NCHRP 25-25, Task 98

PRACTICAL GUIDE FOR DEVELOPING EFFECTIVE SCOPES OF WORK FOR THE GEOPHYSICAL INVESTIGATION OF CEMETERIES

Final Report
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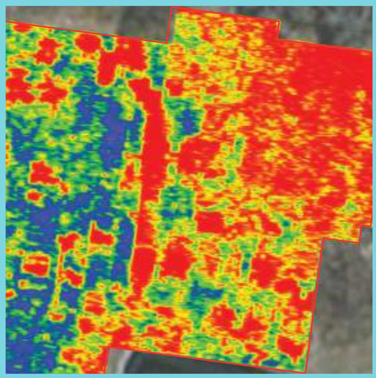
NCHRP Project 25-25/Task 98:

Practical Guide for Developing Effective

SOWs for the Geophysical Investigation of Cemeteries



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Executive Summary

Historic cemeteries are frequently encountered during transportation planning projects conducted in compliance with Section 106 of the National Historic Preservation Act (NHPA). While cemeteries are often assumed to be clearly bounded and well-marked historic properties, unmarked graves are common at most, if not all, cemeteries. Some burial grounds are comprised entirely of unmarked graves. Because the unintended discovery of human remains during construction can lead to project delays, unanticipated costs, and negative publicity, identifying unmarked graves can be critical to the success of transportation projects. Geophysical prospection is a non-invasive approach to identifying and mapping unmarked graves. Most department of transportation archaeologists are familiar with geophysical methods, but may lack understanding of the various technologies, relevant environmental and cultural variables, appropriate methods used in geophysical survey to identify human remains, and qualification standards for archaeological geophysical surveyors. This guidebook is intended to outline a practical guide to developing scopes of work for the geophysical investigation of cemeteries.

Guidebook Objective

The objective of this document is to provide transportation/preservation professionals with a guide to effectively scope geophysical surveys. Information includes explanations of geophysical instruments, possible deliverables, and the tools to assess the project results.

Overview

This guidebook defines and explains five steps to developing an effective geophysical scope of work in cemeteries: determine project goals (Chapter 2), define variables (Chapter 3), conduct background/archival research (Chapter 4), determine field survey and processing parameters (Chapter 5), and outline project deliverables (Chapter 6). In each of these chapters, information important to effectively scope a project is explained and examined using real-world case studies that demonstrate best practices. The final chapter (Chapter 7) summarizes all of the guidebook material with internal links to detailed textual explanations and can be used as a stand-alone management document.

Chapter 2: Determine Project Goals

This chapter discusses how to initiate a scope of work for geophysical survey. The first step in writing an effective scope is to determine the project goals and outline the undertaking that is initiating the geophysical survey. Common project goals are to identify the presence or absence of a cemetery, locate the boundary or extent of a cemetery, and identify and map the number and location of graves, and they can be part of educational, research, and/or preservation efforts. In order to effectively determine the project goals, the survey area must be defined. This can be either through a project's formal area of potential effects (APE) or by determining the study area when there is no formal APE.

Chapter 3: Define Variables

This chapter outlines and defines possible cemetery environmental and cultural variables that will affect geophysical survey methods and results. When creating a scope, compiling a list of known and unknown variables can help the project sponsor and a geophysical practitioner understand the resource.

Environmental conditions can dictate which geophysical method(s) will be effective and where, as well as what kind of work may need to be done prior to survey (e.g. clearing vegetation). Cultural variables such as ethnic affiliation, religious affiliation, age, cemetery type, and geography can directly impact how graves might be oriented. This will help determine the most effective geophysical instruments and data collection parameters, and will provide insight into what grave features might look like in the images produced from geophysical data.

Chapter 4: Background and Archival Research

Archival and background resources such as deeds, cemetery records, local histories, oral histories, cemetery maps, and inventories can help provide a more comprehensive context for a cemetery. This chapter discusses which resources may be available and how they might help support geophysical work. This type of research may not be needed for every project and may be limited by the available resources. These resources may or may not be consulted prior to scoping the geophysical survey. The research portion of the project may be part of the geophysical scope or be conducted by the project sponsor.

Chapter 5: Determine Field Survey and Data Processing Parameters

There are three components to the successful collection and processing of geophysical data in a cemetery: an experienced practitioner, proper field collection methods for the site, and good data processing parameters. This chapter discusses possible practitioner requirements, outlines different field methods and parameters, and gives a general overview of data processing. Practitioners with professional experience collecting and processing geophysical data in cemeteries may be the best choice for this type of project. This is particularly important because data processing and interpretation in cemeteries is complex and can require specific methods. Proper field data collection methods may vary by site and instrument selection. This chapter also outlines common geophysical instruments used in cemeteries and discusses appropriate situations for their use. Basic data collection parameters should be identified in the scope while taking into account the project environmental and cultural variables, goals, and budget. The scope should broadly define the desired data processing parameters. Each geophysical method requires different processing steps. It is important for the practitioner to understand how each processing step works, and know when – and when not – to apply them. This is particularly true in cemeteries where subtle grave features may require more detailed processing and analysis steps.

Chapter 6: Outline Project Deliverables

Project deliverables will depend on the project goals and budget, and they will need to be clearly stated in the project scope. This chapter reviews common deliverables and discusses specific items that might be useful to require. Required deliverables typically include a report and mapping or GIS data, but may also include raw or processed geophysical data, photos, and public outreach. Additional items may be requested based on specific project need, assuming they are clearly stated in the scope.

Chapter 7: Compiling Information in a Scope

The final scope document may be organized based on agency requirements, but it could also mirror the organization of the guidebook. Above all, the scope document should be clear and concise, conveying the project area and objectives. The more specific the scope, the more likely the results will mirror the project expectations.

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CHAPTER 1

Introduction

Historic cemeteries are a property type frequently encountered during transportation planning surveys conducted in compliance with Section 106 of the National Historic Preservation Act (NHPA) on federally funded projects. While cemeteries are often assumed to represent clearly bounded and well-marked historic properties, unmarked graves are common at most, if not all, cemeteries, and some burial grounds are composed entirely of unmarked graves. These situations pose significant challenges to Departments of Transportation (DOTs). The identification of unmarked graves is critical to the successful implementation of transportation projects because the discovery of human remains during construction can lead to costly delays, unintended site disturbance, and negative publicity.

Geophysical prospection is a non-invasive approach to identifying and mapping unmarked graves. Technological improvements in hardware and software combined with a pool of practitioners trained specifically in the application of geophysics to archaeological sites and features have resulted in significant advances. Most DOT archaeologists are familiar with geophysical methods, but may lack understanding of the various technologies, relevant environmental and cultural variables, the appropriate methods used in geophysical survey to identify human remains, and the qualification standards for archaeological geophysical surveyors. In essence, they lack the information necessary to write an effective scope of work.

National Cooperative Highway Research Program (NCHRP) 25-25/Task 98 was designed to address this problem and is a practical guide to developing scopes of work for the geophysical investigation of cemeteries. Research for this project included four stages: literature review, interviews with experienced practitioners, identification of best practices case studies, and a guidebook. Key findings from each are summarized in Table 1, and the full documents are provided in Appendices A and B. The completed best practice case studies are incorporated into the guidebook.

Table 1. Summary of key findings.

	Key Findings	Location
Literature Review	• Published literature falls into archaeological or forensic disciplines with little to no overlap. • Archaeological literature is primarily case studies of an individual cemetery. • Little attention is given to common themes, such as burial depth, burial container, correlations between marked/unmarked graves, or social/cultural factors affecting burial condition. • There is a lack of "ground-truthing" to test geophysical anomalies. • GPR was the most common instrument. • No universal instrument of suite of instruments is applicable in all cases. • Forensic literature focused primarily on clandestine graves. • There is extensive reliance on scientific testing using simulated conditions.	Appendix A
Interviews with Experienced Practitioners	• Surveys were sent to 64 recipients in Academia (n=15), Industry (n=26), Agency (n=13), and Tribal Governments (n=10). • Overall response rate was 23%. • Follow-up interviews were conducted with five individuals using more detailed questions. • Topics covered included Experience, Scoping, Environmental and Cultural Variables, Equipment/Field Survey, Data Processing/Analysis, Reporting. • There was no consensus about instrument selection. • There was a high level of agreement about the need for qualified practitioners, effective scoping, and reporting.	Appendix B
Best Practices Case Studies	• Case studies illustrating best practices were identified based on the literature review and practitioner interviews. • A single case study was selected to represent each major theme. • Case studies were summarized in terms of Project Description, Research Questions, Survey Design, Results, Recommendations, and Key Lessons.	In Guidebook

1.1 Defining a Cemetery

A cemetery, burial ground, or graveyard refers to any area that contains graves. In this document, "cemetery" is used as the preferred term. Cemeteries include a range of burial places and types, including, but not limited to, precontact Native American sites, individual graves, family cemeteries, battlefields, informal community cemeteries, and formal municipal cemeteries. Whether the graves are marked or unmarked, burial in a cemetery implies intent to commemorate an individual by a descendant community. Most, if not all, cemeteries have associated features such as individual grave markers, burial plot boundaries, depressions or mounds, offerings, fences, and ornamental plantings. Individual state and municipal laws may have statutory definitions of a cemetery.

The definition of a cemetery for the purpose of this report does not include clandestine burials, or the burials of crime victims. A clandestine burial is not considered a *cemetery* as defined here because its location is meant to be hidden from public view. Clandestine burials are not typically meant as a respectful gesture to the dead, but they are, rather, the disposal of criminal evidence. Because of the desire for secrecy and expediency, clandestine burials normally use different treatments and are placed in different locations than traditional ones. Therefore, the type of remains below the ground and their geophysical signature will be different than traditionally buried remains. Clandestinely buried decedents are typically not buried in a formal container, are buried at shallow depths, may not be buried in traditional directions (west to east for Christian cemeteries), and can be isolated in unlikely places.

A single, unmarked burial that is not in a coffin or casket, and with no contextual information from associated features, may be extremely challenging to locate. Clandestine burials can be located with geophysical methods, and the methods and instruments used by the forensic community overlap with those used by archaeologists. This burial type will be discussed in this guidebook, as the literature for using geophysics to locate clandestine graves is extensive and can be useful to the understanding of cemeteries. In terms of scoping a geophysical survey, it is important to recognize that location and identification of clandestine graves is not the same as the location and identification of cemeteries.

Cemeteries are a common site type across the landscape. Despite variations in cultural, environmental, and temporal attributes, they face a series of common problems, not least of which is that when graves are unmarked, or markers are removed or moved, it is impossible to determine the size, extent, and location of the cemetery, particularly as local memory fades. Cemeteries are also far from an eternal resting place for the dead. As populations grow and development and infrastructure needs expand, cemetery locations will continue to intersect with development. If the boundaries of cemeteries cannot be established and the locations of graves are lost, it can be difficult to plan for this development.

1.2 Regulatory Framework

Cemeteries are protected places in the United States; however, each is protected differently depending on the type of cemetery; who owns the land it is located on; and the local, state, or municipal laws. Treatment of precontact cemeteries by federal agencies or entities that receive federal assistance is regulated under the Native American Graves and Repatriation Act (NAGPRA) of 1990. Treatment of historic cemeteries may be considered under Section 106 of the National Historic Preservation Act (NHPA) of 1966. However, cemeteries are typically regulated by different state and local laws. These laws vary depending on the geographic location of the cemetery and type of cemetery, but they usually dictate cemetery access, preservation, and procedures for moving a cemetery, regardless of who owns the land. A full exploration of the regulatory structures that dictate the treatment of cemeteries is beyond the scope of this document; however, prior to working in a cemetery, these regulatory structures should be considered.

1.3 Locating Unmarked Graves

Relocating graves and identifying cemetery boundaries are common practices that are usually the first investigatory steps when a cemetery may be impacted in some way. There are multiple methods used for this process. Identification methods range in efficacy at defining graves and their degree of destruction of cemetery resources. Picking the detection method that will best serve the project type and meet project goals is the single best way to ensure a productive survey for unmarked graves.

- Topsoil Stripping
- Probing

Method selection for locating unmarked graves is dependent on the project goals, cemetery variables, and the accuracy level needed to achieve those project goals (Figure 1). Non-destructive cemetery identification methods include geophysical techniques (the subject of this guidebook), pedestrian survey and reconnaissance to map cemetery features, cadaver dogs, and penetrometer or soil compaction survey. Minimally destructive methods include stripping of the topsoil to identify grave shaft soil stains and probing to locate remains. Excavation through either archaeological methods or mechanical removal would be considered a destructive method. Sampling strategies can range from complete, high-density data collection to broad reconnaissance survey. It is beyond the scope of this document to evaluate the efficacy of the non-geophysical methods, but they should be considered when determining the methods that are most appropriate for a cemetery survey.

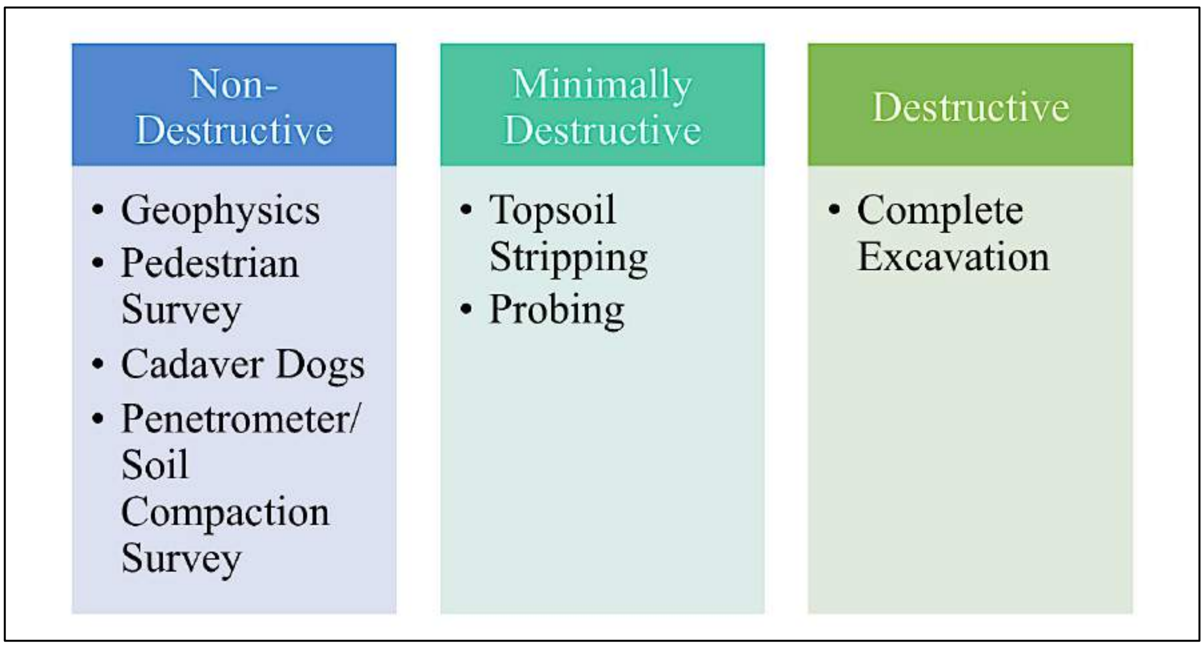

Figure 1. Common methods for identifying unmarked graves.

Cemetery survey goals vary depending on the type of project planned and the type of cemetery to be surveyed. Two important questions should be considered when planning a cemetery survey for unmarked graves: (1) How accurate does this survey need to be? (2) Can the survey cause any destruction in the cemetery? Cemetery surveys do not always need to map all of the unmarked graves with no possibility for error. It is obviously ideal to map all graves with complete confidence, but the only method that is capable of that type of accuracy is complete cemetery excavation. This process is destructive, expensive, and, in many circumstances, emotionally fraught. Excavating the entire cemetery could be an excessive amount of work if destruction can be avoided once the boundaries have been established. If the burials are being moved completely then complete excavation may be acceptable. If plans require avoidance and preservation, then a less destructive method may be needed.

Non-destructive methods are less accurate then excavation. When combined with high-density sampling and multiple methods, they do provide a high level of accuracy. Most cemetery surveys begin with a non-destructive method such as geophysics, pedestrian survey, or penetrometer/soil compaction survey. Then, as the project moves forward, more destructive methods are employed, as necessary. A higher number of methods and a higher sampling density generally increase the cost of the survey and this type of accuracy is not always needed.

1.4 What Is Geophysics?

Geophysics is the non-invasive measurement of subsurface conditions in the earth through measuring, analyzing, and interpreting physical fields at the surface (Environmental and Engineering Geophysical Society). Near-surface geophysical methods predominately focus on the ground directly below the surface (within approximately one to two meters), but some geophysical methods can extend to greater depths. Geophysical surveys are used for a variety of purposes, including mapping the geology, geological structure, groundwater, and contamination below the surface. They are also commonly used to locate utilities or petroleum resources.

Archaeologists and cultural resource specialists use geophysical methods to map cultural changes made within the near-surface. This type of geophysical survey focuses on human modifications made during the historic or precontact periods. These features include architecture, middens, gardens, roads, paths, and cemetery features, among others. Archaeological and cultural features are identified through contrasts between features and their surrounding soils. The type of contrast varies by the instrument and feature type, but if some contrast is not present, features will not be mapped. These contrasts are often the result of different water retention properties between cultural features and their surrounding soils (Conyers 2004a; Pringle et al. 2015; Schultz and Martin 2012).

1.4.1 Common Geophysical Instruments Used in Cemeteries

The most commonly used geophysical methods for archaeological cemetery applications are ground penetrating radar (GPR), magnetometry, electrical resistance, electromagnetic conductivity or induction, and magnetic susceptibility. Light detecting and ranging (LiDAR) is not typically considered a geophysical method because it does not detect below the earth's surface, but it is a remote-sensing method and is included in this guidebook. Each of these instruments operates using different basic principles and maps different properties. These methods are discussed in greater detail in Chapter 5.

1.5 Geophysics in Cemeteries

In cemeteries, near-surface geophysics can be used to map the contrasts between graves and their surrounding soils. When a grave shaft is excavated, this process can create a change in the physical properties of the soils. The burial container, void spaces, and, in very rare circumstances, the remains themselves can create anomalous readings from the surrounding soils. In cemeteries where there are unmarked graves, mapping those changes below the surface can be used to identify possible burials. For burials, contrasts can be produced by a coffin, a casket, a burial shaft, the bottom of the grave, and, occasionally, skeletal remains or a body (Damiata et al. 2013; Lowry and Turco 2016:17; Schultz and Martin 2012). The primary advantage of geophysical methods is that they are non-invasive and can produce comprehensive data over wide areas.

1.5.1 How Well Do Geophysics Work?

Geophysics is just one way unmarked graves can be mapped. Geophysical methods are popular because they allow for efficient and non-invasive mapping of a resource that can be sensitive to excavate, such as a cemetery. Like all of the non-invasive and minimally invasive identification methods, geophysics may not locate every single grave. Increasing the number of instruments used and the sampling density may increase the accuracy of geophysical results, but environmental and budgetary constraints can impose limitations on this. No matter how intensive the geophysical survey, if there is no contrast between grave features and their surrounding soils, graves will not be imaged.

These limitations, however, do not mean that geophysical surveys are not an effective tool to map unmarked graves. It simply means that project goals should be factored into the decision to conduct a geophysical survey. Additionally, all project constituents need to maintain realistic expectations of the reliability of geophysics. Geophysics is one tool in the toolkit for identifying unmarked graves; it can be considered a starting point and, if complete accuracy is needed, additional methods may be considered.

Application of geophysical methods to cemeteries carries with it an acknowledgement that success is defined on a case-by-case basis. Because of the range of environmental, social, cultural, and economic variables, there is no single instrument or combination of instruments that can definitively identify 100 percent of the graves in a particular cemetery.

1.6 Scope of Document

This document is intended as a guide for developing an effective scope of work for geophysical survey in cemeteries. The intended audience is transportation/preservation professionals writing or reviewing scopes, who may not necessarily be experts with geophysical concepts. No knowledge of geophysics is assumed in this document, but a general knowledge of cultural resource management and the regulatory setting in which investigations will be conducted is needed. The document is intended to empower professionals to scope their geophysical surveys properly for geophysical practitioners, to know which deliverables they would like, and to understand the project results.

The following seven chapters outline steps to developing an effective scope. The first chapter introduces the subject and outlines the scope of the guide. The next five chapters outline the steps to developing an effective scope: determine project goals, define variables, conduct background/archival research, determine field survey and processing parameters, and outline project deliverables (Figure 2). These chapters examine information that is needed to effectively scope a project and discuss why this information is important. Each of these chapters uses real-world case studies. The final chapter summarizes all of the guidebook material at a management level and may also be used as a stand-alone management document. It contains internal links to references and more detailed explanations.

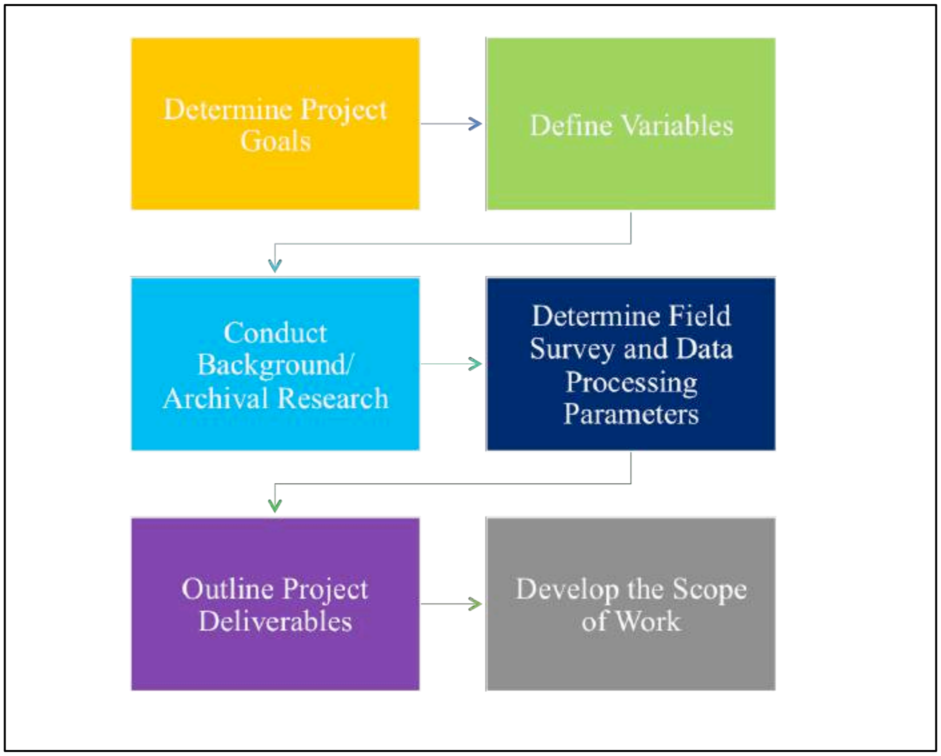

Figure 2. Components of an effective scope of work.

1.7 A Note on Data Confidentiality and Security

In general, cemetery locations and cemetery information are not protected the same way as archaeological site locations. Often, geophysical surveys of cemeteries can be publically shared without redaction or preparing a public version of the report. This could vary depending on the cemetery or the circumstances, and there might be exceptions such as precontact graves or particularly fragile or vulnerable cemeteries. Information accessibility laws, rules, and regulations vary by the state and agency, so it is important to be aware of these issues when considering scoping, reporting, and dissemination of survey results. Each individual project may require a statement on the confidentiality of the reporting and results.

1.8 Zotero Bibliography

Sources consulted during the process of developing this guidebook and all references cited are compiled into a Zotero database of references, annotated bibliography abstracts, and key terms. It is available for download at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3973. Zotero is a free, open-source, bibliographic software program (https://www.zotero.org). Once the bibliographic materials have been downloaded and opened in Zotero, the reference information can be edited and added to by the end user and cited in their own work.

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CHAPTER 2

Determine Project Goals

The first step to writing an effective scope for geophysics in cemeteries is to determine the project goal(s). This may require research questions to be outlined in detail or simply a statement of the problem. Goals can vary depending on the type of project. For example, common project goals include identifying the cemetery boundaries or the number and location of graves (Figure 3). These goals may dictate different survey strategies or levels of effort. Results from a cemetery geophysical survey are not necessarily exclusive to other project goals. A project where the goal is to identify a cemetery boundary may still locate the number and location of graves and contribute to the preservation of the cemetery. Determining the goals is the first step to outlining what kind of survey is necessary for a specific project.

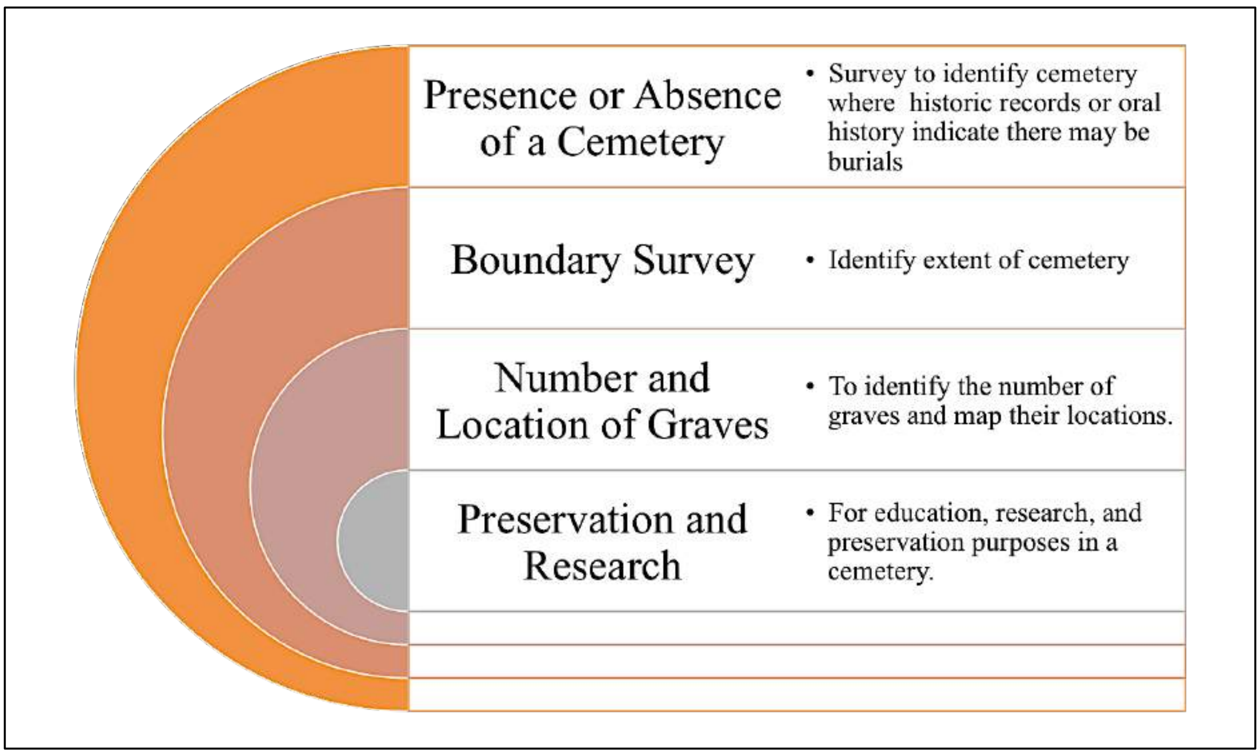

Figure 3. Common reasons geophysical surveys are conducted in cemeteries.

2.1 Scope of Work for Specific Undertaking

Project goal-setting begins with outlining the project undertaking or the possible impacts to the cemetery. This may require reviewing project plans or consulting with other involved parties. During this phase, maps, plans, GIS data, and previously collected data concerning the undertaking should be gathered into one place so a project area can be established. After outlining the project undertaking, the project survey area is established, the project expectations and goals are set, and, finally, the appropriate geophysical instruments can be considered in order to meet those goals.

2.1.1 Project Survey Area

Once the project undertaking has been defined, the next step is to determine the extent to which the cemetery will be impacted. This is often (but not always) defined through establishing a survey area. In many regulatory projects, an area of potential effects (APE) has been established for the entire project, and only a small portion may overlap with the cemetery survey area. For some projects, the APE may overlap with the entire cemetery; for others, it might be a narrow section. The survey area may have no marked graves, but the proximity to the cemetery or oral history of graves in the area may indicate the cemetery extends outside of its known boundaries. It is not always possible to determine the extent of a cemetery from only above-ground features. The survey area must be defined to identify the area to be surveyed using the available information. A defined survey area is essential to accurate scoping.

Often, the survey area will include the APE, where it intersects with the cemetery, plus a buffer. This buffer can range in size based on the topography, number of graves within the cemetery, and the proximity of grave markers to the APE. In some cases, the edge of the survey area may be adjacent to a natural boundary, such as a creek or steep hill. The size of the buffer around the survey area should be considered on a case-by-case basis.

The GPR survey for stone box graves at the Old Town Mississippian Site is a good example of defining the survey area based on the possible impacts. Construction was planned on the Old Natchez Trace Road in Williamson County, Tennessee, where there was a well-known archaeological site adjacent to the road (Old Town Indian Mounds/40WM2) (Lowry and Patch 2014). At this site, precontact Middle Cumberland stone box graves have been identified nearly every time ground was disturbed, and there were no indications that the site stopped prior to the present day road. The area selected for survey included both the present day road and a buffer of land towards the known site (the other side of the road dropped immediately towards a creek). This survey area did not include the entire precontact site, but focused, instead, on the road and areas to be impacted with the goal of identifying the number and location of possible graves within that area.

2.1.2 Project Goals and Expectations

Project goals may be one or more of the common goals listed in Figure 3 or a specific set of goals or research questions customized to the project. Project expectations can be tailored to specific goals. For example, at Wyandotte County Cemetery in Kansas City, Kansas, Jones (2008a) needed to determine the cemetery boundary. This survey targeted areas along the cemetery edges with resistivity, magnetometry, and archaeological testing. Areas outside of the boundary area were not surveyed. The expectations for the geophysical results were to locate the cemetery boundary. In this case, it was not necessary to survey the entire cemetery and project goals and expectations were limited to meet the needs of the project.

Project goals can also help determine the level of accuracy needed for the geophysical survey. No geophysical survey can be completely confident that all of the possible graves have been identified. Steps can be taken to obtain greater accuracy, including increasing sampling density, adding archaeological testing or topsoil scraping, and, in certain cases, increasing the number of instruments used. These steps may be employed depending on the needs of the project. If the project goals require confident interpretation of all of the graves, this should be documented at this stage so this can be considered while scoping the project.

The first variable to outline is the overall project goals. Goals vary depending on the planned undertaking, but common goals include defining a boundary for the burials and determining the locations of burials within a cemetery. Project goals drive the accuracy needed, which can, in turn, define the types of methods employed. For example, if the project goal is to locate a cemetery boundary so the cemetery can be avoided, then a multiple-method survey might be unnecessary. Instead, maybe a buffer could be applied to the boundary identified by the single method. If the graves are going to be moved once they are identified, maybe multiple geophysical methods should be applied, with the addition of scraping the topsoil.

The accuracy needed for the desired results should be evaluated as an element of project goals during scoping. Ideally, all geophysical projects would find all unmarked graves present, but this is not a realistic goal given the constraints of instruments. Project budget and timeframe of can also prohibit intensive testing. It is difficult to determine the accuracy of geophysical projects prior to fieldwork, but no geophysical survey can promise complete accuracy.

2.1.3 Level of Effort

The level of effort for fieldwork, processing, and reporting for a project will typically be determined by the practitioner in their proposal. The level of effort will ultimately be determined depending on the site conditions, geophysical instrument selection, survey method, and data collection parameters. In general, one day of field survey translates to one day of data processing and one day of reporting. However, it is probable that the level of effort for a cemetery will be more extensive because cemeteries are complex and graves are subtle features that may require more processing time. The number of days in the field may increase if collection parameters are complex, if more than one geophysical method is used, or if there is a desire for greater sampling density. Certain geophysical methods, such as electrical resistance, require more collection time than others. Cemeteries may also require more time for data processing and interpretation, since more intensive procedures are often necessary to identify subtle grave features. A practitioner can determine the level of effort for an individual project based on these variables, and it will need to be customized for each cemetery project.

2.1.4 Instrument Selection

Choosing the best geophysical method or methods to align with project goals is an important part of outlining project goals. Method selection should be done as part of a careful evaluation of the accuracy needs of the project, the projects' environmental and cultural variables (Chapter 3), available geophysical methods, and time/cost. Requiring multiple methods may be a way to increase accuracy/reliability (Clay 2001; Gaffney et al. 2015), but it is not always a guarantee of greater accuracy. The multiple methods still have to be well suited to the type of grave and the environmental conditions of the site (see Chapter 4). Simply applying multiple geophysical methods for its own sake will not increase accuracy.

There is variable preservation in most cemeteries, and identifying all of the unmarked graves without ground disturbance may be impossible. When project goals require additional lines of evidence or assurances that 100 percent of graves have been identified, non-geophysical methods may be needed. Additional approaches are excavation, scraping topsoil to identify burials through soil differences, probing, and mapping surface cemetery features. These methods can be applied in support of or as an alternative to geophysics.

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CHAPTER 3

Define Variables

During the scoping process for a geophysical survey, all of the known cemetery variables need to be as clearly defined as possible to lower the probability of surprises during the survey and to enhance the success rate. This serves many purposes; primarily, it identifies the cemetery resource and provides a structure for gathering the known information. When variables are consistently and systematically defined and information concerning the type of cemetery resource and its known condition are presented together, the sponsor of the survey can enhance the survey's success rate. The collected information allows both the person writing the scope and the practitioner to effectively understand the project. Identifying the known variables is essential to identifying the appropriate geophysical instrument or instruments, the sampling strategies, and the possible need for vegetation clearing, mapping, or special techniques.

Project variables can be divided into two main categories: environmental and cultural. Environmental variables include both natural and cultural environmental conditions in the cemetery, such as vegetation, topography, soils, modern disturbances, and surface obstructions. These variables impact the survey conditions and the environment of the cemetery. Cultural variables define the cemetery's cultural context, such as age, periods of use, ethnic associations, geographic location, and cemetery origin. As norms associated with burials can be highly variable based on cultural variables, it is necessary to take these into account when survey planning.

3.1 Environmental Variables

A cemetery's environmental conditions are always important to consider when planning a geophysical survey. For example, surface obstacles, topography, vegetation, soil type, moisture content, and modern disturbances are a few variables that need to be accounted for when making decisions regarding coverage, instrumentation, research design, and expectations. Environmental variables can originate from both natural and cultural sources.

3.1.1 Natural Environmental Variables

Naturally occurring environmental variables include soil types and soil moisture content, topography, vegetation, and weather.

3.1.1.1 Soil Types And Soil Moisture Content

Soil conditions and soil moisture content are the chief environmental factors that determine the effectiveness of geophysical survey. All geophysical methods rely on the presence of contrast between graves and the surrounding soils. If the disturbance from excavating the grave shaft is not distinct from the undisturbed soil profile, a circumstance that can be particularly problematic in sandy conditions, the grave may not be visible (Nobes 2007). In some cases, contrast can be due to differing water retention properties (Conyers 2004a; Pringle et al. 2015; Schultz and Martin 2012). Clay-rich soil has long been considered a negative for all geophysical methods, and it can limit depth penetration of GPR (Freeland et al. 2003). This perception is based on dated research, yet persists despite numerous instances in which it has shown to not be a significant factor. In short, if there is sufficient contrast, geophysics could still be successful in clay soils. Soil and moisture conditions can be highly variable within and across small areas and over time (e.g., days, weeks, or months) depending on precipitation. It is not always possible to know if soil conditions are suitable for geophysics before the instruments are used on site, but preliminary information can be found in soil surveys. As part of the scoping process, it is a good idea to review soil surveys to gather information about the general conditions.

3.1.1.2 Topography

Cemetery topography can present a challenge that will affect instrument selection and data collection procedures. Topographic features, such as steep grade and bodies of water, can help define cemetery boundaries. Steep grades do not necessarily indicate an absence of burials, particularly when considering marginalized groups that may not have been able to command prime burial land. Challenging topography may limit geophysical instrument selection, so steep grades should be noted if they fall within the survey area.

3.1.1.3 Vegetation

Vegetation presents a logistical challenge for geophysical surveys in cemeteries. In well-maintained urban cemeteries, grass tends to be manicured, and other vegetation is limited to isolated trees and other ornamental plantings. Rural or poorly maintained cemeteries are often overgrown, with dense brush, saplings, limbs, and other debris. Dense vegetation will limit access to the ground surface for geophysical instruments and can limit instrument selection and effectiveness of the survey. The presence of dense vegetation does not necessarily make geophysical survey impossible, but it might mean clearing needs to be planned. Due to the fragile nature of cemetery features (particularly historic headstones), this clearing will likely need to be done by hand or, if machinery is used, closely supervised to ensure that no surface features are affected. Clearing the cemetery is an additional expense and can be time consuming, so the condition of the cemetery vegetation must be documented and considered during the scoping process. As a general rule, better ground conditions will produce better results.

3.1.1.4 Weather

Weather is a temporary logistical challenge that can impact project schedules and the efficacy of geophysical instruments. First, some geophysical instruments can be damaged from adverse weather and precipitation and are not normally operated under those conditions. Second, some geophysical results are sensitive to wet or extremely dry conditions, and most geophysical surveys benefit from consistency in soil moisture throughout the survey period. This is not always possible in circumstances where large areas need to be surveyed. For example, electrical resistance is not as effective under extremely dry conditions. If the survey area is in a region prone to extreme weather events or if there is a wet or dry season, this should be noted as an environmental variable.

3.1.2 Cultural Environmental Variables

Cultural factors that may impact the survey environment include the integrity of the cemetery and above-ground disturbances. The condition of the cemetery may impact the feasibility of geophysics. For example, if a cemetery has been altered by post-interment activities (such as construction or other ground disturbance), it may be difficult to image graves. This is particularly the case if modern debris is present that causes magnetic anomalies and masks more subtle grave features (Ellwood et al. 1994; Johnson et al. 2015; King et al. 1993). Surface debris can also inhibit geophysical survey (Meehan et al. 2015). Some types of surface disturbance (e.g., a building) will prevent access to the ground for all geophysical instruments, while others will prevent access for some instruments and not others. For example, GPR is the only suitable method for surveying a paved parking lot (Whiting and Hackenberger 2004), while magnetometer or electromagnetic survey are better for uneven ground surfaces (Meehan et al. 2015).

Prior to scoping a geophysical survey, the environmental conditions in the cemetery need to be considered to develop appropriate expectations and the best survey results. All geophysical methods require either direct or very close ground contact, which means trees, underbrush, fences, grave markers, and other obstacles are all physical impediments to good data collection. In addition to these physical impediments, tree roots can obscure subtle grave anomalies. Best practices involve: 1) ensuring survey areas are free of surface obstructions and debris without disturbing the cemetery features, 2) clearing vegetation or mowing grass as close to the ground surface as possible, and 3) understanding the site soil conditions. Environmental conditions are simply another set of variables to consider. Many challenges can be overcome through survey design or collection strategy, but they must be considered at the beginning of the scoping process.

3.1.3 Case Study – Environmental Variables, Example for Burial Preservation in Different Soil Types

Imaging Skeletal Remains with Ground-Penetrating Radar: Comparative Results over Two Graves from Viking Age and Medieval Churchyards on the Stóra-Seyla Farm, Northern Iceland	
Authors	Brian N. Damaita John M. Steinberg Douglas J. Boender Guðný Zoëga
Date	2013
Publication	Journal of Archaeological Science
Volume	40
Pages	268-278
Abstract	This article discusses the GPR results of two graves in great detail and compares them to the excavation results. Assessment of the GPR data is also compared to modeled GPR results. The authors conclude that in one of the examples they mapped the actual skeleton. In the other example, preservation was poor and no skeleton was mapped, although a more faint reflection was produced by the stratigraphic truncation. This article focuses on a small area survey and looks at burial preservation and how that affects the GPR results.
Cultural Variables	European, Christian, Early Historic Period, Church Cemetery

PROJECT DESCRIPTION

Two cemeteries were identified as part of a Skagafjörður Archaeological Settlement Survey (SASS) of the Stóra-Seyla farm in the Langholt region of northern Iceland. Ground penetrating radar and excavations were used to investigate both the Viking Age (A.D. 871-1104) churchyard above the valley bottom, and the later, medieval (after A.D. 1104) churchyard that was 14 meters higher in elevation. This article focused on two graves that were identified in the interpreted GPR results and were subsequently tested through excavation.

RESEARCH QUESTIONS

This study focuses on one grave from each cemetery to evaluate burial conditions such as soil properties, presence or absence of containers, and positioning of the deceased. Analysis of these burials led to further investigations concerning the relative permittivity of soils and bones embedded in the backfill of graves, and the impact those variables have on how graves are imaged in GPR data.

SURVEY DESIGN

Ground penetrating radar was conducted over selected church cemetery sites, which had been identified during previous surveys. The areas to be surveyed with GPR were cleared of turf to improve energy coupling. GPR data were collected using a 500-megahertz (MHz) antenna and close 20- or 25-centimeter transect spacing. One grave from each cemetery was excavated to verify and supplement the interpretations from the GPR survey.

