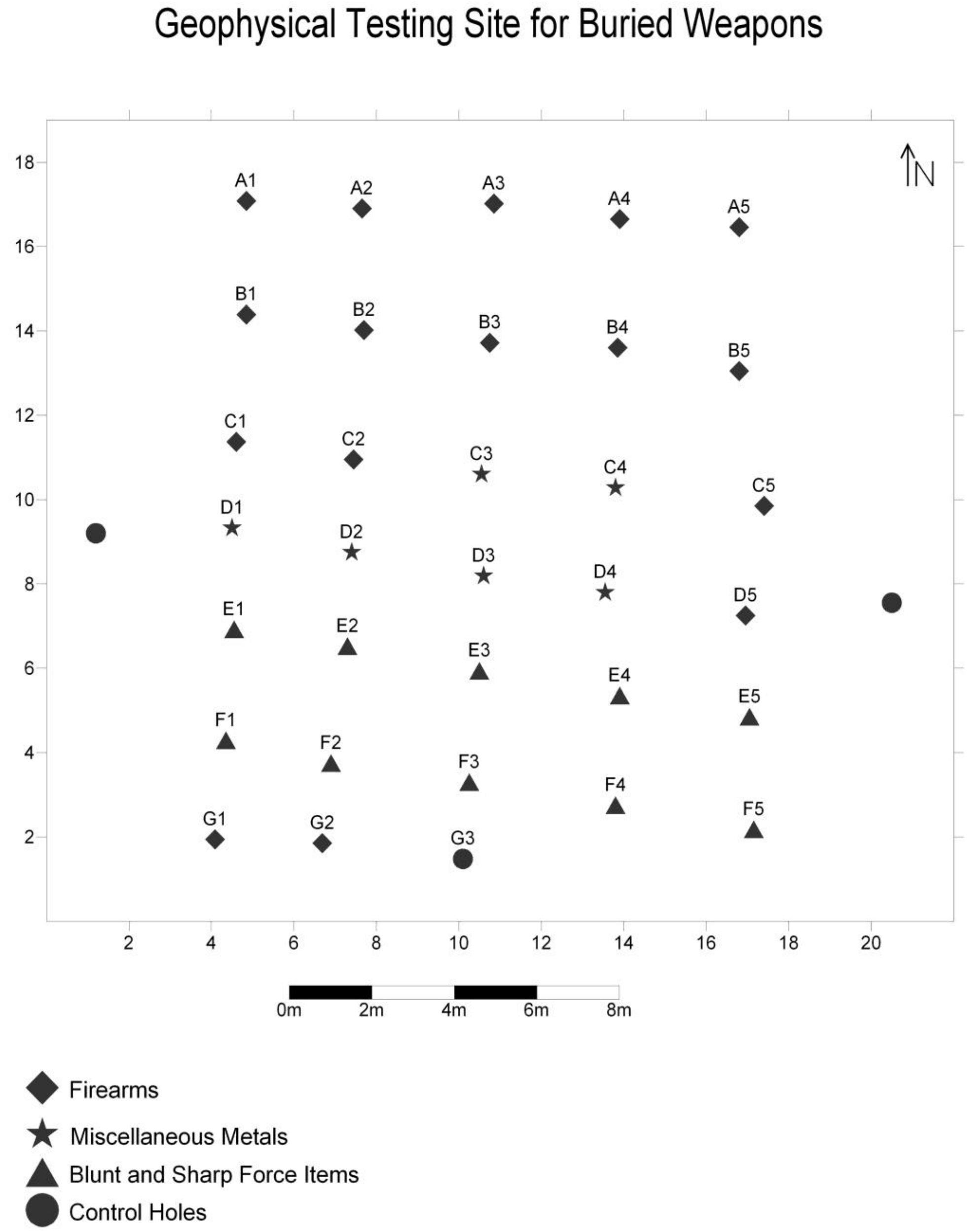

Figure 26: Map of Research Area Containing a Total of Thirty-two Buried Metallic Objects and Three Control Holes. Map Created Using Surfer ® Software.

Forensic Targets

Included in this research were sixteen firearms, six pieces of assorted scrap metals, and ten blunt or edged weapons (Figures 27-29). In order to gain access to the weapons for research, all protocols outlined by the OCSO's security procedures, including the decommissioning of the firearms, were followed. Firearms were decommissioned by removing or filing firing pins and blocking the firing pin channel and barrel with JB Weld® cold-weld liquid epoxy compound. Of note is A5, the Glock 9mm; due to the minimal amount of metal in the polymer frame, the firing pin was removed and welded into the grip, and both the firing pin channel and barrel were blocked.

Firearms

A collection of firearms most commonly associated with street-level crime in Central Florida were provided for this research by the Orange County Sheriff's Office, and consist of a derringer, eight pistols, four revolvers, two shotguns, and a rifle (Figure 27; Table 10). The firearms selected represent a variety of metallic compositions, finishes, and lengths. The majority of the firearm frame compositions consist of steel, with several utilizing other metals or materials, such as zinc, aluminum, or polymer.

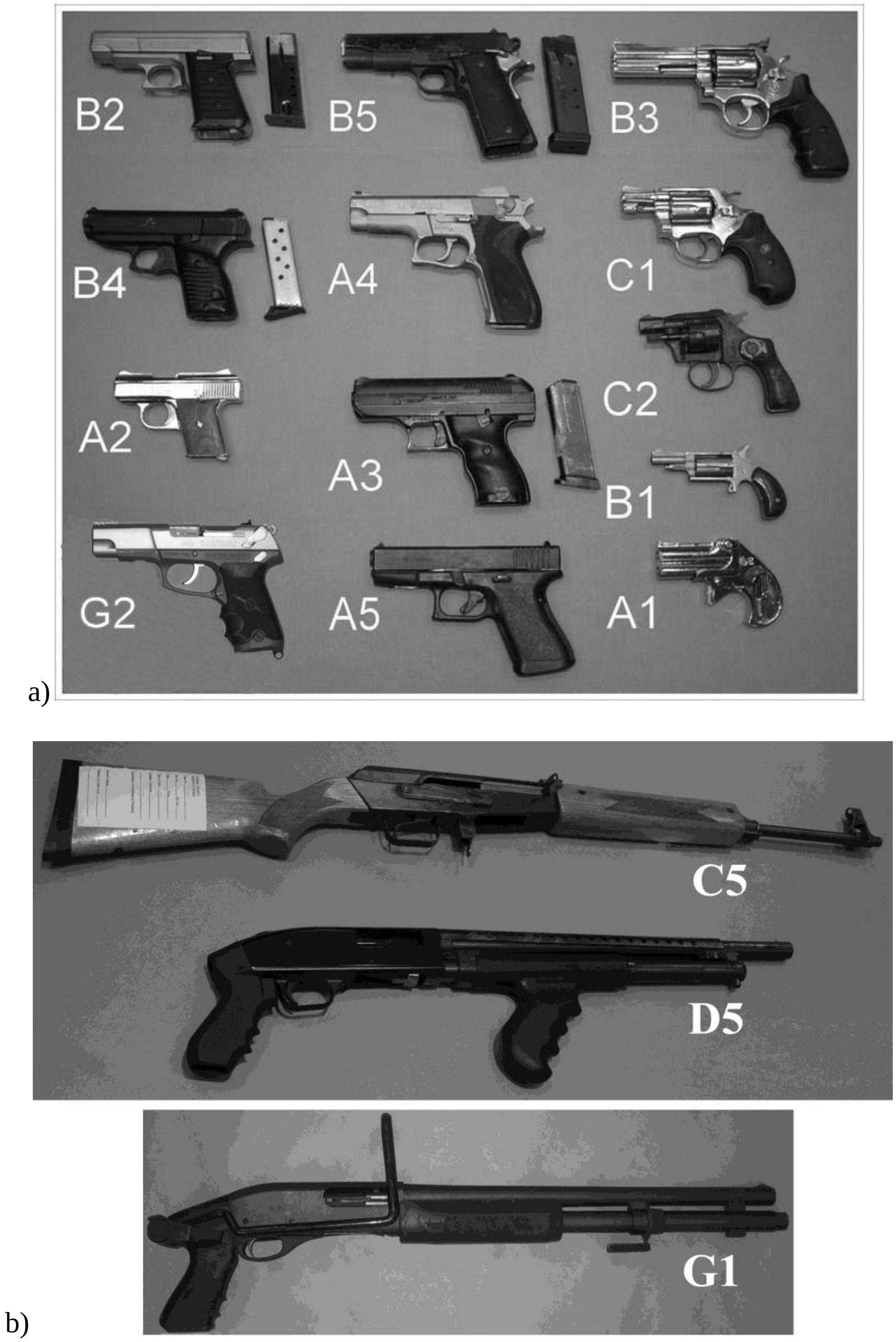

Figure 27: Sixteen Decommissioned Firearms Utilized in the Project. a) Thirteen Handguns, b) Rifle and two Shotguns

Table 10: Firearms

Burial Grid Location	Firearm	Type	Metal/ Composition	Special Finish	Length (mm)	Unloaded Weight (oz.)
A1	Davis Derringer D9	Derringer/ 9mm	Steel	Chrome-plated	119	12.8
A2	Raven Arms MP25	Pistol/.25	Zinc Alloy/Steel	Chrome-plated	123	14.4
A3	Hi-Point Model C	Pistol/9mm	Steel/Polymer	Blued	178	35
A4	Smith & Wesson 5906	Pistol/9mm	Stainless Steel		190	38.3
A5	Glock Model 19	Pistol/9mm	Polymer Frame/ Steel Slide and Firing Pin	Blued/Tenifer	187	20.6
B1	North American Arms Mini-Magnum	Revolver/ .22 Magnum	Stainless Steel		130	6.4
B2	Jennings Bryco 59	Pistol/9mm	Zinc Alloy/Steel Magazine	Satin Nickel-plated	170	33.6
B3	Smith & Wesson Model 686	Revolver/ .357 Magnum	Stainless Steel		235	37
B4	Lorcin L380	Pistol/ .380	Aluminum Frame, Magazine, Slide/ Steel	Blued	171	30.4
B5	Colt Commander	Pistol/ .45 ACP	Steel	Blued	196	27
C1	Smith & Wesson Model 37	Revolver/ .38 Special	Steel	Nickel-plated	167	25
C2	RG Industries RG23	Revolver/ .22 Long rifle	Aluminum Frame/Steel Barrel and Cylinder	Blued	148	14.4
C5	Norinco AK Hunter	Rifle/ 7.62	Steel/Polymer	Blued	1067	125.5 With Stock
D5	Mossberg Model 500A with Knoxx COPStock	Shotgun/ 12 Gauge	Steel/ Polymer	Blued	711	96
G1	Remington 870	Shotgun/ 12 Gauge	Steel	Parkerized	762	120
G2	Ruger P89	Pistol/9mm	Aluminum/ Stainless Steel	Terhune Anticorro	203	32

Scrap Metals and Miscellaneous Weapons

The scrap metals include pieces of copper, aluminum, and iron (including rebar), representing trash metals which are frequently encountered during weapons searches (Figure 28; Table 11). A variety of blunt (mallet, hammer, prybar, baton, brass knuckles) and edged (machete, sword, Buck knife, Philip's head screwdriver, scissors) weapons which have been recovered from OCSO crime scenes were also included, and primarily consist of steel (Figure 29; Table 12).

