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AN EVALUATION OF GEOPHYSICAL METHODS IN THE DETECTION OF TODDLER-  
SIZED BURIALS DURING THE FIRST SIX MONTHS OF BURIAL

A Thesis  
presented in partial fulfillment of requirements  
for the degree of Master of Arts  
in the Department of Sociology and Anthropology  
The University of Mississippi

by

Paul S. Martin

August 2015



## **ABSTRACT**

Geophysical survey has become a major tool in the search for clandestine graves associated with missing person cases. However, relatively little research has been done to evaluate the efficacy of different instruments. Ground-penetrating Radar (GPR), magnetometry, resistivity, conductivity, and susceptibility survey data were collected over the first six months of interment at approximately 30-day intervals for two research plots: an open grassy area and a wooded area. Each area contained five pig burials representing toddler-size (less than 50 pounds) remains and two areas of disturbance or false burials to serve as control graves. The resultant imagery was evaluated in terms of relative utility in burial detection. In general, geophysical survey method results were not very effective in the detection of toddler-sized burials. Under the conditions that this research was conducted, the GPR would have had the maximum potential to provide the best survey results, but this was not the case. The GPR results were only marginally better than the other methods after processing with additional filters. The other methods utilized in this research would be of no benefit in delineating toddler-sized clandestine burials under the conditions that this research was conducted. This is most likely due to the small target size, soil type, and the soil moisture.

## **DEDICATION**

This thesis is dedicated to my children, Ronnie and McKenzie Leanne. They have become my inspiration and provide hope...

## ACKNOWLEDGMENTS

I would like to thank the numerous people that have helped me in this research and assisted me along the way. First, I would like to recognize Dr. Jay K. Johnson, my thesis committee chair, for providing an opportunity to come “home” to the University of Mississippi to further my education as an anthropologist and training in geophysics. Despite his own hectic schedule he provided support and guidance in his own unique way. To my other committee members, Dr. Carolyn Freiwald, and Dr. Robbie Ethridge thank you for encouragement and the patience to just listen. I also appreciate Dr. Maureen Meyers for having an open door just to talk.

I am greatly indebted to Bryan Haley for his friendship, and for walking me through data processing via phone. Without meeting John Sullivan, John Connaway, and Bryan over a decade ago I would not have been introduced to anthropology, archaeology, or geophysics, and certainly would not have found myself where I am now.

Dr. Arpad Vass, all I can say is thank you, words cannot describe my appreciation for our friendship and the encouragement I have felt from you, for well over a decade now. I also have to recognize Dr. Cheryl Johnston, Dr. Anne Rogers, John Schweikart, and Blair Tormey for friendship and mentorship in my educational and research pursuits. Dr. Clark Davenport thank you for taking the time to answer questions in regards to your previous research.

My appreciation is extended to several of my fellow graduate students that assisted in the digging of graves, backfilling of graves, and assisting in data collection, including LeeAnne Wendt, Nick Billstrand, Nick Wood, John Bowler and Spencer Oliver. I also especially want to

recognize LeeAnne, Whitney Hasie, and Spencer for the time and advice shared over coffee, lunch, and phone calls providing feedback.

Most importantly though I wish to thank my family, especially my wife Michelle, that offered me the support and encouragement to return to school. Michelle, along with my mother and father, often believed in me more than I have believed in myself. Ronnie and McKenzie allowed me to escape to just being “Daddy.” Lastly, I wish to recognize Brad Dennis, Director of the KlaasKids Foundation National Search Center for Missing and Trafficked Children, and his wife Tammy Dennis for partial funding of this research. For everyone else that I have failed to mention I apologize, but do appreciate your friendship, guidance, and support.

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## **CHAPTER 1 - INTRODUCTION**

Coverage by the national news media reports another infant or young child disappears from the care of their parent or other trusted caretaker seemingly every month. This unfortunate set of events leads to searches for the child's remains, often leaving investigators with questions despite the money and effort expended as the investigation drags on for months and even years. Investigators have come to rely on geophysical survey tools when available as a primary tool for the detection of clandestine graves as a part of the routine investigation (Pringle et al. 2012). This research sought to answer the question: are geophysical methods effective in finding the remains of infants and small children? More specifically, do buried pigs weighing between fifteen and forty-five pounds used as analogs for toddler-sized children produce significant anomalies that stand out from the homogeneous background within the data collected by geophysical methods? More specifically as the buried remains decomposed, did the anomalies change significantly over a six-month period?

Since the earliest research into the applications of geophysical methods to the search for clandestine graves by NecroSearch International in Colorado in the late 1980s and early 1990s, emphasis has been placed upon searching for adults represented by 100-plus pound pig remains (France et al. 2006:497-507; Schultz 2012:20). Even though searches for the clandestine graves of small children are often conducted using geophysical methods, very little research has been done on the application of those methods to the detection of small child-sized remains.

A review of the literature reveals that research has only begun to focus on the application of geophysical methods to the detection of child-sized remains within the last decade, and that

research has focused only on remains greater than fifty pounds (Schultz 2008). Within the limited literature concerning the application of geophysics to clandestine grave searches, outside of the seminal work by NecroSearch, the research has been primarily conducted within the southeastern United States in Tennessee and Florida (Schultz 2012). There also is an increasing amount of research outside of the United States, but again, with an emphasis on adult-sized remains (Pringle et al. 2012).

Through the work of NecroSearch and others, ground-penetrating radar has been championed as the “Gold Standard” for the application of geophysical methods in the search for clandestine burials (France et al. 2006:497-507; Schultz 2012). Only within the last decade have researchers begun to reexamine the application and the usefulness of magnetometry, resistivity, conductivity, and susceptibility in the search for clandestine graves, while also continuing the research into the use of ground-penetrating radar (France et al. 2006; Larson et al. 2011). This research project not only incorporated these methods, but also focused strictly on toddler-sized remains.

With the permission of Director John Baker I conducted the field portion of this research at the University of Mississippi Field Research Station at Bay Springs, MS, which consists of 740 acres of land that offers a variety of micro-habitats ([www.baysprings.olemiss.edu](http://www.baysprings.olemiss.edu)). Using the USDA Soil Survey Map, Smithdale sandy loam soil was identified as being contiguous between an open grassy field and the forest canopy ([soils.usda.gov/survey/](http://soils.usda.gov/survey/)). I established 10 x 10 meter research plot in the open grassy area and another one in the wooded area. I marked the corners of each test area with plastic and wood stakes so that a grid could easily be repopulated for systematic data collection.

In each area, seven graves utilizing a non-traditional shape were constructed. The outer perimeter of the grave vaults had an oval shape with walls that slope down to form a concave floor that was intentionally left uneven. The rationale behind utilizing the non-traditional grave in the shape of a pit is that it would more closely resemble makeshift graves made by perpetrators in forensic cases. The dimensions of the pits were approximately one meter in length by one-half meter in width and depth. As part of the data collection, the graves were photographed at 30 day intervals to show the different vegetative changes.

I used ten domestic pig (*Sus scrofa domesticus*) carcasses weighing between 10 and 45 pounds as toddler-sized proxies. Domestic pigs have been utilized as human proxies for taphonomic research due to the physiological similarities, such as fat to muscle and hair to skin ratios, as well as a biochemical similarity (France et al. 2006:499). I acquired the pigs from an authorized supplier of “suckling pig” and, as such they are considered to be food products, exempting this research from University guidelines governing the ethical use and treatment of animals.

Two rows of pits were dug, in each area with two in one row and three in the second row. Each row had a same sized pit that was dug and refilled without a burial to serve as a control. In row 1 a pig was placed nude and the second pig was burned utilizing one 64-ounce container of charcoal lighter fluid. The second row consisted of three burials, with the first pig wrapped in a small nylon blanket, the second wrapped in two garbage bags, and the third wrapped in both and then burned utilizing a 64-ounce container of charcoal lighter fluid. The pigs were buried on May 10, 2013 and geophysical survey data was collected until November, thus allowing for monitoring to occur during the first six months of interment.



Five geophysical survey methods, including GPR, magnetometry, resistivity, conductivity, and susceptibility. The sending antenna of a GPR unit transmits radio waves through the ground and records the speed at which they return to the receiver, which then produces a real time display that is visible to the operator (Ruffell and McKinley 2009:77). The magnetometer measures the earth's electromagnetic field while electrical conductivity instruments introduce an electromagnetic field and measure the response of the soil (Ruffell and McKinley 2009:70-73). Resistivity is the most labor intensive of the geophysical methods because the metal probes are fixed in a frame that has to be moved throughout the survey area. This method directly introduces an electrical current through soil and then records the strength of the current upon its return (Ruffell and McKinley 2009:74).

The data was then processed utilizing GPR Slice, Geoplotter, TerraSurveyor and ArchaeoFusion software. The results were then evaluated to determine if there were changes that directly coincided with the presence of the buried remains and if there were changes within the data from different collection periods.

Law enforcement personnel often have to rely on outside resources for geophysical surveys that may or may not be able to provide these services pro bono. Even if there are no direct costs passed on to the law enforcement agency, there are still costs associated with the use of equipment, resources, and hours needed to conduct surveys, process data, and prepare reports that in the end might provide inconclusive results (France et al. 2006:500). This research sought to address the utility shallow surface geophysical methods, including ground-penetrating radar, conductivity, resistivity, and magnetometry in the detection of toddler-sized burials within the first six months of interment.

Chapter 1 of this thesis provides a brief introduction to the identified question of utilizing geophysical tools in the search of clandestine graves of toddler-sized remains. It also provides an outline of the chapters of this research.

Chapter 2 provides an understanding of how this research fits into the overarching theoretical framework of anthropology. It will demonstrate that forensic anthropology does have a theoretical basis which it has borrowed from the sub-disciplines of anthropology.

In Chapter 3, background information about missing children and geophysics will be presented. More specifically the geophysics section will address not only what geophysics is, but how these tools have been utilized by archaeologists in forensic applications and associated research.

Chapter 4 will address the location, materials and methods used for this research. It presents information on the soil, the climate, and how the research areas were established. The geophysical data collection methodology and processing will be presented.

The results of the fieldwork are reported in Chapter 5. This includes maps produced through the analysis of the data recovered using different geophysical survey techniques and examples of the differing data processing techniques. A review of the weather conditions during the data collection periods also is presented to allow for a better interpretation of the geophysical data. The physical surface changes of the individual graves are documented.

The final chapter will discuss the results of this research and offer potential explanations of the findings and directions for future research. In conclusion, this chapter will show how these results might impact future searches for toddlers in regard to not only the initial six month interval that aligns with the research, but also with long term interments. I further review how

this research fits into the discipline of anthropology and how forensic anthropology might impact the discipline in the future.

## **CHAPTER 2 – THEORETICAL FRAMEWORK**

This research is designed as an actualistic study to examine the use of geophysical methods in the detection of toddler-sized burials during the first six months of interment.

Kowalewski and Labarbaera (2004) use the term “actualistic taphonomy” to describe the observations of the decay an organism goes through in order to interpret historical records. The results of this type of research is applicable to forensic investigations for missing children and falls under the sub-discipline that is known as forensic anthropology. My intention is to show how this type of research, and specifically forensic anthropology, is related to anthropology. Anthropology as a whole is a fairly broad academic field that struggles constantly to keep its subfields of archaeology, cultural anthropology, linguistic anthropology, and physical anthropology united (Hegmon 2003:214; Knudson and Stojanowski 2008:397; Ortner 1984:126).

Eric Wolf (1980) suggested that the subfields of anthropology were in fact fracturing the discipline. Sherry Ortner (1984) counters that the disciplines that fall under the umbrella of anthropology were never truly united, although at least they previously had shared common theoretical threads that helped to hold the field together. Ortner (1984) also stated that the tenuous union between the subfields is a stronger bond than perceived by Wolf through the concept of practice, which has been traditionally associated with socio-cultural studies. The concept of practice can be distilled down to the most basic understanding that it is the actions that connect individuals (agents) within a system that is being studied.

### **Origins of Middle-Range Theory**

Binford (1968:17) proposed that archaeological results needed to be verified through “independent empirical data” and that answers had to come from a deductive process. This placed an emphasis on hypothesis testing, and the utilization of the scientific method became the standard for archaeological research and helped further the formation of processual archaeology. It was argued that much of what was considered to be new archaeology was simply the opening of new avenues for archaeological theory. By 1973 there were archaeologists who believed that the discipline had lost its innocence because archaeology had become so “infused by theory” that it seemed disconnected from the work itself (Schiffer 1988:461). During this same time period Raab and Goodyear (1984:255) proposed that order might be established through the development of middle-range theory.

The concept of middle-range theory was borrowed from Robert Merton, a social scientist, as a way to construct empirical inquiry (Merton 1968:38). In 1977, Binford conceptualized middle-range archaeological theory using the principles of archaeological research to gain an understanding of the material evidence (Binford 1977:6). Schiffer (1988:462) defines theory as the development of basic premises or assumptions that often include phenomena that are unobservable to provide answers. Archaeology as a discipline is interdisciplinary in nature, and not only allows for a loose coherence of associations but encourages it (Shiffer 1988:463). As a means to try to find an answer for these phenomena or coherence of associations the researcher is given latitude outside of the traditional bonds of the discipline. One such avenue is actualistic studies.

As previously suggested, actualistic studies focus on observing and documenting visible changes and defining the sequence that changes follow (Lyman 2002:xix). This experimental

research method is viewed as valid due to the uniformitarianism concept that states events from the past would have occurred in the same manner as they do today (Boyd and Boyd 2011:1408).

More specifically, the research that I have conducted is an example of an actualistic study that falls within the range of taphonomic research. In 2011, Boyd and Boyd argued that taphonomic studies were examples of middle-range theory, because through the use of controlled studies and their results, modern observations could be used to better understand the archaeological evidence created by processes in the natural and cultural past (Boyd and Boyd 2011:1408).

They also note that the practitioners and developers of anthropological theory, and more specifically archaeological theory, have had more than a century to better define their theoretical arguments. Forensic anthropologists have only recently begun to develop a theoretical perspective. Boyd and Boyd have been lead contributors to this development with the article “Theory and the Scientific Basis for Forensic Anthropology” in 2011, and their organization of a session during the American Academy of Forensic Sciences Annual Meeting in 2015 that focused on the theoretical underpinnings within forensic anthropology (Boyd and Boyd 2015; Boyd et al. 2015). In their works they acknowledge that even though theory has not been explicitly addressed, there is a hierarchical breakdown within the theory of forensic anthropology to include high-level, middle-range, and lower-level (Boyd and Boyd 2011; Boyd and Boyd 2015).

### **Forensic Anthropology Theory**

Boyd and Boyd (2011, 2015, Boyed et al. 2015) address high-level forensic anthropology theory as being the broad umbrella that all other forensic anthropology theory falls below in a hierarchical fashion, and is superseded by that of biological anthropological theory supported by

Darwinian and punctuated equilibrium models. That is because high-level forensic anthropology theory addresses human variation on an individual basis as it relates to understanding skeletal maturation, biological sex, and potential genetic ancestry (Boyd and Boyd 2011). The practitioner is allowed latitude in the establishment of inferences about an individual's unique biological characteristics based upon the methodological collection of data from skeletal remains. It should be noted that this is only a slight difference from the traditional bioarchaeologists' goals of unifying both the biological and social to infer a better understanding of past societies (Knudson and Stojanowski 2008). Bioarchaeologists usually examine groups of individuals of all ages, while forensic anthropologists usually focus on an individual set of remains (Johnston and Schweichart 2015).

Middle-range theory, both from an archaeological perspective but also from the perspective of hierarchical forensic anthropology theory, provides a bridge between the observations of the archaeological or forensic records and events that have occurred from deposition until observation. Boyd and Boyd (2011:1408) point out that even though this level of inference is not high-level theory, in nature it does link, "remains, their context, recovery, and interpretation to human behavior and ultimately to (help to provide) the explanation of that behavior." They feel that within middle-range forensic anthropology theory there are multiple expressions that can be classified as such, including taphonomic or actualistic studies, agency and behavioral theories, and nonlinear systems theory.

Specific to my research is the use of actualistic studies or taphonomic theory. In forensic anthropology, this type of study uses experimental research to document and examine processes and changes of initial decay to link the natural and cultural events that have created the final state prior to recovery of remains (Boyd and Boyd 2011:1409). It is noted that the concept of

taphonomy was initially defined by paleontologists and then borrowed by archaeologists in their examination of site-formation processes. It has been used by forensic anthropologists to gain a better understanding of human and nonhuman forces as taphonomic agents (Boyd and Boyd 2011:1409). Gaining an understanding of the impact these forces have upon the decomposition process allows for the inference of forensically relevant events.

Actualistic studies are used to not only gain a better understanding of the decomposition process, but have grown to include the application of geophysical remote sensing devices (Boyd and Boyd 2011:1408; Dirkmaat and Adovasio 1997:39). Researchers use geophysical devices to gain a better understanding of how the act of burying remains impacts the decomposition process. This has also led to the evaluation of the methods employed as geoforensic tools, such as this research, and will be addressed in the next chapter.

It is noted that taphonomy, as used by forensic anthropologists in general, is used to define the circumstances surrounding clandestine graves and provides further understanding of the condition of recovered remains in regard to context. This is done through the use of field methods used to record and interpret temporal and spatial context, which are concepts that originated in archaeology. Thus, this is where Boyd and Boyd (2011) begin to build upon their understanding of low-level forensic anthropology theory, which focuses on the relationship between methodology and inferences. This relationship was examined by Schiffer (1988) and presented as methodological theory to explain how interpretations can be biased by both the recovery process and the inferences made.

Recovery theory as described by Boyd and Boyd (2011, 2015) is a low-level forensic anthropology theory that focuses on the documentation and recovery methods used to recover remains. According to Duda and Guillon (2006), Binford had criticized the lack of



methodology in dealing with burials, which created a loss of data needed for higher level inferences. This lack of precision began to be addressed in the 1970s by Duday and others. The precision that eventually developed in the recording and recovery process has been labeled *anthropologie de terrain* (Duday and Guillon 2006). It can assist in the determination of pre- and post-depositional states. But it should be noted that recovery theory goes beyond the methods themselves by encompassing the techniques used to search for clandestine graves and surface remains, as well as their applicability for the setting.

One argument that has been made against forensic anthropology being a discipline has been the perceived lack of a theoretical basis (Boyd and Boyd 2015). There is also the perception that forensic anthropology makes little contribution to anthropology as a whole. Duday and Guillon (2006:136), also note that there has been no real experimentation done by the practitioners of archaeology. They also emphasize that while field archaeologists concerned themselves primarily with archaeological investigations and the recovery of remains, forensic anthropologists emphasized lab work. These differences, they argue, might explain efforts to exclude forensic scientists from anthropology.

This tension was very evident at the 2012 American Academy of Forensic Sciences Annual Meeting during the discussion in the Physical Anthropology Section. At hand was the suggestion that the section should request a name change and also allow forensic archaeologists to join the section. Participants in the discussion argued for and against both suggestions. Traditionalists held that the section was devoted to the analysis and the interpretation of the skeletal remains, while the progressives within the section argued that it was also about the context in which the remains were found. Ultimately, the motion was tabled until 2013 where it passed along with a name change from Physical Anthropology to just Anthropology. It is

interesting to note that most if not all of Physical Anthropology Section members had at one time been or were currently considered to be practicing bioarchaeologists. One major flaw in the argument to not include forensic archaeologists is that both forensic archaeologists and forensic anthropologists have obtained either a master's degree or doctorate in anthropology, so ultimately they are all anthropologists and the two disciplines complement each other much. Dудay and Guillon (2006) argue that archaeology can strengthen forensic anthropology and forensic anthropology can strengthen archaeology, and therefore, a more complete understanding can be found when the two disciplines interact and support each other.