RESULTS

The grave in the older Viking Age cemetery contained skeletal remains that produced hyperbolic reflections in the GPR data and the grave in the more recent medieval cemetery was identified from weaker reflections produced by backfilling the grave shaft. The Viking Age grave was characterized by distinct hyperbolic reflections in several adjacent profiles, totaling approximately two meters, the approximate length of an adult burial. The hyperbolas in profiles to the west were considerably wider than those in profiles to the east. The authors interpreted the wider hyperbolas as products of the skeleton's upper body (which faced east), while the narrower more pointed hyperbolas reflected the leg bones. Several of the wider hyperbolas exhibit normal polarity banding, expected when waves encounter a void space. Excavation of this grave revealed that the skeletal remains were very well preserved with evidence to suggest that there was a void space in the chest cavity. In contrast, no hyperbolas were detected in the GPR data collected in the medieval cemetery. An area of weak reflections was hypothesized to be associated with burial-related ground disturbance. The only skeletal materials recovered through excavation were teeth. The poor preservation of the skeletal remains was attributed to infiltrating groundwater from an overlying gravel layer.

The differences in the detection and preservation of skeletal remains between the two graves led to further investigations concerning the relative permittivity of soil and bones embedded in backfill soil. A greater contrast between bone and soil increases visibility of well-preserved bone in the GPR results. This contrast can vary across environments. Well-preserved bones are best detected when they are in either very moist or very dry environments, conditions that can also impact the preservation of the skeletal remains. The environments of the two cemeteries were distinct and this impacted preservation, and, thus, the type of GPR results that could be mapped.

The frequency of the antenna affects the size of objects that can be detected. Higher frequency antennas can resolve smaller objects, but the radar waves produced at higher frequencies do not penetrate as deeply. Waves produced at lower frequencies penetrate the ground more deeply, but have lower resolution. The antenna used in this study was 500 MHz, which has greater resolution than those often used for archaeological prospection. This undoubtedly contributed to the detection of the skeletal remains. The researchers also collected data in close-interval transects. In the Viking cemetery, transects spaced 20 centimeters apart produced concentrated data over a given area.

RECOMMENDATIONS

The authors recommend further study to assess the conditions in which bones may be detected through GPR. They also suggest that a screening tool be developed that can quickly measure the relative permittivity of the backfill when searching for burials. This will allow archaeologists to determine if skeletal remains have a high potential to be detected in a specified area.

KEY LESSONS

- **Environmental factors influence whether burial materials will be visible in the GPR data.** In this case, skeletal remains contrasted highly with the surrounding soil and were therefore detected by the radar waves. If the relative permittivity of bones or other cultural materials are not distinct from the surrounding material, they are less likely to be detected with radar. For example, in the medieval cemetery, a comparatively recent medieval burial was less visible than the older Viking burial. The authors attribute this to subsurface environmental conditions, which negatively affected the preservation of the medieval grave.

- **Instrument choice and collection methods are important to consider.** The antenna used in this research provided a higher resolution of archaeological materials than other antennas that are often used in archaeological research (i.e. 400 MHz). If the researchers had used a lower frequency antenna (such as 200 MHz), it is unlikely that the skeletal remains would have been detected. The relatively small transect spacing also contributed to the detection of the remains, because greater transect spacing would have resulted in fewer hyperbolas in the profiles from the two meters over the Viking Age burial. In this case, where the authors are attempting to image old graves not buried in coffins or caskets, the high-resolution data were particularly important.

- **It is often the secondary features of burials that are detected through geophysical methods.** A grave shaft was mapped in the medieval cemetery as an area of weak reflections associated with burial-related ground disturbance. This is typical for graves, which are often detected as burial pits or burial containers.

3.2 Cultural Variables

When planning a geophysical survey, it is important to understand and consider a cemetery's cultural context. History, age, periods of use, primary ethnic association, geographic location, and origin all impact the planning of a geophysical survey. Cultural norms associated with burials vary based on ethnicity, geography, and the social conditions at the time of burial. Variations in burial practices can affect geophysical method choice, survey methods, and overall project success. This is because cultural norms often dictate how burials are conducted and, thus, the way in which they contrast with the subsurface, which geophysical method(s) will be most effective, and how to structure a survey. Finally, the way burials are conducted can have a significant bearing on the success of the geophysical survey.

Cemetery type and burial methods vary significantly and can be characterized by a number of attributes, including ethnicity, religious affiliation, cemetery type, age of burial, and specific geographical region (Table 2). These variables do not necessarily determine the specific burial style, but they do influence burial methods, and more information is always helpful in planning a successful geophysical survey. Further, these variables are not exclusive or comprehensive. Rather, they provide a conceptual framework in which to begin listing variables during the scoping phase of a geophysical project.

Table 2. Cemetery variables to consider prior to geophysical survey.

Variables That Influence Burial Type	Categories
Ethnic Affiliation	Native American European American African American Asian American Latin American
Religious	Precontact Christian (Catholic, Protestant) Jewish Non-Western
Age	Precontact Early Historic Period (before nineteenth century) Historic (nineteenth century - early twentieth century) Modern (twentieth century – present)
Cemetery Type	Church Community Municipal Family Ad Hoc (Battlefield, travelers, paupers)
Regional	Rural and Urban Regional Trends

3.2.1 Ethnic Affiliation

The ethnicity of the interred can influence burial styles, grave orientation, and cemetery layouts. For example, historic European American and precontact Native American cemeteries may have had different burial orientations and burial methods, with the typical European American burial orientation being east to west (Jones 2008a; Conyers 2006a) and precontact Native American grave orientations varying within a single site (Lowry and Patch 2014; Bigman 2011; Versteeg et al. 1996). Historic African American communities may have had less access to resources than other communities and, thus, it may be more likely to find shrouded burials, more unmarked graves, or graves in marginal locations (Lowry and Turco 2016; Bigman 2014). These examples illustrate the diversity of cultural traditions that can influence burial styles and, in turn, how these burials may be imaged using geophysical methods.

3.2.2 Religious Affiliation

Religious affiliation is also linked to burial style, treatment of the deceased, and orientation of graves. As described above, in the Judeo-Christian tradition, most graves are oriented east-west and arranged in rows. Precontact Native American cemeteries do not follow the typical patterns for Judeo-Christian cemeteries (Bauman et al. 1995; Bigman 2012; Lowry and Patch 2014). Jewish burials will not be treated with preservatives or chemicals, and Muslim burials will face Mecca (Parker-Pearson 1999:6). The probable orientation of unmarked burials should be used to plan the location and orientation of survey grids and transects (Dionne et al. 2010). In cases where treatment of the deceased can result in lower rates of detectability (e.g. a faster rate of decomposition if not treated with chemicals compared to those that have been treated), geophysical methods that can detect more subtle contrasts associated with burials should be used (Byer and Mundell 2003:78; Damiata et al. 2013; Dionne et al. 2010).

3.2.3 Age

The age of the cemetery is one of the strongest predictors of preservation. This is not only because younger graves are less deteriorated, but also because burial practices became gradually more formalized during the twentieth century. Prior to the early twentieth century, graves show considerable variation in burial container/treatment (e.g., shroud, wooden coffin, lead coffin) and marker type (vernacular/formal) (Mellett 1996; Thieme 2013). In the twentieth century, the industry around cemeteries and death grew more standardized. Cemeteries during this period are more likely to have commercially made markers, and interments were more commonly in caskets and/or burial vaults. Older, pre-twentieth-century burials may only be detected as the subtle contrast produced from the grave shaft or bottom, since the remains and casket may have deteriorated significantly (Byer and Mundell 2003:78; Damiata et al. 2013). In an older cemetery, geophysical methods that are capable of detecting subtle contrasts between a grave shaft and the surrounding soil matrix should be employed (Byer and Mundell 2003; Damiata et al. 2013; Dionne et al. 2010). It is best to conceive of grave age and ability to be detected by geophysical methods as a continuum rather than rigid rules. In relative terms, “older” graves are harder to detect than “younger” graves, but there is so much variation that it is impossible to state with certainty that a particular method will or will not work. The most important variable is contrast.

3.2.4 Cemetery Type

The organization of a cemetery is typically related to its type and may change over time as burial practices and affiliations change. Formal municipal cemeteries typically have established plots (Patch et al. 2011; Sjostrom et al. 2009), whereas community (Lowry 2014) and church cemeteries (Hansen and Pringle 2011) may have a semi-formal layout, but with older sections that followed vernacular burial placement. Cemeteries that were placed in an *ad hoc* fashion during events such as paupers fields, battles, military campaigns, or travelers dying unexpectedly while in transit can be unpredictable and poorly marked (Kalacska et al. 2009; Pomfret 2014).

Knowledge of the type of cemetery can help to determine what sort of cemetery organization can be expected, which can guide geophysical research. For example, a battlefield cemetery with only *ad hoc* burials might be surveyed differently than a municipal cemetery with formal plots. Battlefield dead might be expected to be buried in mass graves or individual graves that are relatively shallow, may not have been placed in any type of container, and may also have personal effects such as uniforms or weaponry. Both the geophysical method to be used and field collection parameters should be informed by the cemetery organization (Jones 2008:32, personal communication Paul Mohler, July 11, 2016, Geoffrey Jones, June, 22, 2016 and Jami Lockhart, June 22, 2016).

3.2.5 Regional Variations

Regional variations, such as population density, can have an impact on burial types and trends in burial styles. For example, rural cemeteries can have different traits than urban cemeteries. Burial and marker styles noted in older and less stylized cemeteries typically persist longer in rural areas. In urban cemeteries, burial density may be higher, space more limited, and the cemetery plots may be more formal (Anderson 2006:9; Trinkley and Hacker-Norton 1999:i). Geophysical methods with good spatial resolution should be considered for urban settings where there may be extreme burial density. Burial records for rural cemeteries are often incomplete (Foster and Eckert 2003:470). In these cases, cemeteries may more directly benefit from marker inventories. Regionally specific burial practices, such as precontact stone box graves or the use of above-ground burial vaults, should be considered while planning a geophysical survey (Lowry and Patch 2014).

3.2.6 Case Study – Cultural Variables, Example for a Rural African American Cemetery

Ground-Penetrating Radar Survey and Marker Map for Historic Graves at the Clarks Creek Cemetery (31MK1080) in the Hampton Place Subdivision, Mecklenburg, North Carolina	
Authors	Sarah Lowry Ellen Turco
Date	2016
Report No.	2584
Institution	New South Associates, Inc.
Place	Stone Mountain, Georgia
Prepared for	Mecklenburg County, North Carolina
Abstract	This archaeological report discusses a ground-penetrating radar (GPR) survey of a probable historic African American cemetery. The cemetery contained no formal markers and was only apparent from a series of collapsed grave depressions and field stone markers. The survey included a limited GPR survey and detailed site map. Together, these data sets were combined to create a cemetery boundary and to estimate the number of individuals interred.
Cultural Variables	African American, Christian (Protestant), Early Historic Period to Historic Period, Community Cemetery, Rural

PROJECT DESCRIPTION

This historic period cemetery was identified during an archaeological pedestrian survey prior to developing a housing subdivision and was avoided during construction. Subsequently, Mecklenburg County acquired the parcel and sought more information about the cemetery in order to properly manage it. The cemetery parcel is approximately 2.5 acres in size and was largely overgrown with dense underbrush. There were visible collapsed grave depressions, fieldstone markers, and cemetery plantings throughout the parcel. The cemetery was built on a slope above Clarks Creek where erosion had impacted the preservation of graves in places.

RESEARCH QUESTIONS

This project was designed to identify the estimated number of graves and establish the boundaries of a historic cemetery with no formal or inscribed markers.

SURVEY DESIGN

Due to the slope and vegetation, a comprehensive geophysical survey of the entire parcel was not possible. Because the research questions did not require knowledge of where each individual grave was located, the survey was designed to include a program of geophysics, detailed mapping, and archival research. Pedestrian survey and a total station were used to identify and map fieldstone markers and collapsed grave depressions. Ground-penetrating radar (GPR) grids were placed to cover the boundaries of the cemetery parcel, where vegetation and slope permitted. Archival research sought to determine the name of the cemetery and link it to a community in the area.

RESULTS

The mapping and GPR survey were able to establish a cemetery boundary. The results of the marker survey identified 212 stone markers, 133 surface depressions interpreted as collapsed coffins, four stone piles thought to be markers, two displaced stone markers, and one rock-lined depression. Taking into account various individual and groups of features, the surface survey produced an estimated number of 276 graves. No inscribed or formal markers were identified. The GPR survey was not comprehensive; roughly 0.76 acre of the 2.5-acre parcel was surveyed. However, in this area 198 possible graves were identified, including 113 that were not recorded from surface indications. Extrapolating from the sampled area, it was calculated that the cemetery contained approximately 389 people, although this number probably underestimates the actual total because of the limited GPR survey coverage. The boundary for the cemetery could be established along the north, east and west edges of the cemetery (where complete GPR data were available), while to the south, topography and the streambed were used as a natural boundary.

The results of the archival research were more ambiguous. No historical information was found regarding the cemetery and it did not appear in any historical maps or deeds. The high number of individuals suggests that it is not a family burial ground and was probably affiliated with a church congregation or nearby community. Local churches had no known connection to the cemetery. The site's location on a rise at the confluence of two streams (Clarks Creek and its tributary), the uninscribed stone markers, and the number of unmarked graves are typical of rural African American cemeteries in the region. If the cemetery was associated with a local African American community or congregation, it might have started as a slave cemetery but continued in use after emancipation. The possible dates for the cemetery span the 1860s to 1920s. The beginning date suggested here is based on the likelihood that the cemetery was used by an African American community. The oldest documented African American congregation in the county is the Clinton Chapel AME Zion Church, founded in 1865. If the Clarks Creek Cemetery related to an African American church, it is assumed to post-date the Clinton Chapel. The end date for the Clarks Creek Cemetery is suggested by the lack of formal grave markers and other cemetery furnishings, which became increasingly common in the early part of the twentieth century.

RECOMMENDATIONS

New South Associates, Inc. recommended that the 389 possible graves identified with GPR and survey all be treated as such and avoided if ground disturbance was planned. Further historic research was recommended to better determine the cemetery's age and affiliation for the purpose of interpretation. Additionally, because vernacular African American cemeteries like the Clarks Creek Cemetery are increasingly rare in Mecklenburg County, the site is unique and was recommended as a potential local landmark.

KEY LESSONS

- **Geophysical survey design must be tailored to answer the research questions and management needs for each cemetery.** In this case, the location of each individual grave was not required so the survey could be structured to work around landscape constraints and still obtain the results needed for the project.

- **Knowledge of cultural practices for the interred community is essential.** This cemetery had no formal or inscribed markers, but 276 graves were visible using surface clues alone. If the practitioner had been unfamiliar with identifying poorly marked or vernacular cemeteries this cemetery might have been missed. As it was, the size of the cemetery had been completely underestimated until this survey was conducted.

- **Archival research is an important component of historic cemetery projects.** The archival research for this project did not determine the specific community or group that used this cemetery. Still, it eliminated erroneous assumptions identified in previous reports and isolated the probable associated community. The end report listed sources consulted, allowing for future research to start with a clear foundation.

The success of geophysical surveys in cemeteries is highly dependent on these environmental and cultural variables. During the scoping phase, having as much information as possible about the cemetery or suspected cemetery can help develop a more robust scope and can help practitioners better understand the project. Defining the variables outlined in this chapter does not need to be a time-consuming process; it might be as simple as listing what is known and unknown about the cemetery. These categories are intended to place this stage within a framework so the process is more organized.

CHAPTER 4

Background and Archival Research

Establishing multiple lines of evidence is best to accurately identify unmarked graves. Archival and background resources can help to determine the history, age, periods of use, and type of the cemetery, and the cultural, religious, and regional affiliations of individuals buried in it. This information can contribute to knowledge about cultural variables in the cemetery, understanding the cemetery boundaries, and gathering information about people buried in the cemetery, including any mapping that may be available in different repositories (e.g., church, historical society, funeral homes). This chapter is intended to provide a framework of the types of background and archival research that might be helpful in a cemetery. The actual research may be part of the work conducted by the firm or practitioner hired for the geophysical survey or the project sponsor. The goal of this chapter is to illustrate the other lines of evidence that will support the geophysical survey.

Not all cemetery geophysical projects will require the same level of background and archival research. The depth and breadth of research will depend on the available sources, the project budget, and the project scope. Most projects will benefit from some form of background or archival research, but not all projects need it to be successful. The level of effort may also be tailored to the specific project. For example, a church cemetery where the survey goal is to locate unmarked graves may only need a search for cemetery mapping to georeference and correlate with the geophysics results. A church cemetery where graves are going to be moved for a road widening may benefit from more thorough research into property records, church history, and burial records. In the case that graves are going to be moved, descendants will need to be contacted (or a good faith effort made) and genealogical research may be needed. More information about the cemetery can sometimes help provide a second line of evidence or inform stakeholders what level of information is available.

4.1 Available Archival and Background Resources

The first step in this process is to determine what types of available background resources are available. This might be possible to do through contacting the cemetery management, the church, or city or town officials. The authorities who manage the cemetery will have the best idea of what kinds of resources are available. These records could include: a cemetery history, deeds, cemetery records and maps, local history, and information from local informants. Available archival and background resources must be identified before determining the scope of further research.

4.2 Research Needed

Once available background and archival resources have been identified and listed, the specific directions for research can be delineated. This work can be written into a scope as a task for the practitioner performing the geophysical survey, it can be completed by the scoping agency, or it can be written as a separate scope for another contractor.

4.2.1 Cemetery History

The cemetery history can be compiled from a variety of sources and may be as simple as interviewing church or city officials, in the case of a church or municipal cemetery, or as complicated as combing multiple archives to locate deed records and any record of the cemetery, in the case of an unmarked or unaffiliated historic cemetery. This section outlines four types of background research commonly available for cemetery research (Figure 4). They will not all be available for every cemetery, and, in some cases, there may be additional sources not listed here.

4.2.1.1 Deed Research

Deed records are used to establish ownership of the land historically and how it changed hands. Sometimes, deeds will contain information about a cemetery on the property. This can be especially helpful if the age of the cemetery is unknown or, in the case of an unmarked cemetery, to determine if there is actually a cemetery on a land parcel. Deeds can also provide landowner names, which can sometimes indicate who is buried in a cemetery or be a good starting point for further research. Deeds are kept in town or county records and can sometimes be accessed online. These records can be missing or incomplete, but they are a good first place to start in documenting a cemetery.

4.2.1.2 Cemetery Records

Some more formal cemeteries have record-keeping systems. These records have varying levels of information available, but can include information about the age of burials, period(s) of use, and layout of the cemetery. These records may have significant demographic information. Sometimes when they are compared to the monuments currently in place in the cemetery, they can help to get an idea of the number of unmarked graves. Records can also help determine the cultural or religious affiliation of individuals buried there. These burial records can be found with the cemetery management, sexton, funeral home, or religious congregation affiliated with the cemetery. They may be housed in a local library or historical society, or published in a genealogy. Additionally, some counties, cities, or regions have published cemetery inventories.

4.2.1.3 Local History

Town, city, county, church, and other written histories may include discussions of cemeteries. These histories can be valuable resources for establishing the age, type, period of use of the cemetery, and the socioeconomic status, cultural background, and religious and regional affiliations of individuals buried there. This is particularly important for cemeteries that are all or partially unmarked or have no institutional affiliation. These histories may include genealogies, which could have published burial records.

4.2.1.4 Oral history

Oral histories can provide historical context and supplement archival resources. This is particularly important when there are no historical records, existing records have been lost, or when they are incomplete. Speaking to people who have personal knowledge of the cemetery or its surrounding community can help determine historical context. Subjects for oral history interviews can be located through speaking to those who manage the cemetery or are affiliated with local community organizations. In many cases, descendants know the locations of family members as part of an oral tradition that has been passed down, even if there is no marker or other feature that might indicate graves.

Resource Type	What is it?	Where can it be found?	What can it tell us?
Deed	A legal form that transfers property	▪ County or town records ▪ Sometimes online	▪ Who owned the cemetery land ▪ When the land became a cemetery ▪ Can help establish the type of cemetery, and if the type changed over time ▪ Can help determine who was buried there, and who was allowed (or not allowed) to be buried there
Cemetery records	Hold information about burials and interred individuals	▪ Cemetery or sexton's (caretaker's) office ▪ Funeral homes ▪ Affiliated religious congregation ▪ Local library or historical society ▪ Published in a genealogy	▪ Age, period of use, type, and layout of a cemetery ▪ Name, birth, death, marriage and burial dates of interred individuals ▪ Cultural, religious, and/or group affiliation of individuals buried in a cemetery ▪ Other details about death, burial, plot, and relationships to others in the cemetery
Local history	Histories of particular areas that usually incorporate local and federal records	▪ Local library or historical society ▪ Published online	▪ Can help establish the age, type, period of use of cemeteries in the area ▪ Can point to socioeconomic status, cultural background, religious and regional affiliations of individuals in cemeteries in the area of focus ▪ May include genealogies, which can have published burial records
Oral history	Transcriptions or recordings of firsthand accounts of historical events or conditions	▪ Local library or historical society ▪ H-ORALHIST online ▪ Can be collected informally by speaking to local individuals who have personal knowledge of the cemetery	▪ Can supplement archival data ▪ Can provide historical context if records are lost, incomplete, or never existed
Marker mapping and inventory	Records marker styles, demographic information derived from markers, and locations of markers	▪ Cemetery office ▪ Online database	▪ Demographic information ▪ Cemetery layout

Figure 4. Possible resources available for background research.

4.2.2 Available Cemetery Mapping and Inventory

Before recommending a research plan for a cemetery, available cemetery mapping and inventory should be consulted. These data may not be available or accessible, but many cemeteries do have hand-drawn or idealized plot maps. Existing cemetery maps, inventories, and records can help determine the historical cemetery layout, interment orientation, depths of burials, types of burial containers, burial styles, and marker styles. This information can guide geophysical survey grid layout, instrument selection, the scope of additional mapping, and can aid in the interpretation of geophysical data. For example, if there is no marker map, or the existing marker map is hand-drawn or not to scale, this information can be useful to scoping the project, but another more accurate marker map may still be needed as part of the geophysical survey. If this information is available, it should be used throughout the scoping process to help determine what kind of marker mapping and inventory might be needed for the planned geophysical survey.

4.2.3 Outline the Type and Extent of Research Needed

The type and extent of research that needs to be included in a cemetery survey will vary depending on the scope of the project. The desired type and extent of research should be outlined in detail for practitioners once the available resources, scope, and budget have been considered. If the scope includes archival research, it should be clearly stated, along with archival sources to be consulted. If this task does not need to be undertaken or any archival or mapping resources have already been compiled, the type and extent of these sources should be noted or that information provided for scoping. The more information the practitioner has available, the better they will be able to tailor the survey to the specific resource.

CHAPTER 5

Determine Field Survey and Data Processing Parameters

The next step after determining project goals, defining variables, and conducting background and archival research is to determine the field survey and data processing parameters. These parameters include practitioner qualifications, instrument selection, survey strategy, and data processing and analysis guidelines. A clearly defined scope will include instrument selection and guidelines on survey strategy in order to allow qualified practitioners to effectively compile a proposal. The information gathered in the proceeding chapters is essential to understanding instrument selection and required survey strategy and processing.

5.1 Practitioner Qualifications

Proper practitioner qualifications are critical to a successful geophysical survey in a cemetery. There are a large number of geophysical consultants and a diversity of geophysical instruments and applications. Selecting a consultant with an appropriate combination of geophysical experience and experience interpreting geophysical results in cemeteries is essential to the success of a survey.

The optimal combination of experience is difficult to quantify as there is no professional certification for archaeological or cemetery geophysics. Requiring consultants to meet the Secretary of the Interior's Professional Standards for Archaeology or History may ensure a firm background in possible feature types (National Park Service, Department of Interior 2014). These standards require both an advanced degree in archaeology, history, or a related field and professional experience. This type of standard would ensure that consultants had the educational background and experience to understand the cultural context of burials and cemeteries.

Experience collecting and processing geophysical data sets and a theoretical understanding of geophysical instruments (their functions and limitations) is also necessary in a practitioner. In certain cases, there may be individuals who do not possess an advanced degree or meet the Secretary of the Interior's standards, yet have sufficient experience to successfully conduct a cemetery geophysical survey. This type of background is difficult to quantify. It requires reviewing the resumes or curriculum vitae of consultants and looking for experience working with geophysical instruments. Qualifications may include a combination of education, formal training, and professional, practical experience. Because of the complexity and subtlety of grave and cemetery features, using consultants with no experience working with graves is not recommended. Utility locating and cemetery surveys require different processing and interpretation skill sets.

Interview respondents agreed that experience was an important qualification to conducting geophysical work in cemeteries. There was also agreement that geophysical work in cemeteries should be done by an archaeologist with experience using geophysics and a strong background in interpreting cultural features.

Two interviewees specifically noted that utility locator specialists and (non-archaeological) geophysicists lacked an understanding of both the instrument parameters and data processing steps considered essential to identifying archaeological features. Formal training was brought up by several respondents, and one interviewee suggested some combination of formal training and experience was the most desirable qualification.

This discussion of qualifications is not intended to outline a specific set of guidelines and minimum requirements for hiring a consultant for cemetery work. It is, however, intended to help managers and scope developers determine who is most qualified to conduct their project. Practitioner qualifications do need to be considered when scoping a geophysical project and selecting the individuals to conduct the survey.

5.2 Field Survey

Clearly defined field survey parameters include choosing the optimal geophysical equipment for the project and developing a sampling and data collection strategy that will support the accuracy needed.

5.2.1 Equipment Selection

When considering geophysical survey for graves and cemeteries, choosing the correct instrument or instruments to apply to a specific cemetery or to search for unmarked graves is one of the primary scoping concerns. In some cases it is useful to apply more than one geophysical method (Clay 2001; Gaffney et al. 2015), but this should be considered along with an assessment of site conditions to determine potential effectiveness of those instruments in the specific cemetery conditions. Requiring multiple instruments simply under the assumption that "more is better" is not necessarily a good use of time and money. The performance of geophysical methods might depend on environmental and cultural variables discussed in Chapter 3. Selection of methods must also consider project budgets. For this volume, ground-penetrating radar, magnetometry, electrical resistance, electromagnetic conductivity/induction, magnetic susceptibility, and LiDAR, are all summarized, as they are the most common geophysical methods used in cemeteries (Table 3). A basic understanding of how these methods work is the first step to choosing the most effective methods for a particular project.

Table 3. Common geophysical methods used in cemeteries and their basic operating principles.

Geophysical Instrument	Method	Environmental Collection Conditions	General Method Reference	Example for Grave Detection
Ground Penetrating Radar (GPR)	This method sends electromagnetic energy into the ground from an antenna, which reflects off of changes in the subsurface. The strength of that reflection and its travel time are then recorded by a receiving antenna. The time traveled can be converted to depth, and reflective strengths are analyzed to look for anomalies.	This method requires direct and continuous ground contact with the antenna.	Conyers 2004b; Gaffney and Gater 2003; Johnson 2006; Witten 2006	Hansen and Pringle 2011
Magnetometry	This method measures the magnetic fields of the subsurface. Cultural features can often have anomalous magnetic fields caused by anthropogenic events that induce magnetism.	Sensors do not require direct contact with the ground, but the environmental conditions must permit free movement across the ground during collection. Metal debris on the surface can negatively impact the results.	Aspinall et al. 2008; Gaffney and Gater 2003; Johnson 2006; Witten 2006	Jones 2008
Electrical Resistance	Electrical currents are sent into the ground, and resistance to the flow of these currents is measured. Cultural features can generate anomalous resistance readings, primarily based on their differential absorption of moisture.	This method requires the ability to place probes in the ground at regular intervals. It can be challenging if the ground is extremely dry.	Gaffney and Gater 2003; Johnson 2006; Schmidt 2013	Jones 2008
Electromagnetic Conductivity/ Induction	The transmitter induces an alternating magnetic field in the ground, which creates electrical currents in the ground. These currents then produce a secondary magnetic field, which is measured by a receiving coil. The strength of the secondary magnetic field is related to the conductivity of the soils. Modification of the subsurface	Sensors do not require direct contact with the ground, but the environmental conditions must permit free movement across the ground during collection. Metal debris on the surface can negatively impact the results.	Gaffney and Gater 2003; Johnson 2006	Bigman 2012

Table 3. Common geophysical methods used in cemeteries and their basic operating principles.

Geophysical Instrument	Method	Environmental Collection Conditions	General Method Reference	Example for Grave Detection
	by cultural activities can cause alterations to the conductivity.			
Magnetic Susceptibility	This instrument measures the ability of a material to become magnetized through inducing alternating magnetic fields in a coil and measuring their magnetism. These surveys can detect the spread of enhanced topsoil, which is a common sign of cultural activity.	Sensors do not require direct contact with the ground, but the environmental conditions must permit free movement across the ground during collection. Metal debris on the surface can negatively impact the results.	Gaffney and Gater 2003; Johnson 2006; Witten 2006	Dalan et al. 2010
Light Detecting and Ranging (LiDAR)	LiDAR is a remote sensing method (not technically a geophysical method) used to examine surfaces either through the air or on the ground surface. It sends laser pulses to measure distances to reflective surfaces and generate precise, three-dimensional maps of the ground surface. This method will map above the surface features (cultural or natural) with precision.	Heavy vegetation can obscure the ability of lasers to "see" cultural features.	Chase et al. 2017	Aziz et al. 2016

5.2.1.1 Descriptions of Geophysical Instruments

5.2.1.1.1 Ground-Penetrating Radar. This method works uses an antenna on the surface to transmit electromagnetic waves into the ground, where they reflect off of buried discontinuities and return to a receiving antenna (Conyers 2013). When the waves return to the antenna, the amplitude and two-way travel time (the time it takes for the wave to be transmitted and reflection to be recorded) of the wave are recorded (Conyers 2013). The amplitude of the wave is determined by the discontinuity, or difference between two mediums in the ground, that produced the reflection (Conyers 2006b:140). These contrasts are usually caused by differential water saturation (Conyers 2013:27). A greater contrast between mediums will cause the velocity of a radar wave to change more drastically, producing a higher amplitude reflection (Conyers 2006b:140). The shape of hyperbolic reflections produced by radar waves are determined by the relative dielectric permittivity (RDP, also called the dielectric constant) of the mediums through which the radar waves travelled (Conyers 2013:48). The RDP of a medium can be calculated in data processing software and used to determine the velocity of radar waves travelling (Conyers 2013:49). The velocity, combined with the two-way travel time can be used to convert time to depth and determine the location of objects or features that produced reflections in the ground (Conyers 2013:14; Gaffney and Gater 2003:74; Witten 2006:214).

Ground-penetrating radar surveys are conducted by passing the antennas back and forth along transects at predetermined intervals within a grid (Conyers 2013:37) (Figure 5). Images are produced from the data so that each transect may be viewed in profile. They can also be combined to produce plan-view images of each grid that are sliced by time (depth) (Conyers 2013:13; Gaffney and Gater 2003). It is important that, during collection, the antenna is placed directly on the ground so that the energy can couple and properly transmit waves into the ground (Conyers 2013:32). This means that while GPR can be conducted in a great variety of environments, the survey area must be clear of dense vegetation or other obstacles that could hinder the ability of the antenna to be placed directly on the ground (Conyers 2013:15, 32). The frequency of antenna to be used is another variable to consider before survey. Higher frequency antennas can resolve smaller features or more subtle discontinuities, but do not penetrate as deeply as lower frequency antennas (Conyers 2013:25–26).

Figure 5. Ground-penetrating radar survey in progress. Image source: New South Associates.

A great variety of archaeological features can be detected with GPR, as long as they contrast sufficiently from the surrounding soil and are not too deep or small for the frequency of antenna being used (Conyers 2013:14, 25). Graves are most easily detected by the grave shaft, casket, or void spaces (Conyers 2006b:154). The grave shaft truncates the natural stratigraphy vertically, which produces a sufficient contrast that can often be detected (Conyers 2006b:154). An intact casket, a collapsed casket, and a void space within a casket can all produce hyperbolic reflections (Conyers 2006b:154). Under rare conditions, preserved skeletal remains and bodies can also produce high-amplitude reflections (Damiata et al. 2013; Schultz and Martin 2012).

5.2.1.1.2 Magnetometry. Magnetometers measure the strength of, and subtle variations within, the Earth's naturally occurring magnetic field (Kvamme 2006a:206). Magnetically enhanced features can subtly impact the magnetic field at a site (Fassbinder 2015; Gaffney and Gater 2003; Kvamme 2006a; Witten 2006). For archaeological and cemetery applications, the most common magnetometers used are magnetic gradiometers, which measure the difference between the Earth's total field and the magnetism on the ground (in nanoteslas or nT). This instrument eliminates the Earth's primary magnetic field through the use of two vertical sensors. The difference between the measurements taken at the top and bottom sensors removes the constant variation in the Earth's magnetism, allowing the examination of local changes.

Magnetometry surveys may be conducted in most environmental conditions (Kvamme 2006a:206) (Figure 6). Vegetation must be cleared so the operator can walk in transects at a consistent pace. Vast areas can be covered relatively quickly, making this method ideal for large survey areas (Kvamme 2006a:205; Witten 2006:73). All gradiometer data are collected within a single plane. Depth penetration is generally limited to one to two meters below the surface (Clark 1996). The greatest disadvantage of magnetometry is the potential for modern metal debris to obscure features of interest (Ernenwein and Hargrave 2009). Small pieces of metal debris, utilities, and even above-ground structures have the ability to prevent the recording of non-metal features, which have much lower nT values. Certain igneous rocks or iron-rich minerals in the soils can also have this effect.

Figure 6. Magnetic gradiometer survey in progress. Image source: New South Associates.

Areas with magnetic anomalies can be indicative of past cultural activities. Ferrous metals produce magnetic anomalies, which usually have very strong magnetism (much higher and lower nT readings). Materials that have been heated beyond the Curie point (approximately 600 degrees Celsius) contain thermoremanent magnetism (Gaffney and Gater 2003; Kvamme 2006b, 2006c). These may include kilns, bricks, fire-cracked rock (FCR), burned buildings, and hearths. Induced magnetism occurs through the enrichment of topsoil, where the accumulation of iron oxides, fermentation, bacteria, and fire all increase the magnetic susceptibility (Aspinall et al. 2008:22–25; Fassbinder 2015:85; Gaffney and Gater 2003:38–39; Kvamme 2006a:208). This will cause human constructions that contain accumulations of topsoil to be recorded as magnetically anomalous (Fassbinder 2015:88; Kvamme 2006a:217–219). Magnetic anomaly strength is related to feature function, size, depth below the ground surface, orientation of the feature's magnetic poles, and materials that comprise a feature (Pacheco et al. 2005; 2009a; 2009b). In a cemetery, the types of features that might be detected with magnetometry include ferrous objects such as coffin nails or hardware, metal caskets, displaced sediments in a grave shaft, and surface features such as fencing.

5.2.1.1.3 Electrical Resistance. The electrical resistance method in archaeological geophysics locates buried archaeological features by measuring the contrast in the ability of the materials and the surrounding soil matrix to resist the passage of an electrical current (Gaffney and Gater 2003:27; Schmidt 2013:7, 24; Somers 2006:109–111; Witten 2006:300). Buried archaeological features alter the flow of an electrical current that passes through them, and these changes can be measured (Schmidt 2013:7). A unit of resistance is an ohm (Witten 2006:300). The degree to which a material resists the passage of an electrical current is based on mobile ions in water and salts that are in the material (Gaffney and Gater 2003:27; Somers 2006:111).

Electrical resistance data are collected by injecting an electrical current into the ground with probes, and measuring the electrical potential of the ground through which the current has passed with a resistance meter (Schmidt 2013:7; Somers 2006:109, 113). Different probe array configurations and separation parameters can control how data are collected and how deep into the ground the current passes (Gaffney and Gater 2003:28, 32; Somers 2006:113) (Figure 7). Resistivity survey can be conducted in most archaeological environments, as long as the ground is accessible to the probes and is not too dry. Lack of any moisture in the soil will mean that the electrical currents cannot travel through the ground (Somers 2006:110).

Figure 7. Square array resistivity configuration. Image from (Somers 2006:116).

A range of archaeological features may be detected through electrical resistance. Some features have intrinsic resistivity and typically exhibit higher resistance values than the surrounding soil matrix (Gaffney and Gater 2003:27; Somers 2006:112). These can be stone coffins, walls, rubble, roads, brick, stone, cement, or highly compacted soils (Gaffney and Gater 2003:26; Somers 2006:112). Other features have developed resistivity and will be recorded as areas of lower resistance values than the surrounding matrix (Gaffney and Gater 2003:27; Somers 2006:112). Examples of low-resistance archaeological features are: graves, ditches, drains, disturbed soil, pits, middens, post molds, field boundaries, footpaths, and metal pipes (Gaffney and Gater 2003:26; Somers 2006:113).

5.2.1.1.4 Electromagnetic Conductivity and Induction. Electromagnetic conductivity (also known as EM) is measured with an electromagnetic induction meter (Bevan 1998:30; Clay 2006:80). The conductivity method discerns subsurface archaeological features by transmitting a current into the ground from a coil, producing a magnetic field, which passes through soils that produce their own magnetic field that is then measured by a receiving coil (Bevan 1998:30; Clay 2006:82; Gaffney and Gater 2003:43). This measurement, recorded in siemens, is the soil's ability to conduct an electromagnetic current (Bevan 1998:30; Clay 2006:82; Gaffney and Gater 2003:43; Witten 2006:151). A buried archaeological feature must be composed of material that contrasts from the surrounding soil so that a change in conductivity may be discerned, indicating the presence of the feature (Bevan 1998:31; Clay 2006:83).

Electromagnetic conductivity data are collected with the operator holding the instrument parallel to and a few centimeters above the ground and walking at a consistent pace in transects of predetermined intervals (Clay 2006:80, 97, 99; Gaffney and Gater 2003:43) (Figure 8). Measurements are recorded in a data logger, from which they can be downloaded onto a computer to be processed and mapped (Clay 2006:89). Since contact with the ground is not required, many environments are appropriate for EM survey as long as the operator can walk through it at a consistent pace (Gaffney and Gater 2003:43). This type of survey is especially sensitive to metal and electrical lines, so urban areas or sites with metal debris or artifacts may not be appropriate (Clay 2006:81).

Archaeological features that consist of materials that produce a significant contrast in conductivity from surrounding soils may be imaged through EM (Bevan 1998:31; Clay 2006:84). These can be features with high conductivity, such as earthworks where soil has been redistributed, or low conductivity features, like stone, foundations, fired clay, or hearths (Clay 2006:84). Mounds, ditches, fortifications, pits, and metallic artifacts are often mapped with relative ease (Clay 2006:84; Gaffney and Gater 2003:43). If the fill of a grave shaft is significantly more or less conductive than the surrounding soil, or if the burial contains metal artifacts or coffin fastenings, it may be detected (Gaffney et al. 2015).

Figure 8. Electromagnetic conductivity survey in progress. Image from (Clay 2006:80).

5.2.1.1.5 Magnetic Susceptibility. Magnetic susceptibility measures the ability of a material to become magnetized (Bigman 2014:22–23; Clark 2003:99; Dalan 2006:161; Dalan et al. 2010:577; Dearing 1999:4; Gaffney and Gater 2003:45). This is done by using one or two coils to send a magnetic field into the ground, where materials become temporarily magnetized and affect the frequency of the magnetic field in proportion to its magnetic susceptibility (Bigman 2014:22–23; Clark 2003:99, 105; Dalan 2006:161; Dalan et al. 2010:577; Gaffney and Gater 2003:45). The ability of a material to become magnetized is dependent on the concentration of magnetic grains, composition of those grains (minerals), and grain size (Bigman 2014:23). Natural processes and human behavior cause surface soils to become magnetically enhanced over time (Bigman 2014:23; Clark 2003:99; Dalan 2006:162–165; Gaffney and Gater 2003:44). These soils and other magnetically enhanced materials can be detected with magnetic susceptibility meters.

There are a few instruments that may be used to measure magnetic susceptibility, and all operate differently. Slingram instruments are dual-coil and can measure both magnetic susceptibility and electromagnetic conductivity (Clark 2003:105; Clay 2006:93; Dalan 2006:167) (Figure 9). This type of instrument can be carried 15 centimeters above the surface, collects continuously, and can measure up to a depth of 70 centimeters (Clark 2003:105; Dalan 2006:167). Surveys are typically conducted in grids with predetermined transect intervals, with the operator moving at a consistent pace and keeping the instrument 15 centimeters above the ground surface (Clay 2006:94–95). Single-coil instruments must be placed on the ground surface to record a measurement (Bigman 2014:24; Dalan 2006:167–168) (Figure 10). The depth of penetration is related to the diameter of the coil, and most single-coil instruments can measure to a depth of just 10 centimeters (Bigman 2014:24; Dalan 2006:167–168). Down-hole instruments are minimally invasive and require that a small borehole be dug so that a susceptibility probe may be inserted into the ground (Dalan 2006:168–170) (Figure 11). These data produce susceptibility profiles of the volume of earth around the down-hole instrument (Dalan et al. 2010:577). Many environments are appropriate for these types of surveys if there is no metal debris or dense vegetation (Dalan 2006:177, 182). Access to the ground surface is necessary if single-coil or down-hole instruments are to be used. Lab analysis of soil samples from survey areas should also be conducted to quantify what type of magnetic enhancement (contrasts in mineralogy, grain size, or grain concentration) produced greater susceptibility (Clark 2003:102–103; Dalan 2006:161, 194–195; Dalan et al. 2010:589; Dearing 1999:8; Gaffney and Gater 2003:46).