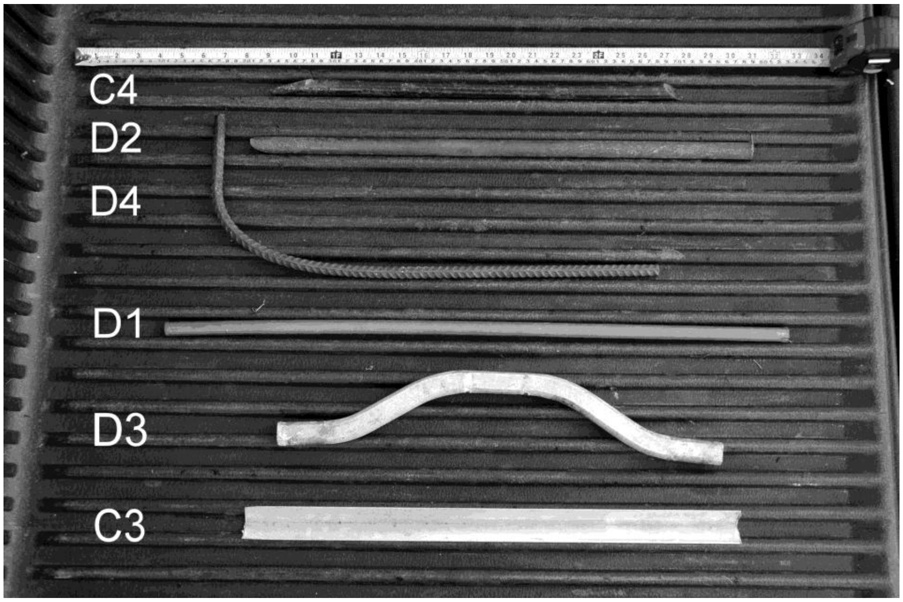

Figure 28: Six Pieces of Assorted Scrap Metals Utilized in the Project

Table 11: Scrap Metals

Burial Grid Location	Type	Metal/Composition	Length (cm)
C3	Aluminum Edging	Aluminum	53
C4	Solid Iron Pipe	Iron	48
D1	Hollow Copper Tube	Copper	68.5
D2	Rusty Iron Pipe	Iron	57
D3	Solid Aluminum Pipe	Aluminum	47.7
D4	Rebar	Iron	66.5

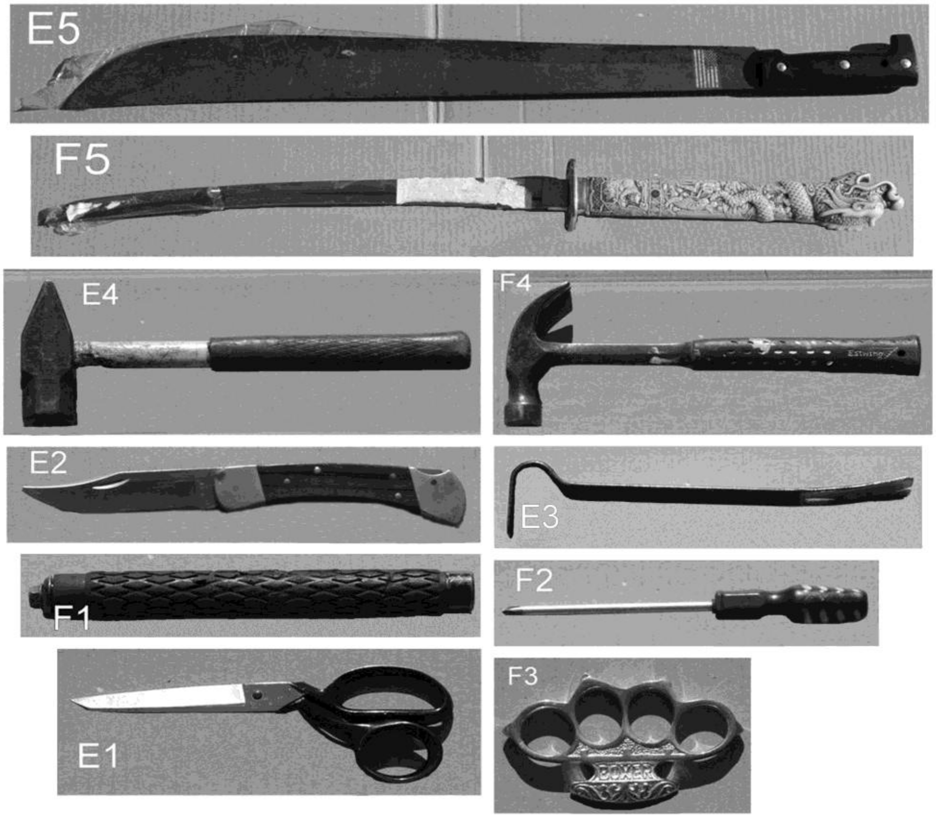

Figure 29: Ten Blunt and Edged Weapons Utilized in the Project

Table 12: Blunt and Edged Miscellaneous Weapons

Burial Grid Location	Type	Metal/Composition	Length (cm)
E1	Scissors	Steel	20
E2	Buck Knife	Stainless Steel	22.2
E3	Prybar	Steel	32.2
E4	Mallet	Steel	38.4
E5	Machete	Steel	68.2
F1	Baton	Steel	25.7
F2	Philip’s Head Screwdriver	Steel	26.2
F3	Brass Knuckles	Brass (Copper and Zinc)	11.6
F4	Claw Hammer	Steel	35
F5	Sword	Steel	81

Geophysical Tool: Minelab Explorer II^{TM}

Metal detectors transmit electromagnetic fields which penetrate the material surrounding the search coil - be it soil, sand, rock, wood, brick, stone, masonry, water, concrete, vegetable, some mineral sources, or air. If the electromagnetic field interacts with a metal, eddy currents will form, creating a secondary field that transmits a detection signal back to the receiver in the unit (Connor and Scott, 1998; Dupras et al., 2006; Garrett, 1998; Nelson, 2004; Nielson, 2003).

The Minelab Explorer II^{TM} advanced metal detector used in this research project has specific metal discrimination capabilities, and also has a specific Learn function wherein signature ranges determined for the weapons and/or metals may be loaded into the machine for easy discrimination upon searching (Figure 30a) (Minelab Electronics Pty Ltd, n.d.). The Explorer II is a rugged, simple to use all-metal detector which utilizes a standard 10.5" Double-D search coil to identify metallic objects by providing both visual and audio responses. According to the manufacturer, the Explorer II is "designed to locate valuable metal objects in a wide variety of ground conditions" (Minelab Electronics Pty Ltd, n.d.: 3).

A second coil was used on the Explorer II in this research: a manufacturer-specific Coiltek 15" after-market coil (Figure 30b). Larger coils are generally used when searching deeper depths for larger targets, so the ability of the after-market coil to detect all targets once deeper depths were reached was tested (Connor and Scott, 1998; Dupras et al., 2006; Garrett, 1998; Hunter and Cox, 2005; Nielsen, 2003).

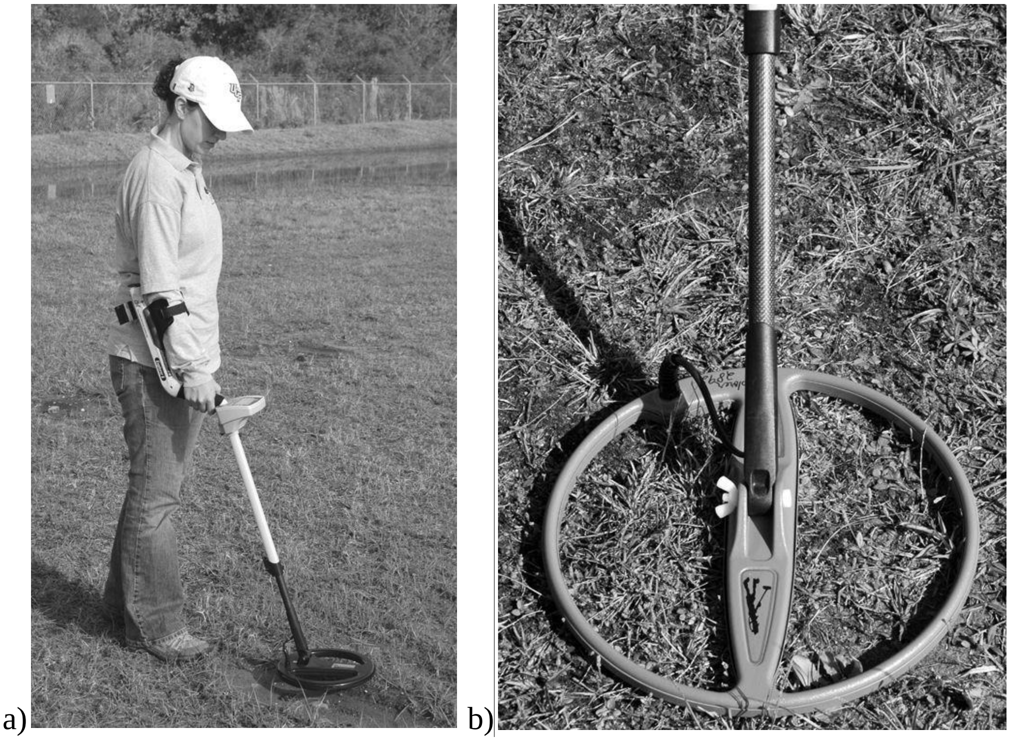

Figure 30: Minelab Explorer II. a) Standard Medium 10.5" Coil; b) Large 15" Coil

Improving upon the single and dual frequency Broad Band Spectrum (BBS) technology of previous metal detectors, the manufacturer asserts that the Explorer II employs a 28 frequency Full Band Spectrum (FBS) detection system (Minelab Electronics Pty Ltd, n.d.). The advantages to this technology are increased depth detection, accurate target identification at those greater depths, improved detection of desired targets among iron trash, greater recognition of ground mineralization, enhanced searching on beaches (salt-water), less background interference from nearby electromagnetic sources, and more accurate identification of target characteristics, including size.

The Explorer II is held and maneuvered as any other metal detector, low and even to the ground in a swaying motion. When an object is located, the pitch of the detector's hum will increase, with highly conductive objects emitting high-pitched sounds and low-pitched tones being emitted by less conductive, more ferrous, objects. Large targets or targets close to the ground surface will emit louder signals. The frequency of the Explorer II ranges from 1.5-100 kHz. Explorer II has two modes: Quickstart and Advanced (Minelab Electronics Pty Ltd, n.d.):

- Quickstart automatically loads the factory presets, which sound as a 6-note musical tone when the machine is started. Providing audible and visual cues (in the form of ferrous content and conductivity values displayed numerically on the screen), Quickstart was utilized at the beginning stages of this project due to being inherently basic. As many law enforcement agencies do not provide training on these devices, the quick and easy approach to detection found in the Quickstart factory presets is highly beneficial.
- Advanced mode allows for the specification of custom targets, enabling the user to edit and save target profiles in order to recognize those objects and reject others. The ability of a metal detector to identify a desired target while eliminating unwanted signals is known as discrimination, and is programmable in the Explorer II. Advanced mode was used in later stages of this project to program any “signature” ranges determined for a carefully selected segment of targets.

Data Collection Parameters

Objectives of data collection consisted of 1) simple detection of the targets, 2) obtaining ferrous content and conductivity readings using the Quickstart method, and 3) programming signature metallic composition patterns using the Advanced Learn feature to test if all targets could be recognized against specific targets of known metallic compositions. Control readings of detection and ferrous content/conductivity were taken for each object, and six specific known metallic composition signature patterns were obtained with the advanced metal detector prior to target burial. The targets were first buried at depths of 20-25cm, and depths were then increased by 5cm each re-burial until detection by the geophysical tool was no longer possible. First, it was determined whether the buried forensic target was detected at specific depths using both coils. Second, the ferrous content and conductivity values were recorded using the standard coil. Third, the Advanced Learn feature was utilized with the standard coil pre-burial to program the signature patterns of a selection of six targets representing the firearm sample in order to test if each target would be detected by a specific metallic composition. In addition, a number of targets were not detected at the 20-25cm depth, and were therefore individually re-buried starting at 0-5cm until a maximum depth of detection was determined.

The Explorer II was initially used in the manufacturer’s recommended “turn on and go” (Quickstart) setting to provide information regarding basic detection of the targets. Quickstart uses factory presets for Discrimination (non-ferrous coin-type targets) and Iron Mask (-6, non-ferrous metals). Swinging the detector side-to-side, low and even to the ground, the normal hum of the detector would become various tonal beeps and the Quickstart Digital display screen showed numerical values when a metallic object was encountered. The Explorer II was used with a digital display in this project, indicating the ferrous content and conductivity of located objects with values ranging from 0-31; a value of 0 represents the lowest ferrous content or conductivity, and the highest ferrous content or conductivity is represented by a value of 31. For example, a reading of 0-24 would be a ferrous content (always first) of 0 and a conductivity value of 24.

Factory presets of the Quickstart mode allowed for detection at multiple depths. Once detection was established, the conductivity and ferrous content values were recorded to determine if any metallic composition patterns could be established. Originally planning on collecting multiple passes on each target to replicate the signatures, the author was advised by the manufacturer that the detector should be run over each target only two to three times. More than these few passes might skew the readings by detecting individual metallic signatures as opposed to the metallic composition of the target as a whole.