It is clear that forensic anthropology is based in the broader field of anthropology and has borrowed from the sub-disciplines of anthropology. Just as archaeology, cultural anthropology, linguistic anthropology, and physical anthropology have borrowed and influenced each other in their theoretical formations over the decades, Johnston and Schweikart (2015) believe in the coming years that forensic anthropology will only increase its influence on anthropology and its sub-disciplines.

## **CHAPTER 3 - BACKGROUND**

The focus of this research is an evaluation of geophysical methods in the detection of toddler-sized remains during the first six months of interment. This chapter provides an overview of the three main components of the research: missing children, geophysics, and taphonomy. The section on missing children will address the number of incidents that occur within a year that result in death and the need for research on geophysical methods despite difficulties in getting accurate statistics. The section on geophysics serves to introduce the principles behind the geophysical methods and to provide an overview of relevant literature on forensic applications of the geophysical methods. The taphonomy section further defines the research that has been undertaken and examines the decomposition process, which will be relevant to the results of this research.

### **Missing Children**

According to the most current information available from the United States Department of Justice in their October 2002 National Incidence Studies of Missing, Abducted, Runaway, and Thrownaway Children bulletin, it is estimated that a total of 1,315,600 children disappear each year in the United States (Sedlak et al. 2002:5). It is estimated that only 797,500 of the cases are actually reported to law enforcement. Boudraux, Lord, and Etter (2000), note that there are multiple dynamics at play in the determination of the numbers. This is in part due to overestimation of incidents in the late 1970s and the early 1980s as a result of the highly publicized cases such as Etan Patz, the Atlanta child murders, and Adam Walsh. These early incident numbers also included combined statistics of family and nonfamily abductions, and age

groups were not clearly defined in order to distinguish between pre-teen and teenage children. Many of the incidents were not reported to the Federal Bureau of Investigation (FBI) or the National Center for Missing and Exploited Children (NCMEC), which was the congressionally mandated response to the Adam Walsh case. State to state, there are variations in the definitions of the laws and discrepancies in data collection methods. This is further hindered on a local level due to classification systems used by agencies where the case is filed or recorded under the end result of the abduction, such as homicide or sexual assault.

The first statistic that must be examined is the number of total estimated missing children, as defined as a child missing from the welfare and care of a caretaker (Sedlak et al. 2002:3). A child is defined as any individual younger than 18 years of age. More specifically for an event to count towards this total estimated number the child had to be missing for at least 1 hour during which the caretaker was unsuccessful in trying to locate the child. For a child to be counted within the estimate for reported missing children, their caretaker had to make a formal report to the police that would then be entered into the National Crime Information Center (NCIC) database that is operated by the Federal Bureau of Investigation (FBI). For the purposes of this research, I have chosen to focus on victims of stereotypical kidnapping under the age of five.

Before going into more specific numbers in regards to stereotypical kidnappings and the age specific breakdowns, the number of estimated caretaker missing and reported missing children must be differentiated. Caretaker missing children are the children that are known to be missing from their immediate caretaker but have not been reported missing to the authorities. Reported missing children are the incidents where the caretaker has found the child to be missing and reported the child missing from care to the authorities. Under the age group of 0-5, there are

an estimated total of 138,200 caretaker missing children, whereas there are only 96,500 reported missing children (Sedlak et al. 2002:7).

“A stereotypical kidnapping occurs when a stranger or slight acquaintance perpetrates a nonfamily abduction...” (Sedlak et al. 2002:3). The numbers are still shocking in the estimated caretaker missing category with an estimated total of 33,000 falling under the nonfamily abduction classification (Sedlak et al. 2002:6). Under the reported missing children there are 12,100 missing children attributed to nonfamily abductions. This comes to a total of 58,200 for all nonfamily abduction victims. Of those there are only 115 that fall under the stereotypical kidnapping scenario (Finkelhor et al. 2002:6). When looked at by age group there are an estimated 20 stereotypical kidnapping victims that fall between the ages of 0-5 (Finkelhor et al. 2002:7) with the majority of the victims estimated to be between the ages 12-14.

Additional elements of nonfamily stereotypical kidnapping include that the child had been sexually assaulted 49% of the time and physically assaulted 33% of the time (Finkelhor et al. 2002:10). The stereotypical kidnapping lasted between 3 to 24 hours 83% of the time, but 8% of the time it lasted 2 hours or less, and 10% of the time it lasted longer than 24 hours. The estimated outcomes predict that 57% of missing children will be returned alive, 32% will be injured, 40% will be killed, and 4% will never be located. The majority of these events occurred during the spring and summer at a rate of 28% and 29% respectively (Finkelhor et al. 2002:11).

According to the study commissioned by the Washington State Attorney General in conjunction with the U.S. Department of Justice, the longer the stereotypical kidnapping lasts, the more likely it is to statistically end in death (Brown et al. 2006:14). The time between the abduction and the death of the child is as follows; 46.8% of the time death will occur in less than 1 hour, 76.2% of the time the child will be killed in under 3 hours, and within 24 hours 88.5% of

the cases end in death. If the event lasts less than seven days, death will result in 97.9% of the cases, and death is almost certain for cases that last 30 days or longer.

After the murder of the child, the killer will dispose of the body 52.6% of the time in a rural area, which is different than adult murder victims that are normally found within an urban environment (Brown et al. 2006:39). Killers deliberately choose the body disposal location an estimated 48% of the time. Only 10.4% of the locations were selected due to forced circumstance, and in 32.6% of the cases the body disposal site was completely random. In 55.4% of the time the killer tried to conceal the victim's body and only left it intentionally open 8.1% of the time (Brown et al. 2006:40). The other 36.4 % of the time the killer was not concerned about whether the body was disposed of in a concealed or open. Though not truly accurately documented, it is believed that killers that have intentionally tried to cover the remains will often do so with a clandestine grave.

Gleason states that clandestine graves have a depth usually no greater than 2.5 feet and will be located off a rural, lightly traveled road (Gleason 2008:24). The graves might be close to water, about 10 feet from the largest tree and within 1.2 miles of an intersection (Gleason 2008:25). Additionally, the remains will typically be on the downhill slope from the road and no further than 150 feet from an access road. The numbers indicate only a small amount of the cases are brought to resolution from an investigative standpoint. Therefore, it is important that the geophysical survey methods and training for visual searches are the most effective.

## **Geophysics**

Geophysics is a sub-field that has been derived from the development of techniques to examine the physical earth through the properties of matter and energy (Killam 2004:71). This is based in the combination of geology, which is the study of the earth, and physics, which is the study of matter and energy. Geophysics can be divided into two main branches, pure and applied (Killiam 2004:72; Ruffell and McKinley 2008:55). The pure branch of geophysics is largely theoretical in nature, focusing mainly on the math used to explore the earth's properties and is an academic pursuit. The applied branch has traditionally focused upon the application of the theory to detect anomalies that were of value because of their mineral or energy content. In general, geophysics as a whole utilizes non-destructive subsurface investigative techniques.

Geophysics has multiple definitions that are dependent on the specific groups that utilize geophysical techniques to explore what lies beneath the surface of the earth. Within the realm of archaeology, Conyers (2010:175) has determined that these applications “consists of near-surface imaging methods used to produce maps and profiles of buried cultural remains and associated stratigraphy, usually within a few meters of the surface”. This is considered an advantage for forensic investigations by Schultz (2003:9) since the techniques as a whole utilize non-destructive subsurface investigative techniques that allow for site preservation.

Geophysical surveying methods can be divided into two main types, active or passive (Table 3.1) (Ruffell and McKinley 2008:55; Schultz 2003:10). Both methods respond to disturbances that are often considered to be undetectable without the assistance of a sensor that measures signals that can be considered either induced or natural. The induced methods are considered to be the active methods that require the instrument to monitor the effect that some subsurface feature has on a signal that has been produced by the instrument. Passive or natural

methods are those where the instruments measure the magnetic fields of the earth. The geophysical survey techniques of ground-penetrating radar, electromagnetics, and electrical resistivity are considered active methods, whereas the fluxgate magnetic gradiometer is considered to be a passive method.

**Table 3.1 Geophysical Instrument Methods**

Method	Geophysical Instrument
Active	Ground-Penetrating Radar Resistivity Electromagnetics
Passive	Magnetics

Most, if not all, of the geophysical tools commonly used by archaeologists were initially developed by geologists. In the United States one of the earliest documented archaeological geophysical surveys utilized resistivity to document a stone vault at a church in Williamsburg, VA in the late 1930s (Bevan 2000). Hunter and Cox (2004:66) state that additional tools were added to the archaeologists' tool kit as geologists and other soil scientists developed them, beginning in the 1950s to include magnetometry and electromagnetics, and then again with the addition of the ground-penetrating radar in the 1970s.

Archaeological research and forensic geophysics use the same methods to detect small, near-surface anomalies. Anomalies are defined as changes that are distinguishable from the background signal of the surrounding substrate data collection (Ruffell and McKinley 2008:56). When these anomalies are viewed in a map or profile view of the area, they are considered to be targets, based upon the conformity to known anomalies such as burials or utility lines. Ruffell and McKinley (2008:57) caution that "targets can remain obscure, even when anomalies are mapped and methods compared." This, they state, is a result of additional targets causing the



principle target to be obscured. Sometimes through processing of the data some of the obscurity can be removed to clarify individual targets.

Forensic geophysical methods are most commonly utilized in the search to locate clandestine graves, but have also been used to locate weapons and evidence. Johnson (2006:8) notes that ground-penetrating radar (GPR) is the most commonly known of the geophysical remote sensing techniques in regards to archaeological applications. But this is true for forensic applications as well, in part due to police procedural shows such as “CSI: Crime Scene Investigation.” But in archaeological applications, there are three additional methods that have been utilized to detect graves, including magnetics (MAG), electromagnetics (EM), and resistivity (Schultz 2003:10).

Currently, there are a limited number of published texts devoted to geoforensics (Ruffell and McKinley 2008), but these are similar in nature to the books on forensic anthropology or archaeology in that they contain a chapter or so on geophysical survey methods (Hunter and Cox 2004; Killam 1990; Dupras et al. 2006). The remaining literature is a patchwork of articles published in different journals with different target audiences such as forensic anthropologists and archaeologists (France et al. 1997; Juerges et al. 2010; Pringle et al. 2012), geophysicists (Fenning and Donnelly 2004; Calkin et al. 1995; Mellett 1996; Scott and Hunter 2004), or archaeologists (Davenport 2001) that present case studies and research projects exploring the applicability of multiple techniques in the detection of clandestine graves (Table 3.2). Traditional archaeological geophysical surveying methods have been borrowed from and are the driving force behind the further development of the instrumentation and processing (Bevan 1991; Bevan 2000; Johnson 2006).

**Table 3.2 Geophysical Survey Methods used for Forensic Applications**

Geophysical Method	Advantages	Disadvantages
Ground-Penetrating Radar (GPR)	Real time display Nonintrusive Can penetrate concrete Medium coverage speed Works over/through snow, fresh water	Clear ground cover required Moderately smooth terrain Little penetration of clay or salt water Interpretation required by experienced operator
Resistivity	Easy to supervise Easy position determination Minimal damage Inexpensive equipment	Data processing isn't available in the field Interpretation required by experienced operator Slow coverage speed Flat terrain Graves may show insufficient contrast Interference from electrical sources
Magnetics (MAG)	Nonintrusive Rapid coverage of large areas Works over snow, fresh water Easy access to equipment	Only for ferrous materials Target could be missed if grid is too large Data must be processed Magnetic interferences by ferrous material
Electromagnetics (EM)	Nonintrusive Rapid coverage of large areas For ferrous/nonferrous materials Records conductivity Works over/through snow Does not have to contact ground	Subject to interference from all metals Target could be missed if grid is too large Data must be processed Difficult in rough terrain

Adapted from France et al. 1997, Killam 2004, and Schultz 2003

The most widely known of these projects was conducted by NecroSearch International in the late 1980s located in Douglas County, Colorado (France et al. 1997:497-509). This multidisciplinary research project brought together forensic and law enforcement personnel in an attempt to determine the best techniques to be used to locate clandestine graves. They studied a total of eighteen gravesites constructed using sixteen domestic pigs weighing approximately

70kg (154lbs). Their research is noted for the use of MAG, EM, and GPR. This research determined the GPR was the most applicable to forensic searches due to the availability of “real time format” unlike the other instrumentation that was considered to be labor intensive in terms of computer processing (France et al. 1997:505). Due to the accessibility and portability of laptop computers today, the “real time format” should not be regarded as a negative in the use of the other instrumentation.

G. Clark Davenport, the principal geophysicist involved in the NecroSearch project in the 1980s, points out that geophysical surveys need to be designed specifically to address the target being sought (Davenport 2001:88). This requires high density surveying intervals in the pursuit of data that is of high quality. Davenport notes several factors that can limit the success of a survey in regards to searching for a desired target. These are resolution, signal/noise ratio, contrasts, size/depth relationships, and that there might be limited difference between the target and the surrounding soils which limits the effectiveness of the surveying, therefore nullifying the effort placed upon the survey. Results might be improved through the use of filters and enhanced computer processing.

Edward Killam was also a collaborator in the NecroSearch research, who was in the process of completing his Master of Arts in anthropology at Colorado State University during that time. His work *The Detection of Human Remains*, first published in 1990 and then reissued as a second edition in 2004, became one of the first books to concentrate on the search for human remains. The research focused on the geophysical survey component of the investigative process and was aimed at educating law enforcement and serving as a reference for future practitioners.

Sabrina Buck (2003) also used a multi-instrumentation approach to test the GPR, MAG, and EM in the detection of graves. Buck utilized the various instruments on a variety of search

implementations ranging from historic cemetery graves to a suspected homicide clandestine grave (Buck 2003:5). The results of this research indicated that the GPR still provided the most success in detection of burials within cemeteries, with the one exception being the Punch Bowl Cemetery in Hawaii.

John Schultz (2003, 2008, 2012; Schultz et al. 2006) has made multiple contributions to the literature in regards to forensic geophysics with his primary research being focused upon the use of GPR to detect clandestine graves. Schultz (2008) notes that previous forensic geophysical research has focused on detecting adult sized remains in proxy research utilizing pig cadavers or other means, and becomes the notable exception in the use of pig cadavers in the range of 25.9 to 33.6 kg ( ~57 to ~74 lbs.) to simulate large children. It is also important that his work has focused upon the sandy soils of Florida while most other research has been conducted in clays. Using known target depths and calibrating the GPR to a set depth of 1 meter prior each survey, he was able to visualize the burials throughout the course of the study with graves producing a parabolic reflection in the data. He notes that there was no parabolic shape in the smaller response from the blank control graves. He concludes that upon skeletonization, the effectiveness of the GPR to detect small graves in sandy soil is limited due to the lack of discernable grave features with respect to the soil type. Schultz (2012) also notes in additional research that the use of electromagnetic induction produced similar results over a 24 month monitoring period with no significant changes that would indicate the presence of burials.

Jamie Pringle et al. (2008, 2012) also have made multiple contributions to the literature of forensic geophysics. In the first of these studies, Pringle et al. (2008) used a variety of materials to create a target to simulate a clandestine grave in an urban environment. This study was an exception to the traditional porcine analog, using plastic resin, human skeletal material,

animal material purchased from a grocery store, and saline solution to create the target anomaly. The geophysical surveying methods utilized in this research included bulk ground resistivity and conductivity, fluxgate gradiometry, ground-penetrating radar, magnetic susceptibility, electrical resistivity tomography, and self-potential. Testing was limited to one month and then three months post-burial. This research showed that bulk ground resistivity and self-potential showed the most optimal results for grave location. GPR and ERT profiles showed the spatial relationship and should be used after the collection of bulk ground resistivity. In further research, Pringle et al. (2012) utilized pigs as proxies and buried them either “wrapped” or “naked” and collected data over a three year period in order to explore changes in the geophysical response using of bulk ground resistivity, electrical resistivity imaging, multi-frequency ground-penetrating radar, and conductivity. This research showed that the naked burials had low resistivity levels versus the high resistivity of the wrapped burials. In the GPR data, the naked burials often could not be resolved from the surrounding background, whereas the wrapped burials could be detected throughout. The results of the conductivity surveys varied by year, with year one showing increasingly higher values at a rapid pace and year two showed an increase in values but only slightly. In year three the values for the graves began to decrease. Pringle and his coauthors also recommend that resistivity surveys should be conducted in high clay soils rather than GPR which would have poor signal propagation. This research showed that a wrapped target should provide a good target due to the contrast with the surrounding soil.

Alanna Juerges et al. (2010) found mixed results using magnetic and electrical resistivity surveying to detect simulated clandestine graves in semi-rural, urban, woodland, and of one known burial location on an archaeological site. Magnetics showed elevated readings for shallow burials, but with deeper burials the levels were lowered or showed no change from the

surrounding area. It is also interesting to note that with surface depositions of remains, anomalies were also detected in the magnetic data, suggesting that it might be possible to locate an initial deposition site where no other physical evidence remains.

Juerges et al. (2010) reported that with electrical resistivity all burials were reactive with the exception of the archaeological analogue. In the creation of the clandestine graves for this research, metal was not included. Their findings suggest that electrical resistivity is more successful in finding clandestine graves than magnetic methods, but this does not discount the use of magnetics, which as it could be deployed as part of a multi-sensor investigation where there would be less influence from metal or electrical sources. The results indicate that there is an increase in iron levels for the graves that create the anomalies, along with decompositional fluid affecting conductivity. In conclusion, neither method proved to be ideal upon individual deployment, but could produce successful results when used together.

Forensic case studies are also important. These reports tend to focus not only on the success of the instruments, but also speak to the failure of the instruments or operators to accurately pinpoint targets that were in fact human burials. The majority of these utilize ground-penetrating radar as the principal tool. The following studies have utilized a multi-disciplinary approach not only of visual survey techniques in conjunction with geophysical survey methods, but they have also been partnered with the use of cadaver dogs. Cadaver dogs, as defined by Rebmann et al. (2000) have specifically been trained to detect the odor of decomposing human remains.

Scott Calkin, Richard P. Allen, and Michael P. Harriman (1995) reported that an adult female had been missing since August 1991 when a survey was conducted in the basement of the suspect's house in September of 1992. The basement had a dirt floor which had produced trained

final responses when searched by cadaver dogs, however upon test excavations no evidence was recovered. A systematic GPR survey was conducted and field analysis showed no concealed grave. This is believed to result from disturbance of the area and the potential target absorbing the signal. Upon further investigation of the area the remains of the missing female were recovered wrapped in plastic and tied with rope. This is an example of a GPR survey that did not work as it was hoped.

James Mellett (1996) notes that GPR has been successful in locating clandestine graves in both archaeological and forensic context, but also recognizes that buried remains are not always located in GPR surveys. This is due to the fact that there either are no remains located within the search area, or that the instrument fails in the detection of the remains. But he also feels that the soil chemistry and hydrology will also impact the detectability of the remains. Within the forensic context, Mellett also states that signal attenuation occurs due to signal absorption into the remains creating signal loss below the remains. This is tempered as the decomposition process continues, allowing for targets to possibly become visualized in the data by the loss of the signal absorbing soft tissues and the exposure of the skeletal elements and clothing. He also notes that the use of GPR allows a more detailed recovery strategy for the remains, which minimizes any damage to the remains that would impact analysis. In his own experience, in the majority of the times that GPR failed to detect a burial, there was no burial present at the location. This is either through false witness or through witnesses remembering the wrong location of the burial. He has also called for the creation of a data base of GPR survey results so that comparisons can be made by operators in the search for clandestine graves. Ultimately, even negative results are important in the search for human burials.

David Nobes (2000) utilized EM and GPR in an attempt to locate human remains from a burial that was 12 years old in an area that was highly disturbed by forestry activities. In this case, disturbances created by stumps and roots resulted in numerous anomalies in the EM survey, but investigation of the anomalies with GPR determined that the remains were located in a shallow grave. Nobes points out that a multi-sensor approach should be used in the application of geophysical surveys for archaeological or criminal investigations.