Figure 9. Slingram instrument being used to collect susceptibility data. Image from (Dalan 2006:168).

Figure 10. Single-coil susceptibility meter. Image from (Dalan 2006:168).

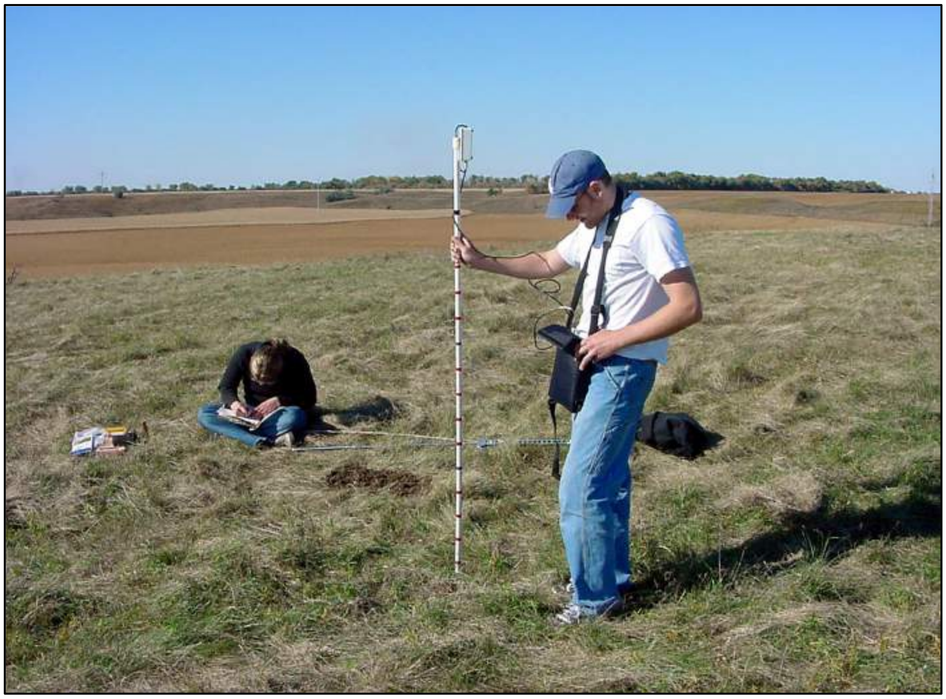

Figure 11. Down-hole magnetic susceptibility meter (Dalan 2006:169).

Archaeological features that can be imaged with magnetic susceptibility are those that are magnetic or contain topsoil (Dalan 2006:178). Magnetic features can be burned features and artifacts, such as hearths or ceramics (Dalan 2006:178). Features containing topsoil are typically earthworks, ditches, pits, or graves (Bigman 2014:25–26; Dalan 2006:178). Buried archaeological sites with magnetically enriched topsoil can also be detected through this method (Clark 2003:99; Dalan 2006:164; Gaffney and Gater 2003:44).

5.2.1.1.6 Light Detecting and Ranging (LiDAR). Light detection and ranging (LiDAR, also laser scanning) is a remote sensing method (not a geophysical method) that uses laser pulses that reflect off of surfaces and are detected by a range finder (Chase et al. 2017:90; Vosselman 2008:609). The time elapsed between when the laser is sent and received is multiplied by the speed of light to discern the distance that it traveled (Vosselman 2008:609–610). This measurement, combined with the angle of the laser when it is received, can be used to calculate where on the surface it traveled (Vosselman 2008:610). From these three-dimensional points, a digital elevation model can be produced, manipulated, and analyzed (Chase et al. 2017).

Archaeologists can employ airborne, terrestrial, and bathymetric LiDAR (Chase et al. 2017:91–92). Airborne LiDAR is primarily used for landscape analysis, where different models and pattern recognition software can be used to identify an array archaeological features (Chase et al. 2017:92–97; Hesse 2010; Grammer et al. 2017; Riley 2009; Riley et al. 2010). This method has been used by archaeologists to locate grave features like burial mounds, grave terraces, monuments, cemetery stones, and enclosures (De Boer 2005; Hesse 2010; Grammer et al. 2017; Kakiuchi and Chikatsu 2008; Price 2012; Riley 2009; Riley et al. 2010; Riley and Tiffany 2014). Terrestrial LiDAR has been used within cemeteries to map gravestones and to produce detailed topographic maps from which subtle changes in elevation may be discerned (Aziz et al. 2016; Weitman 2012). These changes in surface elevation, like depressions or mounds, can be indicative of burials (Aziz et al. 2016). Bathymetric LiDAR can be used to locate and map underwater features or submerged sites (Chase et al. 2017:91). It is important to note, however, that this method does not provide any information about subsurface features.

5.2.1.2 Choosing the Geophysical Method for Your Project

It is difficult to generalize about which methods should be applied universally, and geophysical method selection should be considered individually on a site-by-site basis. Generally, GPR is the most common geophysical method used for the detection of graves amongst archaeological practitioners (Billinger 2009; Conyers 2006a; Damiata et al. 2013; Elliott 2013; King et al. 1993; Lowry 2014; Mellett 1992). There are three primary reasons why GPR is so common: 1) GPR can be used in a variety of environmental settings, including through concrete and asphalt, in an urban environment, or in an area where there is substantial metallic debris; 2) GPR provides three-dimensional imaging below the subsurface, with generally reliable estimated grave depths and detailed spatial returns; and 3) it is the only instrument that allows for (limited) real-time data visualization. The other geophysical methods have less accurate depth estimates and record data as a series of numeric readings that typically need to be processed before they can be visualized.

Although GPR is the dominant method used in cemetery contexts, it is not always the most appropriate method for the cemetery or soil type. There are cases where GPR is not the most effective method (Jones 2008a; Bigman 2012, 2011; Brock and Schwartz 1991). There are also cases, such as the case study discussed in this chapter, where multiple methods should be employed for the most robust survey results (Gaffney et al. 2015).

Most commonly, environmental variables such as soils, vegetation, and cultural surface debris dictate instrument selection (Figures 12-14). For example, if a site has a great deal of metallic surface debris that cannot be removed, it might not be a good candidate for magnetometry, electromagnetic conductivity or induction, or magnetic susceptibility (Figure 13). The flow chart in Figure 12 outlines the conditions commonly present in cemeteries and which geophysical instruments are suitable for those conditions. It is essential to consider these variables because using an instrument in an inappropriate setting could lead to disappointing results.

Cultural variables can also help to determine which geophysical instrument or instruments might be appropriate for a cemetery survey. The type of graves present and expected will dictate the type of subsurface remains and, in turn, which instrument or instruments would be best for finding them. For example, the more subtle soil changes present in an unmarked *ad hoc* cemetery may be good candidates for GPR, magnetometry, electrical resistance, electromagnetic conductivity or induction, or magnetic susceptibility (assuming environmental variables are suitable), but a mostly marked cemetery surrounded by a fence might only be suitable for GPR. Cultural variables can be complicated and are often unique to each cemetery. It is not possible to develop a series of discrete circumstances that call for specific geophysical instruments in specific cemetery types; rather, a series of guidelines that suggest certain instruments should be considered (Figure 15). It is important to consider these variables when making instrument selections, since choosing an instrument poorly suited to mapping the type of grave present may lead to disappointing results.

LiDAR is not considered a geophysical method, and the same environmental and cultural variables do not dictate the success of its application. Both terrestrial and aerial LiDAR's effectiveness is primarily dictated by the ability of the instrument to "see" the objects to be mapped. The view can be blocked by vegetation and objects, including the objects that one is trying to map, which can obscure each other. Depending on the density of the vegetation, a LiDAR map of a cemetery may not be possible. If a large number of objects are being mapped and are blocking each other, collecting LiDAR data from more angles to get a complete point array may be required.

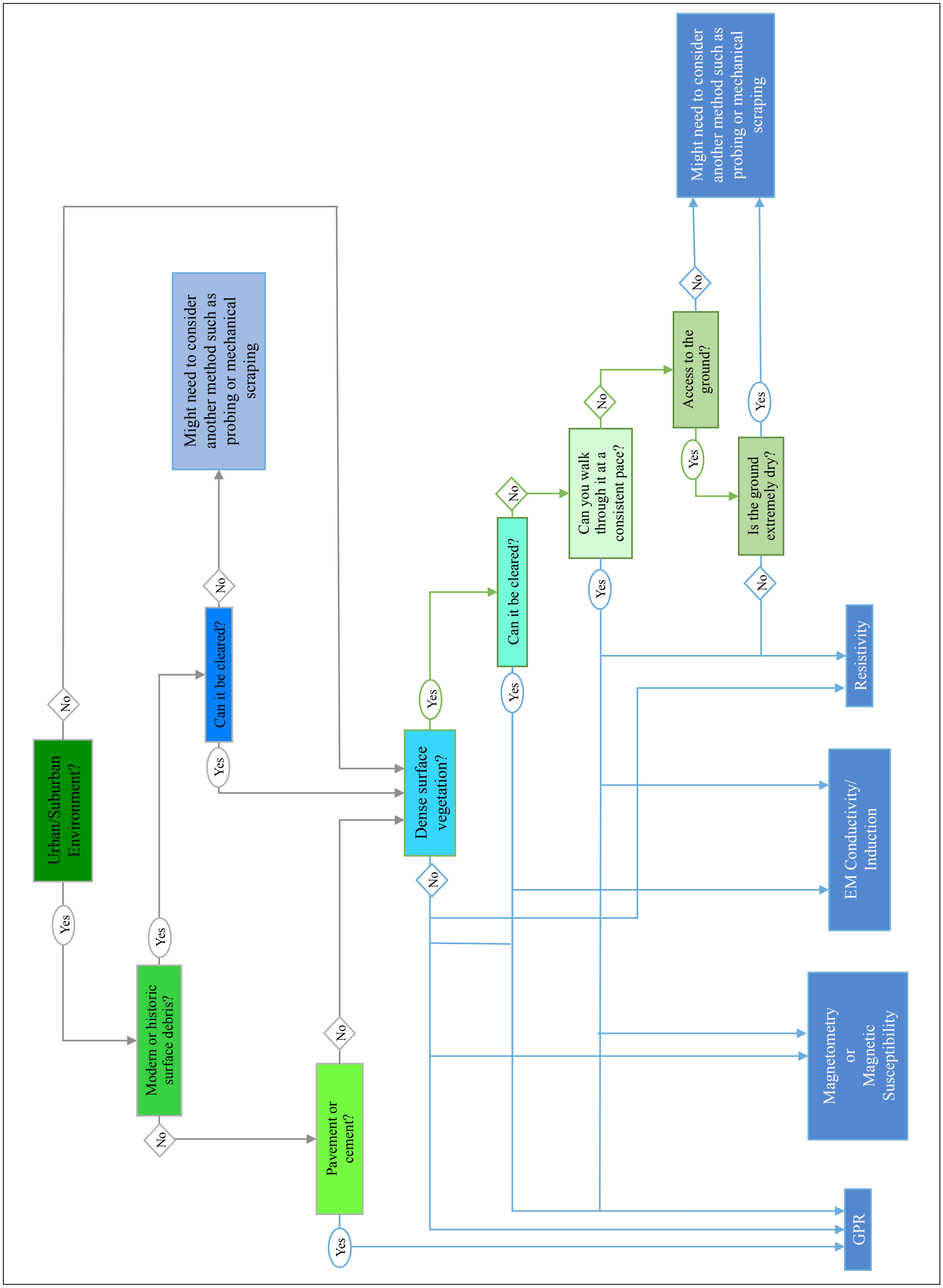

Figure 12. Flow chart for selecting a geophysical instrument based on environmental variables.

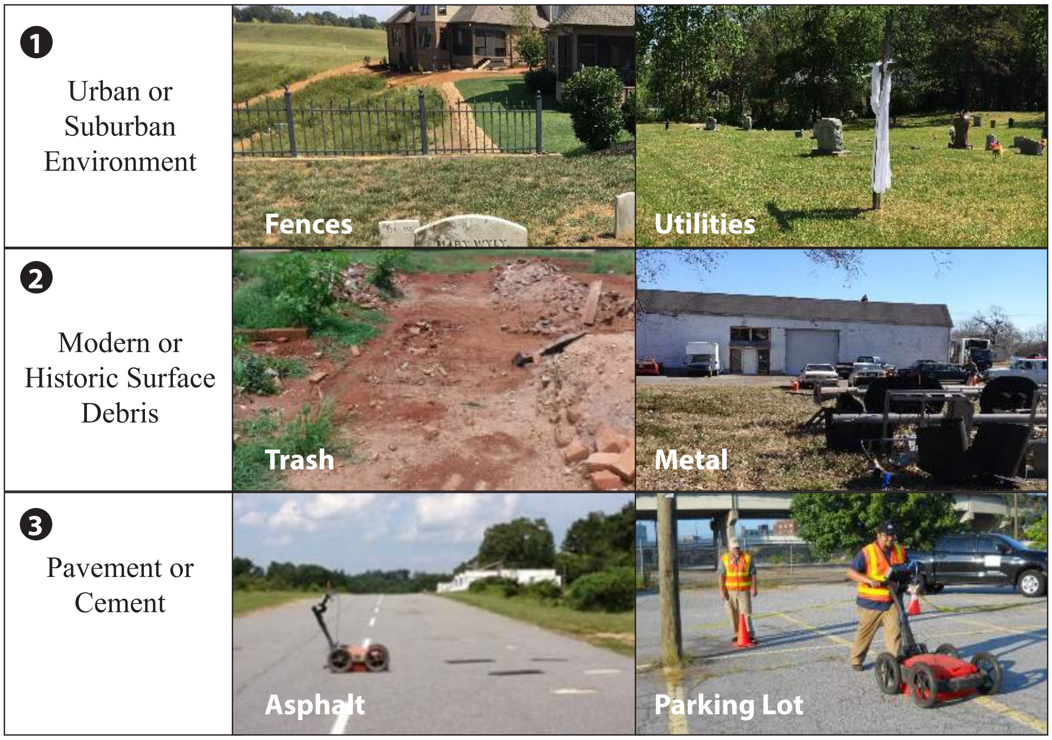

Figure 13. Examples of urban and suburban environments. Image source: New South Associates.

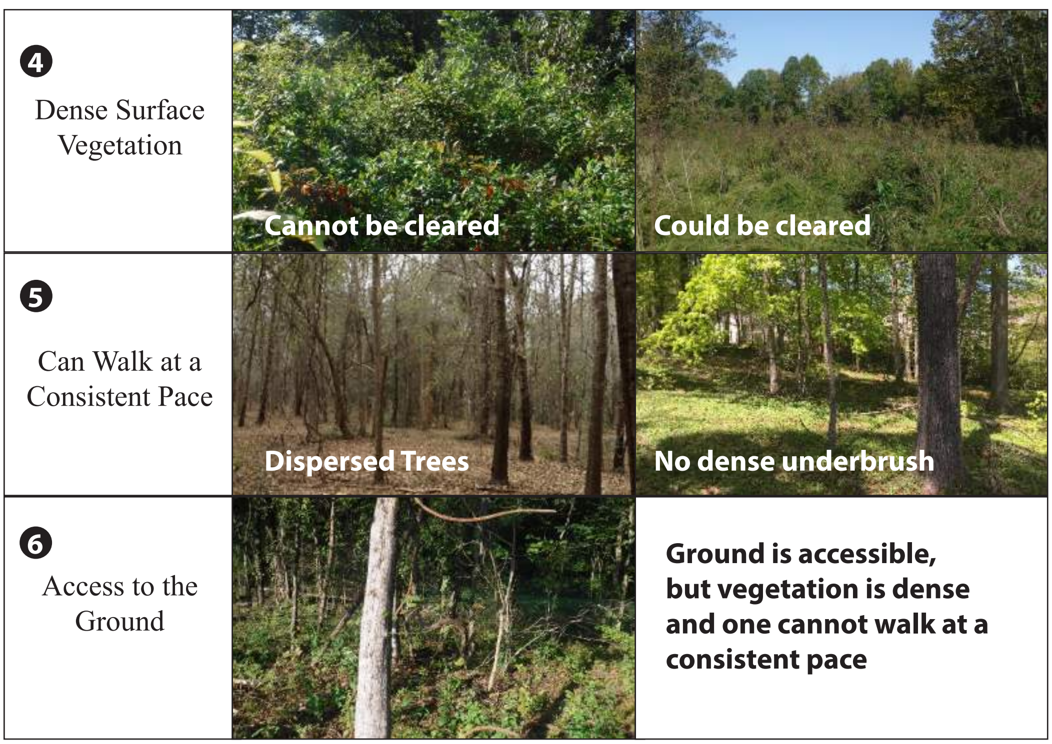

Figure 14. Examples of vegetation. Image source: New South Associates.

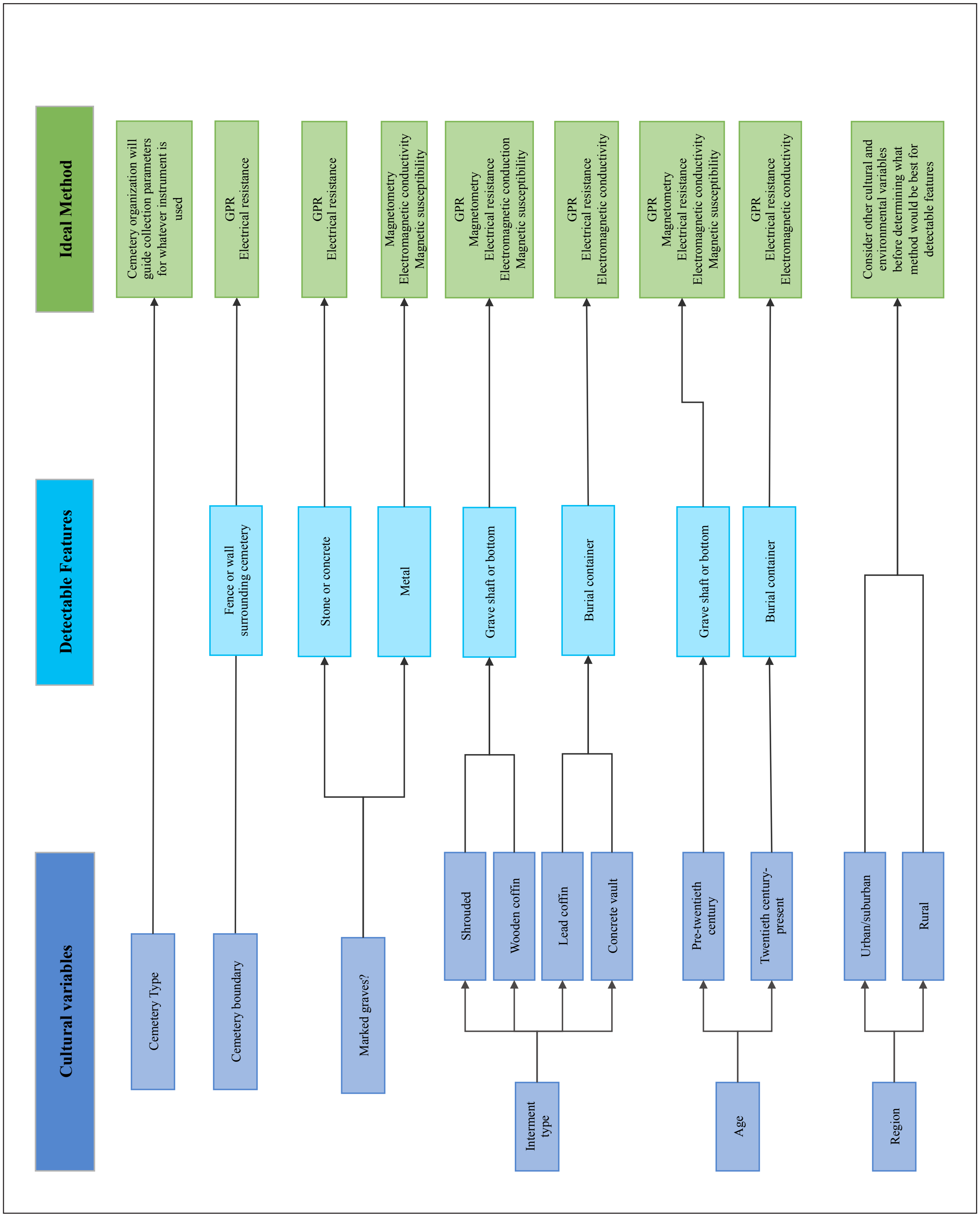

Figure 15. Flow chart for selecting a geophysical instrument based on cultural variables.

5.2.1.3 Case Study Example for Multi-Instrument

Still Searching for Graves: An Analytical Strategy for Interpreting Geophysical Data Used in the Search for "Unmarked" Graves	
Authors	Chris Gaffney C. Harris F. Pope-Carter J. Bonsal R. Fry A. Parkyn
Date	2015
Publication	Near Surface Geophysics
Volume	13
Pages	557-569
Abstract	This article discusses a multi-instrument survey of a historic cemetery. The authors used magnetometer, resistivity (multiple arrays), three-dimensional (multiple antenna) GPR, and EM induction. They then compared their results with the historic burial plots. The argument is that no single method identified all of the graves, and that more techniques may equate with greater success. Additionally, it states that better integration strategies will increase interpretive ability. The integration strategies appeared largely computer-based using the ArcGIS intersection tool.
Cultural Variables	Historic, European, Hospital Cemetery

PROJECT DESCRIPTION

A formal but unmarked cemetery at a defunct psychiatric hospital in the United Kingdom was surveyed using four different geophysical instruments. Magnetic gradiometer, earth resistance, GPR, and electromagnetic induction were used to locate the estimated 1,000 graves of "unclaimed" patients who were buried in the Memorial Garden beginning in 1888. This article focuses on the ways that graves were identified with each instrument, and how the data from each were combined to produce a map of located graves at the site.

RESEARCH QUESTIONS

This research was intended to evaluate ideal geophysical methods for identifying burials.

SURVEY DESIGN

The cemetery was presumed to have followed a pre-interment plan that allotted nearly 1,000 graves in the Memorial Garden. To identify the precise locations of these graves, gradiometer, earth resistance, electromagnetic induction, and GPR surveys were conducted. These data were then integrated with the ArcGIS Intersection tool to visualize which methods could identify specific graves.

The gradiometer survey collected samples at 0.125-meter intervals along transects spaced 0.75 meter apart. Earth resistance was collected with twin probe, square, and trapezoidal arrays. The twin probe and trapezoidal arrays sampled at 0.5-meter intervals on transects spaced 1.0 meter apart. The square array gathered data every 0.5 meter on transects at 0.5-meter intervals. Electromagnetic induction (EMI) sampled every 0.25 meter along transects placed 0.5 meter apart. The EMI survey was conducted twice, with coils rotated ninety degrees in the second survey. The ground-penetrating radar survey used a 400 MHz antenna, and the transect spacing was not provided.

RESULTS

Gradiometer data showed paths throughout the graveyard, which appeared as low-contrast linear features. The gradiometer survey also exhibited many highly magnetic dipolar anomalies. These are indicative of ferrous metal and were believed to have been produced by grave markers in this case. Thus, the gradiometric data confirmed that the cemetery had a formal arrangement and that graves had markers, but did not successfully identify any graves.

The earth resistance data identified rectilinear high-resistance anomalies, oriented southwest-to-northeast, in the northeast quadrant of the trapezoid array. These were hypothesized to represent graves. The square array produced negative linear anomalies on a southwest-northeast axis that were judged to be the near-surface edge of graves. Few grave anomalies were visible in the southeastern area of the survey.

Electromagnetic induction found strong magnetic susceptibility and conductivity in areas corresponding to the ferrous markers. These anomalies are aligned perpendicular to known grave orientation, aligning with the direction that the survey was conducted. The EMI data also exhibit some polarity shifts that are indicative of disturbed and backfilled soil in a grave shaft.

Ground penetrating radar results were analyzed as depth slices. High-contrast rectilinear anomalies were interpreted as grave features. Most were in the southeastern part of the survey area and correlated with the northeast-southwest orientation of known graves. Animal burrows were identified as an issue in GPR data collection and interpretation.

The results from each survey were combined with the ArcGIS Intersection tool. This visual integration of the data showed that there were no graves that were identified with all four methods. Some methods were more effective than others, but there was no one method that found every grave. Additionally, many of the graves in the pre-interment plan were not identified by any method.

The authors intended to conduct the surveys over the same area to compare data, but conceded that precise co-location was not entirely possible. They attribute these inaccuracies to the three-year span over which the surveys were conducted and the various properties of a grave that each method measures. Because of these differences, there would not always be direct spatial correlations between graves identified in distinct data sets.

RECOMMENDATIONS

The authors recommend using more than one geophysical instrument to search for graves. Better integration strategies for improving interpretations of geophysical data are put forth.

KEY LESSONS

- **It is important to use consistent and precise methods to ensure that grids used by different geophysical instruments are co-located accurately.** In this study, which was conducted over a period of three years, the researchers acknowledge that the survey grids were not accurately co-located. This lack of spatial integrity across surveys hindered the ability of the researchers to use geophysical methods to accurately locate graves. A solution would be to create a grid over the entire survey area and tie each grid point into a coordinate system, which would allow the grid to be used repeatedly with different survey instruments. If ground topography hindered collecting spatially accurate GPR survey transects, then perhaps a total station could be used and integrated with the GPR data to correct for topography and distance. The use of GPS systems attached to the antenna, or employing the step method of collection can also help to resolve issues of spatial integrity related to the GPR survey-wheel.

- **Both ground penetrating radar profiles and slice-maps should be part of the interpretation process.** Data processing and interpretation are integral parts of the research process. In the preceding case study (Hansen et al. 2014), researchers could distinguish between different types of burials in profiles. The case study from Iceland discussed in the environmental variables section (Damiata et al. 2013) relied on profiles to identify the highly decomposed medieval burial. For the research discussed here, had profile analysis been used, it would likely improve the results of the GPR survey.

- **Integrating different survey methods can provide greater chances of locating graves.** In this research, no survey method identified all the graves, but each method detected some. Integration of data from multiple instruments adds greater certainty to the identification and location of unmarked graves. Integration needs careful consideration, however. For example, the authors of this study found that the magnetic gradiometer results identified metal plot markers. This could be the desired outcome of the gradiometer survey, but factors such as these should be thought about when choosing instrumentation. Given time and budgetary constraints, not every possible instrument method can be applied to all surveys.

5.2.1.4 Case Study for GPR and Electrical Resistance

GPR and Bulk Ground Resistivity Surveys in Graveyards: Locating Unmarked Burials in Contrasting Soil Types	
Authors	James D. Hansen James K. Pringle Jon Goodwin
Date	2014
Publication	Forensic Science International
Volume	237
Pages	14-29
Abstract	The article reviews GPR and resistivity studies of three formal cemeteries. These studies identified unmarked graves and extra/missing individuals from parish records in a variety of burial styles, including brick-lined interments, stacked individuals, and isolated single graves. Two of the three case studies were excavated and the authors compare the survey and excavation results, including the types of burial containers identified and their relative visibility in the geophysical data sets. The authors determined that GPR worked best in coarse soils, resistivity worked best in clay-rich soils, and both methods worked well in sandy and black earth soils. They outline specific collection parameters and the lessons learned on both instruments. The study also concluded that unmarked burials in a cemetery were very different from clandestine burials of murder victims.
Cultural Variables	European, Early Historic and Historic Periods, Christian, Church Cemetery

PROJECT DESCRIPTION

Three cemeteries in the United Kingdom were surveyed using ground-penetrating radar and electrical resistivity, followed by excavations at two of the cemeteries. The geophysical surveys resulted in the identification of unmarked burials at all three cemeteries, which were then verified through excavations. These findings were compared to parish records and gravestones, which were often vague or inaccurate. This investigation allowed the researchers to compare two geophysical methods and provide recommendations concerning the location of unmarked burials in cemeteries.

RESEARCH QUESTIONS

This research was guided by four principle objectives: 1) to identify any unmarked graves; 2) to compare GPR and resistivity geophysical equipment configurations, data acquisition strategies, and processing methods to gauge best practices for unmarked burial detection; 3) to provide examples to assist with determining the effect of different soil types on geophysical surveys and burial discovery; and 4) to quantify burial styles in the cemeteries and their geophysical responses, and then compare these to clandestine burials of murder victims.

SURVEY DESIGN

Case Study 1

St. James' Church cemetery in Newchapel, Staffordshire, was in use by 1722 and internment continued until 1966. Trial profiles were collected over an exposed burial vault to determine the best antenna frequency to use for the survey. The GPR grid was collected using a 225 MHz frequency antenna and transects 50-centimeter intervals. A twin-probe (0.5-meter fixed-offset) bulk-ground resistivity survey was conducted in a small area to compare with the GPR data. Resistivity measurements were recorded every 25 centimeters on profiles spaced 50 centimeters apart. Unmarked burials detected in the geophysical survey were verified through archaeological excavations. This investigation was conducted in soil that had been repeatedly disturbed, and one meter of soil was removed from the site prior to the survey as part of ongoing development work.

Case Study 2

The cemetery of St. Luke's Church in Endon village, Staffordshire, occupies an area of coarse sandy soil. The first recorded burial dates to 1731. Trial profiles were collected over known burials, indicating that 225 MHz was the ideal frequency to use for the survey. One GPR grid was collected over the cemetery, followed by a resistivity survey in the same grid. The methods from Case Study 1 were repeated. Archaeological excavations were undertaken, but in a separate area outside of the geophysics survey grid.

Case Study 3

Two geophysical grids (A and B) were collected in the cemetery at St. John of Jerusalem church in South Hackney, Hackney. Soils for both were black earth. In situ gravestones were surveyed in both A and B survey areas. Trial profiles were collected and the researchers determined that a 225-MHz antenna should be used in Grid A, while a 450-MHz antenna was most appropriate for Grid B. The resistivity survey covered the same area as the GPR grids and employed the same methodology as Case Studies 1 and 2. Both grids were collected using 50-centimeter transect spacing and no excavation followed this survey.

RESULTS

Case Study 1

Hyperbolic reflections from the GPR profiles were mapped onto the cemetery plan so that unmarked burials could be identified. Time slices showed that these reflections were 1-2 meters long and oriented east-to-west, consistent with Christian burial practices. A 2x2-meter anomaly in the resistivity data correlated with a double burial vault. The highest resistivity values were at the vault edges. The combined geophysical data indicated 10 unmarked burials. These were confirmed through archaeological excavations. Burial environments included single-vaults, brick-lined vaults, and one earth-cut grave. All coffins exhibited copper-alloy ornamentation.

Case Study 2

High-amplitude reflections from the time-slices were correlated with hyperbolic reflections in the GPR profiles. These features measured 1-2 meters long, which is consistent with the length of adult burials. The resistivity data, however, did not show clear burial-sized anomalies. Features detected in the GPR data were correlated with surviving headstones, indicating 19 unmarked and unidentified burials. Based on the characteristics of the hyperbolic reflections, depths, and data from Case Study 1, these were hypothesized to be earth-cut burials. Archaeological excavations located fifteen graves, but the area tested archaeologically did not overlap with the geophysical survey. Copper-alloy and iron furniture were present in many cases.

Case Study 3

Hyperbolic reflections from both survey areas were mapped onto a plan of the cemetery. These were compared to time-slices, which illustrated features measuring one- to two-meters long and oriented northeast-southwest. The resistivity data showed numerous burial-sized anomalies in both A and B grids. Combining the GPR and resistivity data indicated 13 unmarked burials in Area A, and 46 in Area B. Four broken headstone in Area B also indicated unmarked burials. Based on the characteristics of the hyperbolic reflections and extant known graves, the authors hypothesized that the burials were earth-cut. There were no archaeological excavations at this cemetery.

The results from these three case studies led to several findings. Grave markers and parish records did not always have accurate records for burials, and geophysical methods did not find all unmarked burials in the cemeteries. Ground penetrating radar and resistivity worked optimally in black earth soil, while GPR was the preferred method for coarse and pebbly soil. Where the soils were disturbed, most graves were also brick-lined and contrasted strongly with the surrounding soils. Tree roots and animal burrows affected the collection and interpretation of geophysical data. The researchers found it relatively easy to distinguish between graves that were unlined or brick-lined and covered with slabs in GPR profiles, but both types appeared identical in slice maps and resistivity data. Finally, clandestine burials would look quite different from cemetery burials because in cemeteries, graves are typically much deeper and contain coffins that are often adorned.

RECOMMENDATIONS

The authors recommend that prior to a GPR survey, trial profiles should be collected over known burials to discern the ideal antenna frequency to use. Further study is necessary to provide a greater understanding of how GPR, magnetics, and bulk ground electrical resistivity may be integrated in cemeteries with contrasting soil types. This should be done in cemeteries with marked burials and known burial dates.

KEY LESSONS

- **The effectiveness of GPR and bulk ground electrical resistivity is site-dependent.** In Case Study 1, brick-lined burials were easily detected in both GPR and resistivity, despite repeated soil disturbance. Earth-cut graves were identified with GPR in the coarse soil of Case Study 2, but resistivity was ineffective. Both GPR and resistivity data showed numerous burials in Case Study 3, which involved black earth soil. The effectiveness of a geophysical survey can be difficult to predict, but an understanding of how different variables impact different types of geophysical prospection is advantageous.

- **Both profile and plan view analysis of geophysical data are necessary, when possible.** The authors state that while high-amplitude reflections produced from burials may be visible in GPR time-slices, the type of burial can only be identified in profiles. In all three case studies, the researchers could distinguish between brick-lined and earth-cut burials through GPR profile analysis.

- **Clandestine burials will be more difficult to image using geophysics than cemetery burials.** Typically, graves in cemeteries will be quite deep and contain coffins, coffin furniture, adornments, and embalmed bodies, such as those identified by the case studies. Such features are often visible in geophysical data. The authors caution that clandestine burials of murder victims will often be shallow and lacking coffins or grave goods. The bodies may decompose more rapidly and have less contrast with the surrounding soils.

5.2.1.5 Case Study for LiDAR

Locating and Characterizing Burials Using 3D Ground-penetrating Radar (GPR) and Terrestrial Laser Scanning (TLS) at the Historic Mueschke Cemetery, Houston, Texas	
Authors	Azie S. Aziz Robert R. Stewart Susan L. Green Janet B. Flores
Date	2016
Publication	Journal of Archaeological Science: Reports
Volume	8
Pages	392-405
Abstract	Terrestrial laser scanning (LiDAR) and ground-penetrating radar were integrated at the Historic Mueschke Cemetery in Houston, Texas. LiDAR was used to identify surface depressions and mounds correlated with known wooden coffin and concrete vault burials. These findings were then used to locate depressions without associated gravestones, which were predicted to comprise pre-1940 burials. These results guided the implementation of GPR, which successfully detected burials in those locations.
Cultural Variables	Historic, European American, Urban

PROJECT DESCRIPTION

Two types of known burials at the Mueschke Cemetery in Houston, Texas, were analyzed to locate and identify unmarked but documented burials. The researchers integrated GPR, terrestrial laser scanning (LiDAR), cemetery records, and oral history. The article focuses on the how unmarked grave locations were modeled prior to survey and how they were then identified.

RESEARCH QUESTIONS

This research sought to answer the following questions: 1) Is GPR suitable in the soil of the Houston area? 2) Can GPR locate a variety of burial types and features? 3) How do these burial types and features appear in 3D? and 4) Can previously unknown burials be located?

SURVEY DESIGN

Oral histories revealed that family members unable to afford stone markers would mark burials with flowers. This practice has left documented but unmarked burials at the cemetery. It is likely that there are also unrecorded and unmarked burials, but this study did not focus on these. After 1940, cement vaults were used, but simple wooden burial containers prevailed until then. Oral histories also indicated that some burials were visible as depressions resulting from collapsed coffins and compression of backfill. The researchers posited that pre-1940 burials would exhibit surface depressions, while surface mounds would characterize those post-dating 1940.

To detect surface depressions and mounds, the authors used terrestrial laser scanning throughout the cemetery. These data were collected from three locations and integrated. The absolute vertical accuracy was 1-2 centimeters and the relative resolution was 5.0 millimeters. Surface elevations were enhanced so that mounds and depressions became more visible, and these types of features were categorized as anomalies. Seventy-five percent of these anomalies were associated with known burials, indicating that the terrestrial laser scan data could be used to identify potential unmarked graves for GPR survey.

Soil samples were collected to obtain electrical conductivity measurements of soils throughout the site. This information was used to produce models of GPR signatures for different types of burials in the cemetery. Models were produced for concrete and wooden burials based on the soil study results, allowing the researchers to predict what these types of burials would look like in GPR data prior.

These models were supplemented by 2D GPR data. A profile was collected over known burials from 1936-2009 with a 250-MHz antenna. Recent concrete and wooden burials were also replicated by burying concrete blocks and slabs with an interior void space and a wood plank, respectively. Ground penetrating radar data were collected over the simulated burials.

Rebar placed in the simulated burials and common-midpoint measurements allowed the researchers to accurately estimate the velocity of GPR waves in the survey area. Velocity was also calculated using the hyperbola matching method. These assessments aided in precisely determining the depths of buried features.

Six GPR grids were collected with a 250-MHz antenna with 25-centimeter transect spacing. The depth slices from these surveys were overlaid on the terrestrial laser survey data to correlate mounds or depressions with potential graves.

RESULTS

One grave the researchers hoped to locate was that of James Culven Poland, who was buried in 1926. Poland was thought to lie 12 meters from two other headstones in the survey area. In a profile of the projected grave location, a high amplitude area was identified. When the GPR slice map was overlaid on the terrestrial laser survey elevation profile, a surface depression was found to correspond with the high amplitude area identified in profile. Thus, by combining interpretations from GPR profiles, slice maps, and terrestrial laser survey data, Poland's grave was successfully identified.

The second burial the researchers successfully identified was that of James West, which dates to 1875 and is considered the oldest in the cemetery. A hyperbola in a profile correlated with the predicted location of West's grave. The associated slice map was overlain on an exaggerated terrestrial laser survey elevation profile, revealing a surface depression matching the feature believed to be West's grave.

In addition to locating graves, the researchers answered other questions concerning soil, burial characterization, and interpretation. The authors concluded that the soils were suitable for GPR survey. Modeling helped characterize the types of burials and their features. This modeling, combined with surveys of known burials, can be used to locate and identify other unmarked burials. Using different methods to obtain GPR velocities generated more precision in locating graves.

RECOMMENDATIONS

The authors recommend modeling the features and types of burials prior to GPR survey, using multiple techniques to find the velocity of GPR waves in the soils of the survey area. They also recommend integration of terrestrial laser survey and GPR.

KEY LESSONS

- **Unmarked graves can be more readily located and identified if research and modeling is conducted prior to survey.** In this case, numerous studies were conducted on soils and known burials before the researchers attempted to identify unmarked burials with GPR and LiDAR data. Graves were identified more readily and confidently after conducting background research and gaining an understanding of what different types of burials would look like in the GPR and LiDAR data. Where possible, this level of pre-survey research can be beneficial.

- **The integration of different types of remote sensing can be valuable.** Terrestrial LiDAR has the potential to enhance topography, sometimes identifying features that would not be visible otherwise. In this study, terrestrial LiDAR helped delineate subtle surface mounds and depressions that guided GPR interpretations.

- **Cultural variables and site history are important factors to consider.** The way this cemetery was arranged and the burial types and features reflected cultural variables. Burial types also changed over time, with 1940 marking a shift from wooden to concrete burials. The researchers recognized this temporal shift and successfully discerned how these different types of burials would appear in the data

5.2.2 Survey Strategy

Data collection can differ based on cultural and environmental variables and the geophysical method in use. The project's overall goals and budget should be taken into account when planning data collection. Data collection parameters to consider include sampling density, survey grid size and orientation, archival research, and mapping. Instrumentation will influence processing methods, but scoping should include special processing steps for cemetery and grave applications. Field and processing methods are rarely discussed in great detail in widely available publications, and may be more prevalent in technical reports. As a consequence, for the following discussion, the results of the practitioner survey and questionnaire were used as the basis for assessing data collection and processing parameters appropriate for cemeteries and grave prospection. Survey strategies to consider include sampling density, survey grid size and orientation, mapping, and the integration of archival research (personal communication Paul Mohler, July 11, 2016, Geoffrey Jones, June, 22, 2016 and Jami Lockhart, June 22, 2016).

In general, geophysical data are collected in rectilinear grids and transects to maintain accurate spatial control. Once grids are established, geophysical data are collected by traversing transects of predetermined intervals within them, usually in a zigzag pattern. As these transects are traversed, measurements are taken along them and recorded. Down-hole magnetic susceptibility and LiDAR are not collected in this manner. Boreholes for down-hole susceptibility surveys are placed strategically to collect soil profiles, and their positions are largely dependent on the research goals (Dalan et al. 2010). Airborne LiDAR data are collected by planes over swaths of land, and terrestrial LiDAR data are collected by strategically placing the equipment in a few locations from which points can be collected in all directions (Aziz et al. 2016:395; Vosselman 2008:609–610; Weitman 2012) (Figure 16).

Figure 16. Terrestrial LiDAR scanner. Image from (Weitman 2012:78).