A selection of targets was then programmed into the Learn feature in order to determine if the discrimination feature of the advanced detector is more useful than a basic all-metal detector on the variety of objects included in this project for their real-world popularity. Based upon metallic composition, a selection of six firearms of varying size, including examples of stainless steel, aluminum/stainless steel, aluminum/synthetic, basic steel, and tenifered steel, were programmed into the Learn feature, following manufacturer instructions. Selected targets were as follows: S1- Smith & Wesson 686, S2- North American Arms Mini-Magnum, S3-Raven Arms MP-25, S4-Ruger P89, S5-Mossberg 500A, and S6-Glock Model 19. As data collection using the preset signatures can only be conducted using one programmed signature at a time, the detector was set to each saved signature one at a time (S1-S6, sequentially) and run over the research site. Therefore, the detector was run over the individual buried items a total of six times, each time set to a different signature.

Results

Simple Detection

Firearms

Data collection on the buried firearms using the advanced metal detector with the medium coil showed that 14 of 16 firearms (87.5%) were detected, although to varying depths (Figure 31). The Colt Commander (B5), Smith & Wesson 5906 (A4), and Jennings Bryco 59 (B2) were the three firearms detected the deepest, down to a maximum depth of 45-50cm. Four firearms, ranging in size from the second longest shotgun to the smallest handgun, were detected down to a maximum depth of 40-45cm: Remington 870 (G1), Smith & Wesson 686 (B3), RG Industries RG23 (C2), and Davis Derringer D9 (A1). Five firearms, ranging from the largest shotgun to the second smallest handgun, were detected down to a maximum depth of 35-40cm: Mossberg 500A (D5), Ruger P89 (G2), The Hi-Point Model C (A3), Lorcin L380 (B4), and Raven Arms MP25 (A2). The Smith & Wesson Model 37 (C1) was detected down to a maximum depth of 30-35cm. The Norinco AK rifle (C5) was detected the shallowest, down to a maximum depth of only 20-25cm. Finally, the third smallest handgun, the North American Arms Mini-Magnum (B1), was not detected once buried, and the Glock Model 19 (A5) was not detected at all, even pre-burial.

Data collection on the buried firearms using the advanced metal detector with the large coil showed that 14 of 16 firearms (87.5%) were detected, although to varying depths (Figure 32). Several firearms were detected deeper with the large coil, while only one firearm was detected deeper with the medium coil (Table 26). The Remington 870 (G1) was detected deepest, down to a maximum depth of 50-55cm. Four firearms, ranging in size from the third largest handgun to the fourth smallest handgun were detected down to a maximum depth of 45-50cm: Colt Commander (B5), Smith & Wesson 5906 (A4), Jennings Bryco 59 (B2), and RG Industries RG23 (C2). Four of the five largest firearms, the Norinco AK rifle (C5), Mossberg 500A (D5), Smith & Wesson 686 (B3), and Ruger P89 (G2), were detected down to a maximum depth of 40-45cm. Three medium to small handguns were detected down to a maximum depth of 35-40cm: Hi-Point Model C (A3), Lorcin L380 (B4), and Raven Arms MP25 (A2). The fourth smallest and smallest handguns (Smith & Wesson Model 37 (C1) and Davis Derringer (A1)) were detected down to a maximum depth of 30-35cm. Finally, the North American Arms Mini-Magnum (B1) and Glock Model 19 (A5) were not detected at all once buried.

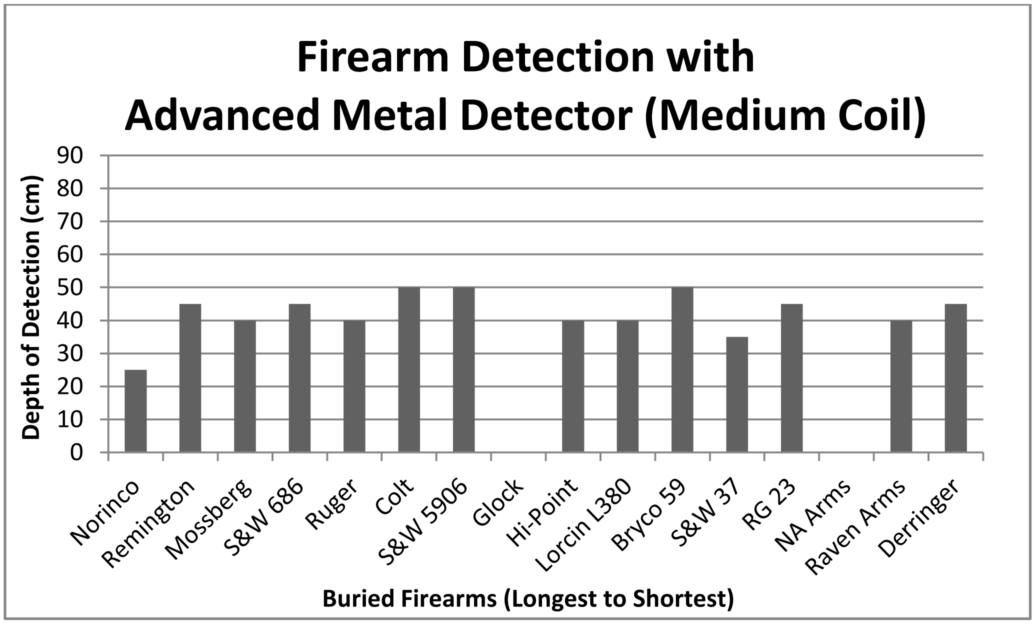

Figure 31: Results from Firearm Detection with Minelab Explorer II^{TM} with Medium Coil

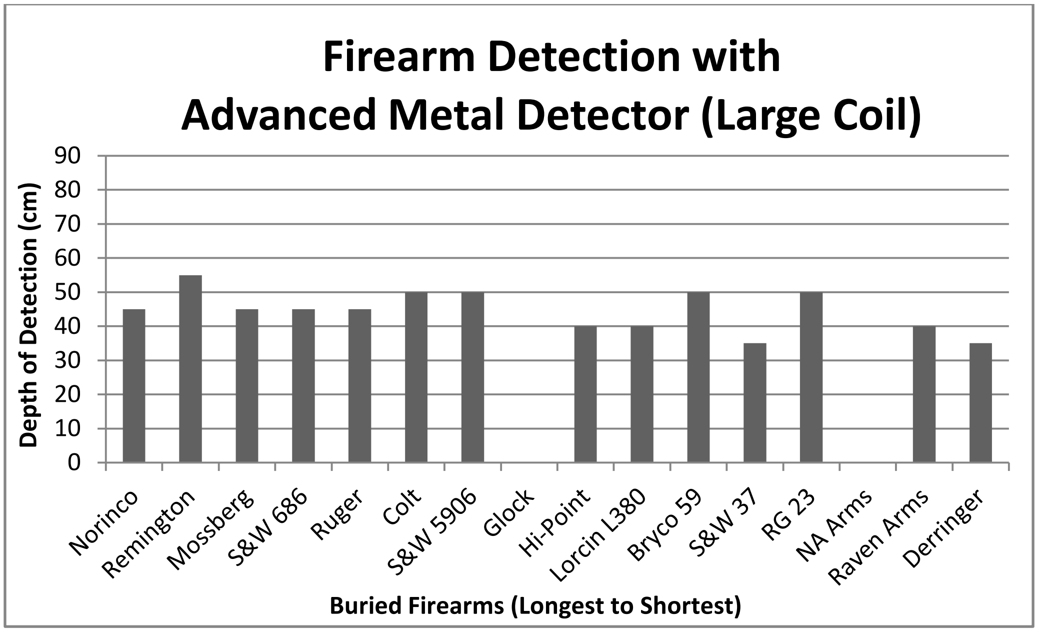

Figure 32: Results from Firearm Detection with Minelab Explorer II^{TM} with Large Coil

Scrap Metals

Data collection on the buried scrap metals using the advanced metal detector with the medium coil shows that three of the six scrap metals (50%) were detected, although at varying depths (Figure 33). The aluminum edging (C3) was detected down to a maximum depth of 40-45cm. The solid aluminum pipe (D3) was detected down to a maximum depth of 30-35cm. The largest piece of scrap metal, the hollow copper tube (D1), was detected down to a maximum depth of 25-30cm. The rebar (D4), rusty iron pipe (D2), and solid iron pipe (C4) were not detected at all, even pre-burial.

Data collection on the buried scrap metals using the advanced metal detector with the large coil showed that the same three targets were detected, although to varying depths (Figure 34). The aluminum edging (C3) was detected down to a maximum depth of 40-45cm. The hollow copper tube (D1) and solid aluminum pipe (D3) were both detected down to a depth of 30-35cm. The rebar (D4), rusty iron pipe (D2), and solid iron pipe (C4) were not detected at all.

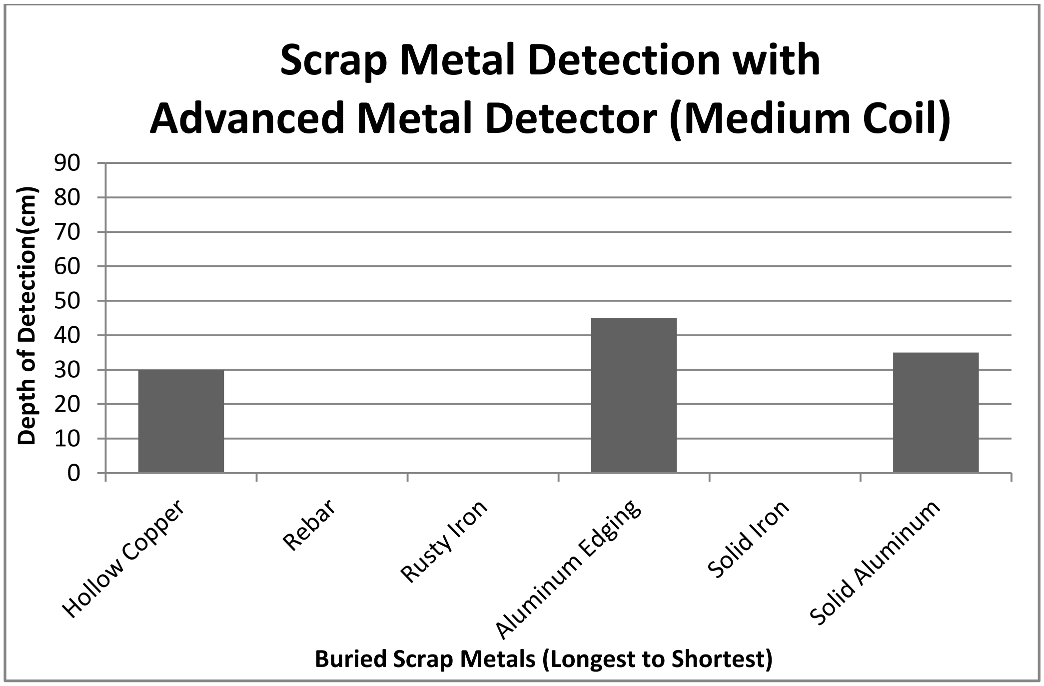

Figure 33: Results from Scrap Metal Detection with Minelab Explorer II^{TM} with Medium Coil