In 2004, John Hunter and Margaret Cox published *Forensic Archaeology: Advances in Theory and Practice* which was written primarily as a text to guide one in the recovery of human remains from the forensic context. Unlike Killam (1990, 2004) and Dupras et al. (2006), Hunter and Cox provide several case studies that are specific to the search for children. In one case, Hunter and Cox (2004:47) detail the search for two juveniles that had gone missing in the early 1970s. Their case was revisited upon the discovery that a pedophile had lived in the area. Using an approach that combined the services of forensic archaeologists, GPR operators, cadaver dog handlers, and other crime scene personnel, a thorough search of the properties that the potential suspect had access to was conducted. Several small anomalies were detected using GPR but upon venting, these locations were ignored by the cadaver dogs. The GPR operators and the cadaver dog handlers were confident in excluding the areas from further investigation, but at the request of the investigators, excavations revealed trash pits and pet burials.

In another case, Hunter and Cox (2004:51) detail a search for a potential child's burial in a garden which was conducted using a multi-disciplinary approach. Anomalies were found in the GPR data, and once again, cadaver dogs did not respond to them. Excavations revealed these anomalies to be pet burials. Hunter and Cox (2004:55) also describe the search for a 12 year old victim of the Moors Murderers which was conducted at the edges of a peat bog. The principal



geophysical method utilized in this search was resistivity combined with probing to determine the composition and depth of suspected burial locations. Using this combined approach, 30 potential targets were identified for further investigation. Upon the alerting by the cadaver dog to two of these targets they were excavated and no human remains were found. The initial plan had been to use magnetometry and then resistivity, but the presence of a fence with iron posts limited the survey to resistivity. Three anomalies were discovered and upon excavation none revealed human remains. No features were found when the topsoil was stripped. The justification for using the non-invasive method prior to the mechanical stripping was that it would help prevent any damage to any potential evidence.

In their 2009 book, *Geoforensics*, Alastair Ruffell and Jennifer McKinley examine different methods of geophysical survey and testing borrowed from the realm of geology that can have forensic applications. In their discussion of GPR, they point out that the use of pigs as research proxies and using cemeteries with marked graves to test and refine geophysical survey techniques are useful, but may pose problems for the operator because actual deployments of the instrument may fall outside the test soil types and environments (Ruffell and McKinly 2009:80). They also note that burial artifacts and treatment of the remains may influence the results.

Saraiva et al. (2011) propose that necroleachate, the liquid that is formed during the destruction of soft tissue, may have an impact on the resistivity of an area, but found that in shallower graves the impact was limited. Although they anticipate that the necroleachate would result in low resistivity, they actually found high resistivity in the vicinity of the burials and speculated that perhaps the soil wasn't porous enough to allow the migration of the necroleachate. The following section will provide a better understanding of the decomposition process and how it may impact the soils surrounding a burial.

## **Taphonomy**

Taphonomy is the combination of the words *taphos* and *nomos*, which are Greek for burial and laws, and was originally coined by Efremov in 1940 (Schultz 2003:33). The study of taphonomy based upon its original inception can be viewed as any aspect that affects the “death assemblage” (Haglund and Sorg 1997:3). But it is more complex than that simple definition. In the 1980s, Olsen and Bonnicksen offered varying definitions of taphonomy and its study, that when synthesized, reveal that taphonomy includes the process enacted upon remains from the time of death until their recovery by the researcher (Haglund and Sorg 1997:3).

In my usage, it is directly related to the human decomposition process, and is considered to include any factor that directly or indirectly affects the decomposition process. Specifically, my application of the term falls within the definition that has been more recently applied by Haglund and Sorg (1997) that focuses upon the destruction of the soft tissue remains of an individual following death (Haglund and Sorg 1997:3). This is a key difference from past understandings of the field that had operated under the “myth of the flesh”, preferring to believe that bone and the associated assemblage had not been affected upon by the decay of soft tissue. This gave notion to the incorrect belief the bones had always been in their present state upon discovery. More directly forensic taphonomy is “the use of taphonomic models, approaches, and analyses in forensic contexts to estimate the time since death, reconstruct the circumstances before and after deposition, and discriminate the products of human behavior from those created by the earth’s biological, physical, chemical, and geological subsystems”(Haglund and Sorg 1997:3).

The addition of geophysical devices to taphonomic study has specifically allowed researchers a better opportunity to understand how different factors affect the decomposition

processes. Schultz (2003:34) attributes Stephen Nawrocki with grouping taphonomic factors into three main categories for burials, including environmental, individual, and cultural factors. Those associated with the environment include such things as “biotic and abiotic forces.” Individual factors include those that are truly specific to the individual, such as age, weight, and overall health. Finally, cultural factors are mortuary practices utilized to dispose of and conceal human remains directly related to “human intervention.” Schultz states that while these forces can be individually impactful on the decomposition process, they do not work in isolation and when combined create a greater complexity that is intensified in burials.

### Human Decomposition

The human decomposition process is one of intricate complexity. Research into the process was born out of necessity and didn’t begin in earnest until the founding of the Anthropological Research Facility at the University of Tennessee, Knoxville in 1981 by Dr. William “Bill” Bass (Sachs 2002:138). The primary motive to understanding the human decomposition process was to help better determine the post mortem interval which is specifically relevant to criminal investigations. As a result of Bass’ research, the process was broken down into distinct stages.

The first of these stages is autolysis, which begins approximately “4 minutes after death” (Vass 2001:190). Autolysis has been defined in a biological sense as “self-digestion.” This process begins due to imbalances created within the cells by the cessation of the circulatory system, depriving them of oxygen and increasing their carbon dioxide levels. Other factors that occur due to this cessation are the accumulation of waste products and a decrease in pH. Due to the occurrence of these imbalances, enzymes within the cells cause the cells to rupture, thus creating a nutrient rich fluid that allows for bacterial growth. Autolysis is often not visible for

several days, but can be observed as water filled blisters followed by skin slippage. With the accumulation of enough of the nutrient-rich fluid released during autolysis to support bacterial growth, the decomposition process moves into the second stage known as putrefaction (Vass 2001:190). The bacterial action combines with the growth of protozoa and fungi to begin soft tissue consumption of the body. The resulting actions can be seen as the building up of gases and fluids within the body, but Vass notes that the “greenish discoloration” of the skin is usually the first visualization of putrefaction. The gaseous buildup is primarily seen within the abdominal area, but has also been observed within the face and the extremities dependent upon position of the body. This gaseous buildup, commonly called bloat, is due to the bacterial activity and the continued breakdown of soft tissue.

Upon reaching the most extreme stage of bloat, the gas and fluid buildup will be purged primarily through the rectum, but will exit through any available orifice (Gennard 2012:30). In the most severe cases, bloat can cause the skin of the extremities to rupture. With the release of the purge fluid, water and chemical compounds are released into the localized environment. The purge fluid, comprised of decomposition chemical compounds, becomes trapped in the surrounding soil and is often times referred to creating a “cadaver decomposition island” or the decomposition shadow (Aitkenhead-Peterson et al. 2012:127). The decomposition process will then be considered to be in active decay after the purge (Vass 2001:190).

Active decay is the stage of decomposition where the remaining soft tissue is destroyed (Vass 2001:191). This destruction of soft tissue is the result of bacteria, insect, or carnivore activity and frees the skeletal remains from any remaining soft tissue. Sometimes the skin is the only true soft tissue remaining (Sachs 2002:135). It has mistakenly been believed that larvae do not consume skin because it has no nutritional value, but research at the Forensic Osteology

Research Station (FOREST), the outdoor human decomposition research facility at Western Carolina University, has shown that skin remains when sub-sensitive developing larva need protection, but may be consumed when the remains are shaded or covered.

Skeletonization is considered to be the final stage of the decomposition process (Galloway 1997:145). Once all of the soft tissue, including muscle tissue and organs, has been removed, all that remains to be destroyed is the skeleton. But sometimes cartilage, ligaments and tendons will still remain, and with time, will be destroyed (Clark et al. 1997:160). The presence of the connective tissue holding skeletal elements together is regarded as partial skeletonization, whereas skeletal material fully devoid of any connective tissue is full skeletonization.

Upon the initiation of the decomposition process, bone is also affected by the chemical solution that has been created through the autolysis process (Gill-King 1997:104). Once the remains have become skeletonized, they are then vulnerable to the surrounding environmental factors (Gill-King 1997:105). This vulnerability is considered to be diagenesis and is considered to be a shift in the organic and inorganic components of the bone (Vass 2001:190). If the bone is left undisturbed and exposed to the natural environment the skeletal material will eventually become a disassociated mass of molecules within the soil matrix.

#### Factors affecting the decomposition process

The decomposition process is a dynamic sequence of events that begins upon death of the individual. However, it is not a static process that systematically progresses from one stage to the next after a set amount of time. This process is affected by a host of outside factors that can either inhibit or accelerate the rate at which the remains will proceed through the decomposition process.

The most influential of these factors is the temperature where the remains are located (Gil-King 1997:93). The higher the average daily temperature, the faster the process of decomposition will occur. A colder average daily temperature will slow down and impede the progress. The ambient temperature is dramatically stabilized upon burial of the remains (Schultz 2003:36). This is especially true with remains buried at a depth below two feet, which prevents the remains from being affected by solar radiation (Rodriguez 1997:459). By burying the remains, the decomposition process will be retarded in contrast to remains that had been left upon the surface

Besides stabilization of temperature, the burial of the remains will have a myriad set of effects upon the decomposition process that will increase the amount of time needed to reach skeletonization. Burial of the remains protects them from insect and carnivore activity (Jaggers and Rogers 2009:1217). Deep burials and soils with high water content will reduce the availability of oxygen and therefore reduce the “oxidative processes,” whereas sandy and aerated soils will have a “high(er) redox potential” (Gil-King 1997:95). It should be noted that water can either come from the remains themselves or it can come from the environment, which serves primarily to stabilize the temperature, but can also buffer the soft tissue against the acidity and alkalinity of the soil (Gil-King 1997:94). Water also serves to dilute corrosive chemical concentrations and will provide hydrogen for biochemical reactions of the decomposition process.

The acidity or alkalinity levels of the soil also can impact the rate of decomposition in burial environments. Soils with more vegetative decay will have lower pH levels or be more acidic (Gil-King 1997:95). This in turn will cause an increase in fungi growth on the remains and an intensified nutrient uptake by plants. Caccianiga et al. (2012:988) note that even though there

might be an increased nutrient uptake, there appears to be no visible change in the vegetation. It is believed that burial depth is a main factor in regard to surface vegetation changes, with deeper burials not having an effect while shallower burials are closer to the feeder or uptake roots.

Through the initial decomposition process, the soils surrounding the body in burials will become more acidic due to the initial release of decomposition compounds. Then as the body progresses through the decomposition process and protein is released into the surrounding soils through proteolysis, the soils become more alkaline. This change can occur from as short a time as a few weeks to as long as multiple months.

### **Connections**

I was unable to find any case studies that reported on the use of geophysical methods in the search for toddler-sized burials. This might be due to either a lack of results or application, therefore creating a gap in the literature. I have also used this literature for the research site selection, the creation of the graves, and the identification of the methods that would possibly prove most useful. This information will also be useful in the analysis and the discussion of the results from the research.

## **CHAPTER 4 – MATERIALS AND METHODS**

This chapter focuses on the field research site and the soil type, the materials used in establishing the research areas, and the methods used to collect data. The location and soil selection for this study was done to provide the greatest chance of success for the geophysical methods utilized. I also address the use of pig remains in taphonomic research and grave construction. Finally, this chapter also addresses the geophysical and visual survey methods used to collect data for this research.

### **The Field Station**

The field research site was located at the University of Mississippi Field Station, which is 11 miles northeast of Oxford, MS in Lafayette County off of County Road 202 ([www.baysprings.olemiss.edu](http://www.baysprings.olemiss.edu)). The Field Station is under the direction of the Office of Research and Sponsored Programs and has been an active research property since its dedication in May of 1985. In its current state, it is a 740 acre site with more than 200 experimental ponds, a turkey aviary, wetlands, grasslands, and closed-canopy forests (Figure 4.1).



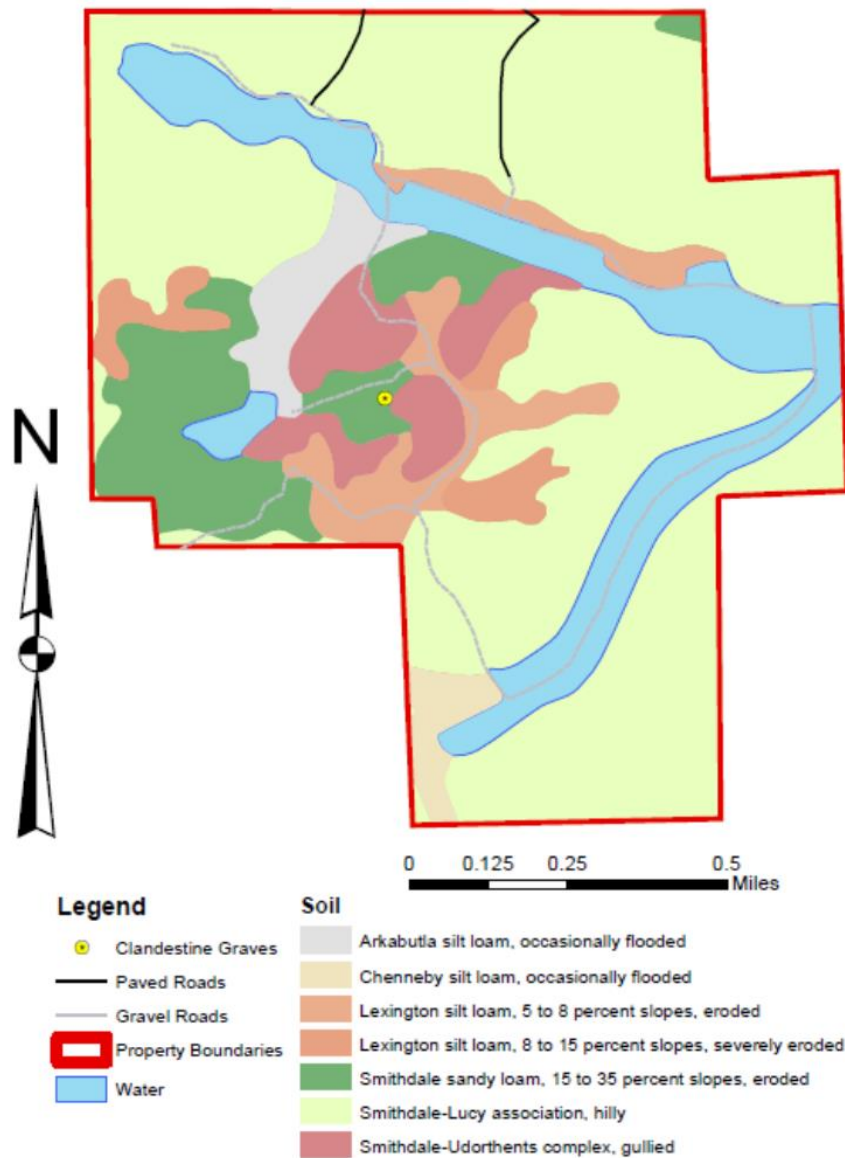


**Figure 4.1 Field Station Map with the Location of Research Plots**

The land has most closely been associated with its use as a minnow farm initially established in 1947 as Ole Miss Fisheries, Inc., and thereafter as Minnows Inc. upon purchase by the Herbert Kohn Corporation of Memphis ([www.baysprings.olemiss.edu](http://www.baysprings.olemiss.edu)). Weyerhaeuser Inc. acquired the property in 1979, and allowed the ponds and the surrounding area to become overgrown and remain fallow until the property was leased by the University of Mississippi in 1983 with the intention of developing a research station (Lafayette County Deed Book 342:176; 359:102). The lease allowed for the clearing of land and reclamation of the ponds for research purposes. Following the final purchase of the property in 1985, research facilities were constructed (Lafayette County Deed Book 373:157). An additional 211 acres of land was purchased in 1990, and it is in this section of land that the research area for this study was located (Lafayette County Deed Book 800:187). In 1996, the University of Mississippi contracted both Weyerhaeuser and Sharp Timber Inc. to harvest timber from the property (Lafayette County Deed Book 445:53; 446:362).

## **Soil**

According to the USDA Soil Survey for the University of Mississippi Field Research Station at Bay Springs, MS, there are seven primary soil classifications found within the property boundaries (Figure 4.2) (<http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>). The soil types include: Arkabutla silt loam, Chenneby silt loam, Lexington silt loam with 5 to 8 percent slopes eroded and 8 to 15 percent slopes eroded, Smithdale-Lucy association, Smithdale sandy loam, and Smithdale-Udorthents complex.

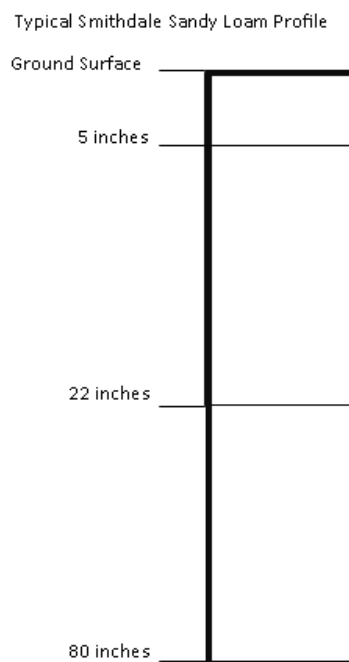


**Figure 4.2 Soil Map of the Field Research Station**

The soil of the designated research site was mapped as Smithdale sandy loam. Smithdale sandy loam is described as being “well drained” and contains no restrictive features for more than 80 inches (<http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>). Smithdale soils are believed to have been formed from “thick beds of loamy marine sediments” and are located in the Southern and Western Coastal Plains ([https://soilseries.sc.egov.usda.gov/OSD\\_Docs/S/SMITHDALE.html](https://soilseries.sc.egov.usda.gov/OSD_Docs/S/SMITHDALE.html)). Smithdale soils are

primarily distributed in Mississippi and Alabama, but also have a geographic extent that includes Arkansas, Kentucky, Louisiana, Oklahoma, Tennessee, and Texas. Because this soil is fairly well distributed throughout the south central United States it is feasible for this research to be applied in areas outside of Lafayette County, Mississippi.

The Smithdale sandy loam identified at the research site has 15 to 35 percent slopes, eroded, and the typical pedon has been described as follows (Figure 4.3). The surface layer, when present, is a “dark brown sandy loam” that is approximately 5 inches thick (Soil Survey 1981:30). The upper level of the underlying subsoil is about 17 inches thick and is typically “red sandy clay loam”. Below that, a “red sandy loam” extends to 80 inches in depth, and consists of “pockets of uncoated sand grains”. According to the USDA Soil Survey published in 1981 it was found that the surface layer had been “removed by erosion” or that plowing had mixed it with the subsoil. It is considered to be an acidic soil, with moderate permeability.



**Figure 4.3 Typical Soil Profile of Smithdale Sandy Loam based on USDA Soil Description**

## **The Climate**

Lafayette County is like most of the south eastern United States and usually experiences only two main seasons, summer and winter. Summers are typically hot, humid and long with temperatures consistently reaching the 90s. Winters are fairly cool, wet, and short with only a few days on average being below 32 degrees. This helps produce a rather temperate annual air temperature of 57 to 63 degrees F, with a total annual precipitation between 45 to 55 inches (<http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx>).