5.2.2.1 Sampling Density

Field collection parameters for cemeteries and grave prospection vary based on desired sampling density (Watters and Hunter 2004). Sampling density relates to the amount of data points that are collected over a given survey area. This involves both the number of recordings taken along a transect and spacing between transects (Jones 2008b:32). Generally, transects should be collected every 50 centimeters or less, and multiple readings for each meter along a transect should be recorded (Jones 2008b:32). Although decreasing the transect intervals would result in higher resolution data, it would also increase data collection and processing time. Increased sampling density typically increases the project budget and field time, but can help to resolve more subtle features. Increasing the resolution of data should be considered in areas where detection may require it, such as older cemeteries or those where the interred may not have been placed in coffins or caskets, both instances where anomalies might be subtle.

5.2.2.2 Survey Grid Orientation and Location

Most practitioners recommended collecting geophysical data within rectilinear grids for spatial control (Jones 2008b:32). Grids should be established in reference to permanent datum points so that they may be reestablished, and surface features within grids should be mapped (Jones 2008b:32). The number and size of grids will vary based on cemetery size, surface obstructions, and desired survey outcomes. All survey respondents recommend that collection transects within grids should run at oblique angles or perpendicular to the suspected grave orientation when possible. Archival research and mapping extant grave features can help to determine cemetery patterning, which can guide grid orientation, size, and location (Jones 2008b:32). If possible, collecting data over marked graves for comparison of geophysical signatures with unmarked graves is advised to help "calibrate" the practitioner to local conditions.

5.2.2.3 Case Study for Data Collection

Delineation and Resolution of Cemetery Graves Using a Conductivity Meter and Ground-Penetrating Radar	
Authors	Charles A. Dionne Dennis K. Wardlaw John Schultz
Date	2010
Publication	Technical Briefs in Historical Archaeology
Volume	5
Pages	20-30
Abstract	This technical brief outlines methods and results from a case study at Greenwood Cemetery in Florida. Data collection using GPR and EM conductivity in two separate areas identified burials from different periods (1957-2002 and older than 75 years). The results indicated both instruments successfully detected modern burials because of concrete vaults. Only GPR detected the non-vaulted older graves. The article recommended using transect spacing of 0.25-meter, collecting data in both directions, and orienting transects perpendicular to graves to produce best imagery.
Cultural Variables	Historic, Modern, European American, Municipal Cemetery

PROJECT DESCRIPTION

A conductivity meter and ground penetrating radar were used to identify modern and historic marked and unmarked graves in a cemetery in Orlando, Florida. These methods were compared to discern the effectiveness of each for identifying different types of graves in homogeneous sandy soils. The researchers also determined ideal GPR collection parameters for locating graves.

RESEARCH QUESTIONS

Three goals guided this research: 1) test the utility of a conductivity meter and GPR to detect different types of marked and unmarked graves; 2) compare the results of the geophysical instruments; and 3) put forth recommendations for surveys using these instruments.

SURVEY DESIGN

Two sections of the cemetery were tested: one containing modern burials and one with historic burials. The grid in the modern section was 11x23 meters and contained 30 marked burials dating from 1957-2002. Five of these burials were in wooden caskets, while the rest were in concrete vaults. There were two headstones that did not have associated burials, and there was no archival information for two of the burials. The grid in the historic area measured 25x30 meters and encompassed only five headstones dating from 1895-1920. There were no discernible rows or documentation, but unmarked wooden burials were believed to be present. Concrete vaults were predicted to be shallower than wooden burials.

The conductivity survey was collected along the y-axis of the grids (north to south), with 50 centimeters between transects. Recordings were collected every 50 centimeters along transects. Conductivity measurements were expected to show contrasting soil, void spaces, or metal in the burials.

Ground penetrating radar data were collected with a 500 MHz antenna. In the modern period area, transects were collected in the y-direction, with 50 centimeters between transects. The historic period area was conducted in both the x- and y-directions, with 25 centimeters between transects. Only every other transect (every 50 centimeters) collected in the y-direction was used when directly comparing the historic and modern period results. To discern ideal collection parameters for unmarked historic period graves, different transect spacing (25- and 50-centimeter) and directions (x and y) were compared.

RESULTS

The conductivity and GPR surveys yielded similar results in the modern period grid. Conductivity data showed east-west oriented anomalies that aligned with the grave markers. All concrete vault burials were identified, but the three without vaults were not detected. Both profile and slice map analysis of the GPR data were used to identify graves, which also detected all the concrete vaults. The authors did not specify if the wooden caskets were visible in the GPR data.

Conductivity in the historic area was unsuccessful. The only feature identified with the conductivity meter was an irrigation pipe near the surface. Graves were not found because they all consisted of wooden caskets and were too deep for the conductivity meter to detect. Moreover, the homogeneous sand of the grave shaft backfill did not provide enough contrast from the surrounding soils for the conductivity meter to register.

Ground penetrating radar in the historic area was generally successful, and eight rows of burials oriented east-to-west were identified. The backfill was homogenous, making the burial shaft imperceptible. Identification was thus dependent on the wooden caskets. Profile and slice map analyses were necessary for accurate identification of graves.

Collection parameters affected how graves in the historic area were identified. The authors found that transects at 25 centimeters apart that also ran perpendicular to the graves provided good resolution, while combining data collected in both the x and y directions (parallel and perpendicular to the graves, respectively) was ideal. The authors found that the data collected every 50 centimeters in the y-direction was distorted because of the greater interpolation required at those intervals. Data collected on 25-centimeter transects along the y-axis produced a sharper resolution of graves. The data collected in the x-axis on transects at 25-centimeter intervals exhibited decreased resolution and fewer graves. Combining data collected on transects spaced 25 centimeters apart in both x- and y-directions produced the best resolution and greatest number of identifiable graves.

RECOMMENDATIONS

Conductivity may be used in modern period cemeteries, but GPR is best for historic period graves. A conductivity survey may be a good method to supplement a GPR survey where there is surface clutter or obstacles that prevent GPR antenna access. The authors recommend collecting GPR data perpendicular to graves and with smaller transect spacing. If possible, data should be collected in both the x and y directions for the best resolution and identification of burials. Ground penetrating radar data should be interpreted as both profiles and slice maps.

KEY LESSONS

- **Smaller transect intervals perpendicular to the orientation of graves are ideal for detecting burials in GPR data.** The authors recommend collecting GPR data on 25-centimeter interval transects perpendicular to burials. This provides better resolution than 50-centimeter spacing and more graves are identified than if transects are parallel to burials. Collecting data on transects placed 25-centimeters apart and in both the x- and y-axes provided the most precise resolution of graves. However, the graves themselves were detected in the data obtained on transects along just the y-axis and at a wider (50-centimeter) interval. The type of survey used is highly dependent on the resolution required.

- **The backfill material can determine if the grave shaft will be visible.** In this case, the backfill of the graves was homogeneous sandy soil. This did not produce a contrast with the surrounding stratigraphy that could be detected in either the conductivity or GPR data. Instead the caskets were identified in this survey. In other conditions, the grave shafts are highly visible, while caskets are not.

- **Knowledge of the types and directions of burials is useful.** This research showed that modern and historic period graves appeared quite differently in the data from each geophysical method. Conductivity was unable to discern any historic period burials. Knowing the direction of burials allows for ideal collection procedures to be followed. Burial orientation can often be assumed to be east-west in Judeo-Christian cemeteries, but this is not always the case and it is not always possible to know the direction of burials.

5.3 Options to Improve Reliability during Data Collection

The reliability of geophysics results in cemeteries is often a concern to those invested in the results. Although there is no way to guarantee that all interments will be located, reliability of results can be improved by using experienced practitioners who understand archaeological and mortuary features, increasing the sampling, adding additional instruments, and physically testing the subsurface.

5.3.1 Increase Sampling Density

Increased sampling density is one way to improve the reliability of most geophysical surveys. Increased sampling density is typically achieved through collecting more closely spaced transects or collecting more data points along each transect (Jones 2008b:32). Sampling density can also be increased by collecting data grids in two perpendicular directions, so that x- and y- direction transects are combined into a single high density grid (Dionne et al. 2010; Watters and Hunter 2004:26). These strategies are applicable to any geophysical instrument. With GPR, greater resolution can be achieved by using a higher frequency antenna, but this also reduces the depth penetration (Conyers 2013:62).

Increased sampling density will be more intensive and more time consuming than collecting data with the more common 50-centimeter spacing and single direction survey. This will add costs to a survey and, likely, the time it takes to collect, process, and interpret the results. Increasing the resolution is a good solution in areas where the scope of the project and the cultural and environmental variables may require it, such as older cemeteries or cemeteries where marginalized or economically disadvantaged communities may not have placed the interred in coffins or caskets. These types of cemeteries may have subtle anomalies. This might also be necessary in a situation where the accuracy of the results trumps both survey time and cost.

5.3.2 Increased Number of Geophysical Instruments

Increasing the number of geophysical instruments used in a cemetery can increase the resolution of the data through the application of complementary data sets. As each geophysical method detects different properties of subsurface features, successful surveys integrating multiple instruments will result in complementary, not redundant, data that can increase the likelihood of locating unmarked graves (Jones 2008b:32). This is not the case within every cemetery. The environmental and cultural variables within the cemetery must be suitable for the geophysical instruments in order to get the positive benefits of multiple instruments (see Figure 12; Table 2). For example, a cemetery located underneath a paved parking lot might only be suitable for GPR survey, whereas an unmarked cemetery in an open field might be amenable to many available and effective instruments.

In some cases it is useful to apply more than one geophysical method (Clay 2001; Gaffney et al. 2015), but this should be considered along with an assessment of site conditions to determine potential effectiveness of different methods in the specific cemetery conditions. More instruments will generally increase the project cost and the time needed for data collection and processing. This cost and time trade-off can be efficient when multiple instruments provide the desired results. It can be frustrating when multiple instruments are applied to unsuitable sites or in unsuitable conditions and when there is no increased data return. The use of multiple instruments should be carefully considered and include an analysis of the project budget and accuracy needs before being universally applied. The published literature indicates that multi-instrument surveys are used in limited circumstances; however, these tend to be evaluations of one instrument over another, and both datasets may not have the same results. Based on practitioner interviews and perusal of the gray literature, single instrument surveys are the norm.

5.3.3 Anomaly Testing, Ground-Truthing, or Field Validation

To further increase the reliability and validity of geophysical survey, various options are available. Anomaly testing, ground-truthing, and field validation are interchangeable terms for the physical investigation of geophysical results through limited ground disturbance. This can be done through selective targeted anomaly testing or testing the entire cemetery. This type of anomaly testing is typically done following the geophysical survey and using those interpretations.

Excavations of some kind are typically done if there is a defined set of impacts, such as the graves needing to be moved. There are a number of issues with ground-truthing, including: permitting, information return, cost, invasiveness, social and political issues, and risks to personnel (Hargrave 2006:271). This is not to say that ground-truthing should not occur when possible, but it should be done with care and discretion. Ground-truthing does not guarantee that all unmarked burials in a survey area will be located. In certain circumstances, the geophysical method is able to detect subtle variations that are not visually apparent through excavation (Hargrave 2006:280).

Typically, anomaly testing does not include excavation of the entire grave and exposing the interred remains. It generally consists of removing the plow zone or disturbed layer either manually or with mechanical equipment to look for soil staining that is consistent with grave shafts. If selected potential graves are tested through scraping, the geophysical data can be interpreted more confidently (Jones 2008b:33).

5.4 Data Processing and Analysis

Post-field data processing and analysis are where the bulk of the time is spent working on geophysical surveys of cemeteries. Geophysical instruments themselves do not “find” graves; this work is done during the data processing and analysis stages when the data collected at the cemetery are synthesized, processed, and interpreted. The results of these interpretations are, typically, the locations of probable or possible graves. As a general rule, graves are not identified in “real-time” during fieldwork because more time and analysis is required to identify subtle grave features.

5.4.1 Data Processing

When geophysical data are collected in the field, the typical data return is considered the "raw" data. The raw data can be manipulated to make them easier to interpret through a variety of steps that can depend on the geophysical instrument. The type of processing needed may depend on the site, environmental and cultural variables, and the specific instrument used. However, regardless of which instrument(s) may have been used, post-processing is critical to a successful geophysical survey, and details should be provided in the technical reports.

5.4.1.1 Software Options

Most geophysical equipment manufacturers have associated software for data processing, and there are some independently designed software packages on the market (Figure 17). The list of software programs in this section is not necessarily comprehensive, and it is not recommended that scopes require data to be processed using a specific software program, as most will allow for the same general processing steps. Common software packages for GPR data are Radan (GSSI), Mala 3D, EkkoMapper, Ekko View Deluxe, Voxler (Sensors and Software), GRED HD (IDS), GPR Process, GPR Viewer, and GPR Slice. TerraSurveyor and Geoplot are often used for magnetic gradiometry and electrical resistance data. Surfer or Geoplot are typically used for conductivity data, which are displayed as contoured maps or gray-scale raster images (Clay 2006:96–97). Multisus, Surfer, and Geoplot are also used to process resistivity data (Dalan 2006:175–176). LiDAR data are usually processed in point cloud programs such as Quick Terrain Modeler, Terrasolid Suite, MARS, or Innovmetric Polyworks, among others. Then the data can be imported into GIS software (Riley 2009; Riley et al. 2010). Geospatial and mapping software programs, such as Surfer, ArcGIS, and IDRISI, are commonly used by many practitioners for presentation and spatial control.

5.4.1.2 Processing Steps

Individual geophysical methods require different processing steps (Figure 18), some of which are outlined below. The optimum processing steps vary based on the survey type, site conditions, data collection parameters, and the data collected. It is important for the practitioner to understand how each processing step works and to know when – and when not – to apply them. It is important for the project sponsor to have a basic understanding of how geophysical data processing works so they can evaluate proposals. This section is not intended to provide a comprehensive listing of all processing steps for the geophysical instruments discussed in this report. This is primarily because there are many specialized processes that may be appropriate in selected situations and that new processing steps are often being developed. Cultural and environmental variables can also help to determine the processing steps, and all processing steps may be completely dependent on the specific site. At minimum, reporting should include a description of processing steps and the purpose of each step.

Software Program	Instruments	Application
Radan (GSSI)	Ground-penetrating radar	▪ Data processing ▪ Gridding ▪ Slicing ▪ Profile and 3D view ▪ Target picking ▪ Analysis
Mala 3DVision	Ground-penetrating radar	▪ Data processing ▪ Gridding ▪ Slicing ▪ Profile and 3D view ▪ Drawing ▪ Analysis
EKKO_Mapper (Sensors and Software)	Ground-penetrating radar	▪ Gridding ▪ Slicing ▪ Processing ▪ View profiles, plan view, and 3D ▪ Feature picking ▪ Analysis
EKKO_View Deluxe	Ground-penetrating radar	▪ View and process profiles ▪ Analysis
Voxler (Golden Software)	Ground-penetrating radar	▪ Slice 2D data and create 3D images from data exported from EKKO_Mapper ▪ Processing ▪ Analysis
GRED HD (IDS)	Ground-penetrating radar	▪ View profiles ▪ Data processing ▪ Mark features ▪ Export slices ▪ View data in 3D and plan view ▪ Analysis
GPR Process	Ground-penetrating radar	▪ Slices data to produce amplitude maps ▪ Analysis
GPR Viewer	Ground-penetrating radar	▪ View and process individual reflection profiles ▪ Analysis
GPR Slice	Ground-penetrating radar	▪ Data processing ▪ Gridding ▪ Slicing ▪ Profile, plan, and 3D view ▪ Drawing ▪ Analysis
TerraSurveyor	Magnetic gradiometery Electrical resistance	▪ View data ▪ Processing ▪ Analysis
Geoplot	Magnetic gradiometry Electrical resistance Electromagnetic conductivity Magnetic susceptibility	▪ View data as shade plots, trace plots (profiles or 3D), pattern plots ▪ Processing ▪ Analysis
Multisus	Magnetic susceptibility	▪ Processing ▪ Reviewing data files ▪ Analysis
Surfer	All	▪ Presentation and spatial control ▪ Analysis
ArcGIS	All	▪ Presentation and spatial control ▪ Mapping ▪ Analysis
IDRISI	All	▪ Presentation and spatial control ▪ Analysis

Figure 17. Available software packages.

Method	Processing step	Result
Ground-penetrating Radar	Time zero correction	The first reflection is moved to the time zero position so that depth can be accurately calculated
	Background removal	Removes horizontal banding from system noise and outside frequency interference
	Frequency filtering	Narrows the range of frequencies to be viewed and analyzed, which can provide greater resolution of certain features
	Range gains	Amplifies reflections collected from later in the time window
	Deconvolution	Removes multiple reflections that can conceal other reflections
	Migration	Collapses large hyperbolas to their point source to reduce the amount of spatial distortion of buried objects
Magnetic Gradiometry	De-spiking	Removes isolated extreme measurements that can conceal other, more subtle values
	Drift correction	The calibrated zero point of magnetic data can be corrected for by averaging zero points between transects
	Heading correction	Makes the mean heading values of transects equal
	Stacking	Can be applied in the field and during processing to produce a smoother image
	Destaggering	Aligns transects to remove herringbone effects caused by timing errors during collection
	Gait correction	Adjusts for changes in magnitude that occur when the height of the instrument varies
	Grid matching	Adjusts for the mean difference in magnitude between the edges of adjacent grids
	Filtering	Filters magnitudes to make features more visible
	Interpolation	Smooths the pixels in images produced from magnetic data
	Contrast manipulation, shadowing, color scales	Enhances specific magnitudes, making some features more visible
Electrical Resistance	Editing	Edit defective data points, which are replaced with the value 2047.5
	Interpolation	Applied to lower data sample density areas
	Filtering	High pass and low pass frequency filtering makes low-contrast features more apparent and to reduce noise, respectively
	Clipping	Low-resistivity features are isolated by clipping the high pass data to negative values
Electromagnetic Conductivity	Drift correction	Apply calibrated zero points taken in the air prior to and throughout a survey to correct for the zero point changing as temperature fluctuates over the course of a survey
	Mapping	Experiment by making contour or image maps with different scales to determine which will make features most apparent
Magnetic susceptibility	Drift correction	Apply calibrated zero points taken in the air prior to and throughout a survey to correct for the zero point changing as temperature fluctuates over the course of a survey
	Convert to volume or mass susceptibility	Data must sometimes be converted, especially if data was collected with an induction meter
	Mapping	Experiment by making contour or image maps with different scales to determine which will make features most apparent

Figure 18. Processing Steps by Instrument.

5.4.1.2.1 GPR. Common processing steps for GPR data include calculating the velocity, setting time zero, background removal, frequency filtering, range gains, deconvolution, and migration (Conyers 2013:129–148). GPR data are often considered the most challenging geophysical data type to process and interpret because, once all of the processing is done, the data are typically combined into a three-dimensional data set and sliced at various depths. Some of these processing steps should be applied universally and some judiciously based on the data returns. The determination of which steps should be applied must ultimately rest with the practitioner processing the data, as they are the ones looking at the results. Generally, however, calculating the velocity, setting time zero, and background removal should be universally applied. Frequency filtering, range gains, deconvolution, and migration should be applied more judiciously based on site-specific variables.

Calculating the velocity, correcting for time zero, and background removal are the first steps to data processing. The average velocity that electromagnetic energy travels through the ground (a function of the soils relative dielectric permittivity or RDP) can be calculated during field data collection, but it is also frequently calculated through hyperbola fitting during data processing (Conyers and Lucius 1996). When this is accomplished, the velocity can be changed in the profiles to display depth instead of time. Correcting for time zero moves the ground surface, or first reflection, to the zero position, so that depth can be accurately calculated (GSSI 2011:32). Background removal removes the horizontal banding that is produced by system noise and outside frequency interference (Conyers 2013:134–136).

Data processing steps, such as frequency filtering, range gains, deconvolution, and migration, should be applied selectively depending on the site conditions and data returns. Frequency filtering processing steps can be applied to narrow the range of frequencies to be viewed and analyzed, which can provide greater resolution of certain features (Conyers 2013:136–137, 141–143). Applying range gains to a data set amplifies reflections collected from later in the time window because radar waves attenuate in the ground, so they, generally, have lower amplitudes than those collected earlier (Conyers 2013:99–100, 130). Deconvolution is used to remove multiple reflections that occur when waves reflect between an object and another surface, which can conceal other reflections (Conyers 2013:137–139). Migration involves collapsing large hyperbolas to their point source to reduce the amount of spatial distortion of buried objects (Conyers 2013:139–140). These processing steps can improve the analysis of GPR data, but each should be considered carefully before being applied to a specific data set.

Following the selected data processing steps, most GPR data should be combined into a three-dimensional block of data and used to export slice maps. The desired interpretations can sometimes be made from the processed profiles alone. This is rare, however, and primarily limited to geological data sets or those where simple linear features (such as trolley tracks) are the sole prospection goal. Slice maps are made within most GPR software packages, and the depth and thickness of each slice will vary based on the site type and geophysical results. These slice maps are often displayed spatially on a site map.

5.4.1.2.2 Magnetometery. Magnetometer data processing is highly dependent on the data collection results and the processes needed to make those results clearer for interpretation and display. Data can be processed in several ways, including de-spiking, correcting for drift and heading errors, stacking, destaggering, correcting for gait, grid matching, filtering, interpolating, and contrast manipulation (Kvamme 2006c). Processing steps such as correcting for gait, destaggering, filtering, interpolation, and contrast manipulation are generally done as a standard practice. Despiking, correcting for drift and heading errors, stacking, and grid matching are typically done on an as-needed basis. All magnetometer data processing should be customized to specific data sets and field conditions.

The most common processing steps applied to magnetometry data sets are correcting for gait, destaggering, filtering, interpolation, and contrast manipulation. Correcting for gait (sometimes called a destripe) adjusts for changes in magnitude that occur when the height of the instrument varies based on the operator's gait (Kvamme 2006c:241–242). Destaggering is applied when timing during collection was slightly off, aligning transects to remove herringbone effects (Kvamme 2006c:241). Filtering parameters can be applied to make features more visible (Kvamme 2006c:242–243). Interpolation smoothes the pixels in images produced from magnetic data and should be applied so that the edges of pixels are not misinterpreted as features (Kvamme 2006c:243). Other processing steps, such as contrast manipulation, shadowing, and applying different color scales, can be used to help enhance specific magnitudes making some features become more visible (Kvamme 2006c:244–247).

Processing steps such as despiking, correcting for drift and heading errors, stacking, and grid matching are applied judiciously depending on the site and survey results. De-spiking removes isolated extreme measurements, usually attributed to ferrous objects, which can conceal other, more subtle values (Kvamme 2006c:237–238). Drift error correction is done when the calibrated zero point of magnetic data can fluctuate, especially as temperature changes throughout a survey, and can be corrected for by averaging zero points between transects (Kvamme 2006c:238). Minor errors in heading are unavoidable, and can be corrected by making the mean heading values of each transect equal (Kvamme 2006c:238). Stacking, which averages samples, should be applied in the field, but can also be applied during processing to produce a smoother image (Kvamme 2006c:238–241). Grid matching, which adjusts for the mean difference in magnitude between the edges of adjacent grids, should be applied when the average magnitudes between grids are very different (Kvamme 2006c:242).

There is not a standard set of processing procedures for magnetic data. Processing can vary between projects and sites or even within sites themselves. Following the selected processing steps, that data are typically displayed spatially in a program such as ArcGIS. From there, results can be displayed and interpreted.

5.4.1.2.3 Electrical Resistance. Electrical resistance data processing is dependent on the type of data collected and the data quality. Resistance data sets are slower to collect and, therefore, tend to be smaller in size. This can make data processing more discrete and simple. Commonly used processing steps include directly editing the data sets, interpolating between data collection points, filtering the data, and clipping the results. Defective data can be replaced with the "dummy" value of 2047.5, which is a number used as a placeholder value in a data set where zero is a meaningful data point (Somers 2006:118). An understanding of appropriate data values for the site-specific geology and archaeology is essential before this type of editing is applied. Interpolation between data points to create a complete grid is commonly done to all geophysical data, and, in lower data sample density areas, more interpolation may be needed (Somers 2006:118). High-pass and low-pass frequency filtering can be applied to make low-contrast features more apparent and to reduce noise, respectively (Somers 2006:118–120). This process isolates high- and low-resistivity features so that they may be analyzed separately. When processing is complete, the data are typically exported into a spatial dataset and visualized in a program like ArcGIS.

5.4.1.2.4 Electromagnetic Conductivity/Induction and Magnetic Susceptibility. Electromagnetic conductivity and induction and magnetic susceptibility have similar processing steps and will be grouped together for the purpose of this discussion. In general, processing for these instruments tends to be minimal and varies depending on instrument manufacturer and the specific site variables. These processing techniques include correcting for drift, converting the data to volume or mass susceptibility, and interpolating between data points to create a complete grid or contour map. Drift occurs when the zero point changes as temperature fluctuates throughout a survey (Clay 2006:88; Dalan 2006:172–173). Conductivity data and susceptibility data should both be drift-corrected by applying calibrated zero points, taken in the air prior to and throughout a survey, to each data set (Clay 2006:88; Dalan 2006:172–173). Susceptibility data must sometimes be converted to volume or mass susceptibility, especially if data have been collected with an induction meter (Dalan 2006:175–176). Interpolation between data points is done with the processed data in order to create a complete grid of data. This is typically visualized through a contour or image map (Clay 2006:96–97; Dalan 2006:175–176). These contour and image maps can then be geo-referenced and viewed as spatial data.

5.4.1.2.5 LiDAR. LiDAR data are collected as a series of points, often referred to as the "point cloud." The point cloud is uploaded into a proprietary LiDAR software program for filtering and editing to clean up collected data points. The data sets can be viewed as three-dimensional models or a digital elevation model (DEM), depending on the collection resolution and how the data will be used. Ground-based LiDAR is usually high-resolution, three-dimensional maps of specific features or the ground surface. Aerial LiDAR is usually large-scale DEM images of broader landscapes. These blocks of LiDAR data can be further processed by applying filtering models and data pattern recognition techniques to the DEM, and by exaggerating profiles from a DEM so more subtle features are easier to see (Aziz et al. 2016; Chase et al. 2017; De Boer 2005; Grammer et al. 2017; Hesse 2010; Kakiuchi and Chikatsu 2008; Majewska 2017; Riley 2009; Riley et al. 2010; Riley and Tiffany 2014). The LiDAR data can be used in a GIS program to analyze the mapped surface elevations.

5.4.1.2.6 Case Study Example for Data Processing Methods

Correcting for Topography and the Tilt of Ground-Penetrating Radar Antennae	
Authors	Dean H. Goodman Yasushi Nishimura Hiromichi Hongo Noriaki Higashi
Date	2006
Publication	Archaeological Prospection
Volume	13
Pages	159-163
Abstract	This article addresses how topographic variation affects the direction GPR energy enters the ground. The authors argue that unless the data are corrected both for terrain and antenna tilt, the end data will be distorted. They suggest using GPR slices to solve this problem and use an example of a burial mound in Japan to illustrate the improved accuracy of data processed to account for tilt. This article provides an excellent best practice for identifying objects buried in a mound.
Cultural Variables	Non-Western, Rural

PROJECT DESCRIPTION

This study considers both the elevation and tilt of the antenna when collecting GPR data over features with significant topographic variations. The authors determined that antenna tilt (the direction the electromagnetic energy entered the ground based on the angle of the slope) affected how features were imaged in the ground. They demonstrate how that variable can be controlled for and how the effects may be reduced through data processing. This research was conducted over a burial mound in the Miyazaki Prefecture, Japan.

RESEARCH QUESTIONS

Does antenna tilt distort the results of GPR surveys over complex ground surfaces? Can data processing accurately correct for antenna tilt?

SURVEY DESIGN

Ground penetrating radar data were collected over a burial mound in Japan. All the reflection traces were corrected for elevation change and time was converted to depth based on the average velocity of the site. The ground slope was computed and the tilt angle of the antenna as it was pulled over the topography was derived from the arctangent of the ground slope. The wavelets were all reassigned based on the calculations of elevation, velocity, and tilt. The cone of transmission was disregarded. Corrections were first made to profiles, which were then used to produce slice maps.

Once the GPR data were corrected for topography and antenna tilt, a feature visible in the data was excavated archaeologically. This allowed the researchers to compare uncorrected and corrected data with the actual feature.

RESULTS

The authors found that the geometry of a burial chamber in the mound was more accurately produced in the tilt corrected data. After the profiles were corrected, they were used to produce slice maps. These show that the size, shape, and location of the burial chamber was calculated more precisely when antenna tilt was taken into account. Excavations confirmed the location and geometry of the burial chamber visible in the GPR data.

RECOMMENDATIONS

Corrections for topography and antenna tilt should be included in the data processing steps when GPR data are collected over differential topography. Tilt meters should be developed so that the tilt of the antenna can be accurately recorded during collection.

KEY LESSONS

- **Collection and site conditions should be considered during data processing.** The setting of a site and the conditions in which data were collected can significantly effect the data. These variables should be considered during data processing. In this case, data were collected over a burial mound with steep topography. Knowledge of the site was important during processing steps, because the authors accounted for the topography and tilt of the antenna.

5.4.2 Analysis and Interpretation

Following data processing, the next step is to interpret the data to identify graves or possible graves. Although rarely discussed in the literature, most practitioners use cemetery-specific interpretive steps (Conyers 2006, Watters and Hunter 2004). These steps primarily involve a closer examination of the data than would normally be done on an archaeological site with less subtle features. It is important to be systematic during analysis and to know how different aspects of a grave may appear in different geophysical data sets and sites.

There is no software program for any instrument with a magic button that will identify all the graves; it requires interpretation. All geophysical data sets must be systematically analyzed visually to look for anomalous readings with the characteristics of graves. These characteristics vary by instrument type and the cemetery, but generally, they must be in size and shape of the burials expected in an area. This can be aided by collecting data on a known or marked grave to "calibrate" expectations. Specific to GPR, analysis of both profiles and slice maps should be used to identify possible graves (Conyers 2012:129–152; Damiata et al. 2013; Lowry 2016). Using manual methods or software to plot possible graves identified in profile to determine their geometry can ensure that the entire survey area is analyzed systematically. Magnetometry, electrical resistance, electromagnetic conductivity and induction, and magnetic susceptibility can be analyzed visually. It can also be useful to shift displays so that individual values from the data sets are emphasized. This could be particularly useful if data have been collected over known burials so that values of magnitude may be compared. Susceptibility data are often supplemented by lab analysis, which can help to determine if and how human processes have impacted the magnetic susceptibility of a sample (Clark 2003:102–103; Dalan 2006:161, 176, 194–195; Dalan et al. 2010:589; Dearing 1999:8; Gaffney and Gater 2003:46).

LiDAR is not geophysical data, so the analysis is more dependent on mathematical models. The process of using spatial models to extract features with specified geometry from LiDAR data can be used to analyze or identify certain types of features. Archaeologists should also examine each feature systematically both in the LiDAR images and in person so that they may be verified (De Boer 2005; Grammer et al. 2017; Hesse 2010; Kakiuchi and Chikatsu 2008; Riley 2009; Riley et al. 2010; Riley and Tiffany 2014). LiDAR data are often interpreted visually, depending on the size and complexity of the data set.

The systematic analysis discussed here is difficult to quantify and could be challenging to write into a scope of work. At a minimum, there should be an expectation that post-field data processing will occur regardless of the geophysical method(s) used. Practitioners should systematically review all of the collected data. Useful discussions of data processing and analysis can often be found in the forensic literature where there are detailed discussions of what forensic graves look like in various conditions (Scott and Hunter 2004; Ruffell and McAllister 2015; Pringle et al. 2012, 2015; Miller et al. 2004). Many of these forensic studies also include controlled tests of graves using pig cadavers (Schultz 2008; Schultz et al. 2006; Schultz and Martin 2011; Pringle et al. 2011; Juerges et al. 2010; Kalacska et al. 2009). It is also useful to compare the images produced from geophysical data sets to cemetery maps and above-ground cemetery features (e.g. markers, depressions, plantings, mounding). The results of the analysis should be documented spatially in a GIS, so that the identified locations of possible graves can be plotted on maps and relocated on the ground easily.

5.4.2.1 Case Study for Clandestine Burials

Monitoring Controlled Graves Representing Common Burial Scenarios with Ground Penetrating Radar	
Authors	John J. Schultz Michael M. Martin
Date	2012
Publication	Journal of Applied Geophysics
Volume	83
Pages	74-89
Abstract	This article outlines the results of a controlled study of the effectiveness of GPR for forensic work. It used pig cadavers buried at varying depths in conditions commonly found at forensic scenes, including wrapped with various materials, covered in stones, and with no treatment. A 250 MHz and a 500 MHz antennae were used monthly over the graves and climate data were recorded. The author concluded that moisture improved the resolution of all graves. Wrapped cadavers or those where items were with the burials were easier to identify. Deeper graves were generally more visible. Both antennae provided resolution of graves throughout the study periods, but the 500 MHz yielded slightly more detail, while the 250 MHz provided better depth penetration. The authors suggested using both antennae if time allows. Finally, they recommend generating both profiles and slice maps for forensic work. This study was well controlled and concisely provided information about GPR and its use for detecting modern burials.
Cultural Variables	Clandestine Burial, North America, Semi-urban

PROJECT DESCRIPTION

This study investigated pig cadavers buried in a variety of circumstances commonly seen in forensic cases. Pig carcasses were buried under different conditions and their visibility in ground penetrating radar data were monitored for a year. This study allowed the authors to draw conclusions about how different burial conditions, antenna frequencies, and decomposition factor into the detection of forensic burials with GPR.

RESEARCH QUESTIONS

The objectives of this research were to: 1) document differences in imagery of each burial over time; 2) compare 250 MHz and 500 MHz frequencies for detecting burials of differing depths and conditions; and 3) determine how soil moisture affects the detection of burials.

SURVEY DESIGN

This research was conducted in a mowed field within a semi-urban forested area in central Florida. The site contained sandy soils. Eight 1x1-meter graves were hand dug. Two of these graves were used as controls and did not contain pig carcasses. One control grave was classified as shallow (50 centimeters), and the other as deep (1.0 meter). Six of the graves contained pig carcasses that were the approximate size of a small human body. One was naked and placed in a shallow grave. Another naked carcass was buried in a 1.0-meter deep grave. The four other carcasses were all placed into deep graves. One was covered in seven centimeters of granite river rocks, one was wrapped in a tarpaulin, one was covered in dolomite lime, and one was wrapped in a cotton blanket.

Once a month for twelve months, a GPR survey was conducted over these burials using both a 250 MHz and 500 MHz antenna. An 11x22-meter grid was established and reused for each survey and data were collected in transects spaced 25 centimeters apart in both west-east and north-south directions. Depth was calibrated before each survey by detecting a piece of rebar buried 1.0 meter deep.

The researchers analyzed both profiles and slice maps to determine the level of visibility of each grave. A four-point scale was used to rank visibility: none, poor, good, and excellent. Climate data were also integrated into data analysis.

RESULTS

The profiles from the 250 MHz antenna indicate that the deep control grave was detected by a high amplitude reflection at the grave floor. The shallow control grave was never detected, but the naked pig in a shallow grave was visible 11 of 12 months. All pigs in the deep graves were visible during most months of the study.

Slice maps from the 250 MHz data show that the shallow control and pig graves were never visible. The deep lime and naked pig graves were only visible five and six of twelve months. The deep control grave and deep pig graves with rocks, a blanket, and a tarpaulin were visible for most of the post-burial months.

The 500 MHz profiles have no indication of the shallow control grave and the visibility of the deep control grave was "good" just once. Visibility was best for the shallow naked pig grave, and the deep graves where the pigs were naked, covered in rocks, and wrapped in a tarpaulin.

Slice maps produced from the 500 MHz data show that the shallow control and pig graves were never detected. The pig covered in lime was detected six of twelve months, and the deep pig grave and blanket-wrapped pig were detected just four of twelve months. The deep control grave, and the pigs covered in rocks and wrapped in a tarpaulin had the highest visibility, appearing in most or all post-burial surveys.

For burials that were detected, visibility increased between months 4 and 8 and then visibility began to decrease. The authors of this study attributed this to soil moisture levels, which increased in the months where burials became more visible. After Month 9, soil moisture decreased and the pigs were more decomposed, so burial visibility also decreased.

The grave shafts were never identified in any circumstance. Burials were always visible as high-amplitude reflections produced from the carcasses, materials covering the carcasses, or grave bases. This can be attributed to the homogenous sandy soils, which did not contrast with the backfill enough to produce reflections. The grave bottom of the deep control grave was visible because the deeper soil contrasted sufficiently to produce reflections.

The two conditions that produced the best reflections were pigs covered in rocks and wrapped in a tarpaulin. The rocks were visible independently and continued to remain visible once the pig had completely decomposed. The tarpaulin retained moisture, which contributed to its visibility.

Both antennas worked, but the 250 MHz was better for detecting deeper burials. The 500 MHz recorded higher resolution data, which resulted in more reflection from the ground and made interpretation more difficult. It was, however, better at detecting the shallow graves.

RECOMMENDATIONS

The authors recommend considering the multiple variables of forensic burials. These include the size of the body, soil type, burial depth, items added to the grave, level of decomposition, and soil moisture. They also advocate the use of different antenna frequencies, if possible, and analyzing both profiles and slice maps.

KEY LESSONS

- **Burial conditions should be considered.** This case shows that different variables impact how burials are detected. Although the nature of clandestine burials is often unknown, this shortfall can be overcome with knowledge of certain variables, such as soil composition, which can help to determine the best antenna frequency for a specific area.

- **Multiple antenna frequencies and collection parameters should be used when searching for clandestine burials or burials outside of a traditional cemetery context.** Because the depths of burials are often unknown, multiple GPR antenna frequencies should be used. This will improve the likelihood of detection. Transects should be collected perpendicular to burials, but if the orientation of a burial is unknown, then grids should be collected in both the X and Y directions.

- **Conducting a GPR survey after rain may improve the likelihood of locating a clandestine burial.** This case study showed that soil moisture enhanced burial detectability. A burial that is not discernable in dry conditions may become visible during the rainy season or after a rainstorm. This finding might also apply in non-forensic situations when graves in a cemetery could retain more moisture than the surrounding soils and so reflect electromagnetic energy better.

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CHAPTER 6

Outline Project Deliverables

An effective geophysical scope will contain a clear outline of expected project deliverables. The deliverables will be dependent on the extent of the geophysical survey and the level and type of additional work (e.g. a marker inventory). This section of the guidebook outlines typical deliverables and some specialized deliverables that might be helpful. Typical deliverables include a full technical report, maps, GIS data, and the raw and processed geophysical data (Figure 19). Specialized deliverables include mapping and GIS, databases, raw and processed geophysical datasets, photos, or public outreach.

6.1 Report

Clear communication, detailed explanation of methodology, and setting realistic expectations of the results from the beginning are key to producing a successful report. Without a complete report the results will not be reported adequately, and there is not sufficient documentation, so the geophysical survey will be considered incomplete. Components of a complete report may vary based on the project type, but at a minimum must include an introduction, project or cemetery background, field data collection and data processing methods, results and interpretations, and conclusions. Reports may also include recommendations for additional work, if appropriate. One important goal of a technical report is to document all phases of the survey in sufficient detail that it can be evaluated and/or replicated by independent parties.

6.1.1 Introduction

The introduction should summarize the project, project scope, address the research design, the objectives of the geophysical survey, and the research questions. An introduction might also include the survey staff, and where and when the survey took place, as well as any legal or statutory regulations that may be applicable. This section should include a brief overview of the rest of the report and a summary of the results.

6.1.2 Background

The project background is an essential part of reporting. The “who, what, when, why, and where” of the cemetery should be covered as well as a detailed historic context when it is available. There should also be an environmental and cultural context, and previous research that has occurred at the cemetery. The environmental context is important for establishing the topography, types of vegetation, soils and moisture conditions that may be encountered, which can greatly affect selection of geophysical methods. Cultural context will influence how people are buried, and understanding this context can ensure that the survey and interpretation steps are carried out appropriately.

Deliverable		Components
Report		▪ Components may vary by project ▪ Documents all phases of survey in detail
Report Sections	Introduction	▪ Project, project scope, research design, objectives, research questions ▪ Survey staff, where and when survey took place ▪ Legal or statutory regulations ▪ Brief overview of report, summary of results
	Background	▪ Who, what, when, why, and where of the cemetery? ▪ Environmental and cultural contexts
	Methods	▪ Detailed equipment specifications ▪ Field collection parameters ▪ Post-field processing steps ▪ Explanation of data integration into GIS, with coordinate system ▪ Discussion of how data were interpreted
	Results and Interpretations	▪ Imagery of data results produced ▪ Interpretations, with explanations ▪ Should be compared to existing cemetery data ▪ Detailed mapping
	Conclusions and Recommendations	▪ How findings address research objectives and project scope ▪ Possible recommendations for further work ▪ State, local, and federal regulations that apply ▪ Plan for avoidance or compliance with statutory requirements
Mapping and GIS		▪ Survey location, site soils, survey grids, surface features, cemetery markers (if present), geophysics results, digitized interpretations ▪ Should be integrated with other spatial data in a predetermined coordinate system and/or projection ▪ Note range of accuracy for method used
Raw or processed Geophysical Data		▪ Raw and processed geophysical data files
Project Photos		▪ Document cemetery conditions and survey ▪ Some may require specific photos of each marker
Public Outreach		▪ Websites, publicly accessible reports, local media coverage, and open site days ▪ Note if confidentiality must be maintained

Figure 19. Deliverables that may be required.