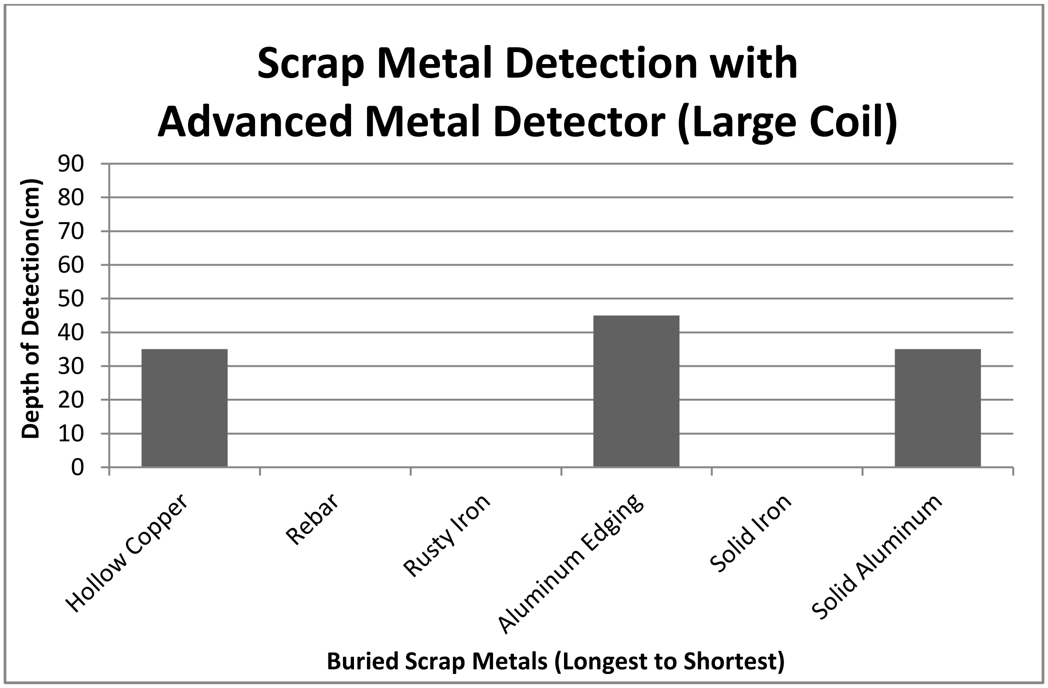

Figure 34: Results from Scrap Metal Detection with Minelab Explorer II^{TM} with Large Coil

Miscellaneous Weapons

Data collection on the buried miscellaneous weapons using the advanced metal detector with the medium coil showed that 8 of the 10 miscellaneous weapons (80%) were detected, although to varying depths (Figure 35). The fourth longest weapon, the claw hammer (F4), was detected down to a maximum depth of 55-60cm. The second longest weapon, the machete (E5), was detected down to a maximum depth of 40-45cm. The two smallest weapons, the scissors (E1) and the brass knuckles (F3), were detected down to a maximum depth of 35-40cm. The longest miscellaneous weapon, the sword (F5), and third longest weapon, the mallet (E4), were detected down to a maximum depth of 30-35cm. The prybar (E3) and Buck knife (E2), both medium sized miscellaneous weapons, were detected down to a maximum depth of 25-30cm. The Philip's Head Screwdriver (F2) and Baton (F1) were not detected at all once buried.

Data collection on the buried miscellaneous weapons using the advanced metal detector with the large coil showed that 8 of the 10 miscellaneous weapons (80%) were detected, although at varying depths (Figure 36). The fourth longest weapon, the claw hammer (F4), was detected down to a maximum depth of 50-55cm. The second longest weapon, the machete (E5), and a medium-sized weapon, the prybar (E3) were detected down to a maximum depth of 40-45cm. The mallet (E4), the third largest weapon, and the two smallest weapons, the scissors (E1) and the brass knuckles (F3), were detected down to a maximum depth of 35-40cm. The longest miscellaneous weapon, the sword (F5), was detected down to a maximum depth of 30-35cm. The Buck knife (E2), the third smallest miscellaneous weapon, was detected down to a maximum depth of 25-30cm. Finally, the Philip's head screwdriver (F2) and baton (F1) were not detected at all once buried.

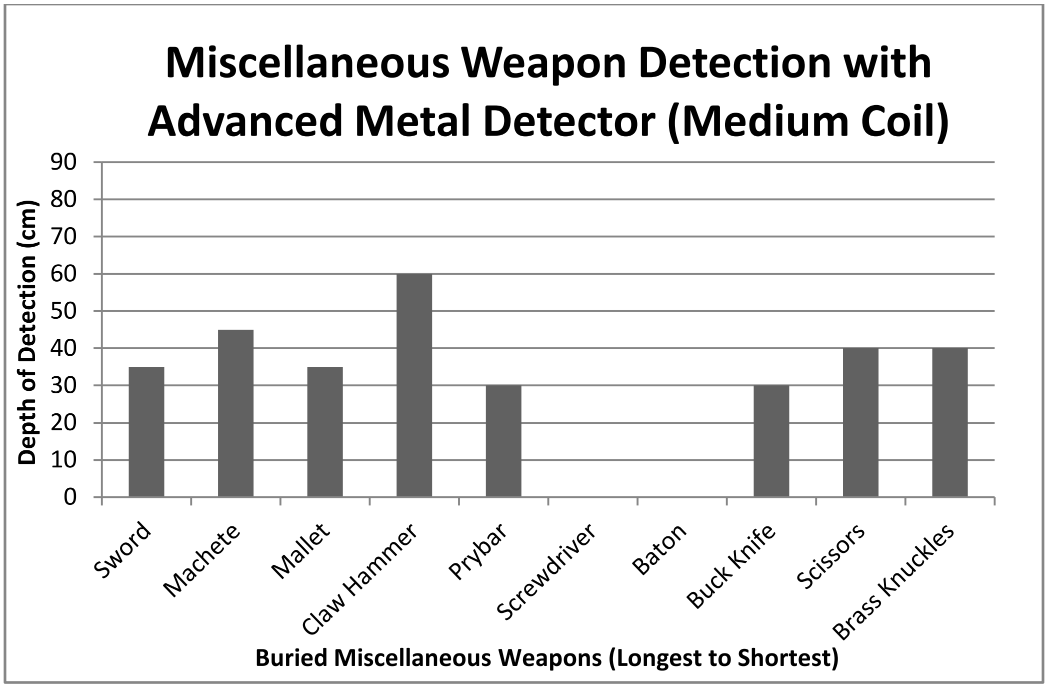

Figure 35: Results from Miscellaneous Weapon Detection with Minelab Explorer II^{TM} with Medium Coil

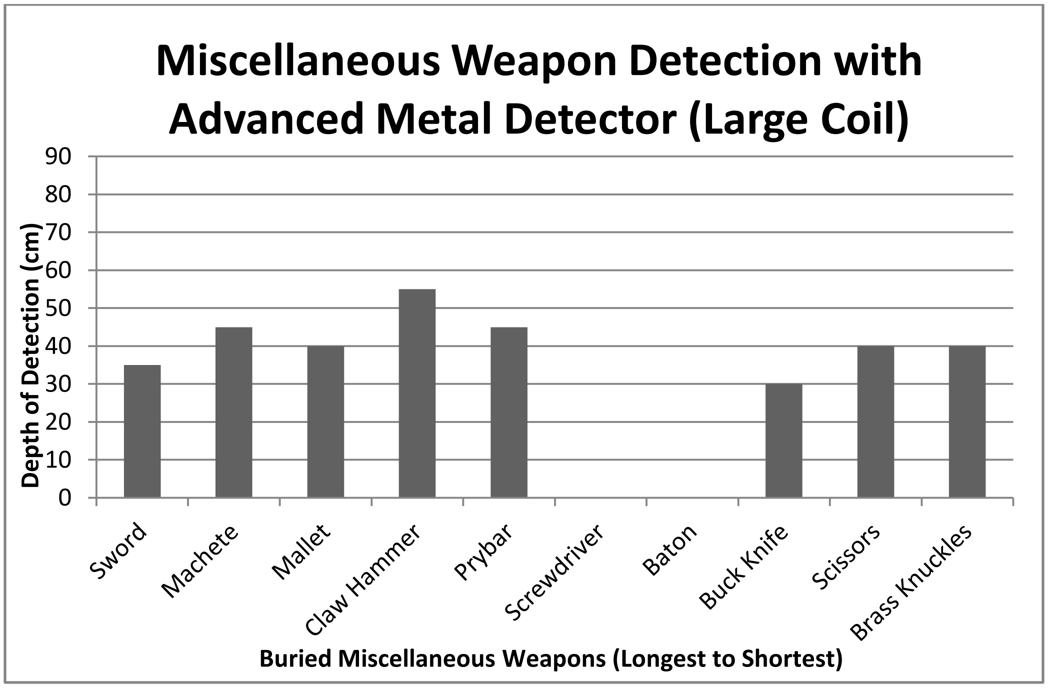

Figure 36: Results from Miscellaneous Weapon Detection with Minelab Explorer II^{TM} with Large Coil

Quickstart Ferrous Content/Conductivity Readings

As advised by the manufacturer, data was collected in three passes over each target so as to ensure proper detection of the metallic target as a whole, not as individual components of its metallic composition. Since both ferrous content and conductivity readings provide values ranging from 0-31, three categories were assigned for each: Low (0-10), Medium (11-20), and High (21-31). Five patterns were noticed while analyzing the data collected on the buried firearms, scrap metal, and miscellaneous weapons using the advanced metal detector with the Medium Coil (Tables 13-15): Low/Medium, Low/High, Medium/Low, Medium/High, and Variable.

One target produced the Low/Medium pattern: the Norinco AK rifle (C5). Low/High was the most frequent pattern, consisting of a total of sixteen targets, including eleven firearms (Davis Derringer (A1), Raven Arms MP25 (A2), Hi-Point Model C (A3), North American Arms Mini-Magnum (B1), Jennings Bryco 59 (B2), Lorcin L380 (B4), Colt Commander (B5), Smith & Wesson Model 37 (C1), RG Industries RG23 (C2), Mossberg 500A (D5), and Ruger P89 (G2)), three miscellaneous weapons (Buck knife (E2), brass knuckles (F3), and claw hammer (F4)), and two scrap metals (aluminum edging (C3) and hollow copper tube (D1)). One target produced the Medium/Low pattern: the Smith & Wesson 5906 (A4). Two targets, the Remington 870 (G1) and the mallet (E4), produced the Medium/High pattern.

The Variable pattern was defined as instances in which the pre-burial pattern was different than the pattern observed once the target was buried. The Variable pattern was only observed in six of the thirty-two tested targets (Smith & Wesson 686 (B3), the scissors (E1), prybar (E3), and machete (E5), sword (F5), and solid aluminum pipe (D3)).

As so many targets of differing metallic compositions fell into each pattern, especially the Low/High pattern, it would therefore be problematic to use this technique during real-world forensic searches in order to distinguish a suspected target as a firearm, scrap metal, or miscellaneous weapon.

Table 13: Firearm Results for the Quickstart Ferrous Content-Conductivity Readings and Associated Patterns

Target	**Pre-Burial**	**20-25cm**	**Pattern**
A1	0-23, 0-25, 03-27	0-26, 0-25, 0-26	Low/High
A2	0-19, 0-24, 0-26	3-28, 3-27, 0-26	Low/High
A3	0-24, 0-26, 0-23	0-23, 0-25, 0-24	Low/High
A4	15-05, 15-08, 15-7	15-5, 16-5, 7-5	Medium/Low
A5			
B1	9-30, 12-27, 6-28	3-23, 11-28, 9-30	Low/High
B2	9-24, 8-26, 0-26	0-24, 0-24, 0-26	Low/High
B3	5-23, 11-19, 10-24	14-11, 13-18, 13-18	Variable
B4	0-25, 0-27, 0-22	11-25, 0-25, 2-24	Low/High
B5	7-26, 3-28, 2-27	3-26, 6-27, 8-28	Low/High
C1	2-28, 5-29, 8-28	5-28, 1-25, 6-27	Low/High
C2	0-27, 0-25, 1-28	0-19, 4-28, 0-25	Low/High
C5	11-17, 7-17, 10-16	7-16, 7-20, 7-16	Low/Medium
D5	6-29, 3-27, 7-27	6-27, 5-28, 2-28	Low/High
G1	12-26, 11-27, 11-26	18-23, 10-26, 11-27	Medium/High
G2	0-23, 0-17, 7-26	8-26, 7-25, 4-23	Low/High

Table 14: Scrap Metal Results for the Quickstart Ferrous Content-Conductivity Readings and Associated Patterns

Target	**Pre-Burial**	**20-25cm**	**Pattern**
C3	0-26, 0-25, 0-28	7-31, 0-25, 12-24	Low/High
C4			
D1	0-29, 0-30, 0-29	9-18, 3-29, 5-26	Low/High
D2			
D3	0-20, 0-23, 0-22	0-23, 11-26, 11-16	Variable
D4			

Table 15: Miscellaneous Weapons Results for the Quickstart Ferrous Content-Conductivity Readings and Associated Patterns

Target	Pre-Burial	20-25cm	Pattern
E1	11-14, 0-5, 11-14	14-8, 11-10, 7-3	Variable
E2	10-18, 6-29, 0-28	2-23, 6-27, 4-28	Low/High
E3	8-27, 7-26, 3-26	12-16, 9-12, 3-8	Variable
E4	13-23, 11-21, 9-16	12-24, 12-24, 11-23	Medium/High
E5	12-23, 6-28, 10-27	7-19, 11-25, 12-21	Variable
F1			
F2			
F3	0-25, 3-26, 11-27	0-27, 0-26, 3-27	Low/High
F4	11-26, 3-26, 11-8	6-4, 6-28, 4-28	Low/High
F5	4-16, 9-29, 11-28	11-17, 10-17, 10-23	Variable

Advanced Learn Feature

Using the Advanced Learn feature to program signature patterns of the firearms, scrap metals, and miscellaneous weapons proved just as difficult as the use of the Quickstart ferrous content/conductivity readings, as many of the targets could be detected with the selected signatures (Tables 16-18). When referring to the Table 10, it can be seen that 12 out of the 16 firearms hit on all six programmed signatures, and the remaining four hit on five out of six programmed signatures. Interestingly, programmed signature S-6 was the Glock Model 19 (A5), which is comprised of a polymer frame and enough steel components to allow for the recognition of 13 out of 16 firearms by its programmed signature. Tables 17 and 18 further illustrate that the miscellaneous weapons and the trash metals are also detected by many of the programmed signatures, all of the miscellaneous weapons hit on at least four of the programmed signatures, while all but one of the trash metals hit on at least four. While this feature is of no doubt great use in the detection of items with standardized metallic composition (i.e. coins and jewelry), the variations in the production of firearms, scrap metals, and miscellaneous weapons included in this study did not allow for a distinction to be made.