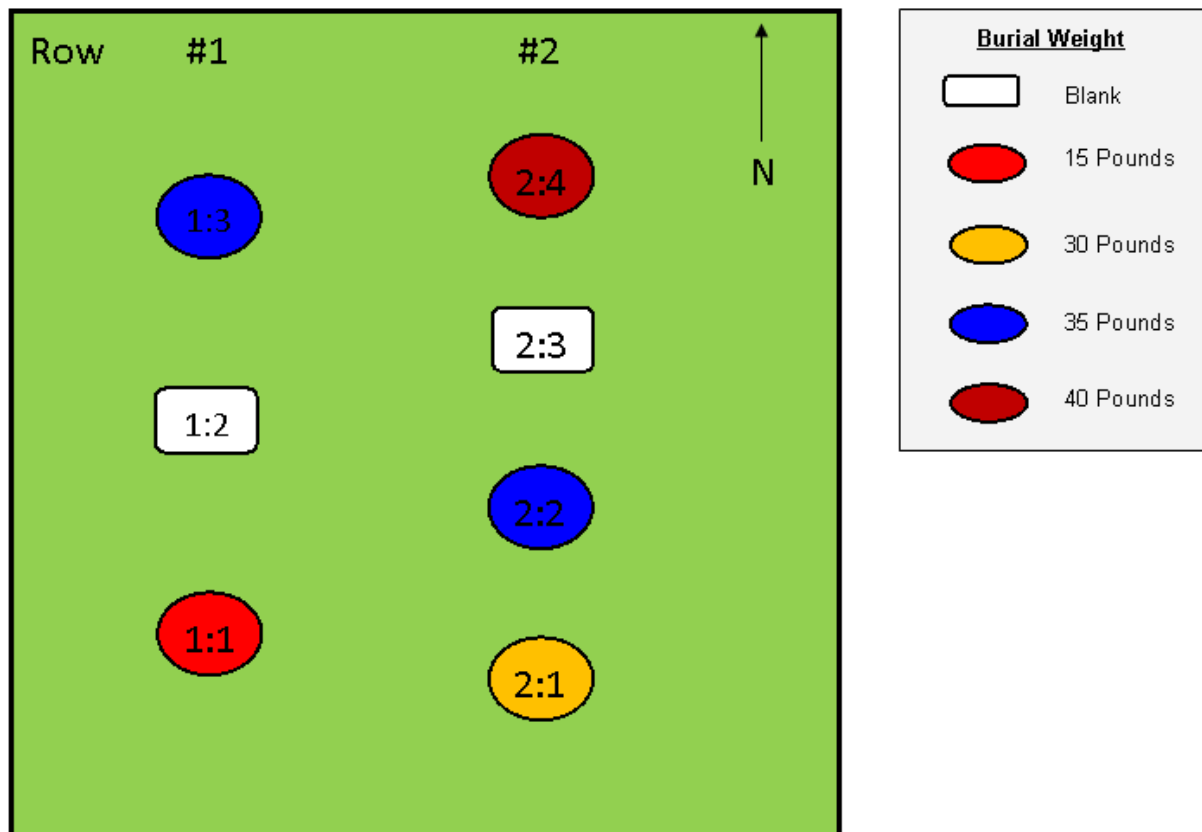
## **Research Areas**

The research area was selected because it was relatively flat and contained a single soil type with both grassy and wooded ground cover. This site was large enough so that two 10 m x 10 m research plots could be established with one plot located in the grassy area and the other plot located in the wooded area. The research site was also selected in an isolated area of the Field Station so as to not interfere with the long-term monitoring stations, the research ponds, and the turkey aviary, as well as to be less likely to be disturbed by curious passersby. The corners of the research plots were marked with wooden survey stakes to ensure that the survey grid could be reestablished accurately each month.

The grassy area was designated as Research Area 1 (Table 4.1; Figure 4.4). It was bordered by woods on the eastern, southern, and western sides. The northern side was bordered by a drainage ditch and gravel road. There were only a few trees showing roots that might extend into the research plot from the western side. Graves were placed far enough away so that there would not be have been any major anomalies created by the root disturbance, which would obscure detection of the pig cadavers. The area had not been regularly maintained and all external maintenance ceased upon the establishment of the research plot.

**Table 4.1 Detailed Information on Area 1 Graves**

	Grave 1	Grave 2	Grave 3	Grave 4
Row 1	15 pound pig	Backfill only	35 pound pig burned	N/A
Row 2	30 pound pig wrapped in nylon blanket	35 pound pig wrapped in 4 garbage bags	Backfill only	40 pound pig wrapped in blanket, garbage bags, and burned



**Figure 4.4 Research Area 1 Map**

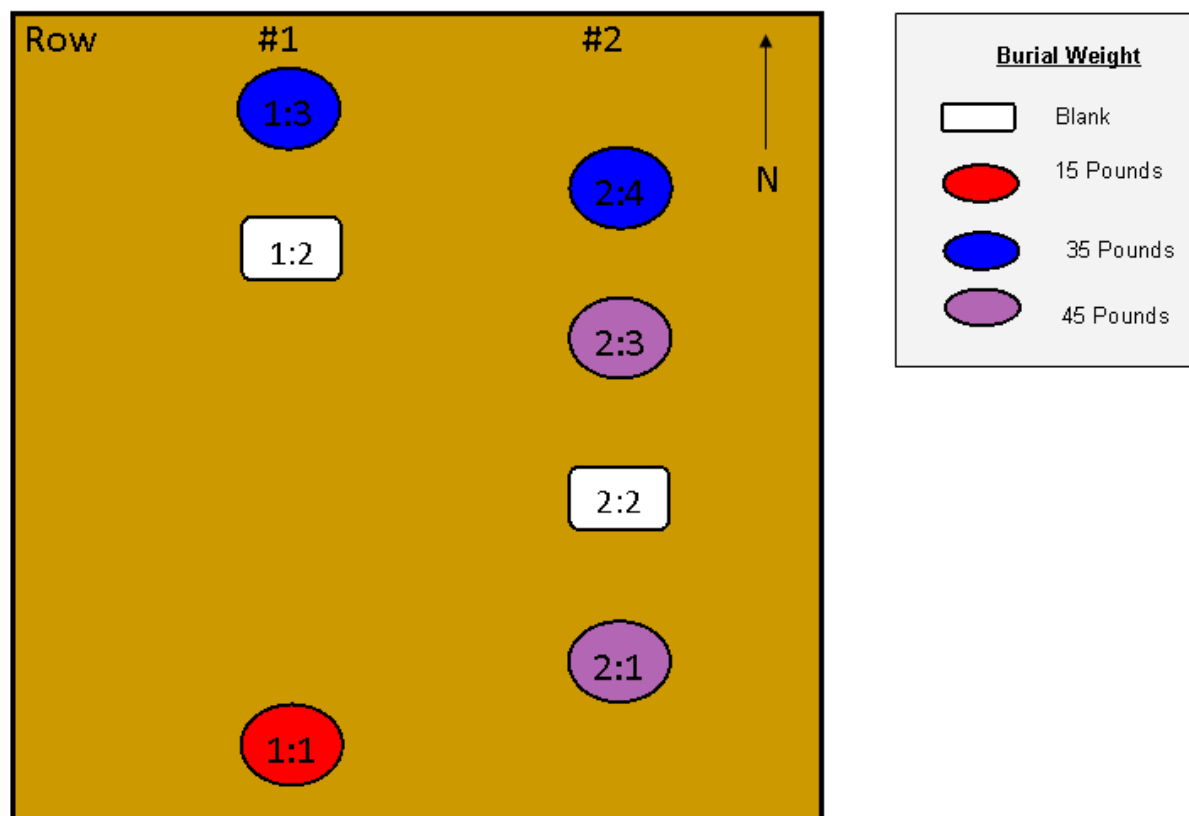
Map not drawn to scale and is only to show general placement of graves.

The wooded area was designated as Research Area 2 (Table 4.2; Figure 4.5). It was fairly clear of underbrush, except for a few briar bushes that were removed to provide an easier traverse of the research plot with the GPR cart. The trees covering the area were primarily saplings with a few well-established trees in the understory, and several large, older trees within the plot and the surrounding area. As a result of the number of trees within area 2, there were

numerous roots that could cause anomalies and possibly obscure a grave. There was also a drainage running from east to west on the south side of the research plot. The plot was bordered on the south side by a downed tree, and the easternmost 1.5 meters of the plot were blocked from data collection by another downed tree.

**Table 4.2 Detailed Information on Area 2 Graves**

	Grave 1	Grave 2	Grave 3	Grave 4
Row 1	15 pound pig	Backfill only	35 pound pig burned	N/A
Row 2	45 pound pig wrapped in nylon blanket	Backfill only	45 pound pig wrapped in blanket, garbage bags, and burned	35 pound pig wrapped in 4 garbage bags



**Figure 4.5 Research Area 2 Map**

Map not drawn to scale and is only to show general placement of graves.

## **Pig Cadavers**

Pigs (*Sus scrofa domesticus*) have commonly been used as human analogues in decomposition studies when human cadavers are unavailable (France et al. 1997:499). Pigs are biochemically and physiologically similar to humans, especially in regard to their digestive tract, which causes them to have a similar decomposition pattern. Other similarities include muscle-to-fat ratio and the limited amount of skin-to-hair. One aspect that is especially important to geophysical research is that, according to Stokes et al. (2013:586), pig skeletal muscle tissue generally has an electroconductivity profile that is quite similar to that of humans. Thus, pigs are a commonly used target for forensic geophysical research. There is only one example of a human cadaver being used as a target in the research by Michelle Lee Miller at the University of Tennessee's Anthropological Research Facility (Miller 2003).

I purchased the pigs from a vendor of "suckling pigs" in western Tennessee, in the morning shortly after they had been euthanized with a single gunshot. This is an acceptable form of euthanasia according to the American Association of Swine Veterinarians and National Pork Board (2009). They were buried on the afternoon of that same day, May 10, 2013. A total of 10 pig cadavers were purchased weighing 15 to 45 pounds each to represent toddler-sized children.

The pigs were divided into two groups of five, allowing for two rows of burials in each research area. A burial depth of 50 cm was determined based upon previous research that established clandestine grave depths varied between 46 cm and 76 cm (Hoffman et al. 2009:6). Clandestine graves are typically semi-rectangular in shape, and just large enough for the placement of the remains, so when the graves were dug by hand they were generally oblong in shape and measured ~0.5m wide by ~0.75m in length. Additionally, the walls were sloping to the



floor, which was more concave than flat, following the recommendation of Dr. Arpad Vass. The graves were oriented east to west and were marked with wooden survey stakes.

Mary Manhein (2006:475) found that in the United States clandestine burials were most commonly clothed or wrapped in plastic or fabric and, although documentation is lacking, there are an increasing number of reports where fire has been utilized as a disposal method for human remains prior to burial. In row one, a pig was placed with no adulteration and a second pig was burned using 64 ounces of charcoal lighter fluid. The second row consisted of three burials; one wrapped in a small nylon blanket, one wrapped in four garbage bags, and one wrapped in both a blanket and bags, and then burned utilizing 64 ounces of charcoal lighter fluid. The interment process was photographed, and the graves were photographed for the duration of the research study as part of the monitoring process.

A control grave was constructed for each row of burials. This was simply a hole that was approximately the same shape, size, and depth of the surrounding graves, that was subsequently refilled with dirt (backfilled). This allowed for a comparison in the various data collections between disturbed soil, and disturbance caused by the buried pig cadaver.

### **Methods**

Ground-penetrating radar, magnetic gradiometer, resistivity, conductivity, and magnetic susceptibility data were gathered at regular intervals. Weather data was also collected; specifically, daily weather conditions and precipitation totals. Surface changes of the graves were documented through photographic means. The geophysical methods, advantages and disadvantages of each, and the processing of the data will be addressed in this section.

## **Geophysical Survey Methods**

Four different instruments were utilized to collect five different types of data in the two research areas. As previously discussed, each area was 10 meters x 10 meters and oriented on a magnetic north – south axis. This allowed for all data to be collected in a uniform fashion for each area, except the easternmost 1.5 meter of the survey area in Area 2. This could not be collected due to downed trees, which would be a scenario faced in a real-world application of these techniques. The southwest corner was used as the origin for the data collection, for both Area 1 and Area 2. The data was collected using 50 centimeter transects (Larson et al. 2011:13).

As initially proposed, I had planned on conducting geophysical surveys on a monthly basis (dependent upon weather) until six months had elapsed from the day of interment of the pig cadavers which was May 10, 2013. However, this was not possible, as some of the equipment was out of the country, and teaching commitments at a Field Recovery of Human Remains field school in North Carolina conflicted with the proposed data collection schedule. Thus, data collection did not begin until July, when the graves had grown over with grass.

### **Ground-Penetrating Radar**

A Geophysical Survey Systems, Inc. (GSSI) SIR 3000 with a 400 MHz antenna mounted in a cart was used for this research. In this configuration, the antenna is located in front of the operator in a plastic tray that enables it to ride along the ground surface as the system is pushed over the survey area, allowing for real time visualization of the data as it is collected. The signal gain was manually adjusted prior to data collection to be optimized for the first meter of penetration. The data were collected at 50 cm transects on the X-axis.

GPR is especially useful in mapping archaeological features and shallow near surface objects (Conyers 2006:136). Radar waves are sent from a surface antenna and when they

encounter an object they are reflected back towards the surface and received by the receiving antenna. The signal is reflected whenever it encounters an abrupt change in the velocity of energy transmission. Three dimensional data can be produced when the signals from the GPR are timed as they pass through soil types that have a known velocity, which allows for the determination of the distance or depth from the antenna. The velocity at which radar signals will pass through different soil types is a function of their relative dielectric constant. Soils with higher clay content will slow the propagation of the signal and attenuate the radar wave (Conyers 2006:140). Soils such as dry sand have a high relative dielectric constant because the signal will quickly pass through the soil to a greater depth. When soils become wet, their electrical conductivity increases, which in turn decreases the depth that radar signals will travel. Eventually all radar pulses will either be reflected or absorbed. Another factor to consider in regard to the depth and resolution is the frequency of the antenna (Conyers 2006:138).

The use of GPR to locate and map features and associated sediment changes became a revolutionary advancement for archaeologists (Conyers 2006:133). GPR is still commonly used today as part of the site survey process prior to excavation. It is used to help target areas of interest to be excavated and, as noted previously, it helps eliminate any unnecessary excavation of the archaeological site. When used in mapping historic cemeteries, GPR has helped prevent unnecessary disturbance of graves. It has become the geophysical survey method of choice for forensic applications, particularly in the search for clandestine burials.

### **Resistivity**

A GeoScan Research Resistance Meter RM15 was used for this research, and was configured in a pole-pole array. This set-up uses two electrodes placed at 50 cm spacing on wooden bar that is connected to another crossbar with handles where the RM15 meter is

mounted. These probes are used to sample the survey area. Two remote electrodes placed in a fixed location outside the survey area complete this configuration. An electrical current is passed through the soil and readings are collected at each mobile probe location in order to measure soil resistivity at that location. As the name implies, resistivity is a measure of the resistance a material has to the conduction of an electrical current and is recorded in ohm-meters. The potential for a soil to conduct electricity is dependent upon porosity, which is often dependent on the compaction of the soil, water content, and salinity levels. It should also be noted that most mineral grains are regarded as insulators to electrical conduction.

The GeoScan RM15 is typically configured with a twin array positioning of the remote or reference probes (Bevan 2000:9). In the twin array, the remote probes are set together in rather close proximity to each other, relatively close to the survey grid. The drawback of this configuration is that it does not allow for comparison of data collected over a period of time or from area to area (Bevan 2000:1). The pole-pole configuration produces results that can be converted to an absolute measure of soil resistance.

### **Magnetic Gradiometer**

A Bartington Grad 601 dual fluxgate magnetic gradiometer was used for this research. It has two recorders, each containing two sensors located one above the other in a plastic tube. These units are set on a crossbar with a recording unit in the center which creates an “H” shaped instrument that is then strapped to the operator using a harness made from a small backpack. The instrument is calibrated to zero out the earth’s magnetic field using an area with a low and consistent magnetic signature, so that only the variations within the survey areas are recorded. For this survey, readings were collected at 25 cm intervals on a Y-axis, and at 50 cm intervals along the X-axis. The bottoms of the sensors were set at 63 cm from the bottom of the crossbar.

The fluxgate magnetic gradiometer utilizes two sensors on a vertical axis to measure and record the differences that occur in the magnetic field as it passes over an object (Kvamme 2006:212). The advantage of this arrangement is that there is no need to adjust for the changes in the overall magnetic field which occur regularly. This produces a map that then shows local variation in the magnetic field. The unit of measurement is the nanotesla or nT. The earth produces about 60,000 nT at the magnetic poles and about 30,000 nT at the equator (Kwamme 2006:208) but because the unit has been zeroed, it is possible to measure meaningful variation in the survey area in the 1 to 5 nT range.

Magnetic susceptibility is a measure of how well an object interacts with the magnetic field. Small, strong susceptible objects create a signature in magnetic data called a dipole, which can be seen with the negative and positive ends aligned with the poles. Strong anomalies (those with a higher ferrous content) will obscure smaller anomalies. The data recorded by a magnetic gradiometer allows for the contrast to be seen in the magnetic signatures throughout a survey area. These areas where contrasts occur are considered to be anomalies, which from an archaeological perspective might be cultural features, or from a forensic perspective may be evidence.

A well-developed A horizon typically shows an increase in magnetic susceptibility. When a grave shaft is dug through the A horizon and later backfilled with a mix of subsoil and topsoil, the top of the grave shaft will have a lower signature. This can be important in archaeological research as well as forensic surveys.

Intentional burning can also be of interest to archaeological surveys and in some forensic cases. This can produce thermo-remnant magnetism. This is where the soil has been heated to a temperature greater than 600° C (1112° F) forcing the iron oxides in the soil to align with the

magnetic field of the earth. For archaeological sites this could occur in a hearth, kilns, or cooking pits, and in forensic cases this could occur at a surface where remains were intentionally burned or a grave where remains were burned within the grave shaft prior to backfilling.

## **Electromagnetics**

A Geonics EM38B was used for this research. It is important to note that it measures both conductivity and magnetic susceptibility simultaneously. This instrument is about one meter in length with sensors located at both ends, and is carried by a frame that allows the instrument to hover just above the surface. A data logger is carried in the opposite hand and stores the readings that are manually collected by trigger. For this research, readings were collected at 50 cm intervals on the Y-axis and 50 cm intervals on the X-axis. This instrument does have limitations. When used in in-phase mode it is susceptible to temperature drift. It is also limited to a sensor depth of 50 cm with the working depth around 20 cm. The size of the object that is detectable is limited to  $1/4$ - $1/3$  of the distance between the two sensors, which generally limits objects to 25-30 cm or larger in diameter (Dalan 2006:177).

A gradiometer measures the magnetic susceptibility created by the earth's magnetic field. The EM38 creates a magnetic field that is introduced into the ground and measures the resulting magnetic susceptibility. This can be measured as susceptibility per unit volume (K), or mass normalized susceptibility (X) (Dalan 2006:162). Through the application of a weak magnetic field, volume susceptibility (K) is calculated as a ratio of the volume magnetization, whereas mass susceptibility (X) is calculated by dividing volume susceptibility (K) by density, and is recorded as units of cubic meters per kilogram.

Due to enhanced magnetic properties of topsoils, magnetic susceptibility can be used to identify subsurface soil properties. Higher susceptibility will be found in soils that have decaying waste material due to high levels of phosphorus and as well as in areas that have been burned.

The measurement of how well an electric current can be passed through an object is called conductivity or electromagnetic survey, and in geophysical applications with the EM38B that object is the soil (Clay 2006:79). This is accomplished through the induction of an electromagnetic signal into the ground, which is then measured as millisiemens per meter, or mS/m. For conductivity to be measured, one of the two EM38 sensors generates the signal that is passed through the ground. The second sensor records the electromagnetic signal that has been created by this interaction. Results can be distorted when highly conductive objects are encountered during the survey, which includes all metals, and not just objects that have ferrous content. Soil conductivity is affected by grain size, composition, and moisture levels. Clark Davenport (personal communication) believes that graves and other areas that are disturbed would be more likely to accumulate water and would have higher conductivity than undisturbed soil.