6.1.3 Methods

The methods section is the most technical report chapter. It should contain a complete explanation of field data collection, post-field processing methods, and interpretive steps. Methods should be consistent with professional standards/practices and be replicable by future surveyors. Any deviations from industry standards should be fully justified and explained with reference to the project and research design. The field collection methods will include detailed equipment specifications, information about the survey itself, explanation of the geophysical method(s), and site mapping. Equipment specifications include equipment manufacturer and model, as well as parameters set on the equipment in the field. Information on the geophysical method, such as a simple explanation of how it works, why it was selected, its strengths, and limitations may be included. Field data collection parameters should be clearly stated, including the survey location and size, transect spacing, and instrument settings. Post-field processing steps need to be listed, including processing software names and specific types of processing and why they were selected. This section should include an explanation of data integration into GIS, including the coordinate system. Finally, the methods section should have some discussion about how the data were interpreted. This may include a discussion of interpretation method and what types of features are expected.

6.1.4 Results and Interpretations

Results and interpretations for a geophysical survey need to be explained in detailed. This section will include any imagery of data results produced, interpretations, and an explanation of the interpretations, including the specific aspects of the geophysical data that led to the identification of a possible grave. Cemetery interpretations should reflect the expectations stated in the methods and background for how the geophysical method will operate in the environmental and cultural context of the cemetery, and how graves may be imaged, given these expectations. Identification of graves in interpretations should be based on several variables, including size, shape, depth (where applicable), orientation, geophysical properties, and comparison with expectations (Patch and Lowry 2014:70). Graves identified with geophysical methods should be compared and correlated with existing cemetery data such as marker locations and maps (if available). This section must include detailed mapping.

In the results and interpretations, it is important to communicate to sponsors that negative results do not necessarily mean the absence of graves, or that the survey was a failure. Because all geophysical surveys are reliant on contrasts between the grave and the surrounding soils, if those contrasts have diminished over time through natural degradation processes the graves might not be visible. This point was frequently cited in practitioner interviews and is widely acknowledged in the geophysical community. No matter how rigorous a particular survey might be, it is essential to recognize that some graves may have been missed and that there could be false positives.

6.1.5 Conclusions and Recommendations

Conclusions should reflect the results of the geophysical survey, and how those findings address the research objectives and project scope. Recommendations might also suggest what further work will be recommended. Where relevant this section may also state applicable state, local, and federal regulations that apply to the cemetery. This section may establish a plan for avoiding the cemetery or for how the proposed undertaking could comply with statutory requirements.

6.2 Other Deliverables

Depending on the project, other deliverables may be required. These deliverables could include mapping and GIS, databases, raw and processed geophysical datasets, photos, or public outreach. This section does not necessarily include a comprehensive list of all other deliverables; depending on the agency, project scope, the specific cemetery, the stakeholder communities, and any number of other variables, the required deliverables may vary. This list can be seen as a starting point, but a scope of work should customize deliverables based on the project and state them clearly.

6.2.1 Mapping and GIS

Successful reports should also contain mapping and graphics, typically within a GIS program. Required mapping may include the survey location, site soils, survey grids, surface features, cemetery markers (if present), geophysics results, and digitized geophysics interpretations. These maps provide a context for the geophysical work and detailed results. Base data may be collected with a GPS unit or total station. Geophysical data sets should be integrated with other spatial data (Patch and Lowry 2014:58). Geophysical data can be referenced spatially in GIS software, which allows for a more accurate and comprehensive representation of that data. The scope of work should specify the coordinate system and/or projection for GIS data deliverables (e.g., State Plane Feet NAD 83), so the data can be incorporated with other spatial data such as engineering design plans.

Mapping deliverables often include the GIS data used to make project maps. These data can be used to relocate geophysical grids and results or be passed on to other involved parties. GIS data could include the vector data (such as interpretations, grids, and cemetery markers) and raster data (such as images made from geophysics results). All data should have a clearly stated projection and datum.

It is a best practice to be as spatially accurate as possible, especially when attempting to locate graves. GPS units usually specify the range of accuracy, and this should be considered when integrating data sets. Total stations are often more precise than most handheld GPS units, and are usually accurate to within a few centimeters, but they do require accurate spatial locations to be used as a base (Weitman 2012:105). Practitioners should specify how features and grids were mapped, and note the typical range of accuracy for the method that was used. If a specific accuracy is required sponsors should specific this in the scoping process. Datum or control points should always be left in the ground at known locations if additional work is anticipated at a future date.

6.2.2 Raw or Processed Geophysical Data

A scope of work may request the raw and processed geophysical data for archival purposes. The types of data and their file extensions will vary by the geophysical instrument, manufacturer, and processing software. It might not be possible for the sponsor to view the actual geophysical data without owning the proper software. However, having the data archived with the report can be a valuable tool in the future if the geophysics results need to be reevaluated.

6.2.3 Project Photos

Requiring photographs of the site and in-field data collection may be a useful deliverable requirement. These photos can be helpful during the interpretation process. They can also provide documentation of cemetery conditions and how the survey was conducted. The type and number of photos required will depend on the project and project goals. Some projects may require specific photos, such as a photo of each marker. This type of specificity might not be necessary and instead stating that photos are required may be adequate.

6.2.4 Public Outreach

In some circumstances, public outreach is an important part of cemetery surveys. Public outreach can take many forms including websites, publicly accessible reports, local media coverage, and open site days. These types of products can be report deliverables if desired and applicable, but they need to be specifically stated in the scope. There may be circumstances in which it is necessary or desirable to maintain confidentiality. If so, this should be identified in the scope of work and procedures outlined for addressing public inquiries.

6.3 Uncertainty in Project Deliverables

Responsible practitioners with extensive experience in cemeteries all recognize that it is impossible to identify all graves in a particular cemetery with geophysical methods. It should be clearly conveyed that possible graves identified in the geophysical data may be false positives, and, conversely, that negative results do not indicate the absence of graves. In situations where known graves are present, yet negative geophysical results are obtained, it is not because the geophysical method(s) did not work, but either because the conditions were not suitable for the detection of graves or there was not sufficient contrast between the graves and the surrounding soils. These circumstances can be addressed by managing expectations about the benefits and limitations of geophysical methods.

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CHAPTER 7

Developing the Scope

All scopes of work will vary in format and organization based on different sponsor requirements and type of project. This document outlines the type of information that may be included in an effective scope. Not all of these materials may be available or applicable in every circumstance. It is important to remember that cemeteries are a diverse cultural resource. Project goals in a cemetery can vary extensively and there is not a "one size fits all" scope for geophysical work in a cemetery. This document is intended to empower project sponsors to select the materials relevant to their project to include in a scope through explaining each of the five scoping variables.

The preceding six chapters of this document introduced the topic of developing effective scopes of work in a cemetery and outlined the components that might be helpful in a scope (Figure 20). The following chapter is intended to be a synthesis of those materials for quick reference and review, while the supporting materials and case studies are available with more details.

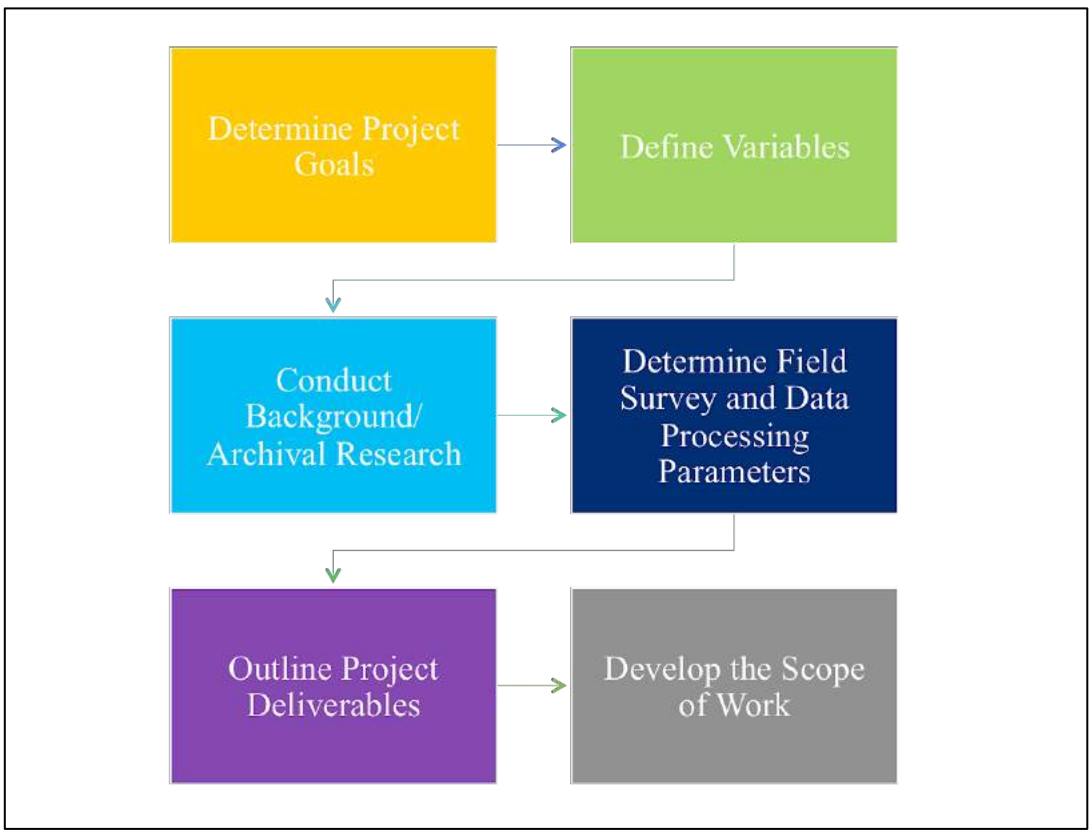

Figure 20. Summarized steps to an effective scope of work for geophysical survey in a cemetery.

7.1 Determine Project Goals

The first step to scoping a geophysical project in a cemetery is determining the project goals and outlining the undertaking that is initiating the geophysical survey. Some common project goals are to identify the presence or absence of a cemetery, locate the boundary or extent of a cemetery, identify and map the number and location of graves, or as part of educational, research, and/or preservation efforts. After the project undertaking and project goals have been established, the survey area must be defined. Many regulatory projects include a formal area of potential effects (APE); in this case the survey area is often defined as the area where the APE intersects with the cemetery. Where there is no formal APE, the survey area should be defined to encompass the area that will be impacted by the undertaking or address the goals for the project. This might be the whole cemetery or a small portion. In many situations, a buffer is added to this area, with the size of the buffer dependent on the site conditions and the cemetery's history. Mapping of the survey area and a calculation of its acreage must be included in the scope.

The level of accuracy needed to meet the goals and expectations should be considered while determining which instrument to use. The choice of geophysical method is based on how the area may be surveyed efficiently and effectively so that the goals and expectations are met. Environmental and cultural variables should also be considered when choosing a method. Multiple geophysical methods or non-geophysical methods may be incorporated if the project goals and expectations require an increased level of accuracy.

Refer to Chapter 2, Determine Project Goals, for more details on this subject.

7.2 Define Variables

Environmental and cultural variables should be defined during the scoping process. The environmental conditions of the cemetery can dictate which geophysical method(s) will be effective, where the survey can take place, and what kind of work will need to be done prior to survey (e.g. clearing vegetation). Cultural variables need to be noted because ethnic affiliation, religious affiliation, age, cemetery type, and geography can impact how people are interred. This will then impact how these graves might contrast with the ground, which will help determine which geophysical instruments might be most effective, what grave features might look like, and to determine data collection parameters.

Environmental variables can include both natural and cultural environmental conditions in a cemetery. Vegetation, topography, soils, modern disturbances, and surface obstructions are all considered environmental variables. The survey areas should be cleared of surface obstructions without disturbing the cemetery features. Dense vegetation should be cleared, and grass should be mowed as close to the ground surface as possible. Clear ground conditions can help produce better geophysical results. Noting the vegetation conditions, any clearing required, and who will be responsible for the clearing is an important component of an effective scope. Site soil conditions should be understood, since soil conditions and soil moisture content are the principal environmental factors that determine the success or failure of geophysical survey.

A cemetery's cultural context is defined by cultural variables, such as age, period(s) of use, ethnic association(s), geographic location, and origin. Cultural norms associated with burials vary based on ethnicity, geography, and the social conditions at the time of burial. These variables do not necessarily determine the specific burial style, but they do influence burial methods and more information is always helpful to planning for a successful geophysical survey.

Defining the variables is not necessarily a complicated or time-consuming process. It can be as simple as listing all that is known about the cemetery's environmental conditions and the cultural affiliations of the interred, while noting unknowns. The variables listed here are not intended to be all-inclusive; in some cases, there will be additional variables and in many these might not apply or be unknown. Simply listing variables during scoping can help the practitioner and the sponsor plan the survey.

Chapter 3, Define Variables, provides more detailed information on different variables to consider and how they may impact a geophysical survey.

7.3 Conduct Background/Archival Research

Establishing multiple lines of evidence is best to accurately identify unmarked graves. The amount of archival and background research conducted is dependent on the project goals and available resources. Archival and background resources such as deeds, cemetery records, local histories, oral histories, cemetery maps, and inventories can help to provide a more comprehensive context for the cemetery. These resources may or may not be consulted prior to scoping the geophysical survey and the research portion of the project may be part of the geophysical scope or be conducted by the project sponsor.

Available archival and background resources must be identified before determining the extent of further research. The type and extent of research that needs to be included in a cemetery survey will vary depending on the scope of the project. The desired type and extent of research should be outlined in detail for practitioners once the available resources, scope, and budget have been considered.

Chapter 4, Conduct Background and Archival Research, contains a list of common resources and where they may be located.

7.4 Determine Field Survey and Processing Parameters

There are three components to the successful collection and processing of geophysical data in a cemetery: an experienced practitioner, proper field collection methods for the site, and good data processing parameters. The geophysical practitioner must have experience collecting and processing geophysical data in cemeteries and a theoretical understanding of how geophysical instruments operate. Requiring consultants to meet the Secretary of the Interior's Professional Standards for Archaeology or History may ensure a firm background in identifying graves, but is not necessarily a requirement for a thorough understanding of cemetery geophysics. Professional experience collecting and processing geophysical data in cemeteries may be the best indicator.

Proper field data collection methods vary by the specific cemetery. Basic data collection parameters should be identified in the scope, taking into account the project goals and budget. Clearly defined field survey parameters include choosing the optimal geophysical equipment for the project and developing a sampling and data collection strategy that will produce the level of accuracy required to meet the project goals. A basic understanding of how different geophysical methods work is the first step to choosing the most effective methods for a project. No geophysical method can be applied universally to all cemeteries and each should be considered individually based on their strengths and weaknesses. Most common options include ground penetrating radar (GPR), magnetometry, electrical resistance, electromagnetic conductivity/induction, and magnetic susceptibility. LiDAR is available for remotely mapping a cemetery and its landscape in three-dimensional space in great details. Data collection parameters will differ based on specific cultural and environmental variables in the cemetery and the geophysical method.

Data processing must be done to attain the best results and each geophysical method requires different processing steps. Processing steps will be custom selected based on the results and condition from the individual survey. It is important for the practitioner to understand how each processing step works, and know when, and when not, to apply them. This is particularly true in cemeteries where subtle grave features may require special processing and analysis steps. It is important for the practitioner to be systematic, and to recognize how graves appear in different geophysical data sets and sites.

Chapter 5, Determine Field Survey and Data Processing Parameters, provides more specific information about each geophysical method, survey parameters, and processing and analysis steps.

7.5 Project Deliverables

Project deliverables will depend on the project goals and budget and they will need to be clearly stated in the project scope. Required deliverables most typically will include a report and mapping or GIS. They may also include raw or processed geophysical data, photos, or public outreach. This is not a conclusive list of possible deliverables and additional items may be requested based on specific project need, assuming they are clearly stated in the scope.

A report is the primary document summarizing the geophysical work. Components of an effective scope should include an introduction, background, methods, results, interpretations, conclusions, and recommendations. Specific projects may warrant the inclusion of special sections, such as a chapter summarizing demographic data from a marker inventory. In general, reports should include enough information to address the project goals and research design, and be replicable.

Maps and images of processed geophysical data are integral to reporting. Any surface features mapped, such as marker locations or geophysical grid locations, can be displayed on maps. Geophysical data should be integrated with other spatial data in GIS software to produce spatially accurate maps. Images produced from the geophysical data should be displayed in plan view, overlying other spatial data. If interpretations are digitized, they should also be displayed on maps. The data used to make the map (i.e. shapefiles, georeferenced raster data) may be collected as a deliverable as well.

Additionally, raw or processed geophysical data, photographs, and public outreach are common deliverables. Raw or processed geophysical data can be archived with the report in case the interpretations need to be reevaluated in the future or processing methods advance. Photographs are useful to understand the site context, record site conditions, and document the survey in progress. Public outreach can take many forms, including speaking to the news media, running tours of the site, and producing publicly accessible reports. The details of each of these tasks would need to be specified in the scope.

Specific details about possible deliverables may be referenced in Chapter 6, Project Deliverables.

7.6 Compiling Information in a Scope

Each of the five scope components discussed in this document is meant to provide a path to gathering all of the information needed to develop an effective scope of work (Figure 21). The final scope document may be organized based on agency requirements, but it could also mirror the organization of this document. Regardless of formatting, the document should be clear and concise, conveying the project area and objectives. Specific cemetery variables should be stated and uncertainties or unknowns can be noted. A background section should provide a history of the cemetery and an outline of specific directions for future historical research if it is going to be required as part of the scope. The scope may list which geophysical instrument(s) will be required based on environmental and cultural variables, time constraints, and budget. In some cases, the scope may simply suggest possible instrumentation and ask practitioners to propose an approach (these approaches can be evaluated using the material provided in this document). Specific collection and processing parameters should be specified. Standards for data collection and representation, such as criteria for spatial control, will be listed. Then a list of deliverables will be included. If practitioner qualifications are part of the scope, these will need to be listed in the document. Many of these sections can be concise or compiled in list or tabular form. The more specific the scope, the more likely the results will mirror the project expectations (Figure 22).

Required parameters or protocols should be identified clearly. It is sometimes appropriate to determine certain parameters in collaboration with the practitioner, or to make suggestions while ultimately deferring certain decisions to the practitioner. This can be particularly appropriate when there are unknown variables or additional variables are identified during fieldwork or during data processing. In these cases, it is important to distinguish suggestions from requirements and communicate clearly with the practitioner selected for the project.

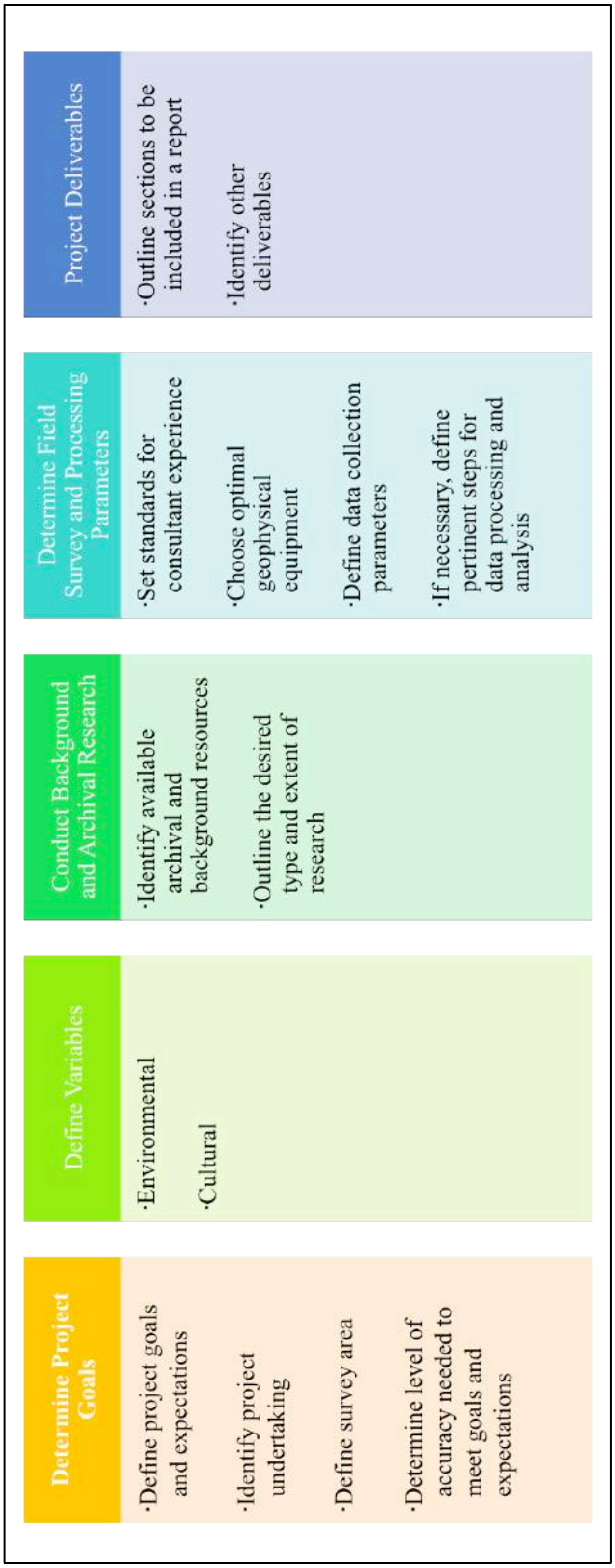

Figure 21. Information required for an effective scope.

Figure 22. Checklist of components needed for an effective scope.

Checklist– Components Needed for an Effective Scope

- ☐ Determine Project Goals
  - ☐ List Objective of Geophysical Survey
  - ☐ Specific Research Questions
  - ☐ Survey Location(s)
  - ☐ Survey Size
- ☐ Define Variables
  - ☐ List Environmental Variables:
    - ☐ Soil Types and Soil Moisture Content
    - ☐ Topography
    - ☐ Vegetation – Does it needed to be cleared? Who is responsible for clearing?
    - ☐ Weather – Are there weather concerns? A rainy or snowy season? An extremely dry season (if considering electrical resistance)?
    - ☐ Above ground disturbance? Obstacles? Debris? Pavement? Structures?
  - ☐ List Cultural Variables:
    - ☐ Ethnic Affiliation(s)
    - ☐ Religious Affiliation(s)
    - ☐ Age
    - ☐ Cemetery Type
    - ☐ Region
- ☐ Conduct Background and Archival Research
  - ☐ Include Available Cemetery Background Information
  - ☐ Include Available Cemetery Mapping
  - ☐ Research Needed for the Project
    - ☐ Specific Sources to be Consulted
    - ☐ Does the Cemetery Need a Marker Map or Inventory?
- ☐ Determine Field Survey and Processing Parameters
  - ☐ List Practitioner Qualifications
  - ☐ List Geophysical Equipment Type(s) to use
  - ☐ Survey Strategy
    - ☐ Sampling Density
    - ☐ Sampling Direction(s)
  - ☐ Data Processing and Analysis
    - ☐ Suggested Processing Steps (remembering the actual processing may vary based on conditions and results.)
    - ☐ Analysis Requirements
- ☐ Outline Project Deliverables
  - ☐ Include list of deliverables
  - ☐ Reporting: Components of Report
  - ☐ Other Deliverables: List Other Required Deliverables
    - ☐ For Mapping and GIS Request Specific Data Types

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2011 Controlled GPR Grave Research: Comparison of Reflection Profiles between 500 and 250 MHz antennae. *Forensic Science International* 209: 64–69.

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NCHRP Project 25-25(B) Task 98: A Practical Guide for Developing Effective SOWs for the Geophysical Investigation of Cemeteries:

APPENDICES

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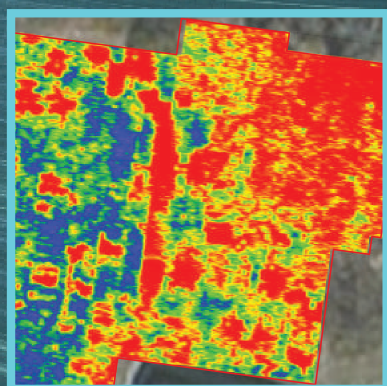
NCHRP Project 25-25(B) Task 98:

Practical Guide for Developing Effective SOWs for the Geophysical Investigation of Cemeteries: Appendices



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Appendices

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APPENDIX A

Annotated Bibliography

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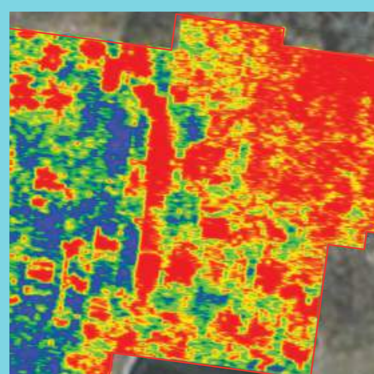
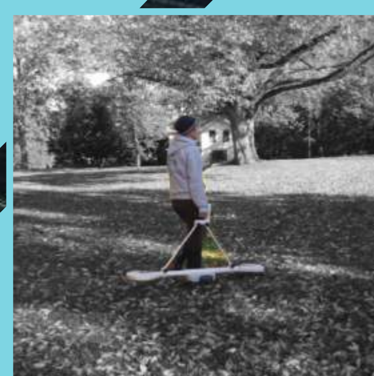
NCHRP Project 25-25(B) Task 98:

Practical Guide for Developing Effective SOWs for the Geophysical Investigation of Cemeteries: Geophysics in Cemeteries Annotated Bibliography





WSP | Parsons Brinckerhoff

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NCHRP Project 25-25(B) Task 98: A Practical Guide for Developing Effective SOWs for the Geophysical Investigation of Cemeteries:

APPENDIX A: GEOPHYSICS IN CEMETERIES ANNOTATED BIBLIOGRAPHY

Introduction

New South Associates has compiled a research tool for the use of geophysics in cemeteries and on gravesites. It is offered as a static print document and as an electronic database created in Zotero (see enclosed CD), a free and user-friendly, online open-sourced reference management software. A copy of the database is also included in an Excel spreadsheet format.

To develop an effective scope of work (SOW) the project manager should have a basic understanding of geophysical instruments, including strengths and weaknesses, typical applications, awareness of how environmental factors (soil, geology, vegetation) and cultural factors (ethnicity, age) affect geophysical survey, and reasonable expectations for results. To that end, the annotated bibliography provides examples that one can consult for background research and context when developing a SOW for a particular cemetery.

The annotated bibliography will enable researchers to search information about geophysics, cemeteries and gravesites, developing policy, and approaches to the cemetery's treatment as a resource. The sources presented are international, national, and local in scope and reflect research and publication from the 1980s onward. The breadth of the sources ranges from conference presentations, agency publications, journal articles, and books.

In the print document, the literature is grouped into six categories: General Reference, Electrical Resistivity, Electromagnetic Induction, Ground Penetrating Radar (GPR), Magnetometer, and Other Instruments. The categories are not mutually exclusive because many of the sources include multiple methods. However, the categories represent logical divisions based on the most common methods that are widely used today in the United States and that a person developing and/or reviewing a scope of work would expect to see.

The sources in the general reference category are reference material such as textbooks that either address a geophysical methodology (e.g. GPR, magnetometry) or general forensics studies. They may not specifically include information about cemeteries or graves, but they do contain some methodological information relevant to the subject. The next four sections are the four most commonly used geophysical instruments in cemetery and grave studies. The Other Instruments group includes sources that discuss much less commonly used methods such as thermal imagery, side scan sonar, seismic, self-potential, remote sensing, metal detector, induced polarization, gravity survey, electrical resistance tomography, and CHIRP sub-bottom profiler.

In addition to the tags referencing the instrument used, each source was tagged by the resource type depending on the kind of survey discussed. Commonly discussed resource types include (but are not limited to): historic cemetery, historic archaeology, prehistoric archaeology, mass burial, forensics, and clandestine grave. Sources were also tagged by the state and country, where applicable. Many of the sources refer to multiple instruments, states, countries, and resource type categories, and these are noted in the annotation.

As a result of the literature review, several trends were observed that may help future resource managers, archaeologists, and geophysical archaeologists target their research. The literature can be broadly divided into two subfields based on the primary research questions and applications: archaeology and forensics. Archaeological literature focuses on modern and historic cemeteries, or prehistoric sites with graves, where geophysical instruments were used to map older burials. These surveys tend to address research questions about cemetery boundaries, the presence or absence of unmarked graves, distribution of graves or availability of cemetery plots for new interments. They are usually presented as case studies, with either a single cemetery or a few cemeteries discussed as representative samples. In rare cases, where supplemental datasets are available (e.g., burial records), additional topics such as social, ethnic, and economic factors might be explored. Typically, with a few notable exceptions, these surveys do not involve excavation or testing of the results.

Many of the archaeological publications tend to focus on case studies. In this sense, they are primarily descriptive, with methods and results but rarely any analysis of the relationships between marked and unmarked graves. There has been almost no attention to specific, yet common, research problems such as burial depth, burial container, correlating existing grave markers with graves detected by geophysical methods, and comparison/contrast of different burial methods among and across different social, cultural, religious, and economic groups. These types of studies would require multiple datasets representing a range of variables likely existing in technical reports that have not been published. Another limitation from the archaeological side is a lack of examples where geophysical surveys have been completed and subsequent excavations were undertaken as part of a specific research design.

Forensic geophysical literature is focused on the identification of modern and clandestine, largely informal burials that are related to criminal cases. In forensic applications, geophysical methods are often used because they are non-invasive, can preserve evidence, and help narrow search areas for more intensive recovery efforts. These articles are largely experimental and driven by specific research questions using cadaver burials (primarily of pig cadavers). In these studies, the cadavers are buried at a known location using a variety of depths, burial styles, grave goods, soil types, etc., to simulate real- world conditions as closely as possible. The goal of these experimental studies is to develop comparative data that can then be applied to specific cases. Geophysical instruments of various technical specifications (e.g., different GPR antenna frequencies) are then tested on the cadavers. These studies are often longitudinal (i.e., for a determined period of time), frequently tested while the cadavers decompose, contain control burials, and sometimes include excavation of the cadaver to examine the state of decomposition. There is also a selection of forensic case study articles that present real-life examples of geophysics being used to locate victims. These articles usually have a ground-truthing element as well.

The division in the literature extends to citations within the two disciplines and the age of articles. In general, archaeological and forensic literature tend to use separate sets of references, with the exception of Bruce Bevan's (1991) archaeological article that is so widely cited by both professions that it is worth noting specifically here. It is generally unlikely that an archaeological text will reference the forensic geophysics research. The disconnect between the two fields may be partially due to an unfamiliarity or inaccessibility of certain publications. But it is quite clear that both fields have the same challenges and enough quality research has been done, particularly in forensics that should help with future advancements.

Publication date seems to be linked to the discipline as well. The most recent articles are predominately from the forensic geophysics community and the older articles predominately from the archaeological community. The archaeological and forensic articles from the 1990s and early 2000s are still applicable. However, because technological advances have been rapid, in terms of image processing and computer memory capabilities, the technology used quickly becomes dated. When reading these articles, it is important to remember that present day data collection parameters, data resolution, and computer processing have improved significantly.

The most discussed instrument for forensic and cemetery applications across disciplines is GPR. Even articles that do not discuss GPR frequently cite that GPR was not feasible in their set of circumstances. GPR is presented as the default method for forensic cases, and there are many examples cited where GPR was the most effective method at identifying graves, although other geophysical methods are commonly used in support of the GPR results. The next most commonly used methods are electromagnetic induction and electrical resistivity. Magnetometery data collection is often hampered by aboveground interference (i.e. metal), but it is still used occasionally. No examples were found of using LiDAR or other ground-based imaging to identify marked and unmarked graves, although there are examples of using the technology to record cemetery markers and for mapping purposes. Possible explanations for this include the relatively recent development of this technology compared to other methods and, as a result of that, insufficient time for any particular studies to have been published. However, even with this limitation, LiDAR applications have tremendous potential for cemetery applications and this is one specific area that should be pursued with additional research.

Many authors seem to be seeking a single method or set of methods that works all of the time in all conditions. The majority of these sources conclude that such a universal solution does not exist, but do often list their best methods. From a review of the literature, the best practices selected by a given researcher or set of researchers seems to be highly dependent on type of burial or grave, region of the study, specific types of soil or ground conditions, available equipment, and experience of the researcher.

There is a strong need for additional publications based on the high frequency of cemetery studies that are carried out on an annual basis in the United States. One limiting factor is that cemeteries represent the most difficult application of geophysical methods in an archaeological setting. The field conditions are challenging, the features of interest are low contrast and not easily detected, many proponents have high, if not unreal, expectations for the results, and cemeteries may not be part of a practitioner's research domain. In spite of these challenges, however, there is an extensive amount of data that can make a significant contribution to archaeological geophysics.

The Zotero database allows researchers to share and develop more advanced or nuanced queries to maximize searchability. For example, more detailed tags appear in the database (see below) that are not necessarily reflected in the print document. To fully use the database, we encourage the download and installation of the Zotero software (https://www.zotero.org). The bibliography produced is dynamic and currently resides in New South Associates' Zotero account. As the project develops, a small number of entries may be added to certain categories if they are directly relevant and/or help highlight a more limited topic or theme. Upon completion of the project, a static copy of the database can be included on CD with hard copies of the final guidebook and/or as a digital download if the guidebook will be distributed online.

Alphabetical list of tags.

Aerial Imagery	African American	Alberta	Arizona
Australia	Barbados	British Columbia	Bronze Age
Burial Mound	Cadaver Dogs	Cairo	California
Canada	CHIRP Sub-Bottom Profiler	Civil War	Clandestine Graves
Colombia	Colorado	Connecticut	Costa Rica
Egypt	Electrical Resistance Tomography	Electrical Resistivity	Electromagnetic Induction
EM Induction	Florida	Forensics	General Cemetery
Georgia	Germany	GPR	Gravity Survey
Historic Archaeology	Historic Cemetery	Holland	Iceland
Illinois	Indiana	Induced Polarization	Ireland
Italy	Japan	Kansas	Kentucky
Louisiana	Magnetometer	Magnetometry	Maine
Maryland	Mass Grave	Medieval	Metal Detector
Mexico	Michigan	Minnesota	Mississippi
Missouri	Modern Cemetery	Nebraska	New Hampshire
New Jersey	New York	New Zealand	Norway
Ohio	Oklahoma	Oregon	Pauper Cemetery
Pennsylvania	Pre-Contact Cemetery	Prehistoric Archaeology	Probe
Protohistoric Archaeology	Remote Sensing	Revolutionary War	Rhode Island
Seismic	Self Potential	Side Scan Sonar	Slave Cemetery
South Carolina	Spain	Sweden	Tennessee
Texas	Thailand	Thermal Imaging	United Kingdom
United States	Vermont	Viking	Virginia
Washington	Worldwide		

General Reference

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Advances in GPR Imaging with Multi-Channel Radar Systems from Engineering to Archaeology

Type Journal Article
Author Dean Goodman
Author Alexandre Novo
Author Gianfranco Morelli
Author Salvatore Piro
Author Doria Kutrubes
Author Henrique Lorenzo
Pages 405-411
Publication Environmental and Engineering Geophysical Society Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems 2001
Date 2011
Abstract Discusses the use of multi-channel GPR systems on five case studies. These systems have advantages over single channel systems because the 5-16-centimeter antenna spacing is so close that interpolation for data gaps may not be necessary. Allows for higher resolution data collection and faster survey time where conditions allow. One case study involved a burial in Norway.
Date Added 5/31/2016, 2:08:37 PM
Modified 6/9/2016, 9:15:44 AM

Tags:

Worldwide, General Reference, Norway, Historic Cemetery, GPR

Archaeological Geophysics for DOD Field Use: A Guide for New and Novice Users

Type Report
Author Eileen Ernenwein
Author Michael L. Hargrave
URL https://www.researchgate.net/publication/228554161_Archaeological_Geophysics_for_DoD_Field_Use_a_Guide_for_New_and_Novice_Users
Place Fayetteville, Arkansas
Date 2009
Accessed 5/9/2016, 8:00:00 PM
Institution Center for Advanced Spatial Technologies, University of Arkansas and The U.S. Army Corps of Engineers, Engineer Research and Development Center Construction Engineering Research Laboratory
Abstract Demonstrates the validity of multi-sensor approach for detecting and characterizing sub-surface deposits at archaeological sites. Includes review of electrical resistance, electrical conductivity, magnetic susceptibility, magnetometry, and GPR. Good focus on determining site suitability, instrument selection, field implementation, estimating time and cost, and expectations. Includes very brief assessment of graves as part of discussion on detectable features and instrument selection.

Date Added	5/10/2016, 10:34:19 AM
Modified	6/9/2016, 8:52:27 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Complementary Geophysical Survey Techniques: Why Two Ways are Always Better than One

Type	Journal Article
Author	R. Berle Clay
Volume	20
Issue	1
Pages	31-44
Publication	Southeastern Archaeology
ISSN	0734-578X
Date	2001
Abstract	This article discusses using two different geophysical instruments to complement each other during archaeological survey. The author used magnetic gradiometer and EM conductivity on a variety of historic and prehistoric sites. The results of each instrument are discussed with the emphasis on how different types of data support each other for interpretive purposes. The article stresses that different geophysical instruments can only work within their limitations but produce complementary results and that practioners should focus on why survey instruments produce results in a specific circumstance when others do not.
Date Added	5/31/2016, 11:06:20 AM
Modified	6/8/2016, 5:00:47 PM

Tags:

historic archaeology, General Reference, United States, electromagnetic induction, Kentucky, Mississippi, Ohio, prehistoric archaeology, Magnetometer

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Correcting for Topography and the Tilt of Ground-penetrating Radar Antennae

Type	Journal Article
Author	Dean H. Goodman
Author	Yasushi Nishimura
Author	Hiromichi Hongo
Author	Noriaki Higashi
Volume	13
Pages	159-196
Publication	Archaeological Prospection
Date	2006

Abstract This article addresses how topographic variation affects the direction GPR energy enters the ground. The authors argue that unless the data is corrected both for the terrain and the antenna tilt, the end data will be distorted. They suggest using GPR slices to solve this problem and use an example of a burial mound in Japan to illustrate the improved accuracy of data processed to account for tilt. This article provides an excellent best practice for identifying object buried within a mound.

Date Added 5/25/2016, 2:25:10 PM

Modified 8/29/2016, 4:18:47 PM

Tags:

General Reference, Japan, Historic Cemetery, GPR, Burial Mound

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Death, Decay, and Reconstruction: Approaches to Archaeology and Forensic Science

Type Book

Editor A. Boddington

Editor A.N. Garland

Editor R.C. Janaway

Place Manchester, England

Publisher Manchester University Press

Date 1987

Abstract Edited volume with articles about various themes related to forensic archaeology. Topics include causes of death, decay processes and rates, recovery, and reconstruction. Individual articles focus on the physical, chemical, and biological processes associated with decay/decomposition of the human body with multiple examples from a wide range of British cemeteries. Does not include any specific information on geophysical applications, but the topics are relevant because they have detailed data on the body, burial treatments, preservation, and burial depths.

Date Added 5/25/2016, 1:08:12 PM

Modified 6/8/2016, 1:59:00 PM

Tags:

General Reference, Clandestine Graves, United Kingdom, Forensics

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Earth Resistance for Archaeologists

Type Book

Author Armin Schmidt

Series Geophysical Methods for Archaeology

Place Lanham, Maryland

Publisher AltaMira Press, a division of Rowman & Littlefield Publishers, Inc.

ISBN 978-0-7591-1204-9

Date 2013

Call Number CC79.G46 S35 2013

Series Number Volume 3

Library Catalog Library of Congress ISBN

Abstract This book provides a theoretical and technical overview of electrical resistance/resistivity. It covers electrical currents, instrument configuration, anomaly signatures, pseudo-sections and vertical profiles, field survey parameters, data processing, and four case studies. Graves are mentioned only incidentally to other discussions.

# of Pages 195

Date Added 5/11/2016, 11:59:30 AM

Modified 6/9/2016, 12:07:43 PM

Tags:

Worldwide, electrical resistivity, General Reference

Electromagnetics for Mapping Buried Earth Features

Type Journal Article

Author Bruce W. Bevan

Volume 10

Issue 1

Pages 47-54

Publication Journal of Field Archaeology

Date 1983

Abstract Article discusses using electromagnetic induction (EM) to more quickly map large earth features and gives examples of EM applications. This is an early article about using EM for archaeology. In the conclusion, it mentions using EM for grave identification for Early Bronze Age shaft tombs in Jordan, but this is the only mention of a cemetery.

Date Added 5/20/2016, 3:08:11 PM

Modified 6/8/2016, 1:53:21 PM

Tags:

historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology

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Forensic Archaeology: Advances in Theory and Practice

Type Book

Author J. Hunter

Author M. Cox

Place London, England

Publisher Routledge

Date 2005

Abstract This book discusses forensics from an archaeological perspective. It contains a chapter that specifically addresses using geophysics for forensic applications, and case studies using geophysics are discussed. The book also summarizes how each instrument functions. This a

textbook-style work that addresses many aspects of forensics and discusses the integration of geophysics with other forensic methods.

Date Added 5/25/2016, 2:33:18 PM

Modified 6/9/2016, 9:37:45 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Clandestine Graves, Forensics, GPR, Magnetometer

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Forensic Geoscience: Applications of Geology, Geomorphology and Geophysics to Criminal Investigations

Type Journal Article

Author Alastair Ruffell

Author Jennifer McKinley

Volume 69

Pages 235-247

Publication Earth-Science Reviews

Date 2005

Abstract This review article summarizes the history of and the modern application of forensic geosciences. "Forensic geoscience" is a broad classification and includes everything from geophysics to geochemistry. The authors begin with a discussion of the discipline's history and finish with an overview of available literature that pertains to each method, including GPR, magnetics, resistivity, and ERT. This discussion extends to cover large scale landforms and microscopic particle forensic studies. The authors conclude with a suggestion that more is being done in the discipline outside of journal publication.