Table 16: Firearm Results for the Learn Feature Indicating Whether the Forensic Targets were Detected, Marked by the "x", When the Advanced Detector was Set to Each of the Saved Signatures (S1 to S6)

Target	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
A1	x	x	x	x	x	x
A2	x	x	x	x	x	
A3	x	x	x	x	x	x
A4	x	x	x	x	x	x
A5	x	x	x	x		x
B1	x	x	x	x	x	x
B2	x	x	x	x	x	x
B3	x	x	x	x	x	x
B4	x	x	x	x	x	
B5	x	x	x	x	x	x
C1	x	x	x	x	x	x
C2	x	x	x	x	x	x
C5	x	x	x	x	x	
D5	x	x	x	x	x	x
G1	x	x	x	x	x	x
G2	x	x	x	x	x	x

Table 17: Scrap Metal Results for the Learn Feature Indicating Whether the Targets were Detected,Marked by the "x", When the Advanced Detector was Set to Each of the Saved Signatures (S1 to S6)

Target	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
C3			x	x	x	x
C4	x	x	x	x		x
D1			x			
D2	x	x	x	x		x
D3		x	x	x	x	
D4	x	x	x	x		x

Table 18: Miscellaneous Weapons Results for the Learn Feature Indicating Whether the Targets were Detected, Marked by the "x", When the Advanced Detector was Set to Each of the Saved Signatures (S1 to S6)

Target	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
E1	x	x	x	x	x	x
E2	x	x	x	x	x	x
E3	x	x	x	x		x
E4		x		x	x	x
E5	x	x	x	x	x	x
F1	x	x	x	x	x	x
F2	x	x	x	x		x
F3		x	x	x	x	
F4	x	x	x	x	x	x
F5	x	x	x	x		x

Discussion

Analyzing the capabilities of an advanced metal detector in locating firearms, scrap metals, and miscellaneous weapons provided for expected and unexpected results. Utilizing both modes for the tool (the factory preset Quickstart and the user programmable Advanced), the advanced metal detector proved to be easier for the author to use with little training while in Quickstart Mode. However, this does not mean to say that dependable, reproducible results will be achieved without proper training, simply that the machine was not difficult to operate in Quickstart mode. As Quickstart is analogous to the turn-on-and-go functioning of a basic all-metal detector (Minelab Electronics Pty Ltd, n.d.), it was not unexpected that Quickstart would be the easier mode to operate in. Making use of ferrous-conductivity readings and Advanced discrimination features warranted more training, and detailed target training with the detector is highly recommended for those considering the machine for their agency.

Due to the metallic compositions of the targets included in this project being mostly of steel, Quickstart ferrous content and conductivity readings did not prove useful in establishing discrimination patterns (Tables 13-15), and the Advanced Learn feature was not helpful in distinguishing unique signature patterns (Tables 16-18). Had the research project incorporated more junk metal or other items normally searched for by hobbyists, the Advanced Learn feature may have been of more use. However, the current research project was designed to determine whether or not the advanced features of this detector were helpful in distinguishing different weapons commonly associated with crime, not discerning a firearm from a wedding band.

Although the Minelab Explorer II^{TM} was able to detect many of the buried targets in both modes, the most useful feature seems to be the simple detection component of the unit; 25 of 32 targets were detected when utilizing the basic detection feature in Quickstart (Figures 31-36).

There are interesting results that can be discussed from Quickstart mode regarding the effect of metallic composition, target size, and coil size on target detection.

Metal

When analyzing whether metallic composition had any effect on target detection, it was confirmed in a few instances: the mostly polymer Glock Model 19 (A5), the steel NA Arms Mini-Magnum (B1), three scrap iron objects (solid iron pipe (C4), rusty iron pipe (D2), and rebar (D4)), and two of the steel miscellaneous weapons (baton (F1) and Phillip’s head screwdriver (F2)) were not detected with either coil. The Glock Model 19 (A5) does have a steel slide, but is extensively polymer, which is non-metallic, and therefore a lack of detection is unsurprising. As the factory presets in Quickstart mode set the Iron Mask at a mode “suitable when detecting non-ferrous metals” (-6) between complete iron discrimination (0) and all-metal detection (-16), the observation that the iron targets or targets with high amounts of iron in their steel composition were not detected is explained (Minelab Electronics Pty Ltd, n.d.: 43).

Size

Target size did not seem to be a factor in maximum depth of detection. In general, smaller targets were detected down to similar, if not deeper, maximum depths of detection as the largest targets. For example, the smallest handgun, the Derringer D9 (A1) was detected to the same maximum depth of detection as the largest shotgun, the Remington 870 (G1) using the medium coil.

Comparison of Medium and Large Search Coils

Another issue to consider was whether the larger manufacturer-specific, after-market, 15" search coil would increase depth detection over the standard 10" search coil of the Minelab Explorer II^{TM} advanced metal detector. Theoretically, the large search coil from the advanced metal detector should provide increased depth detection (Connor and Scott, 1998; Dupras et al., 2006; Garrett, 1998; Hunter and Cox, 2005; Nielsen, 2003). This research produced mixed results, as the larger 15" coil provided greater maximum detection depths for eight out of the 25 detected weapons (Tables 19-21, Figures 37-39). However, it should be noted that the two coils actually displayed the same maximum depth of detection for 15 of the 25 detected weapons. The large coil has a slight advantage in depth of detection for the larger weapons, including four of the five largest firearms: Norinco AK Hunter (C5), Remington 870 (G1), Mossberg Model 500A (D5), and Ruger P89 (G2). Both coils may therefore be valuable in real-life forensic weapon searches. However, if the suspected metallic weapon is large, a large search coil may provide improved depths of detection.

Within the firearm sample, one firearm was best detected by the medium coil: the Davis Derringer D9 (A1). Five firearms were detected deeper with the large coil: the Norinco AK Hunter (C5), Remington 870 (G1), Mossberg Model 500A (D5), Ruger P89 (G2), and RG Industries RG23 (C2). The remaining eight detected firearms were all detected down to the same maximum depth with both coils: Smith & Wesson Model 686 (B3), Colt Commander (B5), Smith & Wesson 5906 (A4), Hi-Point Model C (A3), Lorcin L380 (B4), Jennings Bryco 59 (B2), and Smith & Wesson Model 37 (C1), and Raven Arms MP25 (A2). The North American Arms (B1) and Glock Model 19 (A5) were not detected by either coil (Table 19, Figure 37). Overall, the large search coil seems to best detect the larger firearms of the grid as the four weapons best detected by the large coil are among the five largest firearms. Both coils seem to fare the same with the medium-sized firearms, and the medium coil was better suited for the smallest targets.

Overall, the results support the notion that a large search coil when compared to a smaller search coil detects larger targets deeper (Connor and Scott, 1998; Dupras et al., 2006; Garrett, 1998; Hunter and Cox, 2005; Nielsen, 2003) as the four weapons best detected by the large coil are among the seven largest firearms. Both coils seem to fare the same with the medium and smaller objects as only two of the smallest eight firearms are detected better with the medium coil.

Table 19: Maximum Depth of Detection (cm) for Firearms Comparing the Advanced Metal Detector with the Medium Coil and Large Coil

Firearm (Largest to Smallest)	**Maximum Depth (cm) Minelab Explorer II^{TM} Medium Coil**	**Maximum Depth (cm) Minelab Explorer II^{TM} Large Coil**
Norinco (C5)	20-25	40-45
Remington (G1)	40-45	50-55
Mossberg (D5)	35-40	40-45
S&W 686 (B3)	40-45	40-45
Ruger (G2)	35-40	40-45
Colt (B5)	45-50	45-50
S&W 5906 (A4)	45-50	45-50
Glock (A5)		
Hi-Point (A3)	35-40	35-40
Lorcin L380 (B4)	35-40	35-40
Bryco 59 (B2)	45-50	45-50
S&W 37 (C1)	30-35	30-35
RG 23 (C2)	40-45	45-50
NA Arms (B1)		
Raven Arms (A2)	35-40	35-40
Derringer (A1)	40-45	30-35

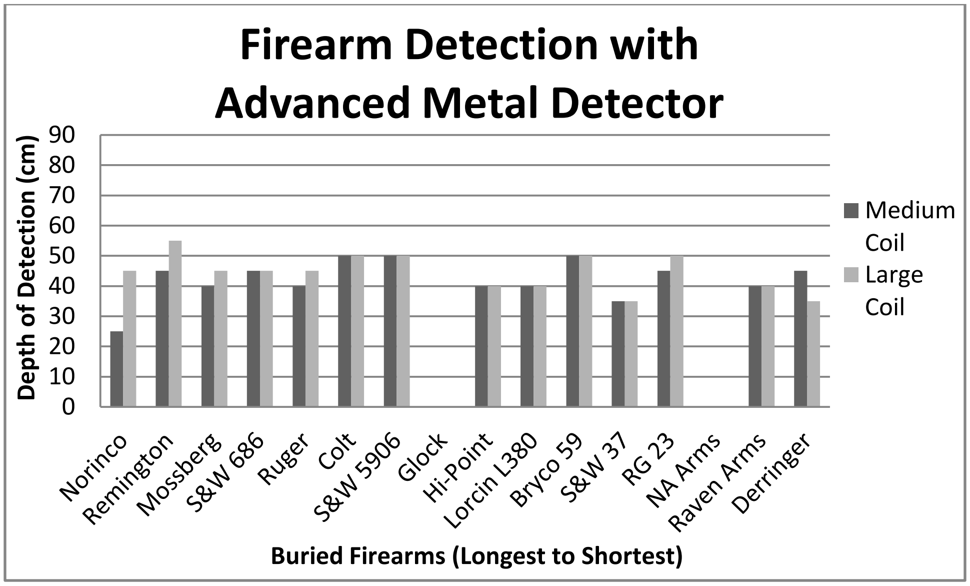

Figure 37: Firearm Detection with the Advanced Metal Detector Comparing the Medium Coil and Large Coil

Out of the six scrap metals, only three weapons (hollow copper tube (D1), aluminum edging (C3), and solid aluminum pipe (D3)) were detected. One piece of scrap metal, the hollow copper tube (D1), was best detected by the large coil, while the other two, the aluminum edging (C3), and solid aluminum pipe (D3) were detected down to the same maximum depth by both coils (Table 20, Figure 38). These scrap metals are three of the smallest items in the grid, and once again the ability of the smaller coil to detect smaller targets is shown.