### **Visual Survey**

When the disposal method used for the concealment of human remains is burial, it is done intentionally to try to make the discovery of the remains harder, if not impossible (Dupras et al. 2006:3). Surface indicators at the location of the burial will change over time until the burial becomes unrecognizable and blends in with the environment. The initial indicators will include mounding of the disturbed soil over the burial because the remains prevent full compaction, soil scattered or mounded surrounding the burial, and disturbed vegetation. Over time these indicators will lessen as the soil becomes more compact and vegetation regrows,

possibly with greater vigor due to the looser soil and additional nutrients provided by the buried remains. It is also possible that vegetative growth could be diminished because roots might be unable to reach the nutrients if the remains have been wrapped in plastic or buried out of reach. Another surface feature that develops over time in some burials is a depression that forms as soft tissue decomposes and the soil becomes more compact. In some burials a secondary depression will form where the abdominal cavity was located. As the depressions are created, cracking of the perimeter of the burial will occur in soils with higher clay concentrations and will be absent from soils that have a high sand content.

In this research, the visual survey focused on the regrowth of vegetation, settling of disturbed soil, and the appearance of cracking around the burials. Each data collection period included photographing each burial, each row of burials, and an overview photo of each area.



## **CHAPTER 5 – RESULTS**

This chapter reviews the relevant weather data from the research period and its potential effects on the geophysical data and the visual survey. It serves to document both the field portion of the study as well as introduce the reader to the results of the study. Although the research design called for the collection of geophysical data every 30 days from the date of interment, dependent upon weather, several of the instruments were not available for data collection for the first two months of the data collection period. This was found to be acceptable because the ground cover had not returned to a normal state for the burials during that initial 60 day interval, and in a “real world” situation would have given rise to suspicion of a potential burial.

The data provide a comparison of the early and late collection periods of the GPR, MAG, EM, and Resistivity, processed and interpreted using the weather data. The most significant of the data sets collected was the GPR data, in that the graves were not easily identifiable, but did show change during the monitoring period. The MAG, EM, and Resistivity data sets do not show a comparable change directly related to the burials.

### **Weather Conditions**

Weather data from Weather Underground ([www.wunderground.com](http://www.wunderground.com)) was used, because the National Climatic Data Center data from the National Oceanic and Atmospheric Administration did not include daily precipitation totals. Precipitation totals were needed to assist in the processing of the GPR data because moisture can impact the dielectric properties of the soil. Also the disturbed soil within a grave shaft theoretically increases the porosity, therefore allowing for more moisture to collect, creating a contrast with the surrounding soils. The entire

report can be accessed online:

[http://www.wunderground.com/history/airport/KUOX/2013/5/10/CustomHistory.html?dayend=8andmonthend=11andyearend=2013andreq\\_city=NAandreq\\_state=NAandreq\\_statename=NA](http://www.wunderground.com/history/airport/KUOX/2013/5/10/CustomHistory.html?dayend=8andmonthend=11andyearend=2013andreq_city=NAandreq_state=NAandreq_statename=NA)

For the data collection period, the mean average temperature was 71° F with a recorded maximum high of 95° F and a recorded minimum low of 32° F (Table 5.1). A total of 22.58 inches of precipitation was recorded, with a maximum daily total of 2.52 inches recorded on September 20, 2013.

**Table 5.1 Temperature and Precipitation Averages 2013 May 10 to November 8**

<b>Temperature</b>	<b>Max</b>	<b>Avg</b>	<b>Min</b>
Max Temp	95° F	81° F	53° F
Mean Temp	84° F	71° F	42° F
Min Temp	75° F	61° F	32° F

For processing the geophysical data, the weather data was divided to coincide with the specific collection intervals, specifically noting precipitation accumulation during the week prior to collection. This revealed that the average monthly rainfall during the research period was 3.76 inches (Table 5.2). The maximum recorded total for a collection interval was 6.42 inches recorded between September 8<sup>th</sup> and October 12<sup>th</sup>. The minimum recorded total was 2.4 inches recorded between August 8<sup>th</sup> and September 7<sup>th</sup>.

**Table 5.2 Precipitation Totals and Averages for 2013 May 10 to November 8**

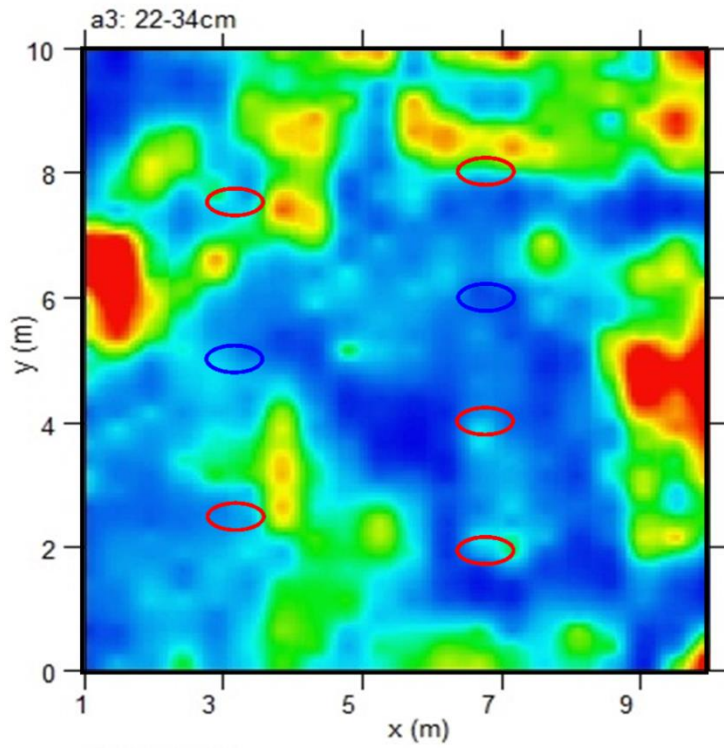
<b>Precipitation</b>	<b>Max</b>	<b>Avg</b>	<b>Min</b>	<b>Sum</b>
Interval 1	2.07	0.14	0.00	4.11
Interval 2	1.01	0.08	0.00	2.42
Interval 3	1.67	0.13	0.00	3.83
Interval 4	1.22	0.08	0.00	2.4
Interval 5	2.52	0.19	0.00	6.42
Interval 6	1.37	0.12	0.00	3.4
Totals	2.52 in	0.12 in	0.00 in	22.58 in
Averages	1.64 in	0.12 in	0.00 in	3.76 in

## **Geophysical Survey Results**

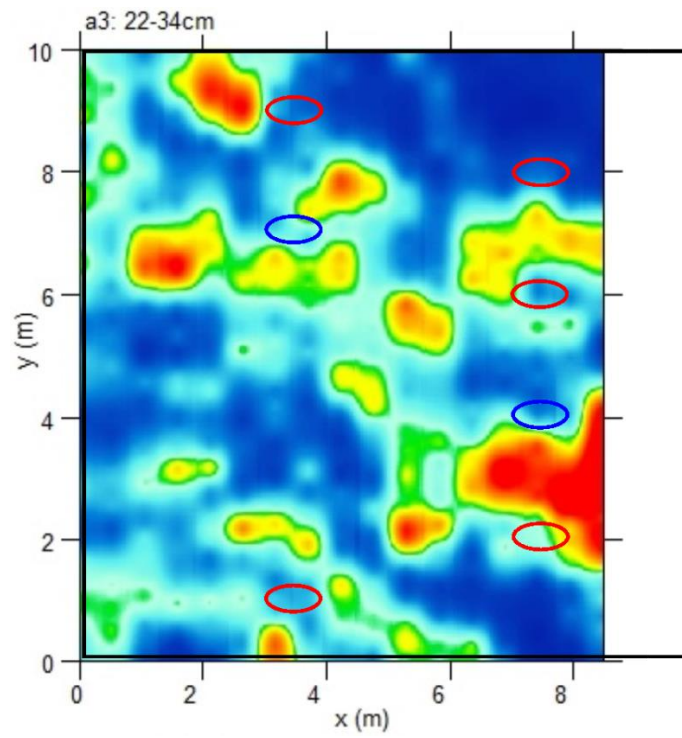
The geophysical survey results were not found to consistently show the location of the graves or the control graves. Of the four methods used in this study, the ground-penetrating radar produced the most promising results, but that was only to the point of being able to contrast the exact known position of the graves versus the control grave and the surrounding substrates in the processed data. This was done by using a map overlay that showed the grave and control grave positions as they should be within the geophysical data maps or GPR radargrams. The data is presented here to show a contrast between early collection intervals and the terminal collection point.

### **Ground-Penetrating Radar**

The survey data collected with GPR was analyzed in different views. The first of these views was through the use of GPR-Slice to create depth slices to see if the graves could be visualized at different depths. As shown in both Figures 5.1 and 5.2, there are no grave size features present within the map that coincide with the known grave locations (indicated by red ovals; control graves indicated by the blue ovals) during the early data collection period in July. This situation continued throughout the data collection period until the end of the study in November.



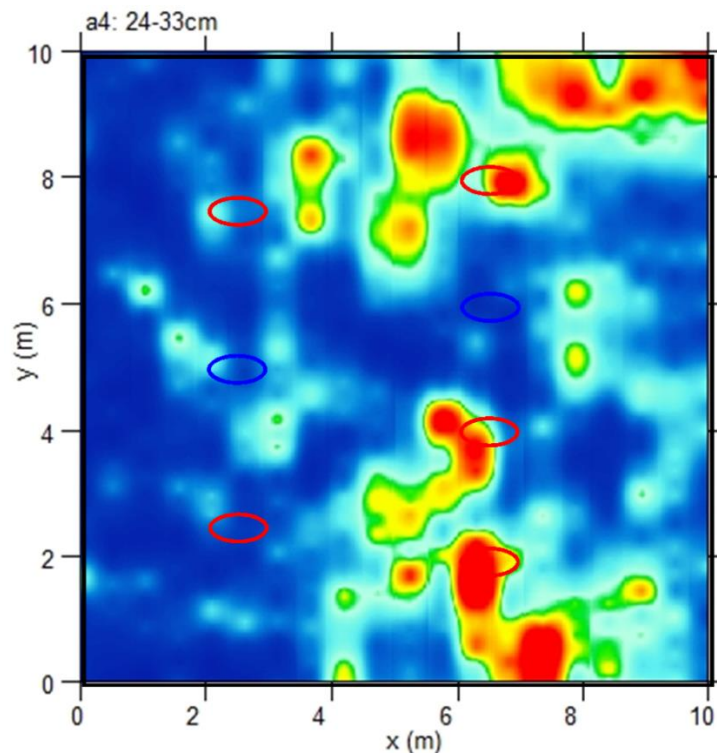
**Figure 5.1 July Area 1 GPR Slice Map**



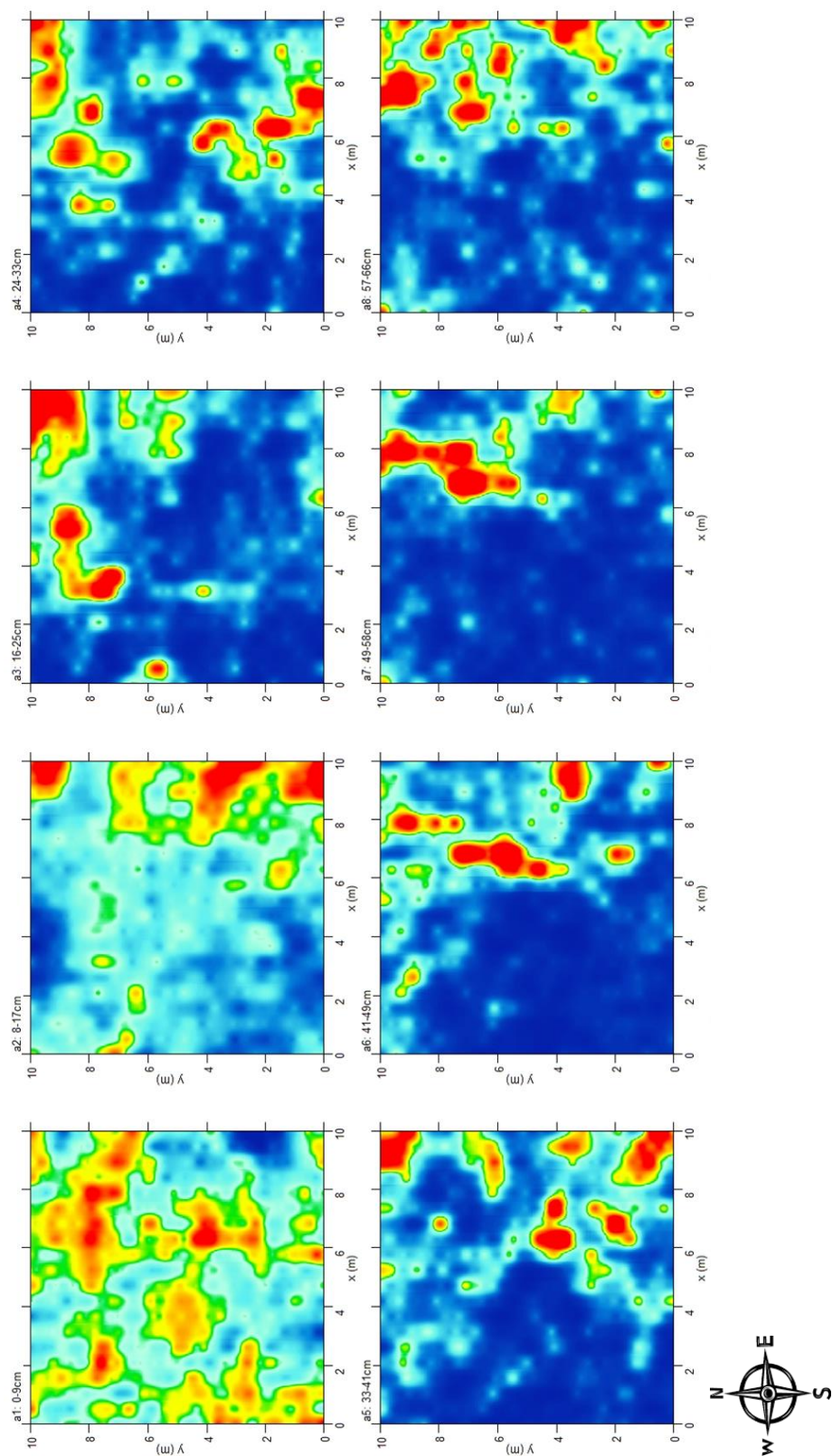
**Figure 5.2 July Area 2 GPR Slice Map**

The GPR data for July was processed with a dielectric value of 10, because during the previous five days there had only been 0.1 inch of precipitation and only 0.77 of an inch during the previous 13 days. As can be seen with the overlay in Figure 5.2, there were no graves or control graves that stood out significantly in contrast to the surrounding area in either research area.

The November, GPR data were processed using a dielectric value of 29.75. This was because within the previous five days there had been 0.36 inch of precipitation and a total of 1.84 inches within the previous 13 days. A total of 3.40 inches of precipitation was recorded for the sixth observation interval. It is interesting to note that in the November, Area 1 24-33 cm slice view (Figure 5.3), the second row of burials does seem to have a greater intensity, but it is unlikely that this is a reflection of the burials, because the high amplitude reflections are not limited strictly to the burials themselves (Figure 5.4).



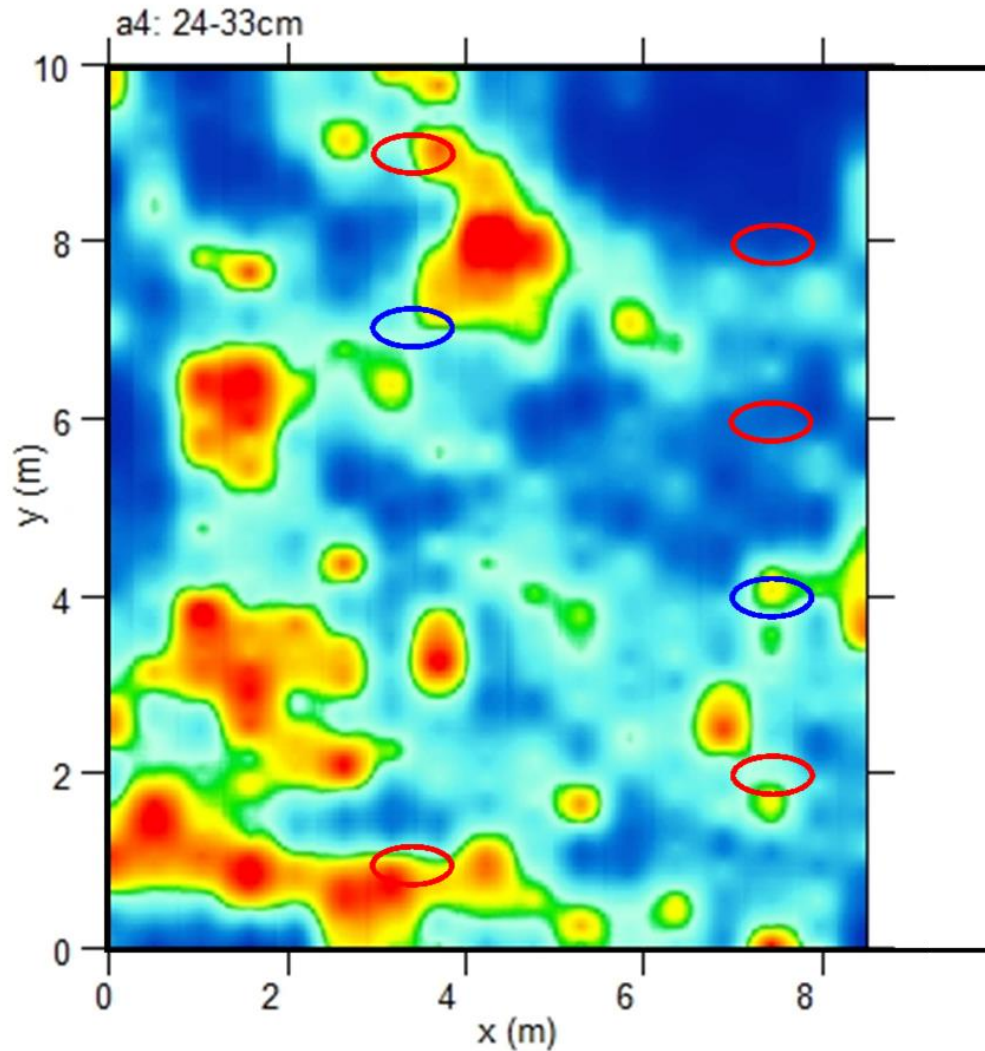
**Figure 5.3 November Area 1 GPR Slice Map**



**Figure 5.4 November Area 1 Slice Maps**



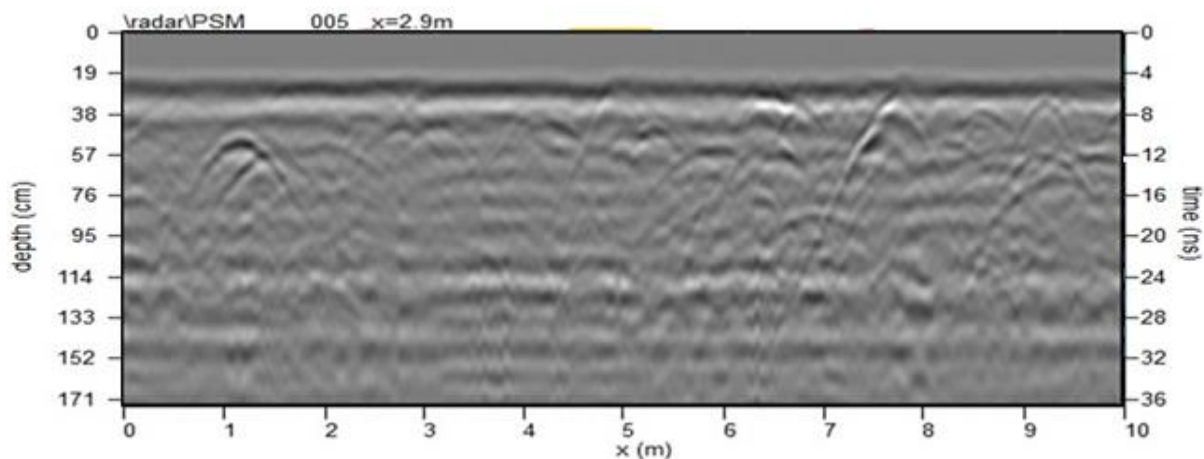
The Area 2 GPR 24-33 cm slice view map for November showed increased anomalies, but not significantly representative of grave locations (Figure 5.5). Especially problematic, is the fact that one of the areas of increased intensity is within the empty control grave.