Date Added 6/2/2016, 8:17:45 AM

Modified 6/9/2016, 12:03:30 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Forensics, electrical resistance tomography, GPR, Magnetometer

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Forensic GPR: Finite-Difference Simulations of Responses From Buried Human Remains

Type Journal Article

Author William S. Hammon

Author George A. McMechan

Author Xiaoxian Zeng

Volume 45

Pages 171-186

Publication Journal of Applied Geophysics

Date 2000

Abstract Discusses the application of GPR to forensic investigations through modeling of reflection properties of human body tissue/bone. Provides several examples of theoretical profiles under varying environmental conditions (soil type, water content, and body part). Concludes that GPR can resolve diagnostic features of the human body; it works better in drier, sandier soils; that antenna frequencies of 900MHz or greater are most effective; and that detection of body parts is limited to before the body becomes completely skeletonized between 6 and 12 months post-mortem.

Date Added 5/25/2016, 2:28:05 PM

Modified 6/9/2016, 9:20:38 AM

Tags:

Worldwide, General Reference, Clandestine Graves, Forensics, GPR

Geophysical Archaeology Research Agendas for the Future: Some Ground-Penetrating Radar Examples

Type Journal Article

Author Lawrence B. Conyers

Author Juerg Leckebusch

Volume 17

Pages 117-123

Publication Archaeological Prospection

Date 2010

Abstract This article is a call for expanded research agendas in archaeological geophysics. It focuses on GPR and asks researchers to extend their work beyond surveys that simply identify features. The authors propose that future geophysical work should focus on answering anthropological questions and developing survey and software technology. Rather than focusing on a specific research item, this article is more of a call for research stem from an anthropological perspective rather than simple prospection.

Date Added 5/23/2016, 1:19:32 PM

Modified 8/29/2016, 4:01:45 PM

Tags:

Worldwide, historic archaeology, General Reference, prehistoric archaeology, GPR

Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration

Type Report

Author Bruce W. Bevan

Place Lincoln, Nebraska

Date 1998

Institution United States Department of the Interior, National Park Service, Midwest Archaeological Center

Abstract One of the first attempts to produce a comprehensive overview of geophysical methods for archaeology. This report includes detailed discussions of resistivity, magnetometry, conductivity (EM), and GPR. Examples focus exclusively on work at Petersburg Battlefield, with nothing specific to cemeteries. It was written before the advent of major advances in computer power and software development.

Report Number Special Report No. 1.

Date Added 1/3/2012, 11:17:14 AM

Modified 6/8/2016, 1:55:11 PM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Geophysical Survey in Archaeological Field Evaluation, Second Edition.

Type Book

Author Andrew David

Author Neil Linford

Author Paul Linford

Place Swindon, United Kingdom

Publisher Historic England

Date 2008

Abstract This manual, produced bv Historic England (formerly English Heritage), outlines geophysical techniques (magnetometery, GPR, electrical resistance, EM induction), their optimal use, basic field configurations, and data processing steps. It is set up to provide specific guidelines for geophysical work done in England and has matrices to assist planners with selecting appropriate instruments based on site-specific conditions. The manual contains a small section on cemeteries, but is extremely cautious in their recommendation to use geophysics in cemeteries.

Date Added 5/23/2016, 11:29:29 AM

Modified 6/9/2016, 8:37:06 AM

Tags:

electrical resistivity, historic archaeology, General Reference, electromagnetic induction, Metal Detector, United Kingdom, prehistoric archaeology, GPR, Magnetometer

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Geophysical Techniques for Forensic Investigation

Type Book Section

Author Peter J. Fenning

Author Laurance Donnelly

Editor Kenneth Pye

Editor Debra J. Croft

Series Special Publications

Place	London, England
Publisher	Geological Society
Pages	11-20
Date	2004
Series Number	232
Abstract	Provides a general outline of geophysical instruments and their applicability towards forensic investigations, and illustrates these with three case studies. A large variety of geophysical instruments are discussed, although the authors note that many of them have not been tested successfully in forensic cases. The case studies include a successful location of burial vaults, an unsuccessful survey for Napoleonic graves, and a large scale metal detector survey looking for secondary forensic evidence. The authors conclude with recommendations about when to use geophysics in forensic cases: primarily to consider the search area and environmental conditions, and to look for indirect evidence. This article discusses slightly outdated equipment and methods, but the conclusions are still relevant.
Book Title	Forensic Geoscience: Principles, Techniques and Applications
Date Added	5/27/2016, 10:35:12 AM
Modified	6/9/2016, 8:57:56 AM

Tags:

Modern Cemetery, electrical resistivity, General Reference, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Historic Cemetery, United Kingdom, Forensics, induced polarization, GPR, seismic, Magnetometer

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Geophysics and Burials: Field Experience and Software Development

Type	Book Section
Author	M. Watters
Author	J.R. Hunter
Editor	Kenneth Pye
Editor	Debra J. Croft
Series	Special Publications 232
Place	London, England
Publisher	Geological Society
Pages	21-31
Date	2004
Abstract	This book chapter outlines a theoretical and methodological approach to collecting and processing GPR data in forensic cases. The authors suggest both high resolution data collection methods and processing methods meant to optimize difficult and ephemeral data sets including, perpendicular grid data sets, making time slices, and using ultra high frequency antennas to target small areas. They also pay particular focus to using an equipment operator who is trained in forensic geophysics and not engineering or geology. Emphasis is also placed on working iteratively with law enforcement and investigators. The paper concludes with thoughts on how GPR might be used to identify, image, and interpret mass graves.
Book Title	Forensic Geoscience: Principles, Techniques and Applications
Date Added	5/27/2016, 10:42:13 AM

Modified 6/9/2016, 2:13:47 PM

Tags:

General Reference, United States, Mass Grave, Historic Cemetery, United Kingdom, New Hampshire, Forensics, GPR

Ground Penetrating Radar: Theory and Applications

Type Book
Author Harry Jol
Place Amsterdam, Netherlands
Publisher Elsevier
Date 2009
Abstract This textbook covers general GPR methods and theory. Consists of an edited volume with chapters on electromagnetic principles, soil properties, GPR system and design, antennas, processing and analysis, different environmental resources and conditions, engineering applications, unexploded ordinance applications, and archaeology. The archaeology chapter (authored by Dean Goodman, Salvatore Piro, Yasushi Nishimura, Kent Schneider, Hiromichi Hongo, Noriaki Higashi, John Steinburg, and Brian Damiata) covers general field and processing methods and a number of case histories dealing with prehistoric and historic archaeological sites from around the world. They include a historic Choctaw Cemetery and two Japanese burials mounds. The case studies are succinct and provide images of representative data.
Date Added 5/25/2016, 2:43:53 PM
Modified 6/9/2016, 10:15:33 AM

Tags:

General Reference, United States, Japan, Louisiana, Historic Cemetery, prehistoric archaeology, GPR, Burial Mound

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Ground Probing Radar for Historical Archaeology

Type Journal Article
Author Bruce W. Bevan
Author J. Kenyon
Volume 11
Pages 2-27
Publication MASCA Newsletter
Date 1975
Date Added 5/25/2016, 12:59:31 PM
Modified 6/8/2016, 1:52:20 PM

Tags:

General Reference, GPR

Ground-Penetrating Radar for Archaeology

Type Book
Author Lawrence Conyers
Place Walnut Creek, California
Publisher AltaMira Press
ISBN 978-0-7591-0772-4
Date 2004
Library Catalog Open WorldCat
Abstract This book was written specifically for the application of GPR to archaeology. It includes a detailed overview of GPR method and theory, equipment, velocity analysis, data processing, and basic data interpretation. A small section is devoted to the identification of graves.
# of Pages 230
Date Added 11/10/2011, 8:40:34 AM
Modified 8/29/2016, 5:37:41 PM

Tags:

Worldwide, General Reference, GPR

Ground-Penetrating Radar Techniques to Discover and Map Historic Graves

Type Journal Article
Author Lawrence Conyers
Volume 40
Issue 3
Pages 64-73
Publication Historical Archaeology
Date 2006
Abstract Conyers outlines how GPR can be used to map graves and makes an argument for GPR as an effective tool in cemetery research. He discusses the history of GPR, how GPR works, and the types of grave features GPR may be able to map in a general sense.
Date Added 12/21/2011, 9:59:01 AM
Modified 6/9/2016, 8:23:45 AM

Tags:

General Reference, graves, Historic Cemetery, GPR

Handbook of Geophysics and Archaeology

Type	Book
Author	Alan Witten
Place	London, England; Oakville, Connecticut
Publisher	Equinox Publishing
ISBN	978-1-904768-59-3
Date	2006
Library Catalog	Open WorldCat
Abstract	Highly detailed book that contains extensive information on theoretical basis for different geophysical methods, including magnetometry, EM induction, GPR, geotomography, and electrical resistance tomography (ERT). Several case studies are used for each method, but none include cemeteries. Useful book for understanding the underlying physics behind each instrument.
Date Added	12/21/2011, 10:43:37 AM
Modified	5/11/2016, 2:31:29 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Geophysics in archaeology, geophysical, electrical resistance tomography, GPR, Magnetometer

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Interpreting Ground-Penetrating Radar for Archaeology

Type	Book
Author	Lawrence Conyers
Place	Walnut Creek, California
Publisher	Left Coast Press
Date	2012
Abstract	This book focuses specifically on interpreting GPR data from a range of archaeological sites, settings, and conditions. Chapter 8, Graves and Cemeteries, has information on the general challenges encountered in cemeteries and case studies. Conyers addresses differences in cultural practices, variation in burial depth, pattern recognition, and need to carefully evaluate individual profiles in conjunction with amplitude slice maps. The entire book provides a comparative basis for interpreting a wide variety of GPR data sets.
Date Added	1/23/2013, 9:58:24 AM
Modified	8/29/2016, 6:06:03 PM

Tags:

Worldwide, General Reference, Historic Cemetery, prehistoric archaeology, GPR

Magnetometry for Archaeologists

Type	Book
Author	Arnold Aspinall
Author	Chris Gaffney

Author Armin Schmidt
Place New York, New York
Publisher Rowman Altamira
ISBN 978-0-7591-1348-0
Date 2008
Library Catalog Google Books
Abstract This book is a detailed overview of magnetic gradiometry as applied to archaeology and includes theory, method, instrumentation, practical applications, and limited case studies but there is no mention of cemeteries.
# of Pages 232
Date Added 9/28/2011, 12:03:47 PM
Modified 6/8/2016, 1:48:37 PM

Tags:

Social Science / Anthropology / General, Worldwide, General Reference, Social Science / Archaeology, Magnetometry in archaeology, Science / Geophysics, Magnetometer, Science / Magnetism

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Moisture and Soil Differences as Related to the Spatial Accuracy of GPR Amplitude Maps at Two Archaeological Test Sites.

Type Presentation
Presenter Lawrence Conyers
Place The Netherlands
Date 2004
Meeting Name Tenth International Conference on Ground Penetrating Radar
Abstract This conference paper discusses a controlled archaeological study where the author did a GPR survey in two different geographic locations (with very different soils). The controlled site had packed earth floors, burned floors, timber, beams, wall trenches, post holes, and burials. The areas were surveyed both before and after a heavy precipitation and the results were compared. The interpreted results found that some features were more visible when saturated with water. Others were less visible based on how much water they absorbed, and the type of surrounding soils. The study also looked at RDP values of soils and found that even a small amount of water can dramatically raise the RDP. The principles discussed in this article are important to both cemetery and non-cemetery GPR studies as moisture retention differences could potentially drastically change the visibility of graves in geophysical data sets.
Date Added 12/21/2011, 9:55:57 AM
Modified 8/29/2016, 4:04:54 PM

Tags:

General Reference, United States, Washington, Illinois, GPR

Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations

Type Book Section
Author Don H. Heimmer
Author Steven L. De Vore
Editor Ray A. Williamson
Editor Paul R. Nickens
Series Advances in Archaeological and Museum Science
Volume 4
Place New York, New York
Publisher Springer US
Pages 53-73
Date 2000
Abstract This book chapter outlines basic geophysical methods as they can be applied to archaeological resource management. It discusses general methods and emphasizes the use of an experienced operator.
Book Title Science and Technology in Historic Preservation
Date Added 5/23/2016, 11:38:53 AM
Modified 6/9/2016, 9:31:13 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation

Type Report
Author Kenneth L. Kvamme
Author Eileen G. Ernenwein
Author Michael L. Hargrave
Author Thomas Sever
Author Deborah Harmon
Author Fred Limp
Place Fayetteville, Arkansas.
Date 2006
Institution Center for Advanced Spatial Technologies, University of Arkansas
Abstract Comprehensive technical report focusing on the application of geophysical methods to four archaeological sites (prehistoric and historic) in different regions of the U.S. Includes information on field survey parameters, overviews of magnetometry, electrical resistivity, EM induction, and GPR, as well as data processing steps for each. One of the few publications to focus specifically on data fusion and interpretation of geophysical data. No discussion specific to cemeteries, although the principles are applicable.

Date Added 10/25/2012, 9:22:06 AM
Modified 6/9/2016, 10:37:03 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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Remote Sensing in Archaeology: an Explicitly North American Perspective

Type	Book
Editor	Jay K. Johnson
Place	Tuscaloosa, Alabama
Publisher	University of Alabama Press
ISBN	978-0-8173-5343-8
Date	2006
Library Catalog	Open WorldCat
Abstract	Edited volume intended for operators and managers with chapters from leading geophysical practitioners in the United States. The book includes background on the development and application of geophysics in North America. The bulk of the book is devoted to chapters on methods (EM conductivity, electrical resistance, GPR, magnetic susceptibility, magnetometry, data processing), and the benefits of multiple methods and ground truthing.
Short Title	Remote sensing in archaeology
Date Added	9/27/2011, 1:05:25 PM
Modified	6/9/2016, 10:05:54 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, Canada, Remote Sensing, Mexico, GPR, Magnetometer

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Revealing the Buried Past: Geophysics for Archaeologists

Type	Book
Author	Chris Gaffney
Author	John Gater
Place	Briscombe Port Stroud, United Kingdom
Publisher	Tempus Publishing Ltd.
ISBN	978-0-7524-2556-6
Date	2003
Library Catalog	Open WorldCat
Abstract	One of the first major publications to address archaeological geophysics. Includes background on development of field, theoretical principles, discussion of most common methods (electrical resistance, magnetic gradiometry, GPR, EM conductivity, metal detecting, magnetic

susceptibility), survey logistics, data processing, and case studies. Includes some discussion of burials specific to the UK, but nothing on cemeteries as a unique site type.

Short Title Revealing the buried past

Date Added 12/21/2011, 10:37:51 AM

Modified 6/9/2016, 9:06:21 AM

Tags:

Worldwide, electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Metal Detector, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Seeing Beneath the Soil: Prospecting Methods in Archaeology

Type Book

Author Anthony Clark

URL http://books.google.com/books/about/Seeing_Beneath_the_Soil.html?id=YRGI_E3-yvgC

Place London, England

Publisher B.T. Batsford, LTD

Date 1996

Accessed 1/3/2012, 10:59:42 AM

Abstract Among the first textbooks dedicated to remote sensing/geophysics and still widely cited. It provides detailed information on the most common instruments, data collection parameters, data processing, and interpretation. The focus is almost entirely on case studies in the United Kingdom. There are two brief references to graves. The first dealt with the identification of Saxon warrior burials and associated weaponry using magnetometry. The second discussed a poor response from known graves to electrical resistance that was attributed to chalky soils in the backfill.

Date Added 1/3/2012, 10:59:42 AM

Modified 6/8/2016, 4:50:35 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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The Use of Geoscience Methods for Terrestrial Forensic Searches

Type Journal Article

Author James K. Pringle

Author Alastair Ruffell

Author John R. Jervis

Author L. Donnelly

Author J. McKinley

Author J. Hansen

Author R. Morgan
Author D. Pirrie
Author M. Harrison
Volume 114
Pages 108-123
Publication Earth-Science Reviews
Date 2012
Abstract This review article surveys geoscientific methods for locating clandestine graves. It starts with broad searching techniques and then focuses on reconnaissance, where seismology, conductivity, resistivity, GPR, magnetometry, probing, geomorphology, among other techniques. Each method is described briefly along with examples and citations of its use. The post-search section discusses topsoil removal, trenches, and excavations. The authors emphasize that there is no method that works every time, success is largely dependent on environmental conditions and the type of burial.
Date Added 5/25/2016, 3:22:08 PM
Modified 6/9/2016, 11:45:53 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Metal Detector, Clandestine Graves, Forensics, GPR, seismic, Magnetometer

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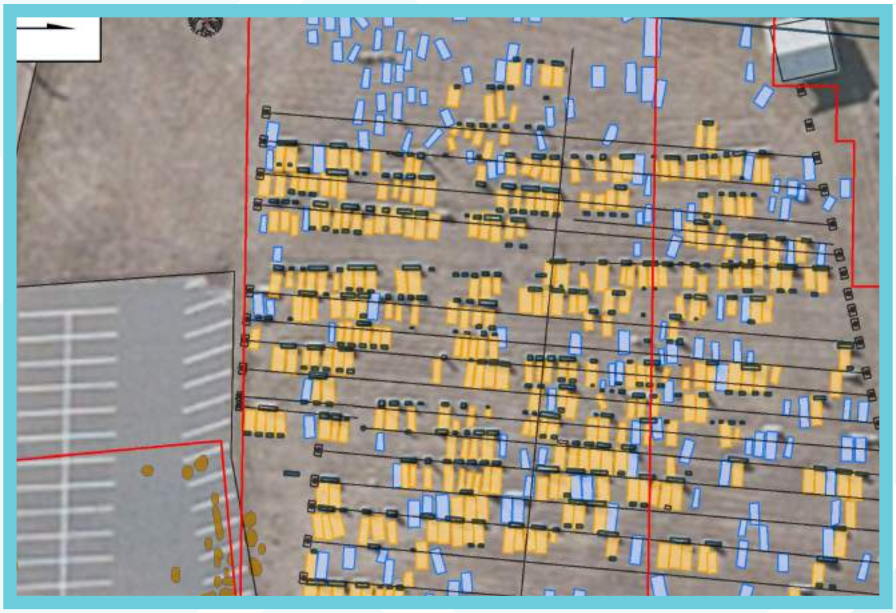
Velocity Analysis in Archaeological Ground Penetrating Radar Studies

Type Journal Article
Author Lawrence Conyers
Author Jeffery Lucius
Volume 3
Issue 1
Pages 25-38
Publication Archaeological Prospection
Date 1996
Abstract This article discusses ways to calculate the accurate conversion of the two-way travel time of electromagnetic energy to depth through velocity calculation. Methods include various reflective-wave methods and direct-wave methods. The authors recommend multiple types of velocity testing for optimal accuracy. This article is a classic methodological study that is still useful today.
Date Added 12/21/2011, 10:07:56 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

General Reference, GPR

Electrical Resistivity



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A Study of the Effect of Seasonal Climatic Factors on the Electrical Resistivity Response of Three Experimental Graves

Type Journal Article
Author John R. Jervis
Author James K. Pringle
Volume 108
Pages 53-60
Publication Journal of Applied Geophysics
Date 2014
Abstract This article discusses a study of perceived seasonal moisture effects on resistivity results obtained from pig cadavers on a test grave site. The authors tested the pig cadavers over three years, while recording weather and moisture data. They found that the observed variation the graves' resistivity was influenced by soil moisture. It is possible there is a better time of year or better weather for collecting resistivity data.
Date Added 5/26/2016, 8:42:32 AM
Modified 6/9/2016, 10:04:15 AM

Tags:

electrical resistivity, Clandestine Graves, United Kingdom, Forensics

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Archaeological Geophysics for DOD Field Use: A Guide for New and Novice Users

Type Report
Author Eileen Ernenwein
Author Michael L. Hargrave
URL https://www.researchgate.net/publication/228554161_Archaeological_Geophysics_for_DoD_Field_Use_a_Guide_for_New_and_Novice_Users
Place Fayetteville, Arkansas
Date 2009
Accessed 5/9/2016, 8:00:00 PM
Institution Center for Advanced Spatial Technologies, University of Arkansas and The U.S. Army Corps of Engineers, Engineer Research and Development Center Construction Engineering Research Laboratory
Abstract Demonstrates the validity of multi-sensor approach for detecting and characterizing sub-surface deposits at archaeological sites. Includes review of electrical resistance, electrical conductivity, magnetic susceptibility, magnetometry, and GPR. Good focus on determining site suitability, instrument selection, field implementation, estimating time and cost, and expectations. Includes very brief assessment of graves as part of discussion on detectable features and instrument selection.
Date Added 5/10/2016, 10:34:19 AM
Modified 6/9/2016, 8:52:27 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Comparisons of Magnetic and Electrical Resistivity Surveys Over Simulated Clandestine Graves in Contrasting Burial Environments

Type Journal Article
Author Alanna Juerges
Author James K. Pringle
Author John R. Jervis
Author Peter Masters
Volume 8
Pages 529-539
Publication Near Surface Geophysics
Date 2010
Abstract This article discusses a controlled pig cadaver study where magnetics and resistivity were tested in conjunction to evaluate their usefulness for detecting clandestine graves. Multiple site types were tested and the study evaluated how these instruments worked over a year. The magnetometer was deemed to be the most effective method, but both instruments working in conjunction were ultimately determined to be preferable. The study also tested the instruments at a medieval monastery where known graves have been identified.
Date Added 5/23/2016, 4:30:05 PM
Modified 6/9/2016, 10:20:00 AM

Tags:

electrical resistivity, Clandestine Graves, Historic Cemetery, United Kingdom, Forensics, Magnetometer

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Detecting Buried Human Remains Using Near-Surface Geophysical Instruments

Type Journal Article
Author Kathryn Powell
Volume 35
Pages 88-92
Publication Exploration Geophysics
Date 2004
Abstract This article discusses the use of geophysics to identify graves in an Australian environment. The author used a controlled grave site containing human cadaver, pig, and kangaroo remains. GPR was successful in locating the pigs than the kangaroo. The author also queried local police and found that searches for forensic remains with geophysics had a poor success rate. Finally, a historic burial was located with resistivity, demonstrating the application of this technique to locate historic graves.
Date Added 5/25/2016, 3:19:13 PM
Modified 6/9/2016, 11:31:35 AM

Tags:

electrical resistivity, Clandestine Graves, Australia, Forensics, GPR, Magnetometer

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Detecting Graves in a Lime Marl Environment: A Comparison of Soil Resistivity and Ground Penetrating Radar Methods

Type	Presentation
Presenter	Patrick Gleason
Presenter	Lynn Smith
Presenter	Christy Goffinet
Presenter	Niki White
Presenter	George Harrivel
Presenter	Bethany Rinard Hinga
URL	http://www.earthdoc.org/publication/publicationdetails/?publication=53081
Place	Charleston, South Carolina
Date	2011
Accessed	5/9/2016, 8:00:00 PM
Type	Poster Presentation
Meeting Name	Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Abstract	This presentation compared results from soil resistivity and a GPR (using a 270 MHz antenna) surveys at a historic cemetery located on Fort Hood, Texas. The resistivity data identified areas that had been disturbed, but not on a scale suited to locating specific graves. The GPR identified 84% of the marked graves and nine unmarked graves. The GPR was deemed more effective in these conditions. There was no discussion of reasons GPR might not have detected burials at the marked graves.
Date Added	5/10/2016, 10:48:49 AM
Modified	6/9/2016, 9:11:45 AM

Tags:

electrical resistivity, United States, Texas, Historic Cemetery, GPR

Earth Resistance for Archaeologists

Type	Book
Author	Armin Schmidt
Series	Geophysical Methods for Archaeology
Place	Lanham, Maryland
Publisher	AltaMira Press, a division of Rowman & Littlefield Publishers, Inc.
ISBN	978-0-7591-1204-9
Date	2013
Call Number	CC79.G46 S35 2013
Series Number	Volume 3
Library Catalog	Library of Congress ISBN

Abstract This book provides a theoretical and technical overview of electrical resistance/resistivity. It covers electrical currents, instrument configuration, anomaly signatures, pseudo-sections and vertical profiles, field survey parameters, data processing, and four case studies. Graves are mentioned only incidentally to other discussions.

# of Pages 195

Date Added 5/11/2016, 11:59:30 AM

Modified 6/9/2016, 12:07:43 PM

Tags:

Worldwide, electrical resistivity, General Reference

Electrical Resistivity Survey to Search for a Recent Clandestine Burial of a Homicide Victim, UK

Type Journal Article

Author James K. Pringle

Author John R. Jervis

Volume 202

Pages e1-e7

Publication Forensic Science International

Date 2010

Abstract The article discusses a case study where resistivity was used in the search for a homicide victim. Other, more traditional, search methods had failed and the resistivity was brought in to map the highest probability area. Investigators identified 7 high-priority anomalies that were comparable to pig cadaver sites where the pigs were buried for a similar period of time. The anomalies were not investigated because directly following the survey the victim was located outside of the search area. The authors believe their results would have helped to eliminate their study area quickly if it had been needed. This study illustrates the efficiency of resistivity, but it also illuminates the difficulty of identifying a small enough search area to make geophysics efficient when searching for clandestine burials.

Date Added 5/27/2016, 10:07:14 AM

Modified 6/9/2016, 11:43:30 AM

Tags:

electrical resistivity, Clandestine Graves, United Kingdom, Forensics

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Electrical Resistivity Surveys in Two Historical Cemeteries in Northeast Texas: A Method for Delineating Unidentified Burial Shafts

Type Journal Article

Author Brooks B. Ellwood

Volume 24

Issue 3

Pages 91-98
Publication Historical Archaeology
Date 1990
Abstract The article addresses using electrical resistivity on a two cemeteries in northeast Texas, one with markers and one without. The first cemetery was used to develop techniques and determine the geophysical signature of marked graves. A survey was then conducted in an unmarked cemetery where eight possible graves were identified. When tested, six of those graves were child burials dating to the 19th and 20th centuries and two were not graves. The conclusion argues for the effectiveness of these types of surveys.
Date Added 5/26/2016, 4:37:05 PM
Modified 6/9/2016, 8:50:09 AM

Tags:

electrical resistivity, United States, Texas, Historic Cemetery

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Environmental Influences on Resistivity Mapping for the Location of Clandestine Graves

Type Book Section
Author J. Scott
Author J.R. Hunter
Editor Kenneth Pye
Editor Debra J. Croft
Series Special Publications
Place London, England
Publisher Geological Society
Pages 33-38
Date 2004
Series Number 232
Abstract This article discusses resistivity surveys as a method for forensic investigation. It outlines how resistivity works and the optimal resolution for the size and type of target presented by forensic unmarked graves. The authors note that there is no "typical" scenario for crime scene variations. Two case studies involved forensic investigations where resistivity was used with limited success, although in both cases it was possible that there were no unmarked grave present in the surveyed areas. The authors concluded that resistivity is prone to detecting all kinds of ground disturbance, which can make the interpretation of grave targets difficult, particularly due to their small size. The resistivity method was determined to have limited utility to locate specific graves.
Book Title Forensic Geoscience: Principles, Techniques and Applications
Date Added 5/27/2016, 10:46:04 AM
Modified 6/9/2016, 1:47:03 PM

Tags:

electrical resistivity, Clandestine Graves, United Kingdom, Forensics

Establishing Forensic Search Methodologies and Geophysical Surveying for the Detection of Clandestine Graves in Coastal Beach Environments

Type	Journal Article
Author	James K. Pringle
Author	Claire Holland
Author	Katie Szkornik
Author	Mark Harrison
Volume	219
Pages	e29-e36
Publication	Forensic Science International
Date	2012
Abstract	This article addresses the detection of burials in coastal environments. In this study, mannequins were buried in the sand in three locations in the dunes and foreshore. The study then used a metal detector, GPR, electrical resistivity, and magnetic susceptibility to locate the mannequin with mixed results. The metal detector was ineffective (likely due to depth penetration limitations). The GPR was only effective in the dry dunes. Resistivity was effective, but not recommended in very dry sand. The magnetic susceptibility was entirely effective, but the instrument was not suitable for collecting large areas. The authors suggested a targeted approach where the specific environment is considered prior to instrument selection.
Date Added	5/27/2016, 10:31:53 AM
Modified	6/9/2016, 11:36:40 AM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, United Kingdom, Forensics, GPR

Forensic Archaeology: Advances in Theory and Practice

Type	Book
Author	J. Hunter
Author	M. Cox
Place	London, England
Publisher	Routledge
Date	2005
Abstract	This book discusses forensics from an archaeological perspective. It contains a chapter that specifically addresses using geophysics for forensic applications, and case studies using geophysics are discussed. The book also summarizes how each instrument functions. This a textbook-style work that addresses many aspects of forensics and discusses the integration of geophysics with other forensic methods.
Date Added	5/25/2016, 2:33:18 PM
Modified	6/9/2016, 9:37:45 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Clandestine Graves, Forensics, GPR, Magnetometer

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Forensic Geoscience: Applications of Geology, Geomorphology and Geophysics to Criminal Investigations

Type	Journal Article
Author	Alastair Ruffell
Author	Jennifer McKinley
Volume	69
Pages	235-247
Publication	Earth-Science Reviews
Date	2005
Abstract	This review article summarizes the history of and the modern application of forensic geosciences. "Forensic geoscience" is a broad classification and includes everything from geophysics to geochemistry. The authors begin with a discussion of the discipline's history and finish with an overview of available literature that pertains to each method, including GPR, magnetics, resistivity, and ERT. This discussion extends to cover large scale landforms and microscopic particle forensic studies. The authors conclude with a suggestion that more is being done in the discipline outside of journal publication.
Date Added	6/2/2016, 8:17:45 AM
Modified	6/9/2016, 12:03:30 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Forensics, electrical resistance tomography, GPR, Magnetometer

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Forensic Methods: Excavation for the Archaeologist and Investigator

Type	Book
Author	Melissa A Connor
Place	Lanham, Maryland
Publisher	AltaMira Press
Date	2007
Abstract	This book is a thorough overview of forensic archaeology, including preparation, fieldwork, soils, taphonomy of forensic sites, locating and excavating buried remains, evidence, documentation, and professionalization of the discipline. Methods for identifying graves include probing, cadaver dogs, test trenches, aerial photographs, and geophysical methods (metal detectors, GPR, EM, electrical resistance, and magnetometers). Includes a geophysical case study and summary of strengths/weaknesses of various methods.
Date Added	6/6/2016, 10:20:10 AM
Modified	6/8/2016, 5:02:47 PM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, Cadaver Dogs, Forensics, Probe, GPR, Magnetometer

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Geophysical Detection of Graves - Basic Background and Case Histories from Historic Cemeteries

Type	Conference Paper
Author	William James Johnson
URL	http://www.archaeology-geophysics.com/PDF%20papers/Geophysical%20Detection%20of%20Graves%202014.pdf
Place	Charleston, West Virginia
Date	2003
Accessed	5/9/2016, 8:00:00 PM
Conference Name	Council for West Virginia Archaeology Spring Workshop
Abstract	This conference paper describes geophysical methods used to identify graves in cemeteries. Discusses a case study involving a historic cemetery in Pennsylvania located adjacent to a possibe Revolutionary War training camp. The geophysical survey identified a number of graves, although did not quantify marked or unmarked grave numbers, along with possible prehistoric and historic features. The author concludes that GPR was the best technique, but other methods may help.
Date Added	5/10/2016, 11:00:08 AM
Modified	6/9/2016, 10:11:39 AM

Tags:

electrical resistivity, United States, Civil War, electromagnetic induction, Revolutionary War, Pennsylvania, Historic Cemetery, GPR, Magnetometer

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Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration

Type	Report
Author	Bruce W. Bevan
Place	Lincoln, Nebraska
Date	1998
Institution	United States Department of the Interior, National Park Service, Midwest Archaeological Center
Abstract	One of the first attempts to produce a comprehensive overview of geophysical methods for archaeology. This report includes detailed discussions of resistivity, magnetometry, conductivity (EM), and GPR. Examples focus exclusively on work at Petersburg Battlefield, with nothing specific to cemeteries. It was written before the advent of major advances in computer power and software development.
Report Number	Special Report No. 1.
Date Added	1/3/2012, 11:17:14 AM
Modified	6/8/2016, 1:55:11 PM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Geophysical Investigations in UK Graveyards: Re-Use of Existing Burial Grounds

Type	Conference Paper
Author	James D. Hansen
Author	James K. Pringle
Place	Leicester, United Kingdom
Publisher	Near Surface
Date	2011
Conference Name	17th European Meeting of Environmental and Engineering Geophysics
Abstract	Discusses the results of GPR and resistance surveys at three cemeteries in the UK. The research problem was a lack of accurate interment records and/or markers that did not accurately reflect who was buried in the cemeteries. Results identified most of the known burials and many probable unmarked burials.
Proceedings Title	Near Surface
Date Added	5/31/2016, 2:30:29 PM
Modified	6/9/2016, 9:26:40 AM

Tags:

electrical resistivity, Historic Cemetery, United Kingdom, GPR

Geophysical Mapping of Historic Cemeteries

Type	Journal Article
Author	Geoffrey Jones
Volume	3
Pages	25-28
Publication	Technical Briefs in Historical Archaeology
Date	2008
Abstract	This article focuses on best practice methods and methodologies for geophysics in cemeteries. Proposes a multiple method approach as well as careful consideration of site conditions and burial practices. The article suggests sampling strategies that account for site settings and research goals. The integration of historical, archeological, environmental, and other data is discussed along with new remote technologies including EM conductivity, thermal infrared imaging, and penetrometers. The Wyandotte County Cemetery in Kansas is used as a case study, where electrical resistance and magnetic gradiometer were used in conjunction with testing to help establish the cemetery boundary. This is an example where the magnetometer and resistance are successfully used in a historic cemetery.
Date Added	12/21/2011, 11:07:29 AM
Modified	11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, electromagnetic induction, Magnetometry in archaeology, geophysical, Historic Cemetery, Thermal Imaging, Probe, GPR, Kansas, Magnetometer

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Geophysical Monitoring of Simulated Clandestine Graves using Electrical and GPR Methods: 0-3 Years after Burial

Type	Conference Paper
Author	J.K. Pringle
Author	J.R. Jervis
Author	J.D. Hansen
Author	N.J. Cassidy
Author	G.M. Jones
Author	G.T. Tuckwell
Place	Leicester, United Kingdom
Date	2011
Conference Name	17th European Meeting of Environmental and Engineering Geophysics
Abstract	A study was conducted to systematically assess changing geophysical responses of simulated clandestine graves during three-year period after burial. Simulated burials included one empty grave, one unwrapped pig cadaver, and one pig cadaver wrapped in a tarp, all buried at 0.5-meters deep to simulate homicide victims. Results indicated the naked burial was difficult to detect after 18 months but the wrapped burial was detectable for up to three years. Resistance may be better choice for clay-rich soils.
Proceedings Title	Near Surface
Date Added	5/31/2016, 3:08:52 PM
Modified	6/9/2016, 11:49:44 AM

Tags:

electrical resistivity, Clandestine Graves, United Kingdom, Forensics, GPR

Geophysical Survey in Archaeological Field Evaluation, Second Edition.

Type	Book
Author	Andrew David
Author	Neil Linford
Author	Paul Linford
Place	Swindon, United Kingdom
Publisher	Historic England
Date	2008
Abstract	This manual, produced bv Historic England (formerly English Heritage), outlines geophysical techniques (magnetometery, GPR, electrical resistance, EM induction), their optimal use, basic field configurations, and data processing steps. It is set up to provide specific guidelines for geophysical work done in England and has matrices to assist planners with selecting appropriate instruments based on site-specific conditions. The manual contains a small section on

cemeteries, but is extremely cautious in their recommendation to use geophysics in cemeteries.

Date Added 5/23/2016, 11:29:29 AM

Modified 6/9/2016, 8:37:06 AM

Tags:

electrical resistivity, historic archaeology, General Reference, electromagnetic induction, Metal Detector, United Kingdom, prehistoric archaeology, GPR, Magnetometer

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Geophysical Surveys at the West End Cemetery, Townsville: An Application of Three Techniques

Type Journal Article

Author Ross Stanger

Author David Roe

Volume 65

Pages 44-50

Publication Australian Archaeology

Date 2007

Abstract This article discusses the application and results of resistance, GPR, and magnetometer survey of the E Block section of the Townsville cemetery in Queensland, Australia. The goal was to examine the cultural and/or ethnic association of the graves and apply geophysical instruments to this section of the country. Resistance and GPR were inconclusive due to environmental factors, but magnetometer produced excellent results. Because of metal grave markers, 65 individuals were identified and confirmed through limited excavations. The authors could then correlate the burial records with the markers to address social research questions. Magnetometer may be the best method in this region for two reasons: 1) the widespread use of metal markers and 2) environmental limits on detecting grave shafts and burial containers.

Date Added 8/9/2013, 10:34:30 AM

Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, Resistivity, Historic Cemetery, Australia, Grave Detection, GPR, Magnetometer, Unmarked Graves

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Geophysical Techniques for Forensic Investigation

Type Book Section

Author Peter J. Fenning

Author Laurance Donnelly

Editor Kenneth Pye

Editor Debra J. Croft

Series Special Publications

Place London, England

Publisher Geological Society

Pages 11-20

Date 2004

Series Number 232

Abstract Provides a general outline of geophysical instruments and their applicability towards forensic investigations, and illustrates these with three case studies. A large variety of geophysical instruments are discussed, although the authors note that many of them have not been tested successfully in forensic cases. The case studies include a successful location of burial vaults, an unsuccessful survey for Napoleonic graves, and a large scale metal detector survey looking for secondary forensic evidence. The authors conclude with recommendations about when to use geophysics in forensic cases: primarily to consider the search area and environmental conditions, and to look for indirect evidence. This article discusses slightly outdated equipment and methods, but the conclusions are still relevant.

Book Title Forensic Geoscience: Principles, Techniques and Applications

Date Added 5/27/2016, 10:35:12 AM

Modified 6/9/2016, 8:57:56 AM

Tags:

Modern Cemetery, electrical resistivity, General Reference, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Historic Cemetery, United Kingdom, Forensics, induced polarization, GPR, seismic, Magnetometer

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GPR and Bulk Ground Resistivity Surveys in Graveyards: Locating Unmarked Burials in Contrasting Soil Types

Type Journal Article

Author James D. Hansen

Author James K. Pringle

Author Jon Goodwin

Volume 237

Pages 14-29

Publication Forensic Science International

Date 2014

Abstract The article reviews GPR and resistivity studies of three formal cemeteries. These studies identified unmarked graves and extra/missing individuals from parish records in a variety of burial styles, including brick-lined interments, stacked individuals, and isolated single graves. Two of the three case studies discussed were excavated and the authors compare the survey results to the excavation results, including the types of burial containers identified and their relative visibility in the geophysical data sets. The authors determined that GPR worked best in coarse soils, resistivity worked best in clay-rich soils, and both methods worked well in sandy and black earth soils. They outline specific collection parameters and the lessons learned on both instruments. The study also concluded that unmarked burials in a cemetery were very different from clandestine burials of murder victims. This article provides an excellent example of using geophysics in a historic cemetery context where excavations were possible. The authors also

discuss geophysics as an important tool in the context of determining how many people are buried in a cemetery and where they are buried.

Date Added 5/25/2016, 2:30:12 PM

Modified 8/29/2016, 5:17:29 PM

Tags:

Modern Cemetery, electrical resistivity, Historic Cemetery, United Kingdom, Forensics, GPR

Handbook of Geophysics and Archaeology

Type Book

Author Alan Witten

Place London, England; Oakville, Connecticut

Publisher Equinox Publishing

ISBN 978-1-904768-59-3

Date 2006

Library Catalog Open WorldCat

Abstract Highly detailed book that contains extensive information on theoretical basis for different geophysical methods, including magnetometry, EM induction, GPR, geotomography, and electrical resistance tomography (ERT). Several case studies are used for each method, but none include cemeteries. Useful book for understanding the underlying physics behind each instrument.

Date Added 12/21/2011, 10:43:37 AM

Modified 5/11/2016, 2:31:29 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Geophysics in archaeology, geophysical, electrical resistance tomography, GPR, Magnetometer

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Looking for Lost Graves

Type Journal Article

Author William James Johnson

Author Donald Johnson

Author Marcella G. Johnson

Volume 20

Issue 2

Pages 20-31

Publication FastTIMES the Environmental and Engineering Geophysical Society

Date 2015

Abstract Updates a 2003 conference presentation with new case studies. Reports GPR, magnetometer, and electrical resistance studies from Pennsylvania, Ohio, and Kentucky. Concluded that GPR was the best method for identifying individual graves, but multiple instruments were recommended. Magnetometry and resistance are more suitable for defining overall cemetery context because of interference and lack of contrasts sufficient for individual grave detection.