Table 20: Maximum Depth of Detection (cm) for Scrap Metals Comparing the Advanced Metal Detector with the Medium Coil and the Large Coil

Scrap Metals	**Advanced Metal Detector Medium Coil**	**Advanced Metal Detector Large Coil**
Hollow Copper (D1)	25-30	30-35
Rebar (D4)		
Rusty Iron (D2)		
Aluminum Edging (C3)	40-45	40-45
Solid Iron (C4)		
Solid Aluminum (D3)	30-35	30-35

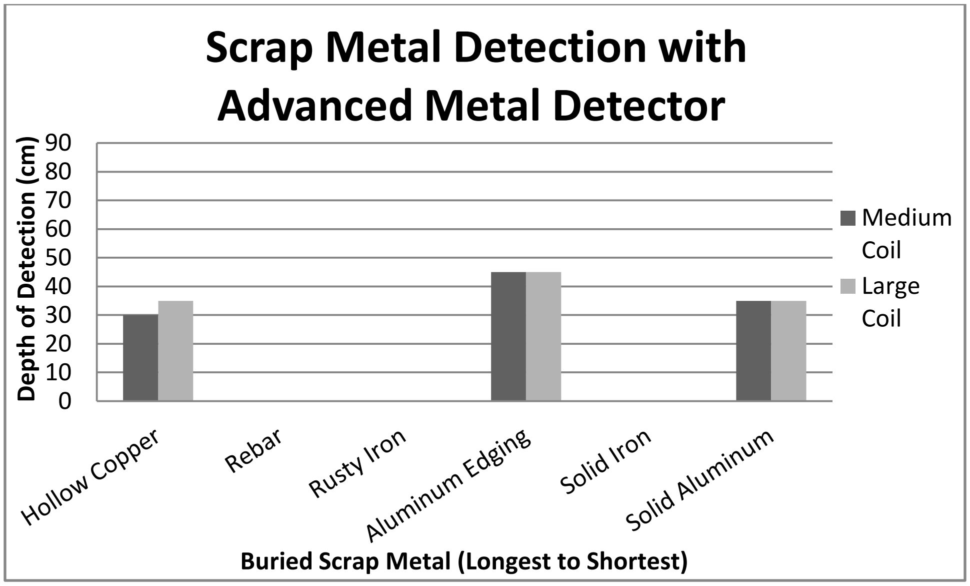

Figure 38: Scrap Metal Detection with the Advanced Metal Detector Comparing the Medium Coil and Large Coil

Out of the ten miscellaneous weapons comprising the sample, one was best detected by the medium coil: the claw hammer (F4). Two miscellaneous weapons were detected deeper with the larger coil: mallet (E4) and prybar (E3). The remaining three detected miscellaneous weapons were all detected down to the same maximum depth with both coils: the sword (F5), machete (E5), buck knife (E2), scissors (E1), and brass knuckles (F3). The Philip's Head Screwdriver (F2) and baton (F1) were not detected once buried (Table 21, Figure 39).

Table 21: Maximum Depth of Detection (cm) for Miscellaneous Weapons Comparing the Advanced Metal Detector with the Medium Coil and the Large Coil

Miscellaneous Weapons	**Advanced Metal Detector Medium Coil**	**Advanced Metal Detector Large Coil**
Sword (F5)	30-35	30-35
Machete (E5)	40-45	40-45
Mallet (E4)	30-35	35-40
Claw Hammer (F4)	55-60	50-55
Prybar (E3)	25-30	40-45
Screwdriver (F2)		
Baton (F1)		
Buck Knife (E2)	25-30	25-30
Scissors (E1)	35-40	35-40
Brass Knuckles (F3)	35-40	35-40

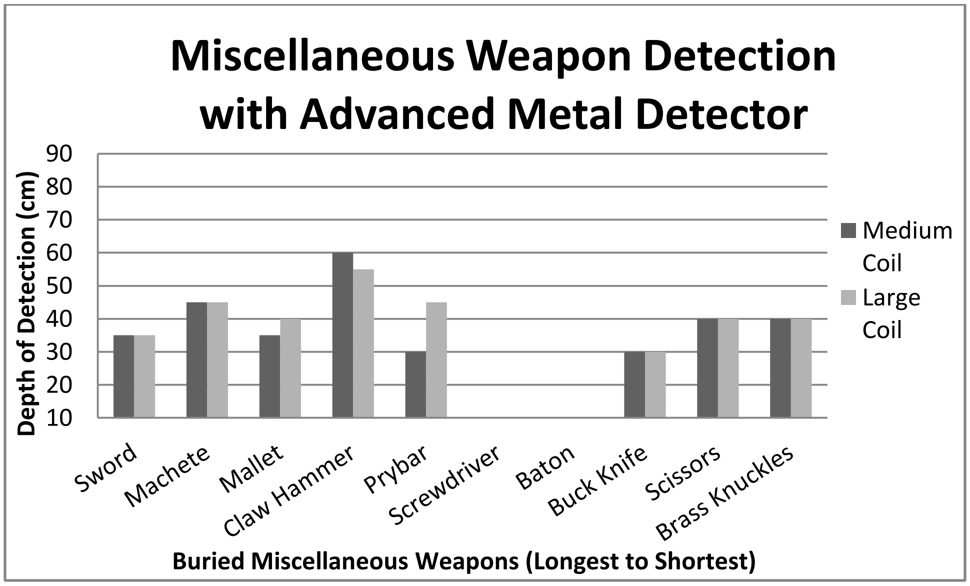

Figure 39: Miscellaneous Weapon Detection with the Advanced Metal Detector Comparing Medium Coil and Large Coil

Conclusions

This research project illustrated that utilizing an advanced metal detector, such as the Minelab Explorer II™ tested here, is beneficial during a forensic search for a suspected weapon. Although we were not as successful with the Advanced features of the detector as we had hoped going into the project, the Minelab Explorer II™ provided helpful results overall by detecting most of the buried firearms and miscellaneous weapons. Depth of detection for each group of targets was also helpful, as it was shown that many of the targets could be detected to deep maximum depths. The amount of training and familiarity needed in order to utilize the Advanced functions of the detector may not be conducive to the amount of training, familiarity, or usage that many law enforcement agencies may be able to provide; however, this should not deter from the fact that the above results show that it is a beneficial tool. In addition, the large coil did not prove as useful in detecting larger items deeper as one would have thought. More positive results in this study came from using the standard 10.5” coil.

LIST OF REFERENCES

Brady NC, Weil RR. 2002. The nature and properties of soil. Upper Saddle, River, NJ: Prentice Hall.

Brockett RC. 1990. Taking a closer look at metal detector discrimination. Sweet Home, OR: White's Electronics, Inc.

Connor M, Scott DD. 1998. Metal detector use in archaeology: an introduction. Historical Archaeology 32(4):76-85.

Davenport GC, France DL, Griffin TJ, Swanburg JG, Lindemann JW, Tranunell V, Armbrust CT, Kondrateiff B, Nelson A, Castellano K, and Hopkins D. 1992. A multidisciplinary approach to the detection of clandestine graves. J Forensic Sci 37(6):1445-1458.

Davenport GC. 2001. Remote sensing applications in forensic investigations. Historical Archaeology 35(1):87-100.

Doolittle JA, Schellentrager G. 1989. Soil survey of Orange County, FL. United States Department of Agriculture, National Cooperative Soil Survey.

Dupras TL, Schultz JJ, Wheeler SM, Williams LJ. 2006. Forensic recovery of human remains: archaeological approaches. Boca Raton, FL: CRC Press, Taylor and Francis Group.

Fisher Research Laboratory. n.d. Fisher m-scope M-97 valve, pedestal, and box locator: operating manual. Los Banos, CA: Fisher Research Laboratory.

France DL, Griffin TJ, Swanburg JG, Lindemann JW, Davenport GC, Trammell V, Travis CT, Kondratieff B, Nelson A, Castellano K, Hopkins D, and Adair T. 1997. NecroSearch revisited: further multidisciplinary approaches to the detection of clandestine graves. In: Haglund WD, Sorg MH, editors. Forensic taphonomy: the postmortem fate of human remains. Boca Raton, FL: CRC Press. pp 497-509.

Garrett CL. 1998. Modern metal detectors. Dallas: Ram Publishing.

Goddard KW. 1977. Crime scene investigation. Reston, VA: Reston Publishing.

Hunter J and Cox M. 2005. Forensic archaeology: advances in theory and practice. London: Routledge.

Isaacson J, Hollinger RE, Gundrum D, and Baird J. 1999. A controlled test site facility in Illinois: training and research in archaeogeophysics. Journal of Field Archaeology 26(2):227-236.

Killam EW. 2004. The detection of human remains. Springfield, IL: Charles C. Thomas.

Murray RC, Tedrow JCF. 1975. Forensic geology: earth sciences and criminal investigation. New Brunswick, NJ: Rutgers University Press.

Nelson CV. 2004. Metal detection and classification technologies. Johns Hopkins APL Technical Digest 25(1):62-67.

Nickell J and Fischer JF. 1999. Crime scene methods of forensic detection. Lexington: The University Press of Kentucky.

Nielsen E. 2003. Metal detectors at the crime scene. Law and Order 51(12):78-81.

Rowlands A, Sarris A. 2007. Detection of exposed and subsurface archaeological remains using multi-sensor remote sensing. Journal of Archaeological Science 34:795-803.

Ruffell A, McKinley J. 2005. Forensic geoscience: applications of geology, geomorphology and geophysics to criminal investigations. Earth-Science Reviews 69:235-247.

Schonstedt Instrument Company. 1998. Instruction manual: model GA-72Cd magnetic locator. Kearneysville, WV: Schonstedt Instrument Company.

Schultz JJ, Collins ME, Falsetti AB. 2006. Sequential monitoring of burials containing large pig cadavers using ground-penetrating radar. J Forensic Sci 51(3):607-616.

Schultz JJ. 2007. Using ground-penetrating radar to locate clandestine graves of homicide victims: forming forensic archaeology partnerships with law enforcement. Homicide Studies 11(11):15-29.

Scott DD, Fox RA, Jr., Connor MA, and Harmon, D. 1989. Archaeological perspectives on the Battle of Little Bighorn. Norman, OK: University of Oklahoma Press.

IV. CONCLUSIONS

Due to the increasing incorporation of geophysical technologies into the process of forensic weapons searches, a need for controlled research and detailed guidelines has arisen. Often, forensic personnel in charge of using the geophysical technologies have negligible or limited training and experience on the specific tools. Increased numbers of false hits that need to be physically checked by digging may then be produced, slowing down investigation time and destroying the scene (Connor and Scott, 1998; Davenport et al., 1992; Dupras et al., 2006; France et al., 1997; Goddard, 1977; Hunter and Cox, 2005; Isaacson et al., 1999; Killam, 2004; Murray and Tedrow, 1975; Nielsen, 2003; Ruffel and McKinley, 2005; Schultz et al., 2006; Schultz, 2007). Controlled research not only allows for testing of geophysical equipment, but also for updating search methodologies.

A variety of geophysical technologies were tested in this project: a basic all-metal detector, a magnetic locator, and an advanced metal detector. Each proved easy to use in basic modes, although accurate and dependable results require training and experience, especially on the magnetic locator to distinguish between the normal hum and some responses. The following sections detail which of the three geophysical tools was better able to detect each of the target groups on both settings utilized (Normal/Medium, High, medium and large coils).

Comparisons

Firearms

For the firearms comparing the all-metal detector and magnetic locator on Normal/ Medium and the advanced metal detector with the medium coil, twelve firearms were best detected with the Minelab Explorer II^{TM} (Table 22, Figure 40). The magnetic locator was next with three, and one target was detected equally with the all-metal and magnetic locator. Although the all-metal did not have any targets down to their maximum depth, it was the only tool to detect all of the firearm targets.