**Figure 5.5 November Area 2 Slice View Map**

A second method of analysis used with the GPR data was to examine vertical transects that crossed directly over the graves. This technique was originally used in GPR surveys, prior to the development of computer software such as GPR-Slice, which allows horizontal representations of vertical slices to be generated. It is also the technique that is most often used in the field using

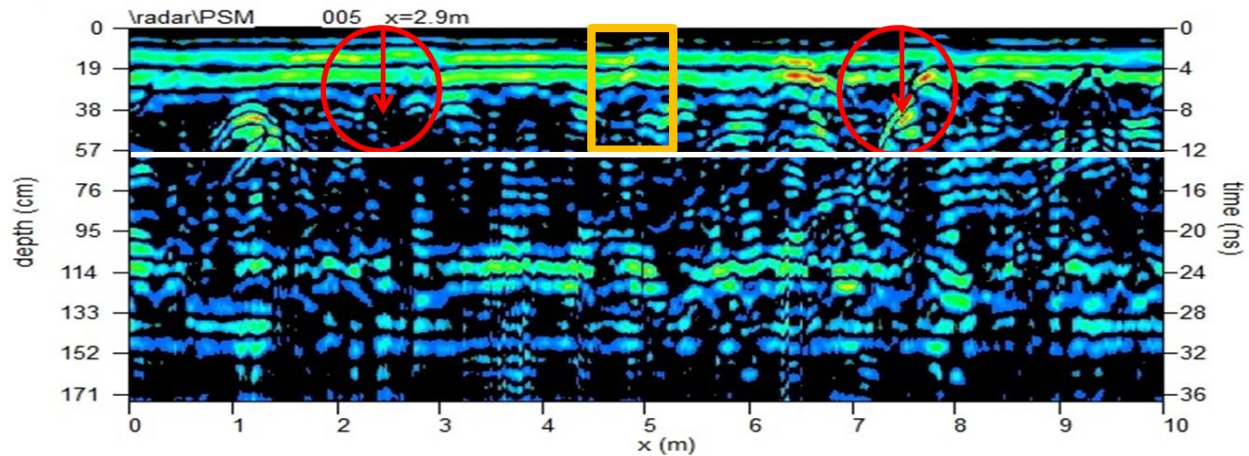
raw radargrams. The radargrams were examined using GPR-Slice intensity enhanced radargrams. This was because within the gray-scale radargrams the parabolic reflection specific to the graves did not stand out as evidenced in Figure 5.6. There is a strong parabolic reflector that can be seen at a depth of approximately 50 cm, and would easily be identified as a possible burial.



**Figure 5.6 July Area 1 Line 5**

When the radargram is intensified with GPR-Slice (Figure 5.7) and examined using an overlay indicating the precise location of the burials and the control grave, the graves themselves are less visible than in the previous grayscale radargram (Figure 5.6). In the overlay, the areas marked with red indicate burials, whereas the orange boxes indicate the control graves. The arrows are pointing to the approximate location of the target. The white line indicates the greatest extent that any grave should penetrate.

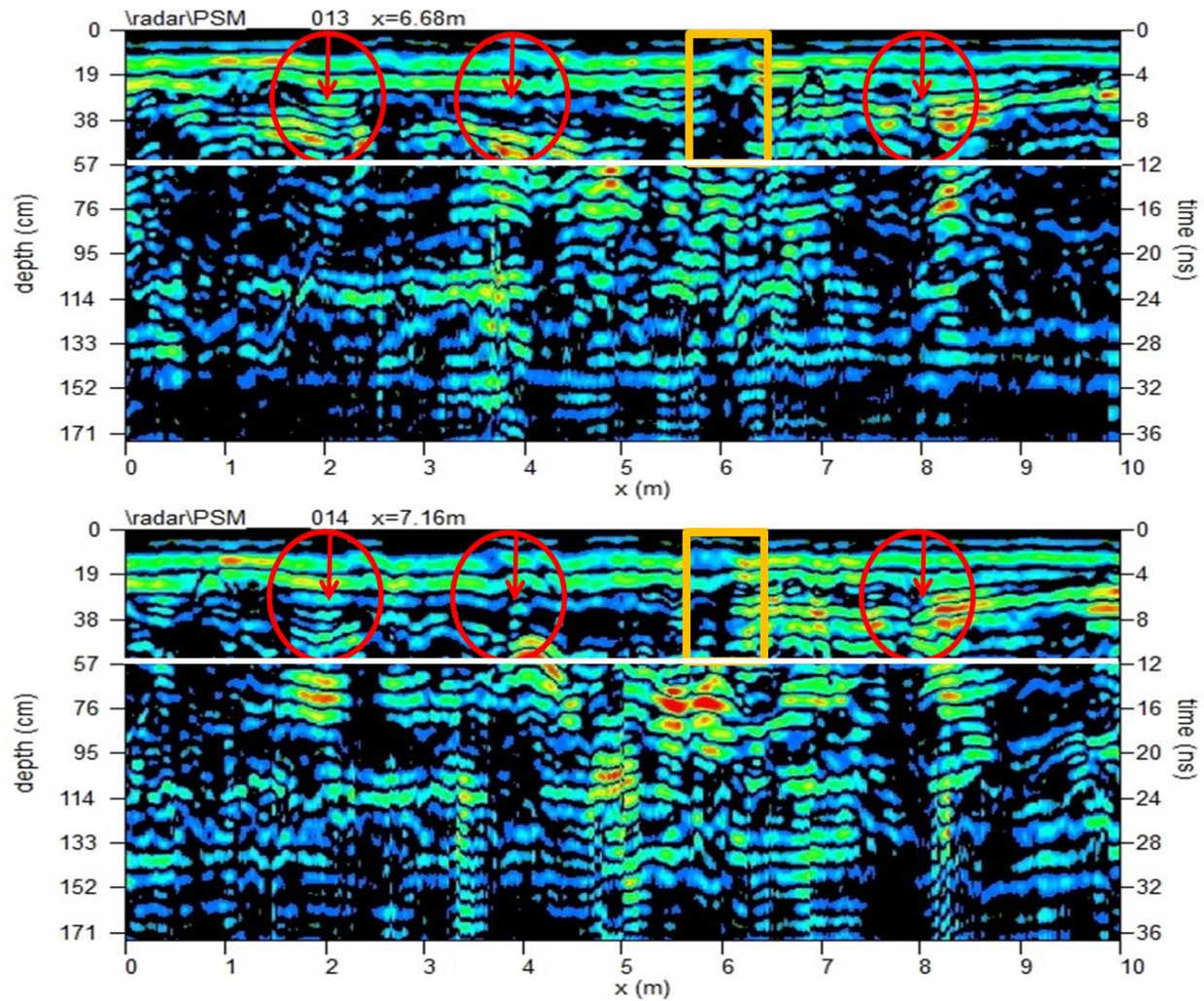




**Figure 5.7 July Area 1 Line 5 GPR-Slice Intensified**

As previously pointed out in the radargram (Figure 5.7) at the 1 meter mark there is a reflector that has a significant return that appears to be a potential grave. However, the first grave is located at the 2.5 meter mark and shows signs of signal attenuation, which is why the grave is not visible in the grayscale view (Figure 5.6). This is not significant by itself, because at approximately the 4 meter mark, the attenuation occurs again. Within the control grave there is disturbance and the appearance of a slight shift in horizontal reflections. Though in the second burial, the return from the grave may be masked by a higher level parabolic anomaly.

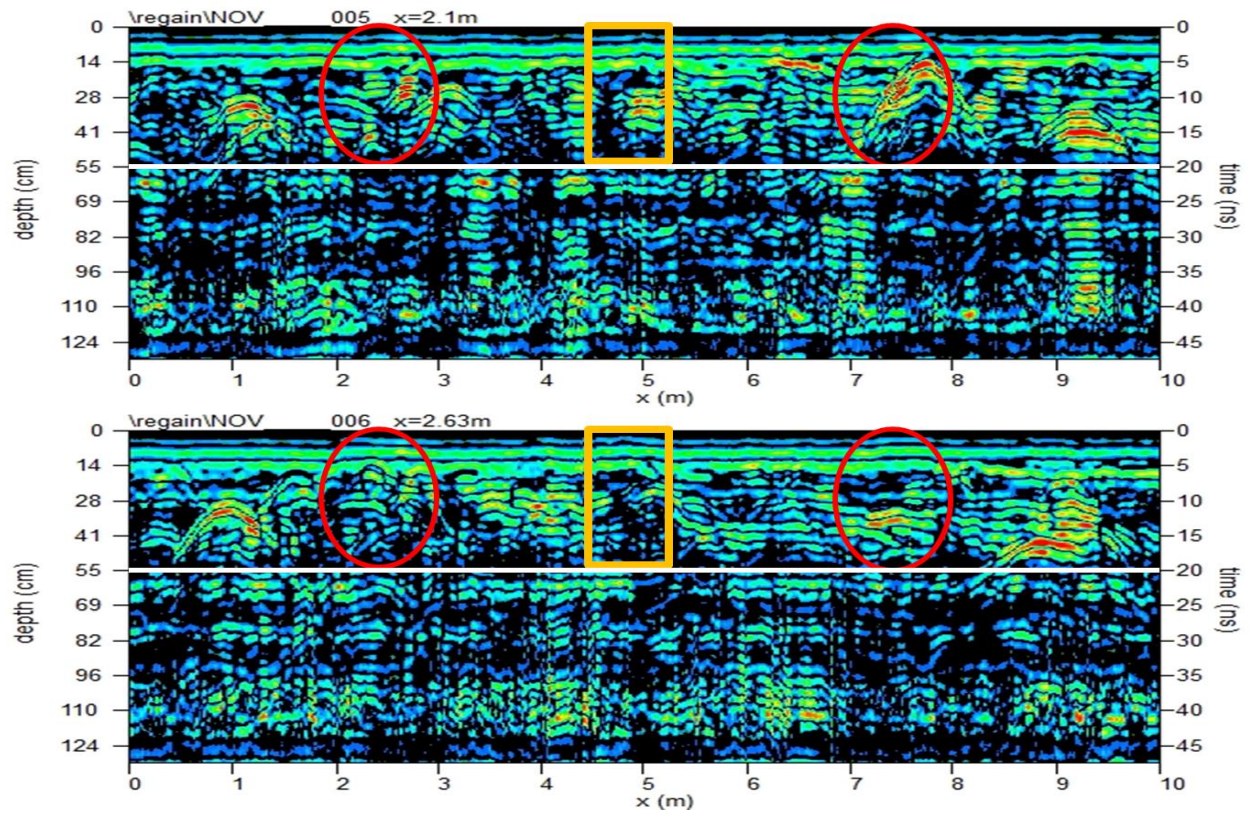
There is no parabolic return for the first burial in the second row of burials (Figure 5.8), but there is a break in horizontal reflections and ground surface indicating, perhaps, the shaft of the grave. In the second grave there is a slight parabolic return, but there is also an area of attenuation where the pig remains are located. However, attenuation by itself cannot be an indicator for the presence of the burial, because it is visible outside areas of disturbance and within the control grave itself. The third burial shows no specific return from the remains, except for a break in the horizontal reflections.



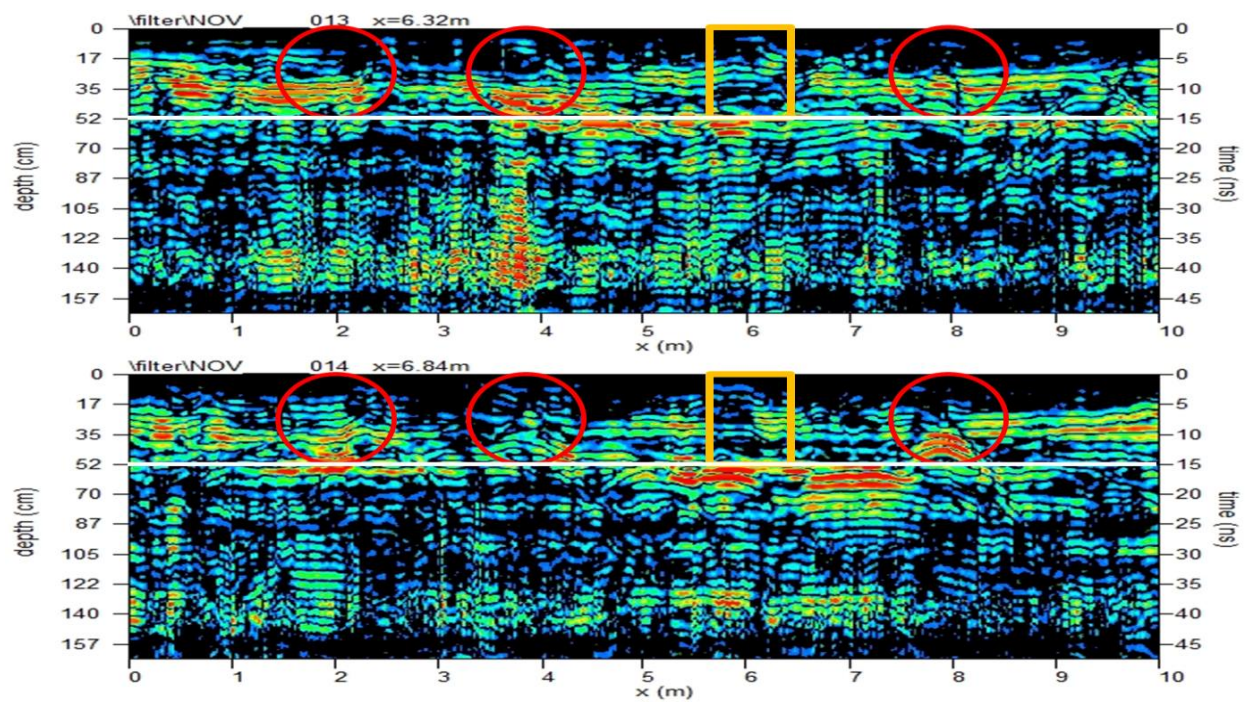
**Figure 5.8 July Area 1 Second Row of Burials**

In November, the profiles of the first row of burials are not any clearer than they were in July. If anything is more apparent, it is the reflector at 9.5 meters that could be easily mistaken as a potential grave (Figure 5.9). There are also no large spaces of attenuation that were evident in the July data, although this might be a result of the regaining process in post-processing. In the second row of burials, there are no major changes with the first two burials or the control grave, but the signal return is improved for the third burial, as seen in Figure 5.10. The second row of burials, were further enhanced by running the data through a band pass filter to help eliminate ground bounce.





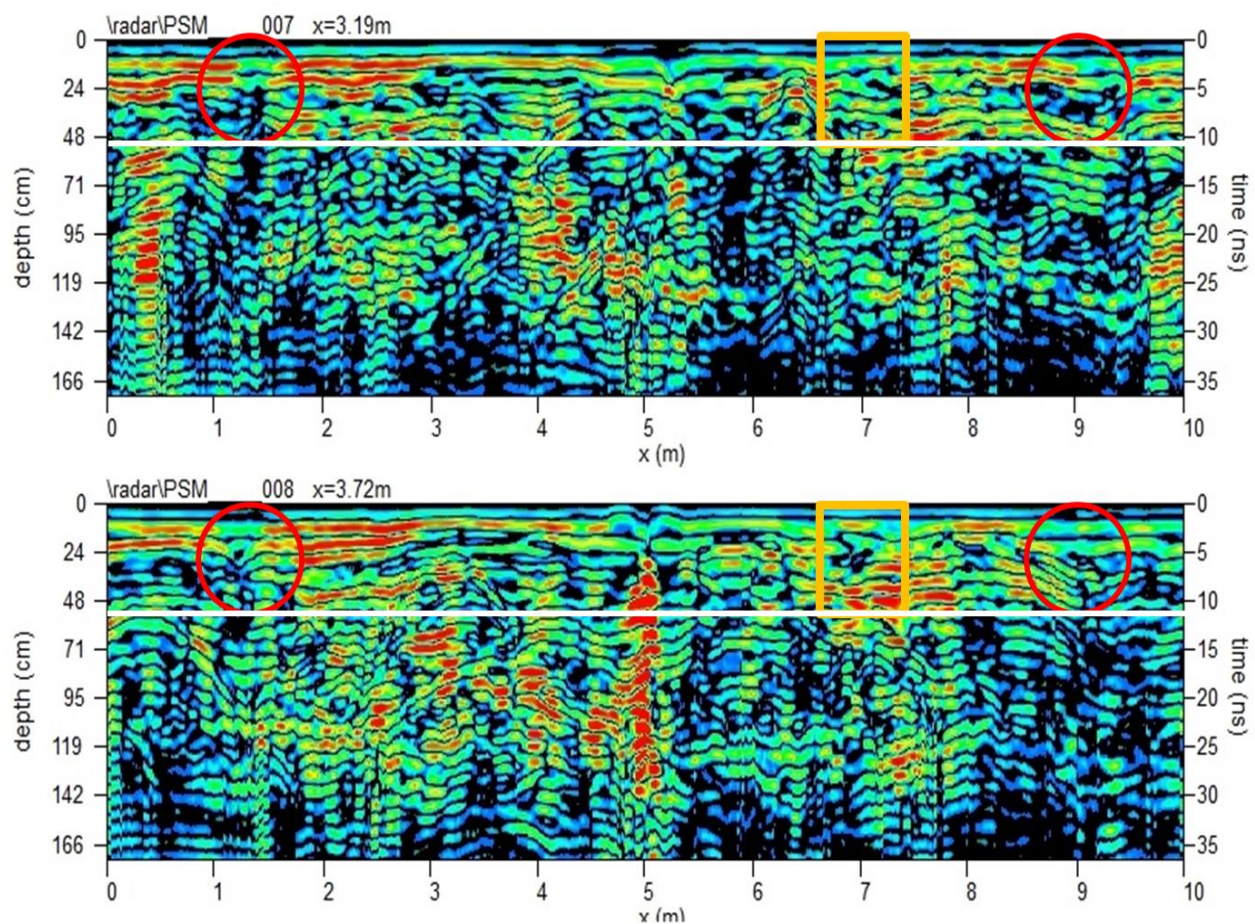
**Figure 5.9 November Area 1 Row 1 Burials**