Date Added 5/10/2016, 11:05:02 AM
Modified 6/9/2016, 10:07:20 AM

Tags:

electrical resistivity, United States, Kentucky, Pennsylvania, Ohio, Historic Cemetery, GPR, Magnetometer

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Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations

Type Book Section
Author Don H. Heimmer
Author Steven L. De Vore
Editor Ray A. Williamson
Editor Paul R. Nickens
Series Advances in Archaeological and Museum Science
Volume 4
Place New York, New York
Publisher Springer US
Pages 53-73
Date 2000
Abstract This book chapter outlines basic geophysical methods as they can be applied to archaeological resource management. It discusses general methods and emphasizes the use of an experienced operator.
Book Title Science and Technology in Historic Preservation
Date Added 5/23/2016, 11:38:53 AM
Modified 6/9/2016, 9:31:13 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation

Type Report
Author Kenneth L. Kvamme
Author Eileen G. Ernenwein
Author Michael L. Hargrave
Author Thomas Sever
Author Deborah Harmon

Author Fred Limp
Place Fayetteville, Arkansas.
Date 2006
Institution Center for Advanced Spatial Technologies, University of Arkansas
Abstract Comprehensive technical report focusing on the application of geophysical methods to four archaeological sites (prehistoric and historic) in different regions of the U.S. Includes information on field survey parameters, overviews of magnetometry, electrical resistivity, EM induction, and GPR, as well as data processing steps for each. One of the few publications to focus specifically on data fusion and interpretation of geophysical data. No discussion specific to cemeteries, although the principles are applicable.
Date Added 10/25/2012, 9:22:06 AM
Modified 6/9/2016, 10:37:03 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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Nondestructive Geophysical Surveys for Delineating Buried Tombs and Identifying their Environmental Status.

Type Journal Article
Author Mohamed G El-Behiry
Pages 399-407
Publication Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems 2000
Date 2000
Abstract This article discusses the use of EM conductivity and supporting resistivity and GPR to identify tombs in the Cairo suburbs. The study was undertaken due to development pressures. The author also discusses data processing and problems associated with complex, urban interference. The geophysical methods were successful at locating graves.
Date Added 5/23/2016, 9:32:09 AM
Modified 6/7/2016, 7:49:28 AM

Tags:

Egypt, electrical resistivity, electromagnetic induction, Historic Cemetery, Cairo, GPR

Preservation of McVicker Family Cemetery, Jonesboro, Georgia

Type Journal Article
Author Gail Tarver
Author Daniel P. Bigman
Volume 41
Issue 2

Pages 211-241
Publication Early Georgia
Date 2013
Abstract This article outlines the steps taken to preserve the McVicker family cemetery beginning with a multi-instrument geophysics survey and concluding with restoration of the cemetery stones and fencing. The geophysics identified two possible graves outside of the cemetery that were determined not related to it.
Date Added 5/25/2016, 3:56:05 PM
Modified 6/9/2016, 1:57:42 PM

Tags:

electrical resistivity, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Remote Sensing Applications in Forensic Investigations

Type Journal Article
Author G. Clark Davenport
Series Archaeologists as Forensic Investigators
Volume 35
Issue 1
Pages 87-100
Publication Historical Archaeology
Date 2001
Abstract This article outlines remote sensing methods used in forensic investigations and discusses the attributes of each type of instrument. Includes an overview of unique circumstances in forensic cases, discussion of methods/techniques that were commonly used at that time, limitations, and special considerations (e.g., results scrutinized in courts, evidence procedures, proper training). The article then briefly describes three case studies where thermal imaging and geophysics were used to assist in forensic cases. The technical sections are dated with respect to equipment advances, making them largely irrelevant, but the general emphasis on choosing the right equipment with the right resolution is remains important.
Date Added 8/6/2013, 4:18:35 PM
Modified 6/9/2016, 8:35:34 AM

Tags:

electrical resistivity, United States, electromagnetic induction, Remote Sensing, Thermal Imaging, Forensics, Grave Detection, GPR, Magnetometer

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Remote Sensing in Archaeology: an Explicitly North American Perspective

Type Book
Editor Jay K. Johnson
Place Tuscaloosa, Alabama

Publisher University of Alabama Press
ISBN 978-0-8173-5343-8
Date 2006
Library Catalog Open WorldCat
Abstract Edited volume intended for operators and managers with chapters from leading geophysical practitioners in the United States. The book includes background on the development and application of geophysics in North America. The bulk of the book is devoted to chapters on methods (EM conductivity, electrical resistance, GPR, magnetic susceptibility, magnetometry, data processing), and the benefits of multiple methods and ground truthing.
Short Title Remote sensing in archaeology
Date Added 9/27/2011, 1:05:25 PM
Modified 6/9/2016, 10:05:54 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, Canada, Remote Sensing, Mexico, GPR, Magnetometer

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Revealing the Buried Past: Geophysics for Archaeologists

Type Book
Author Chris Gaffney
Author John Gater
Place Briscombe Port Stroud, United Kingdom
Publisher Tempus Publishing Ltd.
ISBN 978-0-7524-2556-6
Date 2003
Library Catalog Open WorldCat
Abstract One of the first major publications to address archaeological geophysics. Includes background on development of field, theoretical principles, discussion of most common methods (electrical resistance, magnetic gradiometry, GPR, EM conductivity, metal detecting, magnetic susceptibility), survey logistics, data processing, and case studies. Includes some discussion of burials specific to the UK, but nothing on cemeteries as a unique site type.
Short Title Revealing the buried past
Date Added 12/21/2011, 10:37:51 AM
Modified 6/9/2016, 9:06:21 AM

Tags:

Worldwide, electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Metal Detector, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Search for the Grave of the Hanged Texas Gunfighter, William Preston Longley

Type Journal Article
Author Brooks B. Ellwood
Author Douglas W. Owsley
Author Suzanne H. Ellwood
Author Patricia A. Mercado-Allinger
Volume 28
Issue 3
Pages 94-112
Publication Historical Archaeology
Date 1994
Abstract This article details a search for the Longley grave in a Texas cemetery. The authors started with historic records and informant interviews, and then used resistivity and magnetometry to locate the grave. When both methods were less conclusive than hoped for due to modern debris and soil moisture conditions, probing and augering were used to identify multiple graves. Following those tests, a number of areas were tested using a backhoe. Many unmarked graves were tested, unfortunately they were all unlikely to be Longley due to sex, racial, or temporal distinctions. The authors concluded that their search hampered by the number of unmarked graves in the cemetery and the possibility they may have been looking in the wrong location. The technology has improved for both methods since this survey was conducted, but the authors of this study still used a robust research design for combining archival work, geophysics, and testing.
Date Added 8/5/2013, 11:54:16 AM
Modified 6/9/2016, 8:46:32 AM

Tags:

Cemetery Survey, electrical resistivity, United States, Texas, Historic Cemetery, Magnetometer, Unmarked Graves

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Searching for Graves Using Geophysical Technology: Field Tests with Ground Penetrating Radar, Magnetometry, and Electrical Resistivity.

Type Journal Article
Author Sabrina C. Buck
Volume 48
Issue 1
Pages 1-7
Publication Journal of Forensic Science
Date 2003
Abstract This article outlines field experiments using various configurations of GPR, magnetometry, and electrical resistivity to look for historic and forensic burials. The studies stated goal was to review the utility of these methods for finding human burials. The author had limited success identifying human remains and concluded that the technology methods and user skills need development. Notably, she did much of her processing in the field and used technology that would be considered outdated today.
Date Added 12/21/2011, 9:22:25 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, Magnetometry in archaeology, geophysical, Historic Cemetery, Forensics, GPR, Magnetometer

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Seeing Beneath the Soil: Prospecting Methods in Archaeology

Type	Book
Author	Anthony Clark
URL	http://books.google.com/books/about/Seeing_Beneath_the_Soil.html?id=YRGI_E3-yvgC
Place	London, England
Publisher	B.T. Batsford, LTD
Date	1996
Accessed	1/3/2012, 10:59:42 AM
Abstract	Among the first textbooks dedicated to remote sensing/geophysics and still widely cited. It provides detailed information on the most common instruments, data collection parameters, data processing, and interpretation. The focus is almost entirely on case studies in the United Kingdom. There are two brief references to graves. The first dealt with the identification of Saxon warrior burials and associated weaponry using magnetometry. The second discussed a poor response from known graves to electrical resistance that was attributed to chalky soils in the backfill.
Date Added	1/3/2012, 10:59:42 AM
Modified	6/8/2016, 4:50:35 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Situating Remote Sensing Anthropological Archaeology

Type	Journal Article
Author	Victor D. Thompson
Author	Philip J., III Arnold
Author	Thomas J. Pluckhahn
Author	Amber M. Vanderwarker
Volume	18
Pages	195-213
Publication	Archaeological Prospection
Date	2011
Abstract	This article argues that many geophysical or remote sensing projects are not integrated fully into research designs. By developing research questions that incorporate geophysics, archaeologists can address more complex anthropological questions. The authors outline a series of landscape, temporal, and construction related problems they think can be considered using geophysical data sets. They provide examples from prehistoric sites in Mexico, Georgia, and Florida to illustrate

this argument. The focus is on a theoretical approach based on the analysis of “persistent places within a regional context” rather than specific case study details.

Date Added 5/23/2016, 3:47:25 PM

Modified 8/29/2016, 4:03:16 PM

Tags:

electrical resistivity, historic archaeology, United States, Florida, Georgia, Mexico, electrical resistance tomography, prehistoric archaeology, GPR, Magnetometer

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Still Searching for Graves: An Analytical Strategy for Interpreting Geophysical Data Used in the Search for “Unmarked” Graves

Type Journal Article

Author Chris Gaffney

Author C. Harris

Author F. Pope-Carter

Author J. Bonsall

Author R. Fry

Author A. Parkyn

Volume 13

Pages 557-569

Publication Near Surface Geophysics

Date 2015

Abstract This article discusses a multi-instrument survey of a historic cemetery. The authors used magnetometer, resistivity (multiple arrays), three dimensional (multiple antenna) GPR, and EM induction. They then compared their results with the historic burial plots. The argument is that no single method identified all of the graves, and that more techniques may equate with greater success. Additionally, better integration strategies will increase interpretive ability. It should be noted that the integration strategies appeared largely computer based using the ArcGIS intersection tool.

Date Added 5/24/2016, 2:47:54 PM

Modified 6/9/2016, 9:07:58 AM

Tags:

electrical resistivity, electromagnetic induction, Historic Cemetery, United Kingdom, GPR, Magnetometer

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Techniques for Locating Burials, with Emphasis on the Probe

Type Journal Article

Author Douglas W. Owsley

Volume 40

Issue 5

Pages 735-740
Publication Journal of Forensic Sciences
Date 1995
Abstract This article discusses how probing can be a superior grave detection method in smaller, expedient surveys and in areas where geophysical survey would be impossible. The author summarizes geophysical methods and their use in forensic applications. He then discusses the application of probing in a forensic setting. The article provides a series of case studies illustrating successful uses of probes. The examples include modern forensic cases in environments unsuited to geophysics and two small historic cemetery studies requiring expedient methods. Probing does need a skilled operator and systematic methods, but the cost is considerably lower.
Date Added 6/6/2016, 4:32:34 PM
Modified 6/9/2016, 11:14:43 AM

Tags:

electrical resistivity, United States, Texas, Clandestine Graves, Virginia, Historic Cemetery, Forensics, Probe, GPR, Magnetometer

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The Detection of Human Remains

Type Book
Author Edward W. Killam
Edition Second Edition
Place Springfield, Illinois
Publisher Clarence C. Thomas, Publisher, LTD
Date 2004
Abstract This updated reference for forensic investigators is intended as a guide for locating human remains by law enforcement, archaeologists, and other investigators. Methods include ground contact, proximate, geophysical, and aerial remote sensing. Includes general overview of theory and applicability of each method. Geophysical methods can be used as principal means of location/identification, or to refine, corroborate, or eliminate certain areas. No single method is best for all situations.
Date Added 5/25/2016, 2:48:24 PM
Modified 6/9/2016, 10:32:45 AM

Tags:

electrical resistivity, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Forensics, Probe, GPR, Magnetometer

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The Use of Geoscience Methods for Terrestrial Forensic Searches

Type Journal Article
Author James K. Pringle

Author Alastair Ruffell
Author John R. Jervis
Author L. Donnelly
Author J. McKinley
Author J. Hansen
Author R. Morgan
Author D. Pirrie
Author M. Harrison
Volume 114
Pages 108-123
Publication Earth-Science Reviews
Date 2012
Abstract This review article surveys geoscientific methods for locating clandestine graves. It starts with broad searching techniques and then focuses on reconnaissance, where seismology, conductivity, resistivity, GPR, magnetometry, probing, geomorphology, among other techniques. Each method is described briefly along with examples and citations of its use. The post-search section discusses topsoil removal, trenches, and excavations. The authors emphasize that there is no method that works every time, success is largely dependent on environmental conditions and the type of burial.
Date Added 5/25/2016, 3:22:08 PM
Modified 6/9/2016, 11:45:53 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Metal Detector, Clandestine Graves, Forensics, GPR, seismic, Magnetometer

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Time-Lapse Geophysical Investigations over a Simulated Urban Clandestine Grave

Type Journal Article
Author James K. Pringle
Author John Jervis
Author John P. Cassella
Author Nigel J. Cassidy
Volume 53
Issue 6
Pages 1405-1416
Publication Journal of Forensic Science
Date 2008
Abstract This article discusses a study of the usefulness of geophysical instruments in locating a clandestine burial site in an urban environment. For the study a cadaver mannequin was buried along with animal organs and fluids. The area was examined over three months with multiple geophysical instruments. As a control, the study area was also tested with all instruments prior to installing the simulated grave. The resistivity was best at resolving the grave location, while electrical resistance tomography (ERT) and GPR were better for providing spatial information. The authors suggest that resistivity surveys be conducted prior to collecting GPR and ERT data

in forensic search conditions.

Date Added 5/27/2016, 10:26:18 AM

Modified 6/9/2016, 11:41:23 AM

Tags:

electrical resistivity, electromagnetic induction, Clandestine Graves, United Kingdom, Forensics, electrical resistance tomography, GPR, Magnetometer

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Time-Lapse Resistivity Surveys Over Simulated Clandestine Graves

Type Journal Article

Author John R. Jervis

Author James K. Pringle

Author George W. Tuckwell

Volume 192

Pages 7-13

Publication Forensic Science International

Date 2009

Abstract This article outlines a controlled study using pig cadavers and resistivity survey. Tests were conducted on wrapped and unwrapped pigs, as well as an empty grave. Resistivity surveys were performed every 28 days. Additionally, soil porosity and ground water conductivity were examined. The surveys were unable to locate the empty grave, but identified both pigs. Tests suggested that localized changes in ground water conductivity from the decomposing cadavers caused the change in resistivity.

Date Added 5/27/2016, 11:00:11 AM

Modified 6/9/2016, 9:40:56 AM

Tags:

electrical resistivity, Clandestine Graves, United Kingdom, Forensics

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Electromagnetic Induction

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A Multidisciplinary Approach to the Detection of Clandestine Graves

Type	Journal Article
Author	D.L. France
Author	T.J. Griffin
Author	J.G. Swanburg
Author	J.W. Lindemann
Author	G. Clark Davenport
Author	V. Tranunell
Author	C.T. Armbrust
Author	B. Kondratieff
Author	A. Nelson
Author	K. Castellano
Author	D. Hopkins
Volume	37
Issue	6
Pages	1445-1458
Publication	Journal of Forensic Sciences
Date	1992
Abstract	This article discusses a forensic research team assembled in Colorado. The multidisciplinary team buried pig carcasses and evaluated various techniques that included GPR, magnetics, and electromagnetics for their ability to locate the graves. Of the geophysical methods tested, GPR was the most effective. The article further recommends that law enforcement seek out a multidisciplinary approach to forensic work.
Date Added	5/20/2016, 3:49:53 PM
Modified	6/9/2016, 9:03:09 AM

Tags:

Modern Cemetery, United States, electromagnetic induction, Clandestine Graves, Forensics, Colorado, GPR, Magnetometer

Archaeological Geophysics for DOD Field Use: A Guide for New and Novice Users

Type	Report
Author	Eileen Ernenwein
Author	Michael L. Hargrave
URL	https://www.researchgate.net/publication /228554161_Archaeological_Geophysics_for_DoD_Field_Use_a_Guide_for_New_and_Novice_Users
Place	Fayetteville, Arkansas
Date	2009
Accessed	5/9/2016, 8:00:00 PM

Institution	Center for Advanced Spatial Technologies, University of Arkansas and The U.S. Army Corps of Engineers, Engineer Research and Development Center Construction Engineering Research Laboratory
Abstract	Demonstrates the validity of multi-sensor approach for detecting and characterizing sub-surface deposits at archaeological sites. Includes review of electrical resistance, electrical conductivity, magnetic susceptibility, magnetometry, and GPR. Good focus on determining site suitability, instrument selection, field implementation, estimating time and cost, and expectations. Includes very brief assessment of graves as part of discussion on detectable features and instrument selection.
Date Added	5/10/2016, 10:34:19 AM
Modified	6/9/2016, 8:52:27 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Complementary Geophysical Survey Techniques: Why Two Ways are Always Better than One

Type	Journal Article
Author	R. Berle Clay
Volume	20
Issue	1
Pages	31-44
Publication	Southeastern Archaeology
ISSN	0734-578X
Date	2001
Abstract	This article discusses using two different geophysical instruments to complement each other during archaeological survey. The author used magnetic gradiometer and EM conductivity on a variety of historic and prehistoric sites. The results of each instrument are discussed with the emphasis on how different types of data support each other for interpretive purposes. The article stresses that different geophysical instruments can only work within their limitations but produce complementary results and that practioners should focus on why survey instruments produce results in a specific circumstance when others do not.
Date Added	5/31/2016, 11:06:20 AM
Modified	6/8/2016, 5:00:47 PM

Tags:

historic archaeology, General Reference, United States, electromagnetic induction, Kentucky, Mississippi, Ohio, prehistoric archaeology, Magnetometer

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Delineation and Resolution of Cemetery Graves Using a Conductivity Meter and Ground-Penetrating Radar

Type	Journal Article

Author Charles A. Dionne
Author Dennis K. Wardlaw
Author John Schultz
Volume 5
Pages 20-30
Publication Technical Briefs in Historical Archaeology
Date 2010
Abstract Technical brief that outlines methods and results from a case study at Greenwood Cemetery in Florida. Data collection using GPR and EM conductivity in two separate areas identified burials from different periods (1957-2002 and older than 75 years). Results indicated both instruments successfully detected modern burials because of concrete vaults. Only GPR detected the non-vaulted older graves. The article recommended using transect spacing of 0.25-meter, collecting data in both directions, and orienting transects perpendicular to graves to produce best imagery.
Date Added 3/18/2015, 3:52:23 PM
Modified 8/29/2016, 4:17:13 PM

Tags:

Modern Cemetery, United States, Florida, electromagnetic induction, Historic Cemetery, GPR

Detecting Buried Remains Using Ground-Penetrating Radar

Type Report
Author John Schultz
Date 2012
Institution U.S. Department of Justice
Report Type Final Report Submitted to the National Institute for Justice, Award number: 2008-DN-BX-K132.
Abstract The study reported here involved periodic GPR and EM induction surveys of buried pig carcasses in a controlled grid over a 30-month period. EM was found to be ineffective, while GPR performed well, particularly in wet soils.
Date Added 5/25/2016, 3:39:11 PM
Modified 6/9/2016, 12:09:50 PM

Tags:

United States, Florida, electromagnetic induction, Clandestine Graves, Forensics, GPR

Effect of Grain Size on the Geophysical Responses of Indigenous Burial Sites

Type Conference Paper
Author David C. Nobes
Place Istanbul, Turkey
Publisher Near Surface
Pages 1-5
Date 2007

Conference Name 13th European Meeting of Environmental and Engineering Geophysics

Abstract This is paper discusses grave detection in clay, loess, and sand using five Maori cemeteries from New Zealand using magnetics, EM, and GPR. The results show burials in clay and loess can be identified but burials in sand do not always show responses. Different results are likely due to depositional setting. Clay and loess are usually deposited as layers or massive beds, and therefore disturbances are clear, while fluvial and Aeolian sand contain sedimentary structures that can mask geophysical responses.

Proceedings Title Near Surface

Date Added 5/31/2016, 2:56:53 PM

Modified 8/29/2016, 5:47:53 PM

Tags:

electromagnetic induction, New Zealand, Historic Cemetery, Pre-contact cemetery, GPR, Magnetometer

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Electromagnetics for Mapping Buried Earth Features

Type Journal Article

Author Bruce W. Bevan

Volume 10

Issue 1

Pages 47-54

Publication Journal of Field Archaeology

Date 1983

Abstract Article discusses using electromagnetic induction (EM) to more quickly map large earth features and gives examples of EM applications. This is an early article about using EM for archaeology. In the conclusion, it mentions using EM for grave identification for Early Bronze Age shaft tombs in Jordan, but this is the only mention of a cemetery.

Date Added 5/20/2016, 3:08:11 PM

Modified 6/8/2016, 1:53:21 PM

Tags:

historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology

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Establishing Forensic Search Methodologies and Geophysical Surveying for the Detection of Clandestine Graves in Coastal Beach Environments

Type Journal Article

Author James K. Pringle

Author Claire Holland

Author Katie Szkornik

Author Mark Harrison

Volume 219

Pages e29-e36

Publication Forensic Science International

Date 2012

Abstract This article addresses the detection of burials in coastal environments. In this study, mannequins were buried in the sand in three locations in the dunes and foreshore. The study then used a metal detector, GPR, electrical resistivity, and magnetic susceptibility to locate the mannequin with mixed results. The metal detector was ineffective (likely due to depth penetration limitations). The GPR was only effective in the dry dunes. Resistivity was effective, but not recommended in very dry sand. The magnetic susceptibility was entirely effective, but the instrument was not suitable for collecting large areas. The authors suggested a targeted approach where the specific environment is considered prior to instrument selection.

Date Added 5/27/2016, 10:31:53 AM

Modified 6/9/2016, 11:36:40 AM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, United Kingdom, Forensics, GPR

Forensic Archaeology: Advances in Theory and Practice

Type Book

Author J. Hunter

Author M. Cox

Place London, England

Publisher Routledge

Date 2005

Abstract This book discusses forensics from an archaeological perspective. It contains a chapter that specifically addresses using geophysics for forensic applications, and case studies using geophysics are discussed. The book also summarizes how each instrument functions. This a textbook-style work that addresses many aspects of forensics and discusses the integration of geophysics with other forensic methods.

Date Added 5/25/2016, 2:33:18 PM

Modified 6/9/2016, 9:37:45 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Clandestine Graves, Forensics, GPR, Magnetometer

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Forensic Geoscience: Applications of Geology, Geomorphology and Geophysics to Criminal Investigations

Type Journal Article

Author Alastair Ruffell

Author Jennifer McKinley

Volume	69
Pages	235-247
Publication	Earth-Science Reviews
Date	2005
Abstract	This review article summarizes the history of and the modern application of forensic geosciences. "Forensic geoscience" is a broad classification and includes everything from geophysics to geochemistry. The authors begin with a discussion of the discipline's history and finish with an overview of available literature that pertains to each method, including GPR, magnetics, resistivity, and ERT. This discussion extends to cover large scale landforms and microscopic particle forensic studies. The authors conclude with a suggestion that more is being done in the discipline outside of journal publication.
Date Added	6/2/2016, 8:17:45 AM
Modified	6/9/2016, 12:03:30 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Forensics, electrical resistance tomography, GPR, Magnetometer

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Forensic Methods: Excavation for the Archaeologist and Investigator

Type	Book
Author	Melissa A Connor
Place	Lanham, Maryland
Publisher	AltaMira Press
Date	2007
Abstract	This book is a thorough overview of forensic archaeology, including preparation, fieldwork, soils, taphonomy of forensic sites, locating and excavating buried remains, evidence, documentation, and professionalization of the discipline. Methods for identifying graves include probing, cadaver dogs, test trenches, aerial photographs, and geophysical methods (metal detectors, GPR, EM, electrical resistance, and magnetometers). Includes a geophysical case study and summary of strengths/weaknesses of various methods.
Date Added	6/6/2016, 10:20:10 AM
Modified	6/8/2016, 5:02:47 PM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, Cadaver Dogs, Forensics, Probe, GPR, Magnetometer

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Geophysical Detection of Graves - Basic Background and Case Histories from Historic Cemeteries

Type	Conference Paper
Author	William James Johnson

URL	http://www.archaeology-geophysics.com/PDF%20papers/Geophysical%20Detection%20of%20Graves%202014.pdf
Place	Charleston, West Virginia
Date	2003
Accessed	5/9/2016, 8:00:00 PM
Conference Name	Council for West Virginia Archaeology Spring Workshop
Abstract	This conference paper describes geophysical methods used to identify graves in cemeteries. Discusses a case study involving a historic cemetery in Pennsylvania located adjacent to a possibe Revolutionary War training camp. The geophysical survey identified a number of graves, although did not quantify marked or unmarked grave numbers, along with possible prehistoric and historic features. The author concludes that GPR was the best technique, but other methods may help.
Date Added	5/10/2016, 11:00:08 AM
Modified	6/9/2016, 10:11:39 AM

Tags:

electrical resistivity, United States, Civil War, electromagnetic induction, Revolutionary War, Pennsylvania, Historic Cemetery, GPR, Magnetometer

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Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration

Type	Report
Author	Bruce W. Bevan
Place	Lincoln, Nebraska
Date	1998
Institution	United States Department of the Interior, National Park Service, Midwest Archaeological Center
Abstract	One of the first attempts to produce a comprehensive overview of geophysical methods for archaeology. This report includes detailed discussions of resistivity, magnetometry, conductivity (EM), and GPR. Examples focus exclusively on work at Petersburg Battlefield, with nothing specific to cemeteries. It was written before the advent of major advances in computer power and software development.
Report Number	Special Report No. 1.
Date Added	1/3/2012, 11:17:14 AM
Modified	6/8/2016, 1:55:11 PM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Geophysical Identification of Unmarked Historic Graves

Type	Journal Article
Author	Rinita Dalan
Author	Steven L. De Vore

Author R. Berle Clay
Volume 25
Issue 5
Pages 572-601
Publication Geoarchaeology: An International Journal
Date 2010
Abstract Article focuses on application of magnetic susceptibility through down-hole testing to identify graves. The method was applied to three cemeteries and supplemented prior geophysical survey (GPR, electrical resistance, conductivity, and magnetometry). Results indicated that grave shafts had lower magnetic signatures related to differential compaction. Distinctions were most apparent at depths beyond the reach of penetrometers. Magnetic studies of interments suggested spatially patterned magnetically enhanced zones might also aid in detection.
Date Added 3/18/2015, 2:36:06 PM
Modified 6/9/2016, 8:31:49 AM

Tags:

United States, electromagnetic induction, Nebraska, Kentucky, Historic Cemetery, Kansas

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Geophysical Mapping of an Entire Municipal Cemetery

Type Journal Article
Author Keith J. Sjostrom
Author Kenneth J. Ryerson
Author James Watson
Author Douglas Bock
Author Dan Rush
Pages 1032-1041
Publication 9th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 2009
Abstract This article summarizes a multi-channel GPR and EM survey of an active cemetery in Arizona. The survey utilized concurrent and optimized collection strategies so the 6.2 acre cemetery could be collected in two days. The authors discuss a variety of proprietary software collection and interpretation packages that allowed them to create a grave map for the town. Notably there is no discussion of nuance and variability in cemetery interpretation.
Date Added 5/11/2016, 12:01:19 PM
Modified 6/9/2016, 1:47:45 PM

Tags:

Modern Cemetery, United States, Arizona, electromagnetic induction, Historic Cemetery, GPR

Geophysical Mapping of Historic Cemeteries

Type Journal Article
Author Geoffrey Jones
Volume 3
Pages 25-28
Publication Technical Briefs in Historical Archaeology
Date 2008
Abstract This article focuses on best practice methods and methodologies for geophysics in cemeteries. Proposes a multiple method approach as well as careful consideration of site conditions and burial practices. The article suggests sampling strategies that account for site settings and research goals. The integration of historical, archeological, environmental, and other data is discussed along with new remote technologies including EM conductivity, thermal infrared imaging, and penetrometers. The Wyandotte County Cemetery in Kansas is used as a case study, where electrical resistance and magnetic gradiometer were used in conjunction with testing to help establish the cemetery boundary. This is an example where the magnetometer and resistance are successfully used in a historic cemetery.
Date Added 12/21/2011, 11:07:29 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, electromagnetic induction, Magnetometry in archaeology, geophysical, Historic Cemetery, Thermal Imaging, Probe, GPR, Kansas, Magnetometer

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Geophysical Survey in Archaeological Field Evaluation, Second Edition.

Type Book
Author Andrew David
Author Neil Linford
Author Paul Linford
Place Swindon, United Kingdom
Publisher Historic England
Date 2008
Abstract This manual, produced bv Historic England (formerly English Heritage), outlines geophysical techniques (magnetometery, GPR, electrical resistance, EM induction), their optimal use, basic field configurations, and data processing steps. It is set up to provide specific guidelines for geophysical work done in England and has matrices to assist planners with selecting appropriate instruments based on site-specific conditions. The manual contains a small section on cemeteries, but is extremely cautious in their recommendation to use geophysics in cemeteries.
Date Added 5/23/2016, 11:29:29 AM
Modified 6/9/2016, 8:37:06 AM

Tags:

electrical resistivity, historic archaeology, General Reference, electromagnetic induction, Metal Detector, United Kingdom, prehistoric archaeology, GPR, Magnetometer

Geophysical Surveys of Burial Sites: A Case Study of the Oaro Urupa

Type Journal Article
Author David C. Nobes
Volume 64
Issue 2
Pages 357-367
Publication Geophysics
Date 1999
Abstract The article outlines a survey in a Maori cemetery in use since the 19th century. EM, magnetometer and GPR were used to map the cemetery. These datasets were then normalized and combined to make a grave probability map for the present populations to use when they are looking for appropriate burial locations. The article focuses on survey design and best practices for a practical report product.
Date Added 5/25/2016, 3:11:21 PM
Modified 8/29/2016, 4:07:59 PM

Tags:

electromagnetic induction, New Zealand, Historic Cemetery, Pre-contact cemetery, GPR, Magnetometer

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Geophysical Techniques for Forensic Investigation

Type Book Section
Author Peter J. Fenning
Author Laurance Donnelly
Editor Kenneth Pye
Editor Debra J. Croft
Series Special Publications
Place London, England
Publisher Geological Society
Pages 11-20
Date 2004
Series Number 232
Abstract Provides a general outline of geophysical instruments and their applicability towards forensic investigations, and illustrates these with three case studies. A large variety of geophysical instruments are discussed, although the authors note that many of them have not been tested successfully in forensic cases. The case studies include a successful location of burial vaults, an unsuccessful survey for Napoleonic graves, and a large scale metal detector survey looking for secondary forensic evidence. The authors conclude with recommendations about when to use geophysics in forensic cases: primarily to consider the search area and environmental conditions, and to look for indirect evidence. This article discusses slightly outdated equipment and methods, but the conclusions are still relevant.
Book Title Forensic Geoscience: Principles, Techniques and Applications
Date Added 5/27/2016, 10:35:12 AM

Modified 6/9/2016, 8:57:56 AM

Tags:

Modern Cemetery, electrical resistivity, General Reference, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Historic Cemetery, United Kingdom, Forensics, induced polarization, GPR, seismic, Magnetometer

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Ground-Penetrating Radar Profile Spacing and Orientation for Subsurface Resolution of Linear Features.

Type Journal Article
Author James E. Pomfret
Volume 13
Pages 151-153
Publication Archaeological Prospection
Date 2006
Abstract Discusses transect/profile spacing for GPR survey on two different sites in the Georgia Coastal Plain.
Date Added 12/21/2011, 11:28:59 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

African American, cemetery, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Handbook of Geophysics and Archaeology

Type Book
Author Alan Witten
Place London, England; Oakville, Connecticut
Publisher Equinox Publishing
ISBN 978-1-904768-59-3
Date 2006
Library Catalog Open WorldCat
Abstract Highly detailed book that contains extensive information on theoretical basis for different geophysical methods, including magnetometry, EM induction, GPR, geotomography, and electrical resistance tomography (ERT). Several case studies are used for each method, but none include cemeteries. Useful book for understanding the underlying physics behind each instrument.
Date Added 12/21/2011, 10:43:37 AM
Modified 5/11/2016, 2:31:29 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Geophysics in archaeology, geophysical, electrical resistance tomography, GPR, Magnetometer

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Identifying and Protecting Native American Graves Using Electromagnetic Induction: A Case Study From Central Georgia

Type	Journal Article
Author	Daniel Bigman
Volume	19
Pages	31-39
Publication	Archaeological Prospection
Date	2011
Abstract	Bigman outlines the principles of EM induction and discusses why these principles could provide good data resolution at the Ocmulgee Funeral Mound. The survey successfully documented over 60 possible prehistoric graves and a few possible prehistoric or historic structures. There is a possibility that there may be some false positives and no testing was possible.
Date Added	5/31/2016, 2:19:36 PM
Modified	6/7/2016, 8:17:33 AM

Tags:

United States, electromagnetic induction, Georgia, prehistoric archaeology

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Magnetic Ghosts: Mineral Magnetic Measurements on Roman and Anglo-Saxon Graves

Type	Journal Article
Author	Neil T. Linford
Volume	11
Pages	167-180
Publication	Archaeological Prospection
Date	2004
Abstract	The article discusses finding graves with magnetics and discusses the challenges associated with the magnetic identification of graves. The author discusses two case studies which both identified graves, one using the magnetometer and the other using magnetic susceptibility. The study also assessed the magnetic properties of the soils and discusses the biogenic enhancement of soils due to decomposing organic materials.
Date Added	5/25/2016, 2:54:08 PM
Modified	6/9/2016, 10:37:56 AM

Tags:

electromagnetic induction, Historic Cemetery, United Kingdom, Magnetometer

Mapping Social Relations: Geophysical Survey of a Nineteenth-Century Slave Cemetery

Type Journal Article
Author Daniel P. Bigman
Volume 6
Pages 17-30
Publication Archaeological and Anthropological Science
Date 2014
Abstract A single section of a known cemetery was surveyed for unmarked graves with GPR, EM, and magnetic susceptibility because it was thought to contain unmarked slave burials. Multiple graves were identified with GPR and magnetic susceptibility and some were tested with a probe. Bigman concludes by making the argument that because the identified possible graves are in an orderly row next to the cemetery the planter family had a more progressive attitude to the slave than was typical at the time.
Date Added 8/6/2015, 1:44:26 PM
Modified 6/8/2016, 1:56:17 PM

Tags:

United States, electromagnetic induction, Slave Cemetery, Georgia, Historic Cemetery, GPR

Merging Cultures and Curriculums: Enriching Heritage and Education With Applied Geophysics.

Type Journal Article
Author Tate Meehan
Author Timothy S. De Smet
Author Charles Stanford
Volume 20
Issue 2
Pages 61-70
Publication FastTIMES the Environmental and Engineering Geophysical Society
Date 2015
Language 2015
Abstract Discusses blending of geophysical survey with community outreach involving a historical African American cemetery in Texas. The authors created a high-precision topographic map and conducted magnetic and EM surveys of the cemetery. GPR was not suitable because of ground conditions. The community wanted to know precise grave locations but there was ambiguity with interpretations.
Date Added 5/10/2016, 1:54:54 PM
Modified 6/9/2016, 10:40:36 AM

Tags:

African American, United States, electromagnetic induction, Texas, Historic Cemetery, Magnetometer

Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations

Type Book Section
Author Don H. Heimmer
Author Steven L. De Vore
Editor Ray A. Williamson
Editor Paul R. Nickens
Series Advances in Archaeological and Museum Science
Volume 4
Place New York, New York
Publisher Springer US
Pages 53-73
Date 2000
Abstract This book chapter outlines basic geophysical methods as they can be applied to archaeological resource management. It discusses general methods and emphasizes the use of an experienced operator.
Book Title Science and Technology in Historic Preservation
Date Added 5/23/2016, 11:38:53 AM
Modified 6/9/2016, 9:31:13 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation

Type Report
Author Kenneth L. Kvamme
Author Eileen G. Ernenwein
Author Michael L. Hargrave
Author Thomas Sever
Author Deborah Harmon
Author Fred Limp
Place Fayetteville, Arkansas.
Date 2006
Institution Center for Advanced Spatial Technologies, University of Arkansas
Abstract Comprehensive technical report focusing on the application of geophysical methods to four archaeological sites (prehistoric and historic) in different regions of the U.S. Includes information on field survey parameters, overviews of magnetometry, electrical resistivity, EM induction, and GPR, as well as data processing steps for each. One of the few publications to focus specifically on data fusion and interpretation of geophysical data. No discussion specific to

cemeteries, although the principles are applicable.

Date Added 10/25/2012, 9:22:06 AM

Modified 6/9/2016, 10:37:03 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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Nondestructive Geophysical Surveys for Delineating Buried Tombs and Identifying their Environmental Status.

Type Journal Article

Author Mohamed G El-Behiry

Pages 399-407

Publication Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems 2000

Date 2000

Abstract This article discusses the use of EM conductivity and supporting resistivity and GPR to identify tombs in the Cairo suburbs. The study was undertaken due to development pressures. The author also discusses data processing and problems associated with complex, urban interference. The geophysical methods were successful at locating graves.

Date Added 5/23/2016, 9:32:09 AM

Modified 6/7/2016, 7:49:28 AM

Tags:

Egypt, electrical resistivity, electromagnetic induction, Historic Cemetery, Cairo, GPR

Preservation of McVicker Family Cemetery, Jonesboro, Georgia

Type Journal Article

Author Gail Tarver

Author Daniel P. Bigman

Volume 41

Issue 2

Pages 211-241

Publication Early Georgia

Date 2013

Abstract This article outlines the steps taken to preserve the McVicker family cemetery beginning with a multi-instrument geophysics survey and concluding with restoration of the cemetery stones and fencing. The geophysics identified two possible graves outside of the cemetery that were determined not related to it.

Date Added 5/25/2016, 3:56:05 PM

Modified 6/9/2016, 1:57:42 PM

Tags:

electrical resistivity, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Remote Sensing Applications in Forensic Investigations

Type	Journal Article
Author	G. Clark Davenport
Series	Archaeologists as Forensic Investigators
Volume	35
Issue	1
Pages	87-100
Publication	Historical Archaeology
Date	2001
Abstract	This article outlines remote sensing methods used in forensic investigations and discusses the attributes of each type of instrument. Includes an overview of unique circumstances in forensic cases, discussion of methods/techniques that were commonly used at that time, limitations, and special considerations (e.g., results scrutinized in courts, evidence procedures, proper training). The article then briefly describes three case studies where thermal imaging and geophysics were used to assist in forensic cases. The technical sections are dated with respect to equipment advances, making them largely irrelevant, but the general emphasis on choosing the right equipment with the right resolution is remains important.
Date Added	8/6/2013, 4:18:35 PM
Modified	6/9/2016, 8:35:34 AM

Tags:

electrical resistivity, United States, electromagnetic induction, Remote Sensing, Thermal Imaging, Forensics, Grave Detection, GPR, Magnetometer

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Remote Sensing in Archaeology: an Explicitly North American Perspective

Type	Book
Editor	Jay K. Johnson
Place	Tuscaloosa, Alabama
Publisher	University of Alabama Press
ISBN	978-0-8173-5343-8
Date	2006
Library Catalog	Open WorldCat
Abstract	Edited volume intended for operators and managers with chapters from leading geophysical practitioners in the United States. The book includes background on the development and application of geophysics in North America. The bulk of the book is devoted to chapters on methods (EM conductivity, electrical resistance, GPR, magnetic susceptibility, magnetometry,

data processing), and the benefits of multiple methods and ground truthing.

Short Title Remote sensing in archaeology

Date Added 9/27/2011, 1:05:25 PM

Modified 6/9/2016, 10:05:54 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, Canada, Remote Sensing, Mexico, GPR, Magnetometer

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Revealing the Buried Past: Geophysics for Archaeologists

Type Book

Author Chris Gaffney

Author John Gater

Place Briscombe Port Stroud, United Kingdom

Publisher Tempus Publishing Ltd.

ISBN 978-0-7524-2556-6

Date 2003

Library Catalog Open WorldCat

Abstract One of the first major publications to address archaeological geophysics. Includes background on development of field, theoretical principles, discussion of most common methods (electrical resistance, magnetic gradiometry, GPR, EM conductivity, metal detecting, magnetic susceptibility), survey logistics, data processing, and case studies. Includes some discussion of burials specific to the UK, but nothing on cemeteries as a unique site type.

Short Title Revealing the buried past

Date Added 12/21/2011, 10:37:51 AM

Modified 6/9/2016, 9:06:21 AM

Tags:

Worldwide, electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Metal Detector, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Seeing Beneath the Soil: Prospecting Methods in Archaeology

Type Book

Author Anthony Clark

URL http://books.google.com/books/about/Seeing_Beneath_the_Soil.html?id=YRGI_E3-yvgC

Place London, England

Publisher B.T. Batsford, LTD

Date 1996

Accessed 1/3/2012, 10:59:42 AM

Abstract Among the first textbooks dedicated to remote sensing/geophysics and still widely cited. It provides detailed information on the most common instruments, data collection parameters, data processing, and interpretation. The focus is almost entirely on case studies in the United Kingdom. There are two brief references to graves. The first dealt with the identification of Saxon warrior burials and associated weaponry using magnetometry. The second discussed a poor response from known graves to electrical resistance that was attributed to chalky soils in the backfill.