Table 22: Maximum Depth of Detection (cm) for Firearms Comparing the All-Metal Detector and Magnetic Locator on Normal/Medium Setting, and the Advanced Metal Detector with Medium Coil Using only Audible Responses Classified as Strong

Firearms (Largest to Smallest)	Maximum Depth (cm) Fisher M-97 All-Metal Detector	Maximum Depth (cm) Schonstedt GA-72Cd® Magnetic Locator	Maximum Depth (cm) Minelab Explorer II Advanced Metal Detector
Norinco (C5)	25-30	45-50	20-25
Remington (G1)	30-35	50-55	40-45
Mossberg (D5)	25-30	25-30	35-40
S&W 686 (B3)	20-25	15-20	40-45
Ruger (G2)	20-25	15-20	35-40
Colt (B5)	25-30	40-45	45-50
S&W 5906 (A4)	20-25	20-25	45-50
Glock (A5)	15-20	15-20	
Hi-Point (A3)	15-20	15-20	35-40
Lorcin L380 (B4)	15-20		35-40
Bryco 59 (B2)	15-20	10-15	45-50
S&W 37 (C1)	15-20	20-25	30-35
RG 23 (C2)	15-20	0-5	40-45
NA Arms (B1)	10-15	15-20	
Raven Arm (A2)	15-20		35-40
Derringer (A1)	10-15	5-10	40-45

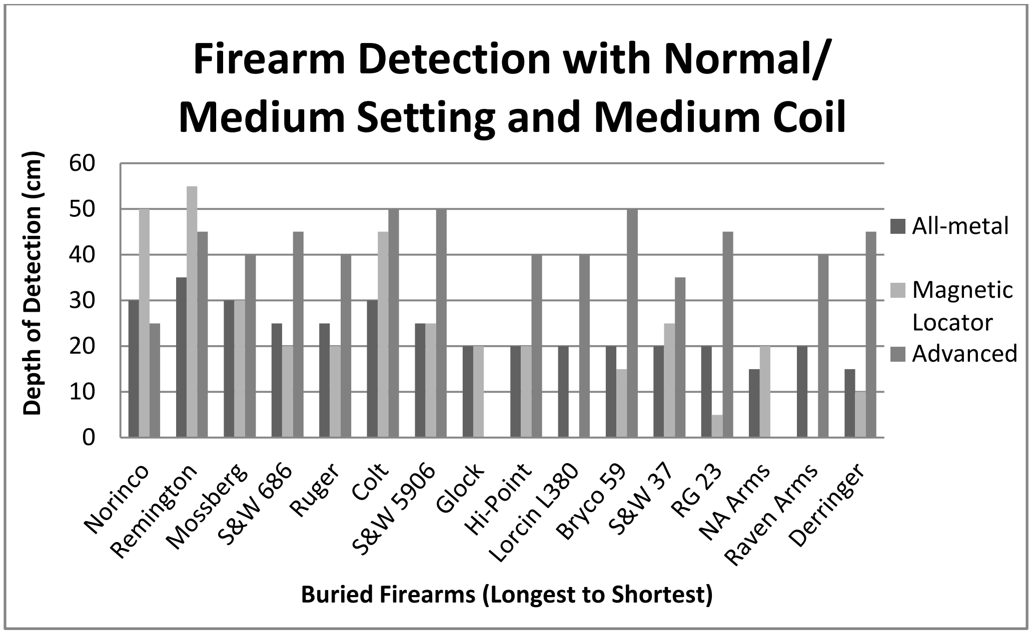

Figure 40: Firearm Detection with the All-metal Detector and Magnetic Locator on Normal/Medium Setting and the Advanced Metal Detector with the Medium Coil

For the firearms comparing the all-metal detector and magnetic locator on High setting and the advanced metal detector with the large coil, seven targets were best detected by the advanced metal detector, while four targets were best detected with the magnetic locator (Table 23, Figure 41). Two firearms were detected equally with the all-metal detector and the magnetic locator, one firearm was detected equally with the all-metal detector and the advanced metal detector, and one firearm was detected equally with the magnetic locator and the advanced metal detector. One firearm was detected equally with all three geophysical tools.

Table 23: Maximum Depth of Detection (cm) for Firearms Comparing the All-Metal Detector and Magnetic Locator on High Setting, and the Advanced Metal detector with the Large Coil Using Only Audible Responses Classified as Strong

Firearm (Largest to Smallest)	Maximum Depth (cm) Fisher M-97 All-Metal Detector	Maximum Depth (cm) Schonstedt GA-72Cd® Magnetic Locator	Maximum Depth (cm) Minelab Explorer II Advanced Metal Detector
Norinco (C5)	45-50	70-75	40-45
Remington (G1)	50-55	70-75	50-55
Mossberg (D5)	40-45	55-60	40-45
S&W 686 (B3)	35-40	30-35	40-45
Ruger (G2)	35-40	40-45	40-45
Colt (B5)	35-40	55-60	45-50
S&W 5906 (A4)	35-40	35-40	45-50
Glock (A5)	30-35	30-35	
Hi-Point (A3)	35-40	25-30	35-40
Lorcin L380 (B4)	30-35	5-10	35-40
Bryco 59 (B2)	35-40	30-35	45-50
S&W 37 (C1)	30-35	30-35	30-35
RG 23 (C2)	30-35	10-15	45-50
NA Arms (B1)	25-30	25-30	
Raven Arms (A2)	25-30	5-10	35-40
Derringer (A1)	25-30	20-25	30-35

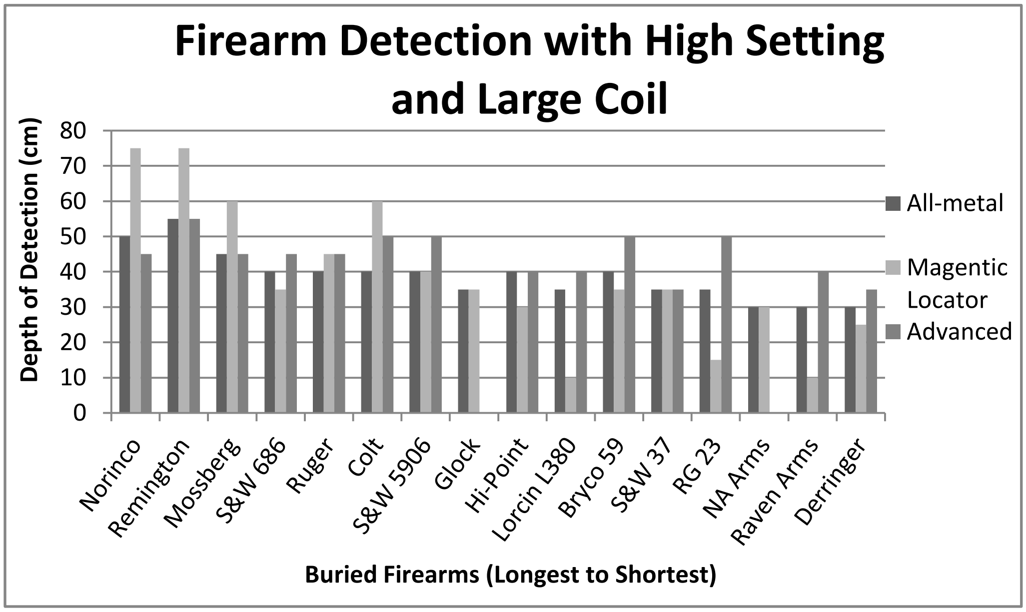

Figure 41:Firearm Detection with the All-metal Detector and Magnetic Locator on High Setting and the Advanced Metal Detector with the Large Coil

Scrap Metals

For the scrap metals comparing the all-metal detector and magnetic locator on Normal/Medium settings and the advanced metal detector with the medium coil, three targets were best detected with the advanced metal detector (Table 24, Figure 42). The magnetic locator best detected two, while the all-metal detector detected one target equally with the magnetic locator.

For the scrap metals comparing the all-metal detector and magnetic locator on High setting and the advanced metal detector with the large coil, three targets were best detected with the advanced metal detector. The magnetic locator best detected two, while the all-metal detector best detected one target (Table 25, Figure 43).

Table 24: Maximum Depth of Detection (cm) for Scrap Metals Comparing the All-Metal Detector and Magnetic Locator on Normal/Medium Setting, and the Advanced Metal Detector with the Medium Coil Using Only Audible Responses Classified as Strong

Scrap Metals (Largest to Smallest)	**Maximum Depth (cm) Fisher M-97 All-Metal Detector**	**Maximum Depth (cm Schonstedt GA-72Cd® Magnetic Locator**	**Maximum Depth (cm) Minelab Explorer II Advanced Metal Detector**
Hollow Copper (D1)	10-15		25-30
Rebar (D4)	15-20	15-20	
Rusty Iron (D2)	25-30	55-60	
Aluminum Edging (C3)	15-20		40-45
Solid Iron (C4)	25-30	40-45	
Solid Aluminum (D3)	10-15		30-35

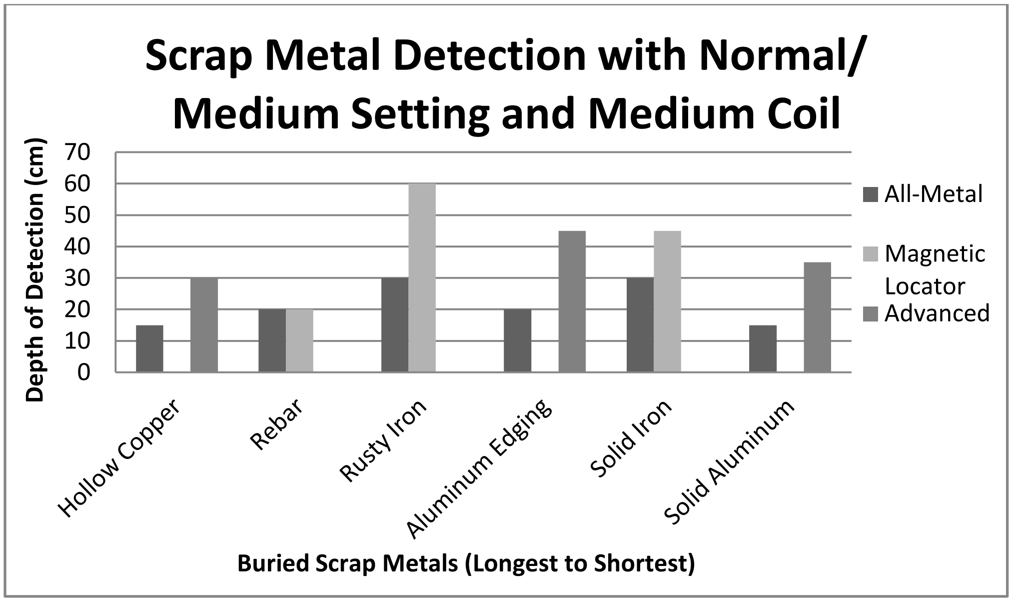

Figure 42: Scrap Metal Detection with the All-metal Detector and Magnetic Locator on Normal/Medium Setting and the Advanced Metal Detector with the Medium Coil

Table 25: Maximum Depth of Detection (cm) for Scrap Metals Comparing the All-Metal Detector and Magnetic Locator on High Setting, and the Advanced Metal detector with the Large Coil Using Only Audible Responses Classified as Strong

Scrap Metals (Largest to Smallest)	**Maximum Depth (cm) Fisher M-97 All-Metal Detector**	**Maximum Depth (cm) Schonstedt GA-72Cd® Magnetic Locator**	**Maximum Depth (cm) Minelab Explorer II Advanced Metal Detector**
Hollow Copper (D1)	25-30		30-35
Rebar (D4)	30-35	25-30	
Rusty Iron (D2)	40-45	65-70	
Aluminum Edging (C3)	30-35		40-45
Solid Iron (C4)	40-45	55-60	
Solid Aluminum (D3)	20-25		30-35

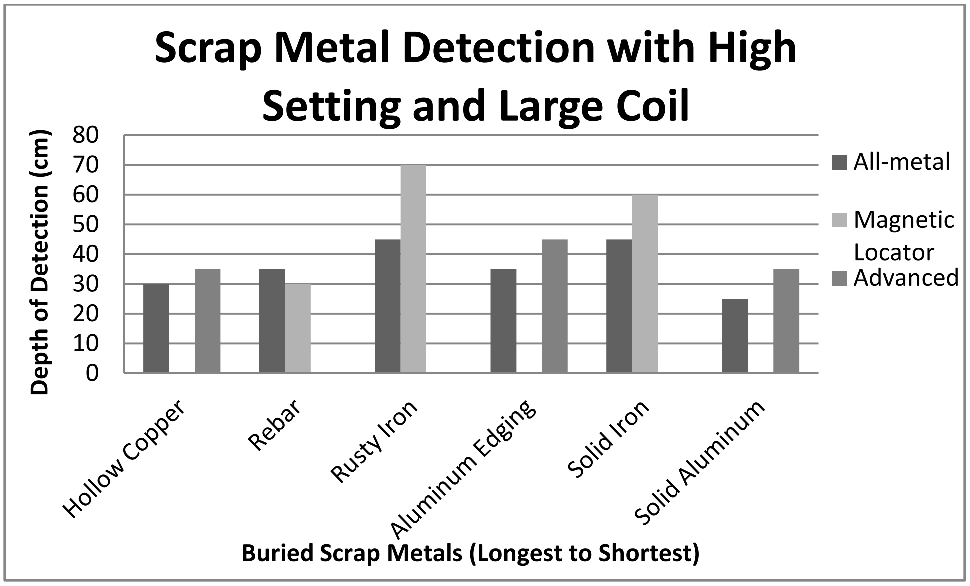

Figure 43: Scrap Metal Detection with the All-metal Detector and Magnetic Locator on High Setting and the Advanced Metal Detector with the Large Coil

Miscellaneous Weapons

For the miscellaneous weapons comparing the all-metal detector and magnetic locator on Normal/Medium setting and the advanced metal detector with the medium coil, five weapons were detected deepest with the advanced metal detector, three targets were detected best with the magnetic locator, and one was detected deepest with the all-metal detector (Table 26). One target was detected equally with magnetic locator and the advanced metal detector.