**Figure 5.10 November Area 1 Row 2 Burials**



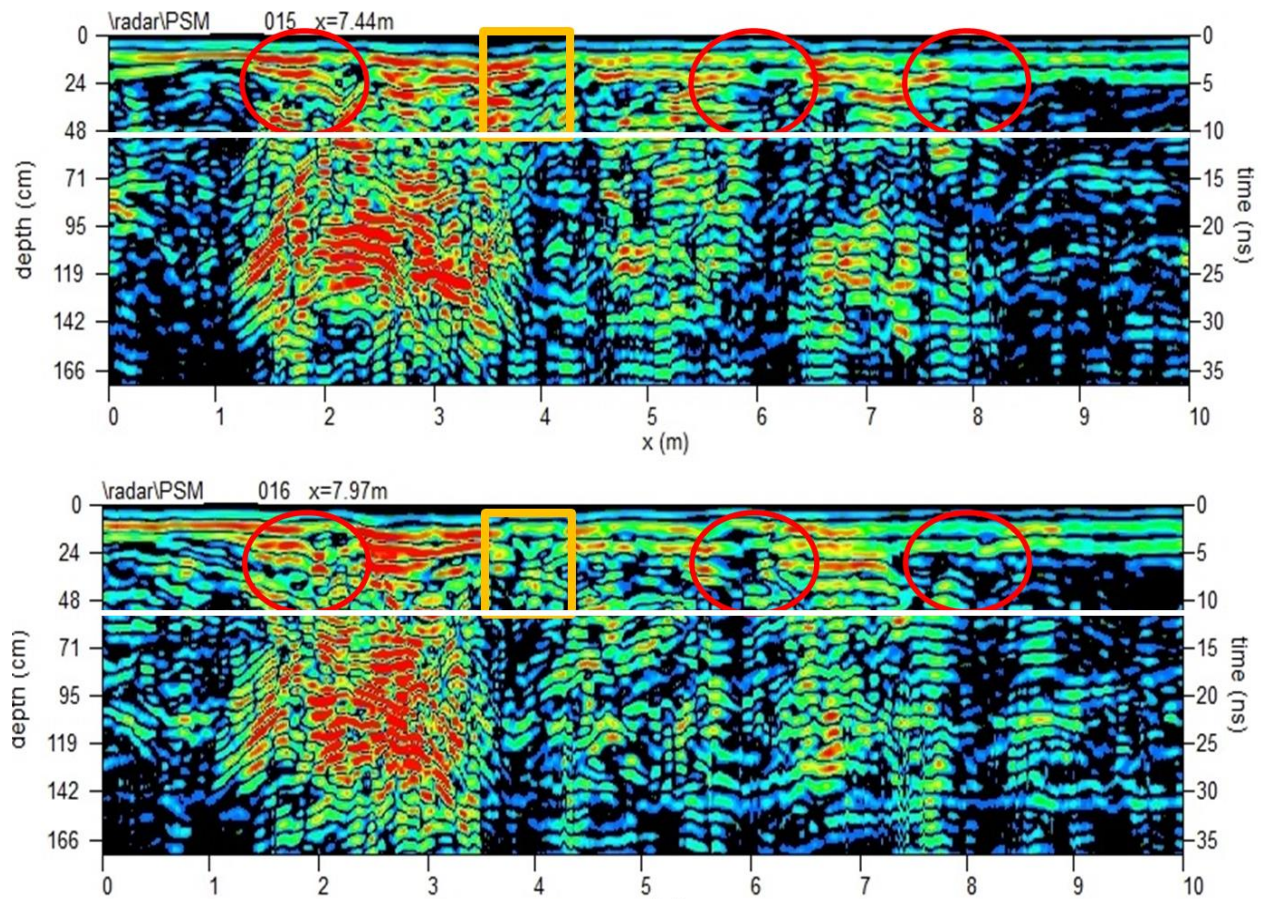
The GPR data radargrams for Area 2 were similar to Area 1 in that the burials were not clearly identifiable in July or November. A clear break is seen in the horizontal reflections of burial 1 in Row 1, but no reflector can be detected that coincides with the burial itself (Figure 5.11). There is an area of attenuation for the second burial present in the first transect but not the second.



**Figure 5.11 July Area 2 Row 1 Burials**

In Area 2, the Row 2 burials (Figure 5.12) did show breaks in the horizontal reflections, specifically at the location of the burials and the control grave. A parabolic reflector was seen in the first transect for the first grave, but was not present in the second transect. However,

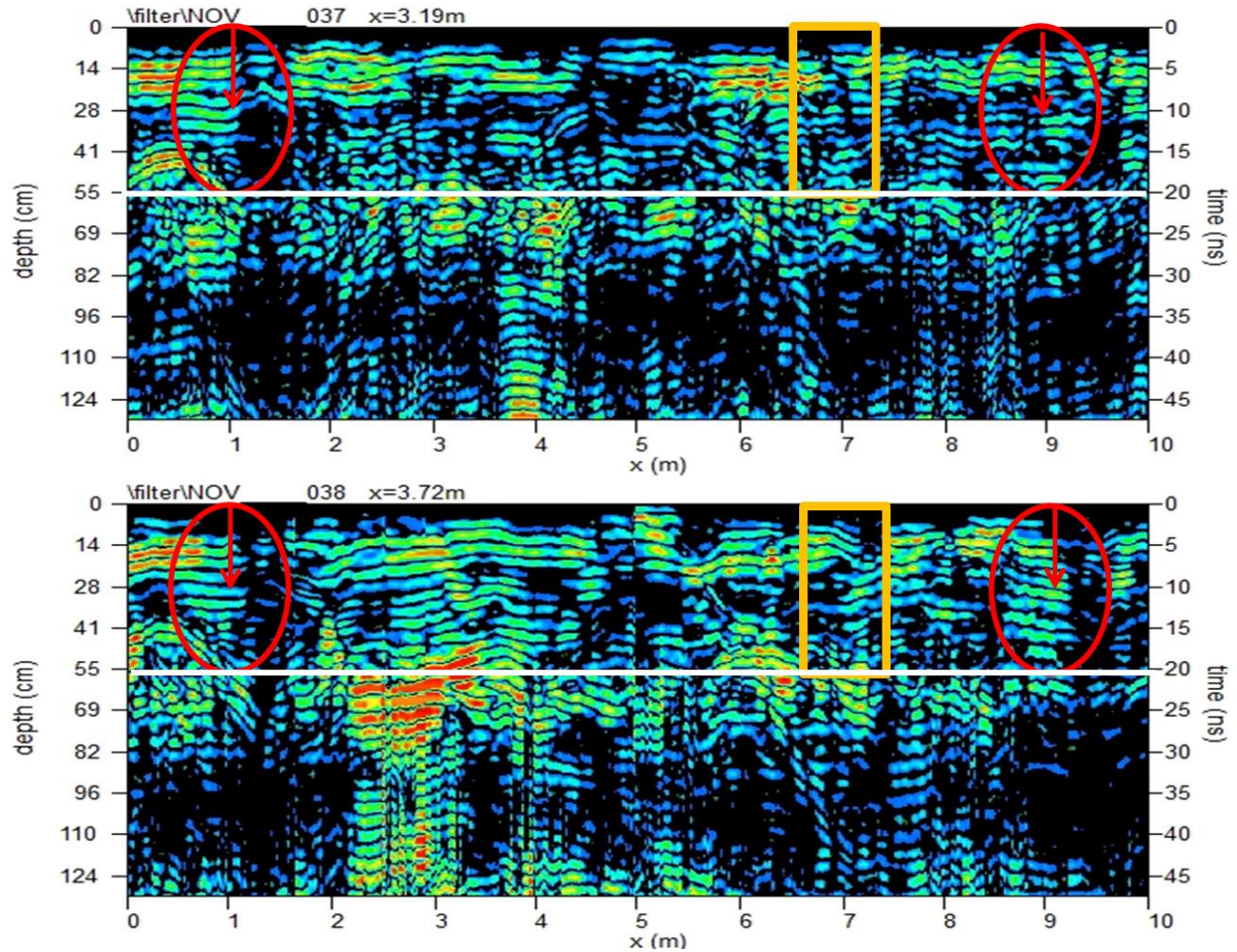
attenuation and a reflector was evident in the second burial, principally in the second transect. The third burial only showed a break in horizontal reflections and attenuation.



**Figure 5.12 July Area 2 Row 2 Burials**

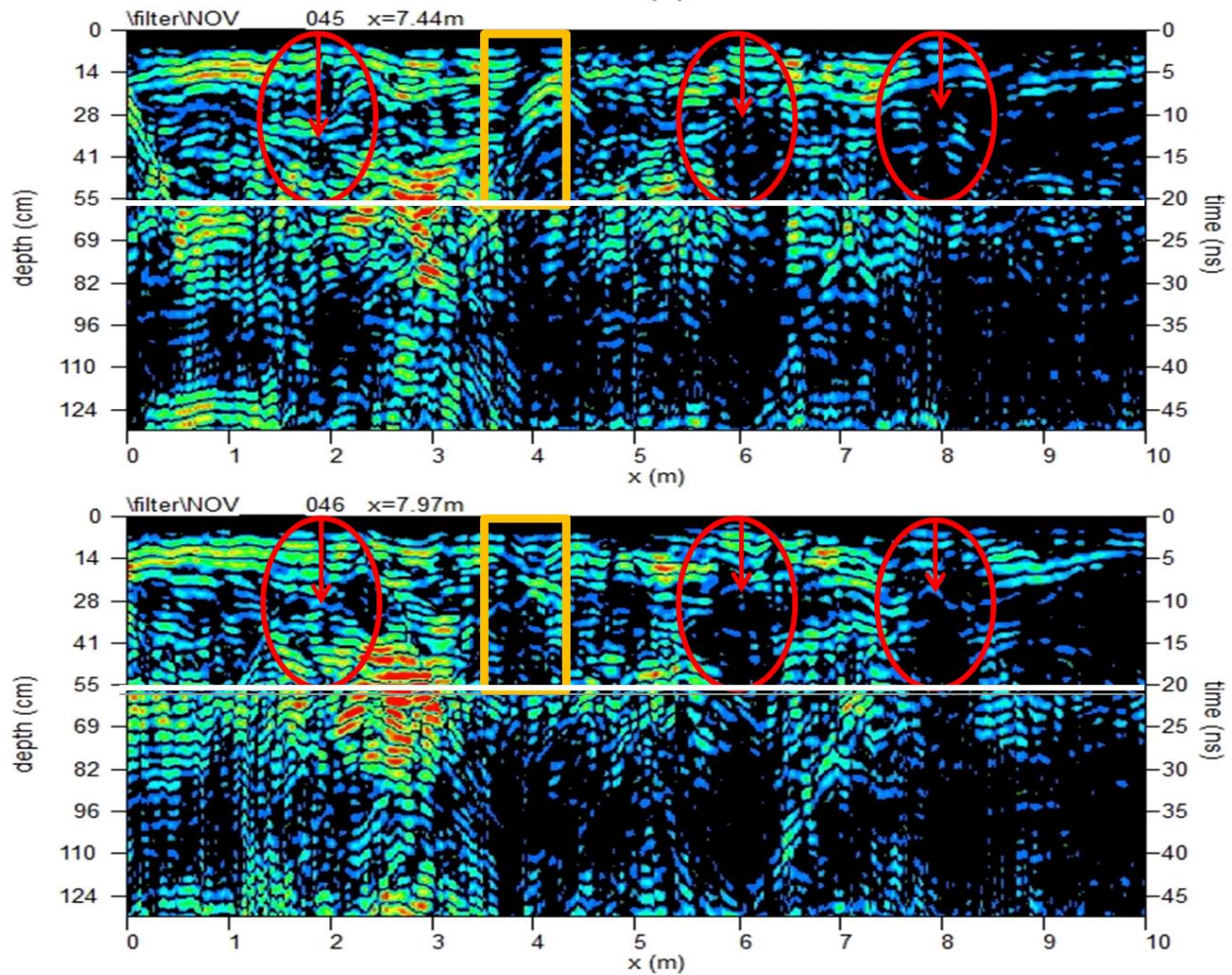
The November Area 2 GPR data were regained and run through a band pass filter to help minimize the effects of the ground bounce (Figure 5.13). In Row 1, burial 1 shows attenuation, and what appears to be a break in the horizontal layering, giving the appearance of the grave shaft in both transects. Burial 2 shows no major changes versus the surrounding substrate.





**Figure 5.13 November Area 2 Row 1 Burials**

In the second row of burials (Figure 5.14), there is attenuation in the area of the first burial but that by itself, as previously discussed, is not an indicator for a burial. This is especially true when looking at the control grave, where attenuation can be seen in conjunction with breaks in horizontal reflections and the presence of a parabolic reflector. The third and fourth burials show both a small parabolic reflector and a large area of attenuation.



**Figure 5.14 November Area 2 Row 2 Burials**

### **Magnetometry**

The magnetometry survey data failed to show anomalies that could be related to the location of the graves for Area 1. A comparison of the August (Figure 5.15) and November Area 1 surveys did not show significant differences. But in Area 2, the third burial in the second row of graves does have a higher reading than the other burials (Figure 5.16). This by itself is not diagnostic because there are other points throughout the survey that have the same intensity.



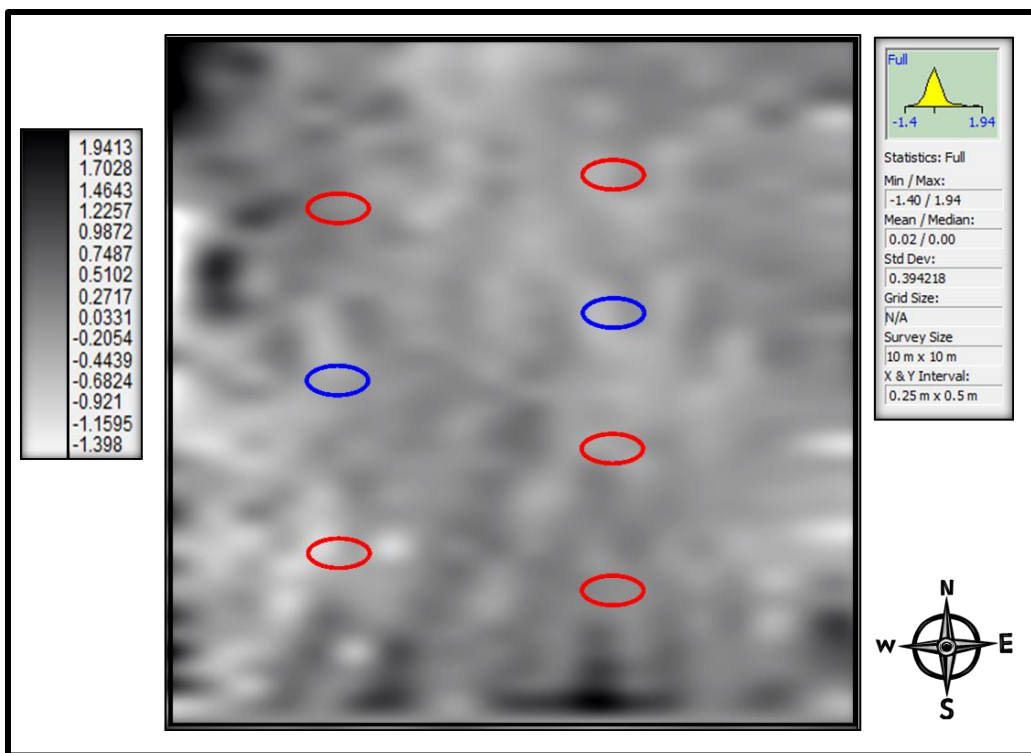


Figure 5.15 July Area 1 Gradiometer Survey

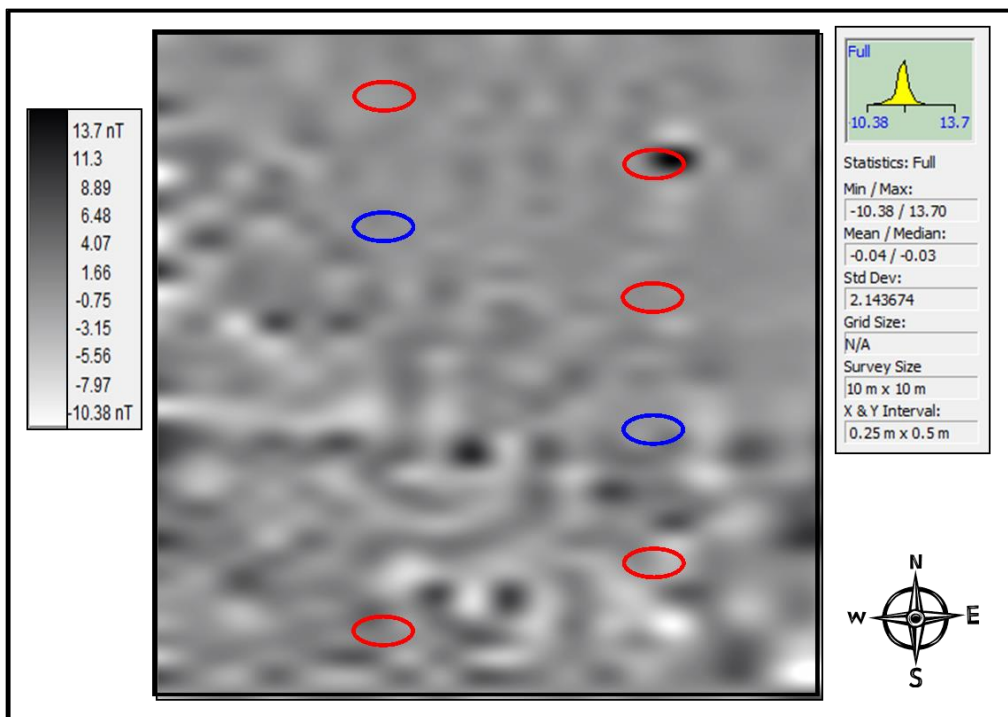
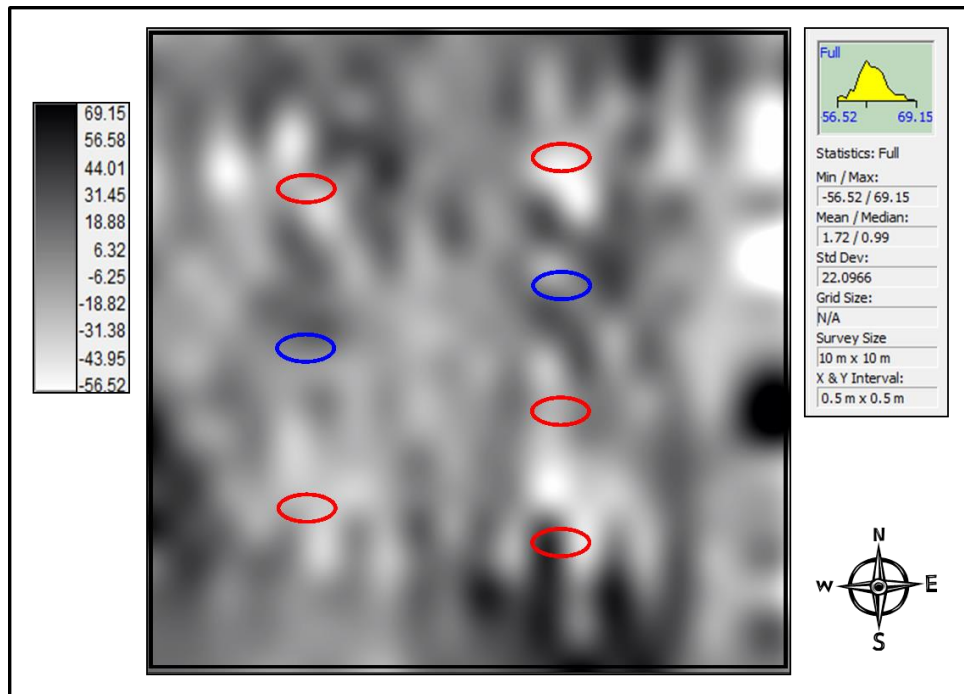


Figure 5.16 November Area 2 Gradiometer Survey



## Resistivity

Area 1 and Area 2 were surveyed collecting both 50 cm and 100 cm spacing on the movable probes, but only the 50 cm data were processed because the target size of the burials is smaller than 100 cm. There were no major differences between the July and the November Area 1 resistivity surveys so, for the sake of brevity, only the November example is included (Figure 5.17). The Area 2 surveys produced greater contrast between early collection periods and the terminal collection period in November as can be shown in Figures 5.18 and 5.19. Throughout all collection periods, when processed, the resistivity data failed to produce targets that could be attributed directly to the presence of the burials within the areas.



**Figure 5.17 July Area 1 Resistivity 50 cm Survey**

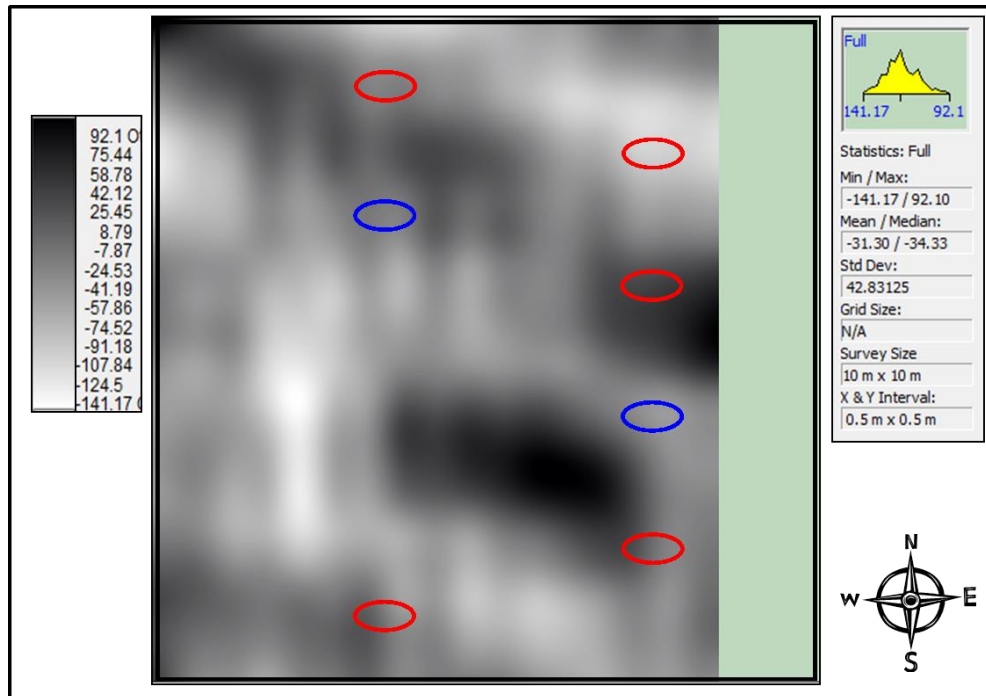


Figure 5.18 July Area 2 Resistivity 50 cm Survey

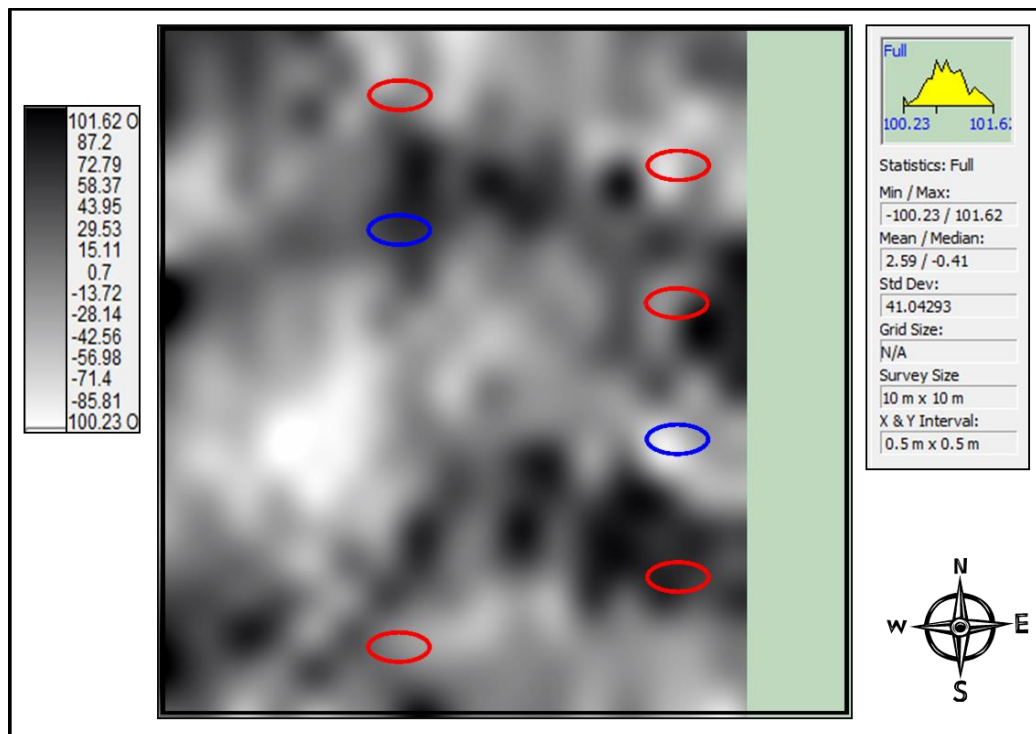
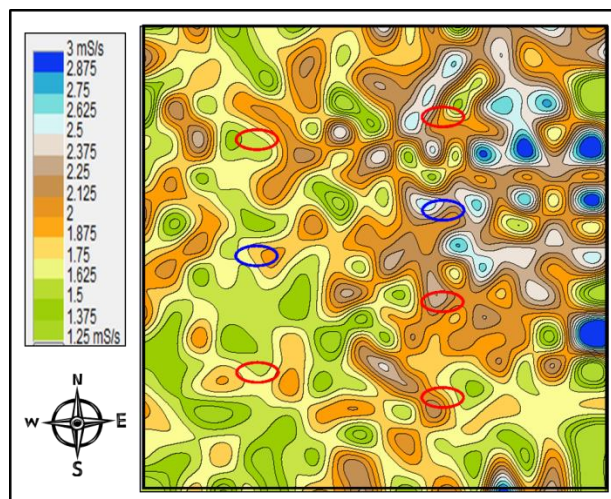


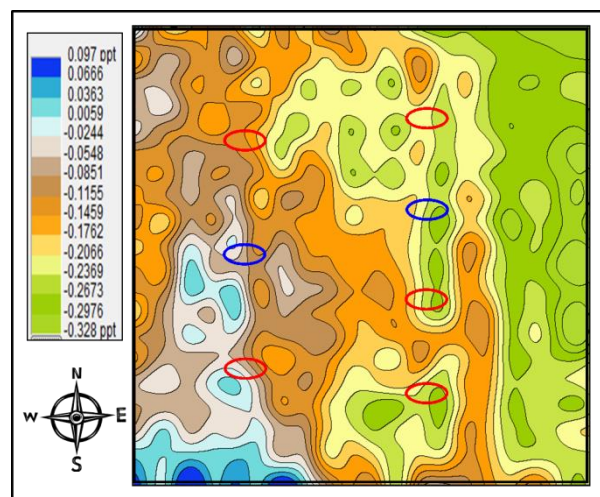
Figure 5.19 November Area 2 Resistivity 50 cm Survey

## Electromagnetic Survey

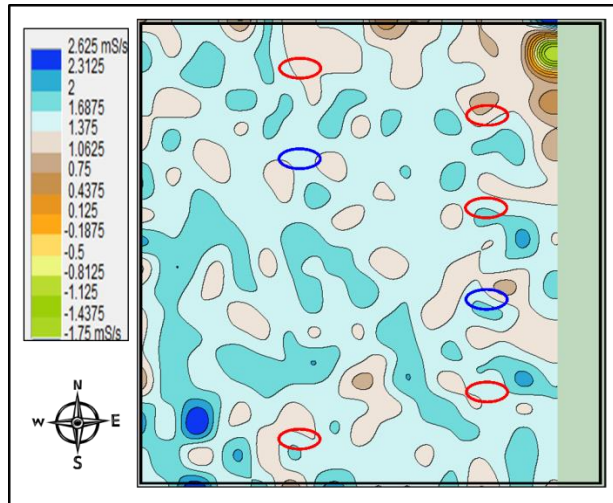
The EM survey recorded two different measurements, conductivity (Figures 5.20 and 5.22) and magnetic susceptibility (Figures 5.21 and 5.23). Neither set of results showed patterns that could be related to the graves. It was anticipated that ground moisture would collect in the grave shafts creating higher areas of conductivity, which should have produced significant contrast for the October and November collection intervals of the conductivity survey as a result of the increase in rainfall prior to those collection dates.



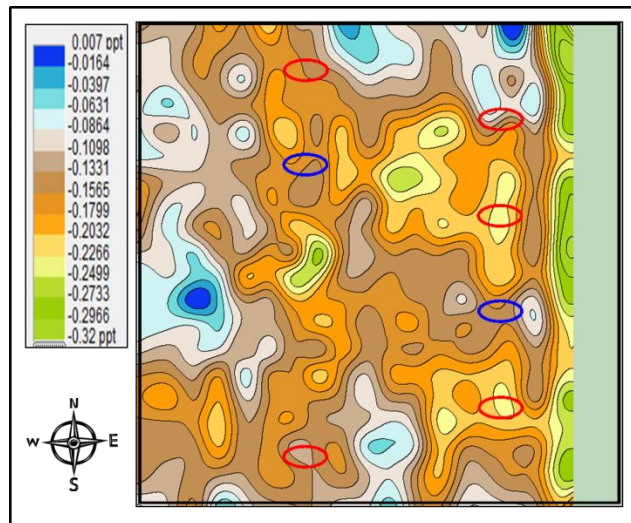
**Figure 5.20 November Area 1 Conductivity**



**Figure 5.21 November Area 1 Magnetic Susceptibility**



**Figure 5.22 November Area 2 Conductivity**



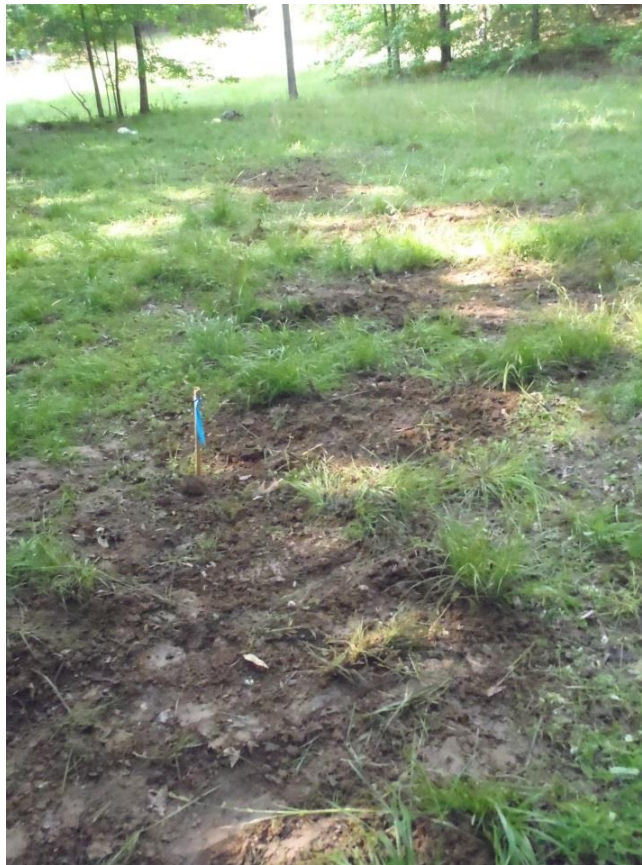
**Figure 5.23 November Area 2 Magnetic Susceptibility**

Only the November results from the EMI survey are included, because they should have shown the most significant contrast between the graves and the surrounding undisturbed soils. It is interesting to note that the conductivity survey from November does show an overall elevated level of conductivity, which might be due to the increased ground moisture from the overall amount of precipitation that had been recorded during the previous observation intervals. However, once again, it is not possible to relate any patterns in the data to the location of the burials.



### **Visual Survey**

The research areas were inspected for changes to the graves each time the geophysical survey data were collected. This was documented through a series of photographs including overviews of the individual research areas, of each row of burials, and then of each individual grave. This was done to look for signs of animal activity from opportunistic scavengers, the regrowth of disturbed vegetation, and slumping of the grave shaft. These changes were documented from the time the graves were created (Figure 5.24) until the termination of the research in November (Figure 5.26). Figure 5.25 shows the regrowth that occurred during the first two months of the research.



**Figure 5.24 Area 1 Row 2 after interment Facing North**



**Figure 5.25 July 22nd Area 1 Row 2 Facing South**



**Figure 5.26 November Area 1 Row 2 Facing North**

## **CHAPTER 6 – DISCUSSION AND CONCLUSION**

The implication of my research is that geophysical survey methods combined with visual survey techniques might be ineffective in the search for toddler-sized burials during the initial six months of interment. The principle reason is that toddler-sized individuals and the disturbance needed to conceal them in a burial produce minimal to no distinguishable geophysical disturbances. This contrast with prior research and case studies that have shown that geophysical methods were capable of detecting adult human or adult-sized human analog burials within a forensic context. It should be noted that research on child-sized burials is limited and a review of the literature failed to find any geophysical studies concerning themselves specifically with toddler-sized remains. This research was designed to fill that void. Even though the results were disappointing, according to Mellett (1996) they need to be reported.

### **Discussion**

#### **Visual Survey**

The visual survey portion of this research was the most unsettling. This is because the disturbed areas of both Area 1 and Area 2 were indistinguishable from the surrounding undisturbed areas within two months of interment. In Area 1, the grass had regrown to the same height as the surrounding grasses. In Area 2, the sandy soil easily blended with the undisturbed surrounding soil and regained the same leaf cover from the forest canopy. The recovery from disturbance is believed to have been assisted by the amount of rainfall between interment and the evaluation periods. But it is also possible that in the grassy area, the roots of the grass were not impacted by the decomposition process. In addition, the disturbance of the soil matrix likely

allowed for additional water and nutrients to be taken up by the vegetation to repair the growth interruption that would have occurred from the creation of the graves. Rain is also likely to have helped smooth any disturbed soils and would have assisted the blending of soils to camouflage surface disturbances.

The sandy soil has an impact on how the grave features are expressed in that if there been more clay in the soil, there should have been cracking along the perimeter of the pits. However, it was surprising not to observe any slumping or collapse of the grave during the research period. If monitoring had been continued for an extended period of time, then slumping or collapse might have been observed as the soil settled and compacted upon itself as the soft tissue was destroyed through the stage of active decay.

By burying the remains, the progression through the decomposition process was altered in multiple ways. The primary factor in any decomposition process is temperature. Even though the burials were 0.5 meters deep, the variations in the ambient air temperature would have been stabilized. Burial also minimizes the access and effects that insects, scavengers, and even bacteria have upon the remains. Specifically, bacterial action will primarily be limited to anaerobic activity, but the impact of bacteria will have already been altered due to the stabilization of the temperature.

### **Geophysical Survey**

In short, the geophysical survey methods failed to produce results that would have been of assistance in a forensic case. GPR, which has been championed in the literature for its usefulness in locating burials, proved to be inconsistent. There were few examples of reflectors that coincided with the known location of a burial, and those that did seem to relate to one of the test burials could not be distinguished from those that did not.



Although limited previous research using the additional geophysical techniques of conductivity, magnetometry, and resistivity showed potential value in their inclusion in the search for clandestine graves, the results from this research were contradictory. Even when processed with different software programs, the findings were not sufficient to say that any specific targets could be identified that could correspond to the burials.

The ineffectiveness of the geophysical survey methods demonstrated in this research is most likely due to the small target size minimizing disturbance and effectively concealing the remains. The concave shape of the floor of the graves could have potentially impacted the GPR signal, but since the soil was a sandy loam, there should have been good signal propagation and return from the burials. The soil type could have been a hindrance to the effectiveness of the other methods. Theoretically, all disturbed areas should have had higher moisture content than the surrounding undisturbed matrix and should have been detected in the conductivity and resistivity results. It is possible that the overall drainage potential of the disturbed areas was equal to the surrounding matrix and diminished the total soil moisture content. An additional factor to consider is that the small size of the graves would have minimized the amount of water accumulation. Alternatively, the amount of rain accumulated during the data collection period may have kept the soil saturated to the point that contrast between the graves to the surrounding undisturbed soil was too small.

Another factor that potentially interfered with the geophysical methods was the prior disturbance to the area by agricultural practices that would have disturbed the Horizon A or the initial surface of the soil. With an underdeveloped Horizon A, the effectiveness of magnetometry is compromised.

## **Future Research Questions**

Under the circumstances that this research was conducted, geophysical tools and visual survey proved to be ineffective in the detection of toddler-sized burials. If the research had been allowed to continue for an additional period of time, the effectiveness of the geophysical tools would have likely diminished further, as Schultz (2003) has noted in his research. However, it is possible that had the graves begun to collapse, they might have been detected visually. It is important to note that the results possibly would have been the same if this research had been started at a different point within the calendar year. If this research were to be conducted again under these conditions, soil samples would need to be tested to more accurately assess the dielectric, and to monitor soil moisture changes throughout the research period. Using soils with higher clay content would most likely increase effectiveness for the conductivity, resistivity, and magnetometry, but would diminish the effectiveness of the GPR even further.

## **Conclusion**

Based on the findings of this research it is not recommended that one rely solely on geophysical tools in the search of toddler-sized burials. In addition, investigators and searchers, some of whom may not be used to searching for graves, should be extremely cautious in searching for this type of burial using only visual survey. Instead, it is recommended that investigators continue to utilize a multi-disciplinary approach including visual survey, geophysical methods, and cadaver dogs in the search for toddler-sized burials. During a search if geophysical survey methods are inconclusive or fail to show a signature for a potential burial, but other information indicates that a burial is potentially present, then the area needs to be evaluated through the excavation process.

It is hoped that this thesis can help add to the small but growing discussion in regards to the theory of forensic anthropology and how it relates to the discipline of anthropology as a whole. Through the use of an actualistic study, middle-range forensic anthropology theory, this research has evaluated geophysical survey methods that would be more closely related to recovery theory, which has been classified by Boyd and Boyd (2011) as a method found within low-level forensic anthropology theory. It is proposed herein that the actual interpretation of the geophysical data could potentially rise to the level of high-level forensic anthropology theory, because it requires interpretation of a lower-level methodological approach.

Boyd and Boyd (2011) and Johnston and Scheikart (2015) are certainly correct when they argue that it is time for forensic anthropology to stop being regarded as a consumer of techniques and methods. Forensic anthropology, to be fully recognized and respected, needs to become a contributor to the discipline as a whole. Actualistic studies and the models that have been created through taphonomic research have the potential to contribute to a better understanding of human interaction in funerary contexts. This understanding will provide insight into the action of the human agents in the context of surrounding environment.

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## **VITA**

Paul S. Martin was born in Greenville, Mississippi on July 6, 1977. After graduating from Washington School in 1995, he attended the University of Memphis, Mississippi Delta Community College, and Northwest Mississippi Community College where he earned a certificate in Paramedic Technology. After becoming involved with search and rescue in 1997 and working with the Washington County, Mississippi, Sheriff's Department as a human remains detection canine handler, he was introduced to the world of archaeology and anthropology when the search for a clandestine grave took an investigation to the McGee Mounds.

In August 2010, he entered Western Carolina University in the Anthropology and Sociology Department. In December 2011, he received the degree of Bachelor of Science in anthropology with a concentration in forensic anthropology and an approved minor from the Honors College in victim advocacy. As a student at Western Carolina University, he designed and helped found the Cadaver Dog Training Program that is offered through the Forensic Osteology Research Station (FOReSt). His work and research with cadaver dogs has been written about in the book "What the Dog Knows" by Cat Warren.

In August 2012, he entered the Master's program at the University of Mississippi and was awarded an assistantship from the University of Mississippi Sociology and Anthropology Department. He also was granted Affiliate Faculty status in the Anthropology and Sociology Department at WCU where he assists in the instruction of the Field Recovery of Human Remains field school course and serves as a mentor to students and a collaborator with faculty in on-going

research, and as a consultant to law enforcement. He has currently been accepted in the Doctoral program in the Department of Earth Sciences at the University of Memphis, Tennessee.