For the miscellaneous weapons comparing the all-metal detector and magnetic locator on High setting and the advanced metal detector with the large coil, five targets were detected deepest with the magnetic locator, three were detected deepest with the advanced metal detector, one was detected deepest with the all-metal detector, and one was detected equally with the all-metal and advanced metal detectors (Table 27).

Table 26: Maximum Depth of Detection (cm) for Miscellaneous Weapons Comparing the All-Metal Detector and Magnetic Locator on Normal/Medium Setting, and the Advanced Metal detector with the Medium Coil Using Only Audible Responses Classified as Strong

Miscellaneous Weapons (Largest to Smallest)	**Maximum Depth (cm) Fisher M-97 All-Metal Detector**	**Maximum Depth (cm) Schonstedt GA-72Cd® Magnetic Locator**	**Maximum Depth (cm) Minelab Explorer II Advanced Metal Detector**
Sword (F5)	20-25	15-20	30-35
Machete (E5)	20-25	0-5	40-45
Mallet (E4)	20-25	15-20	30-35
Claw Hammer (F4)	25-30	60-65	55-60
Prybar (E3)	15-20	15-20	25-30
Screwdriver (F2)	5-10	70-75	
Baton (F1)	20-25	15-20	
Buck Knife (E2)	10-15	25-30	25-30
Scissors (E1)	10-15	60-65	35-40
Brass Knuckles (F3)	10-15		35-40

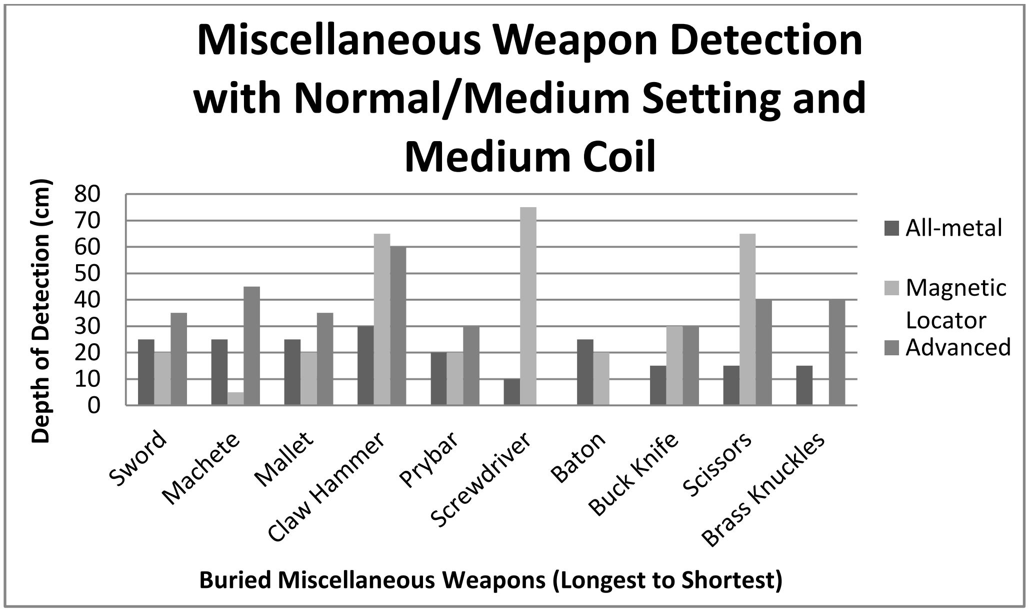

Figure 44: Miscellaneous Weapon Detection with the All-metal Detector and Magnetic Locator on Normal/Medium Setting and the Advanced Metal Detector with the Medium Coil

Table 27: Maximum Depth of Detection (cm) for Miscellaneous Weapons Comparing the All-Metal Detector and Magnetic Locator on High Setting, and the Advanced Metal detector with the Large Coil Using Only Audible Responses Classified as Strong.

Miscellaneous Weapons (Largest to Smallest)	**Maximum Depth (cm) Fisher M-97 All-Metal Detector**	**Maximum Depth (cm) Schonstedt GA-72Cd Magnetic Locator**	**Maximum Depth (cm) Minelab Explorer II Advanced Metal Detector**
Sword (F5)	35-40	40-45	30-35
Machete (E5)	35-40	25-30	40-45
Mallet (E4)	35-40	20-25	35-40
Claw Hammer (F4)	40-45	60-65	50-55
Prybar (E3)	30-35	25-30	40-45
Screwdriver (F2)	15-20	80-85	
Baton (F1)	30-35	25-30	
Buck Knife (E2)	25-30	35-40	25-30
Scissors (E1)	25-30	60-65	35-40
Brass Knuckles (F3)	25-30		35-40

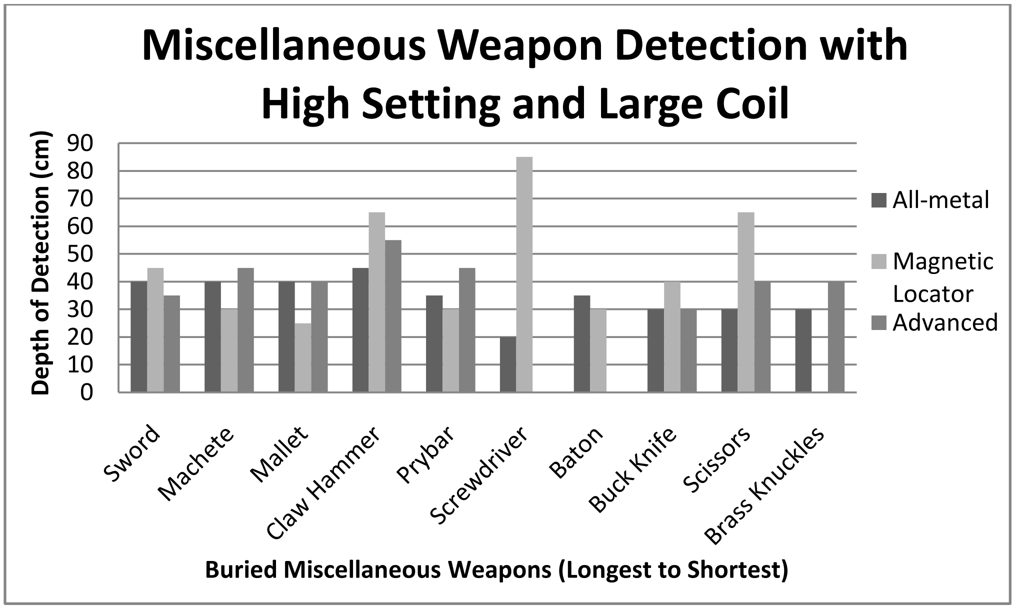

Figure 45: Miscellaneous Weapon Detection with the All-metal Detector and Magnetic Locator on High Setting and the Advanced Metal Detector with the Large Coil

Conclusions

Overall, the all-metal detector detected all of the metallic targets in the research project; however, it had the fewest amounts of targets that were detected deepest with the tool. As expected, the magnetic locator detected ferric targets made of iron and steel and not those of non-ferric copper or aluminum composition. Using the Minelab Explorer II^{TM} with the standard 10.5” medium coil proved to be the best geophysical tool for detecting the metallic targets the deepest and reducing the number of scrap metals detected. While this may seem like a negative result, it would actually be a beneficial ability in the field, as common types of scrap metals would be excluded from the search area, increasing the potential for finding the actual suspected weapon. Finally, the advanced metal detector was able to detect the highest amount of miscellaneous weapons the deepest, and was unable to detect only two. Again, this would be beneficial in the field, if investigators are not looking for screwdrivers or police batons.

Taking all three geophysical tools and their multiple settings into consideration, Table 28 illustrates which tool would be most useful in detecting each category of metallic target included in this project:

Table 28: Comparison of Geophysical Tools

Category of Detection	**Fisher M-97**	**Schonstedt GA-72Cd**	**Minelab Explorer II^{TM}**
Unknown Metallic Composition	X		X
Known Ferromagnetic Composition	X	X	
Shallow Depth (<45cm)	X	X	X
Deeper Depths (>45cm)		X	X
Large Firearms to Deepest Depths		X	
Handguns to Deepest Depths		X	X
Scrap Metals to Deepest Depths		X	
Miscellaneous Weapons to Deepest Depths		X	

Future Considerations

Although all current objectives were explored and answered, additional research options arose during the research. Further controlled research projects could include such objectives as an assessment of the capabilities of each tool in different soil conditions, testing of a broader array of metallic targets, and utilization of additional advanced features of the Minelab Explorer II^{TM}. Any additional research can only strengthen the foundations of forensic investigation.

LIST OF REFERENCES

Connor M, Scott DD. 1998. Metal detector use in archaeology: an introduction. Historical Archaeology 32(4):76-85.

Davenport GC, France DL, Griffin TJ, Swanburg JG, Lindemann JW, Tranunell V, Armbrust CT, Kondrateiff B, Nelson A, Castellano K, and Hopkins D. 1992. A multidisciplinary approach to the detection of clandestine graves. J Forensic Sci 37(6):1445-1458.

Dupras TL, Schultz JJ, Wheeler SM, Williams LJ. 2006. Forensic recovery of human remains: archaeological approaches. Boca Raton, FL: CRC Press, Taylor and Francis Group.

France DL, Griffin TJ, Swanburg JG, Lindemann JW, Davenport GC, Trammell V, Travis CT, Kondratieff B, Nelson A, Castellano K, Hopkins D, and Adair T. 1997. NecroSearch revisited: further multidisciplinary approaches to the detection of clandestine graves. In: Haglund WD, Sorg MH, editors. Forensic taphonomy: the postmortem fate of human remains. Boca Raton, FL: CRC Press. pp 497-509.

Goddard KW. 1977. Crime scene investigation. Reston, VA: Reston Publishing.

Hunter J and Cox M. 2005. Forensic archaeology: advances in theory and practice. London: Routledge.

Isaacson J, Hollinger RE, Gundrum D, and Baird J. 1999. A controlled test site facility in Illinois: training and research in archaeogeophysics. Journal of Field Archaeology 26(2):227-236.

Killam EW. 2004. The detection of human remains. Springfield, IL: Charles C. Thomas.

Murray RC, Tedrow JCF. 1975. Forensic geology: earth sciences and criminal investigation. New Brunswick, NJ: Rutgers University Press.

Nielsen E. 2003. Metal detectors at the crime scene. Law and Order 51(12):78-81.

Ruffell A, McKinley J. 2005. Forensic geoscience: applications of geology, geomorphology and geophysics to criminal investigations. Earth-Science Reviews 69:235-247.

Schultz JJ, Collins ME, Falsetti AB. 2006. Sequential monitoring of burials containing large pig cadavers using ground-penetrating radar. J Forensic Sci 51(3):607-616.

Schultz JJ. 2007. Using ground-penetrating radar to locate clandestine graves of homicide victims: forming forensic archaeology partnerships with law enforcement. Homicide Studies 11(11):15-29.