Date Added 1/3/2012, 10:59:42 AM

Modified 6/8/2016, 4:50:35 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Soilwater Conductivity Analysis to Date and Locate Clandestine Graves of Homicide Victims

Type Journal Article

Author James K. Pringle

Author John P. Cassella

Author John R. Jervis

Author Anna Williams

Author Peter Cross

Author Nigel J. Cassidy

Volume 60

Issue 4

Pages 1052-1060

Publication Journal of Forensic Sciences

Date 2015

Abstract This article discusses the results of a controlled study using pig cadavers and testing soil water resistivity over six years. The study controlled for variables of moisture and typical ground conditions. It found that soil water conductivity was highest two years after burial, but declined to background levels 4.25 years after burial.

Date Added 5/27/2016, 11:15:22 AM

Modified 6/9/2016, 11:33:21 AM

Tags:

electromagnetic induction, Clandestine Graves, United Kingdom, Forensics

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Still Searching for Graves: An Analytical Strategy for Interpreting Geophysical Data Used in the Search for "Unmarked" Graves

Type Journal Article

Author Chris Gaffney
Author C. Harris
Author F. Pope-Carter
Author J. Bonsall
Author R. Fry
Author A. Parkyn
Volume 13
Pages 557-569
Publication Near Surface Geophysics
Date 2015
Abstract This article discusses a multi-instrument survey of a historic cemetery. The authors used magnetometer, resistivity (multiple arrays), three dimensional (multiple antenna) GPR, and EM induction. They then compared their results with the historic burial plots. The argument is that no single method identified all of the graves, and that more techniques may equate with greater success. Additionally, better integration strategies will increase interpretive ability. It should be noted that the integration strategies appeared largely computer based using the ArcGIS intersection tool.
Date Added 5/24/2016, 2:47:54 PM
Modified 6/9/2016, 9:07:58 AM

Tags:

electrical resistivity, electromagnetic induction, Historic Cemetery, United Kingdom, GPR, Magnetometer

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The Application of Geophysics to Archaeologic Mapping of Prehistoric, Protohistoric, and Historic Sites in Western Canada

Type Journal Article
Author Paul Bauman
Author Rod Heitzmann
Author Jack Porter
Pages 359-373
Publication 9th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 1995
Abstract This article outlines a study done at two fur trading posts, native campsites, and historic cemeteries in Alberta. The survey consisted of GPR, magnetometer, and EM conductivity. Because the fort was burned after abandonment, the magnetometer was most effective at mapping post holes. The GPR was effective at locating cellars and clearly pinpointed several burial sites. The article argues that multiple instruments are important in geophysical survey. Notably, this is an early article and equipment and software has improved significantly since this was published.
Date Added 5/25/2016, 9:29:21 AM
Modified 6/8/2016, 1:51:49 PM

Tags:

historic archaeology, electromagnetic induction, Canada, protohistoric archaeology, Alberta, Historic Cemetery, prehistoric archaeology, GPR, Magnetometer

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The Detection of Human Remains

Type	Book
Author	Edward W. Killam
Edition	Second Edition
Place	Springfield, Illinois
Publisher	Clarence C. Thomas, Publisher, LTD
Date	2004
Abstract	This updated reference for forensic investigators is intended as a guide for locating human remains by law enforcement, archaeologists, and other investigators. Methods include ground contact, proximate, geophysical, and aerial remote sensing. Includes general overview of theory and applicability of each method. Geophysical methods can be used as principal means of location/identification, or to refine, corroborate, or eliminate certain areas. No single method is best for all situations.
Date Added	5/25/2016, 2:48:24 PM
Modified	6/9/2016, 10:32:45 AM

Tags:

electrical resistivity, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Forensics, Probe, GPR, Magnetometer

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The Search for "Yvonne": A Case Example of the Delineation of a Grave Using Near-Surface Geophysical Methods

Type	Journal Article
Author	David C. Nobes
Volume	45
Issue	3
Pages	715-721
Publication	Journal of Forensic Sciences
Date	2000
Abstract	This article outlines a search for the remains of a homicide victim. The searchers had a reasonable idea about where the victim might be, but needed a more certain target. They covered a large area with EM and a smaller area with GPR. The area was heavily disturbed by forestry operations and there were a number of anomalous readings due to metal debris and tree roots. An isolated EM anomaly on the edge of the grid located the body and GPR was of minimumal use due to the complexity of the subsurface.
Date Added	5/25/2016, 3:14:13 PM
Modified	6/9/2016, 11:08:15 AM

Tags:

electromagnetic induction, New Zealand, Clandestine Graves, Forensics, GPR

The Search for Graves

Type	Journal Article
Author	Bruce W. Bevan
Volume	56
Issue	9
Pages	1310-1319
Publication	Geophysics
Date	1991
Abstract	One of the first publications to deal specifically with cemeteries. Bevan used GPR and EM conductivity at nine different cemeteries in the U.S (diverse environmental settings). GPR tends to detect the bottom of the grave or the shaft. EM tends to detect grave shafts and/or metal (if in sufficient quantities in detectable range). Bevan concluded that there is no guarantee of success because of false positives and not detecting marked graves in certain cases. Although dated, this is an important article because it contains a range of cemetery types and has technical information assessing the results and it still holds relevance.
Date Added	8/6/2013, 1:45:00 PM
Modified	6/8/2016, 1:54:13 PM

Tags:

Cemetery Survey, Modern Cemetery, United States, electromagnetic induction, Slave Cemetery, New York, Maryland, Rhode Island, Ohio, Historic Cemetery, Pauper Cemetery, Minnesota, GPR, Viriginia

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The Tulsa Race Riot of 1921: A Geophysical Study to Locate a Mass Grave

Type	Journal Article
Author	Alan Witten
Author	Robert Brooks
Author	Thomas Fenner
Volume	20
Pages	655-660
Publication	The Leading Edge
Date	2001
Abstract	This short article discusses the search for a mass grave of the African American victims of the Tulsa Race Riot of 1921. Magnetometer and electromagnetic induction were used in an area where an eye witness recalled seeing crates of bodies. Two specific anomalies identified with magnetic instruments were tested with GPR and one anomaly with trench-like features was isolated for further testing. The article was written prior to testing.
Date Added	5/24/2016, 9:24:25 AM
Modified	5/24/2016, 9:26:04 AM

Tags:

United States, electromagnetic induction, Mass Grave, Historic Cemetery, Oklahoma, Forensics, GPR, Magnetometer

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The Use of Electromagnetic Induction in Locating Graves and Mapping Cemeteries: an Example from Native North America

Type	Journal Article
Author	Daniel P. Bigman
Volume	19
Pages	31-39
Publication	Archaeological Prospection
Date	2012
Abstract	Bigman outlines the principles of EM induction and discusses why these principles could provide good data resolution at the Ocmulgee Funeral Mound. The survey successfully documented over 60 possible prehistoric graves and a few possible prehistoric or historic structures. There is a possibility that there may be some false positives and no testing was allowed on the site.
Date Added	8/6/2013, 1:05:18 PM
Modified	8/29/2016, 5:53:46 PM

Tags:

United States, electromagnetic induction, Georgia, prehistoric archaeology

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The Use of Geoscience Methods for Terrestrial Forensic Searches

Type	Journal Article
Author	James K. Pringle
Author	Alastair Ruffell
Author	John R. Jervis
Author	L. Donnelly
Author	J. McKinley
Author	J. Hansen
Author	R. Morgan
Author	D. Pirrie
Author	M. Harrison
Volume	114
Pages	108-123
Publication	Earth-Science Reviews
Date	2012

Abstract This review article surveys geoscientific methods for locating clandestine graves. It starts with broad searching techniques and then focuses on reconnaissance, where seismology, conductivity, resistivity, GPR, magnetometry, probing, geomorphology, among other techniques. Each method is described briefly along with examples and citations of its use. The post-search section discusses topsoil removal, trenches, and excavations. The authors emphasize that there is no method that works every time, success is largely dependent on environmental conditions and the type of burial.

Date Added 5/25/2016, 3:22:08 PM

Modified 6/9/2016, 11:45:53 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Metal Detector, Clandestine Graves, Forensics, GPR, seismic, Magnetometer

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Time-Lapse Geophysical Investigations over a Simulated Urban Clandestine Grave

Type Journal Article

Author James K. Pringle

Author John Jervis

Author John P. Cassella

Author Nigel J. Cassidy

Volume 53

Issue 6

Pages 1405-1416

Publication Journal of Forensic Science

Date 2008

Abstract This article discusses a study of the usefulness of geophysical instruments in locating a clandestine burial site in an urban environment. For the study a cadaver mannequin was buried along with animal organs and fluids. The area was examined over three months with multiple geophysical instruments. As a control, the study area was also tested with all instruments prior to installing the simulated grave. The resistivity was best at resolving the grave location, while electrical resistance tomography (ERT) and GPR were better for providing spatial information. The authors suggest that resistivity surveys be conducted prior to collecting GPR and ERT data in forensic search conditions.

Date Added 5/27/2016, 10:26:18 AM

Modified 6/9/2016, 11:41:23 AM

Tags:

electrical resistivity, electromagnetic induction, Clandestine Graves, United Kingdom, Forensics, electrical resistance tomography, GPR, Magnetometer

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Use of Precision Mapping and Multiple Geophysical Methods at the Historic Reese Cemetery in Muncie, Indiana

Type	Journal Article
Author	Gregory B. Byer
Author	John A. Mundell
Pages	68-79
Publication	16th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems.
Date	2003
Abstract	This article outlines a program of geophysical research at a historic cemetery in Indiana. This cemetery could not be excavated due to both regulatory and ethical concerns but was known to contain unmarked burials. The survey team used EM metal detector, EM conductivity, and GPR. The EM metal detecting was of limited utility and the EM conductivity was somewhat more useful. The GPR provided the most data about marked and unmarked graves including the more subtle, older graves.
Date Added	5/23/2016, 2:17:15 PM
Modified	6/8/2016, 2:31:13 PM

Tags:

United States, Indiana, electromagnetic induction, Metal Detector, Historic Cemetery, GPR

GPR
(Ground Penetrating Radar)

Intentionally Left Blank

3D GPR in Forensics: Finding a Clandestine Grave in a Mountainous Environment

Type Journal Article
Author Alexandre Novo
Author Henrique Lorenzo
Author Fernanando I. Rial
Author Mercedes Solla
Volume 204
Pages 134-138
Publication Forensic Science International
Date 2011
Abstract This article outlines a forensic investigation in a mountainous setting. The authors discuss choosing an antenna frequency that was best suited to rough terrain (250 MHz). They then outline the results they provided law enforcement, which includes a hierarchy of certainty. No excavation or testing results are provided. Although the title references three-dimensional GPR, the actual work was conducted with a single antenna, not an array of antenae.
Date Added 5/27/2016, 11:04:04 AM
Modified 6/9/2016, 11:11:26 AM

Tags:

Spain, Clandestine Graves, Forensics, GPR

A Multidisciplinary Approach to the Detection of Clandestine Graves

Type Journal Article
Author D.L. France
Author T.J. Griffin
Author J.G. Swanburg
Author J.W. Lindemann
Author G. Clark Davenport
Author V. Tranunell
Author C.T. Armbrust
Author B. Kondratieff
Author A. Nelson
Author K. Castellano
Author D. Hopkins
Volume 37
Issue 6
Pages 1445-1458
Publication Journal of Forensic Sciences
Date 1992

Abstract This article discusses a forensic research team assembled in Colorado. The multidisciplinary team buried pig carcasses and evaluated various techniques that included GPR, magnetics, and electromagnetics for their ability to locate the graves. Of the geophysical methods tested, GPR was the most effective. The article further recommends that law enforcement seek out a multidisciplinary approach to forensic work.

Date Added 5/20/2016, 3:49:53 PM

Modified 6/9/2016, 9:03:09 AM

Tags:

Modern Cemetery, United States, electromagnetic induction, Clandestine Graves, Forensics, Colorado, GPR, Magnetometer

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A Radar Search for Burials in Sandy Soil

Type Report

Author Bruce W. Bevan

Place Pitman, New Jersey

Date 1987

Institution Geosight

Abstract This report is an early example of prospecting for prehistoric graves. The author was using GPR in sandy soils and had good results, although he was concerned that some possible graves may also be buried tree features. There was one known burial that was not detected during GPR survey. It was possible no graves were located within the study area.

Report Number NPS Order No. PX-6115-7-0163

Date Added 6/8/2016, 10:48:18 AM

Modified 6/8/2016, 11:10:51 AM

Tags:

United States, Minnesota, prehistoric archaeology, GPR

A RAG system for the Management Forensic and Archaeological Searches of Burial Grounds

Type Journal Article

Author Alastair Ruffell

Author Sean McAllister

Series Special Issue: Archaeological Sciences

Volume 3

Issue 1-1

Pages 1-8

Publication International Journal of Archaeology

Date 2015

Abstract This article presents a system for evaluating and interpreting grave locations in cemeteries both for archaeological and forensic searches. The system is based on a British Army mapping convention to classify land according to its suitability for tanks. The authors adapted the system for mapping unmarked graves, with red meaning there is a grave, amber meaning there is likely a grave, and green meaning there is likely no grave. Grave identification is predicated on the use of multiple lines of evidence including markers, informants, ground surface, GPR, and soil data, all combined in a GIS. Graves with more than one line of evidence are classified as red and with only one as amber. The combined classification approach is a simplified way to explain uncertainty and certainty to interested parties.

Date Added 5/25/2016, 3:31:53 PM

Modified 6/9/2016, 11:57:29 AM

Tags:

Clandestine Graves, Historic Cemetery, United Kingdom, Forensics, GPR, Ireland

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Advances in GPR Imaging with Multi-Channel Radar Systems from Engineering to Archaeology

Type Journal Article

Author Dean Goodman

Author Alexandre Novo

Author Gianfranco Morelli

Author Salvatore Piro

Author Doria Kutrubes

Author Henrique Lorenzo

Pages 405-411

Publication Environmental and Engineering Geophysical Society Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems 2001

Date 2011

Abstract Discusses the use of multi-channel GPR systems on five case studies. These systems have advantages over single channel systems because the 5-16-centimeter antenna spacing is so close that interpolation for data gaps may not be necessary. Allows for higher resolution data collection and faster survey time where conditions allow. One case study involved a burial in Norway.

Date Added 5/31/2016, 2:08:37 PM

Modified 6/9/2016, 9:15:44 AM

Tags:

Worldwide, General Reference, Norway, Historic Cemetery, GPR

Applications of the Ground-Penetrating Radar Technique in the Detection and Delineation of Homicide Victims and Crime Scene Paraphernalia

Type Journal Article
Author Michael S. Roark
Author Jeremy Strohmeyer
Author Neil Anderson
Author Michael Shoemaker
Author Shauna Oppert
Pages 1063-1071
Publication 11th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 1998
Abstract This article discusses a simulated grave study done with two deer carcasses and a metal object the size of a gun or knife. The trench, deer carcasses, and metal object were all successfully identified in GPR profiles over a period of seven months, leading the authors to conclude that GPR is an effective means to locate homicide victims and crime scene paraphernalia.
Date Added 5/24/2016, 11:59:56 AM
Modified 6/9/2016, 11:51:26 AM

Tags:

United States, Clandestine Graves, Missouri, Forensics, GPR

Archaeological Geophysics for DOD Field Use: A Guide for New and Novice Users

Type Report
Author Eileen Ernenwein
Author Michael L. Hargrave
URL https://www.researchgate.net/publication/228554161_Archaeological_Geophysics_for_DoD_Field_Use_a_Guide_for_New_and_Novice_Users
Place Fayetteville, Arkansas
Date 2009
Accessed 5/9/2016, 8:00:00 PM
Institution Center for Advanced Spatial Technologies, University of Arkansas and The U.S. Army Corps of Engineers, Engineer Research and Development Center Construction Engineering Research Laboratory
Abstract Demonstrates the validity of multi-sensor approach for detecting and characterizing sub-surface deposits at archaeological sites. Includes review of electrical resistance, electrical conductivity, magnetic susceptibility, magnetometry, and GPR. Good focus on determining site suitability, instrument selection, field implementation, estimating time and cost, and expectations. Includes very brief assessment of graves as part of discussion on detectable features and instrument selection.
Date Added 5/10/2016, 10:34:19 AM
Modified 6/9/2016, 8:52:27 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

Archival Research, Mapping, and Ground Penetrating Radar Survey at Elmwood/Pinewood Cemetery, Mecklenburg County, North Carolina

Type	Report
Author	Shawn M. Patch
Author	Sarah Lowry
Author	Mark T. Swanson
Author	Valerie Davis
Author	Christopher T. Espenshade
Place	Stone Mountain, Georgia
Date	2012
Institution	New South Associates, Inc.
Abstract	This archaeological report outlines a ground penetrating radar (GPR) survey, marker inventory, and history of cemetery sections that are adjacent to railroad tracks. The study area covers segments of paupers burials and formally marked burial plots within both the white Elmwood Cemetery and the African American Pinewood Cemetery. Study authors compared results of the GPR survey to the marker maps and identify marked and unmarked graves with detailed mapping. Research questions focused on the number of individuals interred adjacent to the railroad tracks and the number of unmarked graved.
Report Number	New South Associates Technical Report No. 2101
Date Added	7/3/2013, 11:31:36 AM
Modified	8/29/2016, 3:57:45 PM

Tags:

United States, North Carolina, Historic Cemetery, GPR

Burial Detection Using Ground Penetrating Radar

Type	Presentation
Presenter	Steve Persons
Place	Lakewood, Colorado
Date	1990
Meeting Name	Third International Conference on Ground Penetrating Radar
Abstract	This conference paper discusses two historic cemeteries that were surveyed with GPR in conjunction with an archaeological survey. At both cemeteries, graves were identified with GPR and were "ground-truthed." The article compares GPR profiles to trenches to compare profiles and talks about soils identified during testing. One of the cemeteries was avoided due to this information and other was moved.
Date Added	6/6/2016, 3:48:15 PM
Modified	6/9/2016, 11:22:09 AM

Tags:

United States, Virginia, Historic Cemetery, South Carolina, GPR

Buried in the Basement: Geophysics Role in a Forensic Investigation

Type Journal Article
Author Scott F. Calkin
Author Richard P. Allen
Author Michael P. Harriman
Pages 397-403
Publication 8th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 1995
Abstract This article outlines the authors' GPR survey to assist in a modern forensic case. A missing woman was found buried underneath the basement of her house, and her husband was subsequently convicted of murder. Notably, the body was identified with GPR after the failure of cadaver dogs.
Date Added 5/24/2016, 3:25:48 PM
Modified 6/8/2016, 4:46:40 PM

Tags:

United States, Clandestine Graves, Forensics, Maine, GPR

Confederate Guns in the Graveyard

Type Journal Article
Author Jessica Cook Hale
Author Sheldon Skaggs
Volume 41
Issue 2
Pages 243-255
Publication Early Georgia
Date 2013
Abstract Archaeologists responded to a local legend of two cannons buried in a cemetery in Rome, Georgia during the Confederate retreat. They conducted a GPR and gradiometer survey and identified an unknown anomaly that was too small to be a cannon but they did not think it was a grave. Excavation revealed it was an iron coffin. The article also goes into detail about managing public expectations and the press.
Date Added 5/25/2016, 1:25:32 PM
Modified 6/9/2016, 8:28:03 AM

Tags:

historic archaeology, Civil War, Georgia, Historic Cemetery, GPR, Magnetometer

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Controlled GPR Grave Research: Comparison of Reflection Profiles between 500 and 250 MHz antennae

Type Journal Article
Author John J. Schultz
Author M.M. Martin
Volume 209
Pages 64-69
Publication Forensic Science International
Date 2011
Abstract This article describes the results of a test to evaluate 250MHz and 500MHz GPR antennae for resolving buried pig carcasses and an empty control grave after six months. Results showed that both antennae detected the pig carcass and control grave, but the 500MHz had greater detail and better resolution. Reflections in the pig grave were from the carcass itself and not the disturbed soil from the shaft. Recommendations stated that a 500MHz is a good compromise between depth and resolution and that surveying in perpendicular directions (X and Y) provides increased resolution.
Date Added 5/25/2016, 3:48:57 PM
Modified 6/9/2016, 12:28:39 PM

Tags:

United States, Florida, Clandestine Graves, Forensics, GPR

Correcting for Topography and the Tilt of Ground-penetrating Radar Antennae

Type Journal Article
Author Dean H. Goodman
Author Yasushi Nishimura
Author Hiromichi Hongo
Author Noriaki Higashi
Volume 13
Pages 159-196
Publication Archaeological Prospection
Date 2006
Abstract This article addresses how topographic variation affects the direction GPR energy enters the ground. The authors argue that unless the data is corrected both for the terrain and the antenna tilt, the end data will be distorted. They suggest using GPR slices to solve this problem and use an example of a burial mound in Japan to illustrate the improved accuracy of data processed to account for tilt. This article provides an excellent best practice for identifying object buried within a mound.
Date Added 5/25/2016, 2:25:10 PM
Modified 8/29/2016, 4:18:47 PM

Tags:

General Reference, Japan, Historic Cemetery, GPR, Burial Mound

Delineation and Resolution of Cemetery Graves Using a Conductivity Meter and Ground-Penetrating Radar

Type	Journal Article
Author	Charles A. Dionne
Author	Dennis K. Wardlaw
Author	John Schultz
Volume	5
Pages	20-30
Publication	Technical Briefs in Historical Archaeology
Date	2010
Abstract	Technical brief that outlines methods and results from a case study at Greenwood Cemetery in Florida. Data collection using GPR and EM conductivity in two separate areas identified burials from different periods (1957-2002 and older than 75 years). Results indicated both instruments successfully detected modern burials because of concrete vaults. Only GPR detected the non-vaulted older graves. The article recommended using transect spacing of 0.25-meter, collecting data in both directions, and orienting transects perpendicular to graves to produce best imagery.
Date Added	3/18/2015, 3:52:23 PM
Modified	8/29/2016, 4:17:13 PM

Tags:

Modern Cemetery, United States, Florida, electromagnetic induction, Historic Cemetery, GPR

Detecting Buried Human Remains Using Near-Surface Geophysical Instruments

Type	Journal Article
Author	Kathryn Powell
Volume	35
Pages	88-92
Publication	Exploration Geophysics
Date	2004
Abstract	This article discusses the use of geophysics to identify graves in an Australian environment. The author used a controlled grave site containing human cadaver, pig, and kangaroo remains. GPR was successful in locating the pigs than the kangaroo. The author also queried local police and found that searches for forensic remains with geophysics had a poor success rate. Finally, a historic burial was located with resistivity, demonstrating the application of this technique to locate historic graves.
Date Added	5/25/2016, 3:19:13 PM
Modified	6/9/2016, 11:31:35 AM

Tags:

electrical resistivity, Clandestine Graves, Australia, Forensics, GPR, Magnetometer

Detecting Buried Remains Using Ground-Penetrating Radar

Type Report
Author John Schultz
Date 2012
Institution U.S. Department of Justice
Report Type Final Report Submitted to the National Institute for Justice, Award number: 2008-DN-BX-K132.
Abstract The study reported here involved periodic GPR and EM induction surveys of buried pig carcasses in a controlled grid over a 30-month period. EM was found to be ineffective, while GPR performed well, particularly in wet soils.
Date Added 5/25/2016, 3:39:11 PM
Modified 6/9/2016, 12:09:50 PM

Tags:

United States, Florida, electromagnetic induction, Clandestine Graves, Forensics, GPR

Detecting Graves in a Lime Marl Environment: A Comparison of Soil Resistivity and Ground Penetrating Radar Methods

Type Presentation
Presenter Patrick Gleason
Presenter Lynn Smith
Presenter Christy Goffinet
Presenter Niki White
Presenter George Harrivel
Presenter Bethany Rinard Hinga
URL http://www.earthdoc.org/publication/publicationdetails/?publication=53081
Place Charleston, South Carolina
Date 2011
Accessed 5/9/2016, 8:00:00 PM
Type Poster Presentation
Meeting Name Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Abstract This presentation compared results from soil resistivity and a GPR (using a 270 MHz antenna) surveys at a historic cemetery located on Fort Hood, Texas. The resistivity data identified areas that had been disturbed, but not on a scale suited to locating specific graves. The GPR identified 84% of the marked graves and nine unmarked graves. The GPR was deemed more effective in these conditions. There was no discussion of reasons GPR might not have detected burials at the marked graves.
Date Added 5/10/2016, 10:48:49 AM
Modified 6/9/2016, 9:11:45 AM

Tags:

electrical resistivity, United States, Texas, Historic Cemetery, GPR

Disturbances in the Soil: Finding Buried Bodies and Other Evidence using Ground-penetrating Radar

Type	Journal Article
Author	Peter S. Miller
Volume	41
Issue	4
Pages	648-652
Publication	Journal of Forensic Sciences
Date	1996
Abstract	This article summarizes the use of GPR to locate bodies or other evidence. The author discusses how GPR works and its potential usefulness in the search for disturbed soils. Provides detailed lists of data collection methods and survey strategies. The author concludes that GPR is an effective way to locate burials and disturbed soils. Additionally, the success of GPR is dependent on searching the right area, the composition of soils, and the experience of the operator. The equipment used by the author is dated, making the survey methods less useful now. The author also speaks with authority and certainty that seems unwarranted given other scholarship in the field.
Date Added	5/25/2016, 3:05:18 PM
Modified	6/9/2016, 10:50:38 AM

Tags:

United States, Clandestine Graves, Historic Cemetery, Forensics, GPR

Effect of Grain Size on the Geophysical Responses of Indigenous Burial Sites

Type	Conference Paper
Author	David C. Nobes
Place	Istanbul, Turkey
Publisher	Near Surface
Pages	1-5
Date	2007
Conference Name	13th European Meeting of Environmental and Engineering Geophysics
Abstract	This is paper discusses grave detection in clay, loess, and sand using five Maori cemeteries from New Zealand using magnetics, EM, and GPR. The results show burials in clay and loess can be identified but burials in sand do not always show responses. Different results are likely due to depositional setting. Clay and loess are usually deposited as layers or massive beds, and therefore disturbances are clear, while fluvial and Aeolian sand contain sedimentary structures that can mask geophysical responses.
Proceedings Title	Near Surface
Date Added	5/31/2016, 2:56:53 PM
Modified	8/29/2016, 5:47:53 PM

Tags:

electromagnetic induction, New Zealand, Historic Cemetery, Pre-contact cemetery, GPR, Magnetometer

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Establishing Forensic Search Methodologies and Geophysical Surveying for the Detection of Clandestine Graves in Coastal Beach Environments

Type	Journal Article
Author	James K. Pringle
Author	Claire Holland
Author	Katie Szkornik
Author	Mark Harrison
Volume	219
Pages	e29-e36
Publication	Forensic Science International
Date	2012
Abstract	This article addresses the detection of burials in coastal environments. In this study, mannequins were buried in the sand in three locations in the dunes and foreshore. The study then used a metal detector, GPR, electrical resistivity, and magnetic susceptibility to locate the mannequin with mixed results. The metal detector was ineffective (likely due to depth penetration limitations). The GPR was only effective in the dry dunes. Resistivity was effective, but not recommended in very dry sand. The magnetic susceptibility was entirely effective, but the instrument was not suitable for collecting large areas. The authors suggested a targeted approach where the specific environment is considered prior to instrument selection.
Date Added	5/27/2016, 10:31:53 AM
Modified	6/9/2016, 11:36:40 AM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, United Kingdom, Forensics, GPR

Forensic Application of FM-CW and Pulse Radar

Type	Journal Article
Author	Robert S. Freeland
Author	Michelle L. Miller
Author	Ronald E. Yoder
Author	Steven K. Koppenjan
Volume	8
Issue	2
Pages	97-103
Publication	Journal of Environmental and Engineering Geophysics
Date	June 2003

Abstract Article discusses application of FM-CW (multi-channel) and single channel GPR for identification of test graves. Human cadavers were buried under controlled conditions at the University of Tennessee and materials were added to simulate clandestine burials. Results indicated both instruments could resolve the burials at shallow depths but neither system penetrated more than 1-meter because of clay-rich soil.

Date Added 5/25/2016, 2:19:52 PM

Modified 6/9/2016, 9:04:20 AM

Tags:

Tennessee, United States, Clandestine Graves, Forensics, GPR

Forensic Application of Ground-Penetrating Radar

Type Book Section

Author K.B. Strongman

Editor J.A. Pilon

Series Paper 90-4

Place Ottawa, Ontario

Publisher Geological Survey of Canada

Pages 203-212

Date 1992

Abstract This chapter in the book "Ground Penetrating Radar" specifically addresses forensic applications. The chapter begins by discussing a staged test case using bear and goat cadavers. The surveyors did not know where the cadavers were located, but were able to successfully detect all three. The author outlines three actual crime scenes where GPR was successfully used. The study recommends that GPR be made a common and widely available tool for police departments. The technology discussed in the article is dated, but the general principles remain applicable.

Book Title Ground Penetrating Radar

Date Added 5/25/2016, 3:53:25 PM

Modified 6/9/2016, 1:55:54 PM

Tags:

Canada, British Columbia, Clandestine Graves, Forensics, GPR

Forensic Archaeology: Advances in Theory and Practice

Type Book

Author J. Hunter

Author M. Cox

Place London, England

Publisher Routledge

Date 2005

Abstract This book discusses forensics from an archaeological perspective. It contains a chapter that specifically addresses using geophysics for forensic applications, and case studies using geophysics are discussed. The book also summarizes how each instrument functions. This a textbook-style work that addresses many aspects of forensics and discusses the integration of geophysics with other forensic methods.

Date Added 5/25/2016, 2:33:18 PM

Modified 6/9/2016, 9:37:45 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Clandestine Graves, Forensics, GPR, Magnetometer

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Forensic Geoscience: Applications of Geology, Geomorphology and Geophysics to Criminal Investigations

Type Journal Article

Author Alastair Ruffell

Author Jennifer McKinley

Volume 69

Pages 235-247

Publication Earth-Science Reviews

Date 2005

Abstract This review article summarizes the history of and the modern application of forensic geosciences. "Forensic geoscience" is a broad classification and includes everything from geophysics to geochemistry. The authors begin with a discussion of the discipline's history and finish with an overview of available literature that pertains to each method, including GPR, magnetics, resistivity, and ERT. This discussion extends to cover large scale landforms and microscopic particle forensic studies. The authors conclude with a suggestion that more is being done in the discipline outside of journal publication.

Date Added 6/2/2016, 8:17:45 AM

Modified 6/9/2016, 12:03:30 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Forensics, electrical resistance tomography, GPR, Magnetometer

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Forensic GPR: Finite-Difference Simulations of Responses From Buried Human Remains

Type Journal Article

Author William S. Hammon

Author George A. McMechan

Author Xiaoxian Zeng

Volume 45
Pages 171-186
Publication Journal of Applied Geophysics
Date 2000
Abstract Discusses the application of GPR to forensic investigations through modeling of reflection properties of human body tissue/bone. Provides several examples of theoretical profiles under varying environmental conditions (soil type, water content, and body part). Concludes that GPR can resolve diagnostic features of the human body; it works better in drier, sandier soils; that antenna frequencies of 900MHz or greater are most effective; and that detection of body parts is limited to before the body becomes completely skeletonized between 6 and 12 months post-mortem.
Date Added 5/25/2016, 2:28:05 PM
Modified 6/9/2016, 9:20:38 AM

Tags:

Worldwide, General Reference, Clandestine Graves, Forensics, GPR

Forensic Methods: Excavation for the Archaeologist and Investigator

Type Book
Author Melissa A Connor
Place Lanham, Maryland
Publisher AltaMira Press
Date 2007
Abstract This book is a thorough overview of forensic archaeology, including preparation, fieldwork, soils, taphonomy of forensic sites, locating and excavating buried remains, evidence, documentation, and professionalization of the discipline. Methods for identifying graves include probing, cadaver dogs, test trenches, aerial photographs, and geophysical methods (metal detectors, GPR, EM, electrical resistance, and magnetometers). Includes a geophysical case study and summary of strengths/weaknesses of various methods.
Date Added 6/6/2016, 10:20:10 AM
Modified 6/8/2016, 5:02:47 PM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, Cadaver Dogs, Forensics, Probe, GPR, Magnetometer

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Geophysical Archaeology Research Agendas for the Future: Some Ground-Penetrating Radar Examples

Type Journal Article
Author Lawrence B. Conyers
Author Juerg Leckebusch

Volume 17
Pages 117-123
Publication Archaeological Prospection
Date 2010
Abstract This article is a call for expanded research agendas in archaeological geophysics. It focuses on GPR and asks researchers to extend their work beyond surveys that simply identify features. The authors propose that future geophysical work should focus on answering anthropological questions and developing survey and software technology. Rather than focusing on a specific research item, this article is more of a call for research stem from an anthropological perspective rather than simple prospection.
Date Added 5/23/2016, 1:19:32 PM
Modified 8/29/2016, 4:01:45 PM

Tags:

Worldwide, historic archaeology, General Reference, prehistoric archaeology, GPR

Geophysical Detection of Graves - Basic Background and Case Histories from Historic Cemeteries

Type Conference Paper
Author William James Johnson
URL http://www.archaeology-geophysics.com/PDF%20papers/Geophysical%20Detection%20of%20Graves%202014.pdf
Place Charleston, West Virginia
Date 2003
Accessed 5/9/2016, 8:00:00 PM
Conference Name Council for West Virginia Archaeology Spring Workshop
Abstract This conference paper describes geophysical methods used to identify graves in cemeteries. Discusses a case study involving a historic cemetery in Pennsylvania located adjacent to a possibe Revolutionary War training camp. The geophysical survey identified a number of graves, although did not quantify marked or unmarked grave numbers, along with possible prehistoric and historic features. The author concludes that GPR was the best technique, but other methods may help.
Date Added 5/10/2016, 11:00:08 AM
Modified 6/9/2016, 10:11:39 AM

Tags:

electrical resistivity, United States, Civil War, electromagnetic induction, Revolutionary War, Pennsylvania, Historic Cemetery, GPR, Magnetometer

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Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration

Type Report

Author Bruce W. Bevan
Place Lincoln, Nebraska
Date 1998
Institution United States Department of the Interior, National Park Service, Midwest Archaeological Center
Abstract One of the first attempts to produce a comprehensive overview of geophysical methods for archaeology. This report includes detailed discussions of resistivity, magnetometry, conductivity (EM), and GPR. Examples focus exclusively on work at Petersburg Battlefield, with nothing specific to cemeteries. It was written before the advent of major advances in computer power and software development.
Report Number Special Report No. 1.
Date Added 1/3/2012, 11:17:14 AM
Modified 6/8/2016, 1:55:11 PM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Geophysical Investigations at a Potential Mass Grave Site in Bethlehem, PA

Type Presentation
Presenter Charles Messler
Presenter Laura Sherrod
Presenter James Higgins
URL http://www.earthdoc.org/publication/publicationdetails/?publication=53081
Place Charleston, South Carolina
Date 2011
Accessed 5/9/2016, 8:00:00 PM
Type Poster Presentation
Meeting Name Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Abstract This poster outlines efforts to locate Spanish Influenza victims in a pauper’s cemetery where mass burial was thought to have occurred. It includes a three dimensional data set.
Date Added 5/23/2016, 4:50:18 PM
Modified 6/9/2016, 10:43:59 AM

Tags:

Modern Cemetery, United States, Pennsylvania, Historic Cemetery, GPR, Magnetometer

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Geophysical Investigations in UK Graveyards: Re-Use of Existing Burial Grounds

Type Conference Paper
Author James D. Hansen
Author James K. Pringle
Place Leicester, United Kingdom

Publisher	Near Surface
Date	2011
Conference Name	17th European Meeting of Environmental and Engineering Geophysics
Abstract	Discusses the results of GPR and resistance surveys at three cemeteries in the UK. The research problem was a lack of accurate interment records and/or markers that did not accurately reflect who was buried in the cemeteries. Results identified most of the known burials and many probable unmarked burials.
Proceedings Title	Near Surface
Date Added	5/31/2016, 2:30:29 PM
Modified	6/9/2016, 9:26:40 AM

Tags:

electrical resistivity, Historic Cemetery, United Kingdom, GPR

Geophysical Mapping of an Entire Municipal Cemetery

Type	Journal Article
Author	Keith J. Sjostrom
Author	Kenneth J. Ryerson
Author	James Watson
Author	Douglas Bock
Author	Dan Rush
Pages	1032-1041
Publication	9th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date	2009
Abstract	This article summarizes a multi-channel GPR and EM survey of an active cemetery in Arizona. The survey utilized concurrent and optimized collection strategies so the 6.2 acre cemetery could be collected in two days. The authors discuss a variety of proprietary software collection and interpretation packages that allowed them to create a grave map for the town. Notably there is no discussion of nuance and variability in cemetery interpretation.
Date Added	5/11/2016, 12:01:19 PM
Modified	6/9/2016, 1:47:45 PM

Tags:

Modern Cemetery, United States, Arizona, electromagnetic induction, Historic Cemetery, GPR

Geophysical Mapping of Historic Cemeteries

Type	Journal Article
Author	Geoffrey Jones
Volume	3
Pages	25-28

Publication Technical Briefs in Historical Archaeology
Date 2008
Abstract This article focuses on best practice methods and methodologies for geophysics in cemeteries. Proposes a multiple method approach as well as careful consideration of site conditions and burial practices. The article suggests sampling strategies that account for site settings and research goals. The integration of historical, archeological, environmental, and other data is discussed along with new remote technologies including EM conductivity, thermal infrared imaging, and penetrometers. The Wyandotte County Cemetery in Kansas is used as a case study, where electrical resistance and magnetic gradiometer were used in conjunction with testing to help establish the cemetery boundary. This is an example where the magnetometer and resistance are successfully used in a historic cemetery.
Date Added 12/21/2011, 11:07:29 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, electromagnetic induction, Magnetometry in archaeology, geophysical, Historic Cemetery, Thermal Imaging, Probe, GPR, Kansas, Magnetometer

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Geophysical Monitoring of Simulated Clandestine Graves using Electrical and GPR Methods: 0-3 Years after Burial

Type Conference Paper
Author J.K. Pringle
Author J.R. Jervis
Author J.D. Hansen
Author N.J. Cassidy
Author G.M. Jones
Author G.T. Tuckwell
Place Leicester, United Kingdom
Date 2011
Conference Name 17th European Meeting of Environmental and Engineering Geophysics
Abstract A study was conducted to systematically assess changing geophysical responses of simulated clandestine graves during three-year period after burial. Simulated burials included one empty grave, one unwrapped pig cadaver, and one pig cadaver wrapped in a tarp, all buried at 0.5-meters deep to simulate homicide victims. Results indicated the naked burial was difficult to detect after 18 months but the wrapped burial was detectable for up to three years. Resistance may be better choice for clay-rich soils.
Proceedings Title Near Surface
Date Added 5/31/2016, 3:08:52 PM
Modified 6/9/2016, 11:49:44 AM

Tags:

electrical resistivity, Clandestine Graves, United Kingdom, Forensics, GPR

Geophysical Survey in Archaeological Field Evaluation, Second Edition.

Type Book
Author Andrew David
Author Neil Linford
Author Paul Linford
Place Swindon, United Kingdom
Publisher Historic England
Date 2008
Abstract This manual, produced bv Historic England (formerly English Heritage), outlines geophysical techniques (magnetometery, GPR, electrical resistance, EM induction), their optimal use, basic field configurations, and data processing steps. It is set up to provide specific guidelines for geophysical work done in England and has matrices to assist planners with selecting appropriate instruments based on site-specific conditions. The manual contains a small section on cemeteries, but is extremely cautious in their recommendation to use geophysics in cemeteries.
Date Added 5/23/2016, 11:29:29 AM
Modified 6/9/2016, 8:37:06 AM

Tags:

electrical resistivity, historic archaeology, General Reference, electromagnetic induction, Metal Detector, United Kingdom, prehistoric archaeology, GPR, Magnetometer

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Geophysical Survey in Archaeological Field School Evaluation

Type Report
Author Andrew David
Author Neil Linford
Author Paul Linford
Place Swindon, England
Date 2008
Institution English Heritage
Date Added 5/10/2016, 10:26:51 AM
Modified 5/23/2016, 11:51:13 AM

Tags:

Magnetometry, United Kingdom, EM induction, General Cemetery, GPR

Geophysical Surveys at the West End Cemetery, Townsville: An Application of Three Techniques

Type Journal Article
Author Ross Stanger

Author David Roe

Volume 65

Pages 44-50

Publication Australian Archaeology

Date 2007

Abstract This article discusses the application and results of resistance, GPR, and magnetometer survey of the E Block section of the Townsville cemetery in Queensland, Australia. The goal was to examine the cultural and/or ethnic association of the graves and apply geophysical instruments to this section of the country. Resistance and GPR were inconclusive due to environmental factors, but magnetometer produced excellent results. Because of metal grave markers, 65 individuals were identified and confirmed through limited excavations. The authors could then correlate the burial records with the markers to address social research questions. Magnetometer may be the best method in this region for two reasons: 1) the widespread use of metal markers and 2) environmental limits on detecting grave shafts and burial containers.

Date Added 8/9/2013, 10:34:30 AM

Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, Resistivity, Historic Cemetery, Australia, Grave Detection, GPR, Magnetometer, Unmarked Graves

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Geophysical Surveys of Burial Sites: A Case Study of the Oaro Urupa

Type Journal Article

Author David C. Nobes

Volume 64

Issue 2

Pages 357-367

Publication Geophysics

Date 1999

Abstract The article outlines a survey in a Maori cemetery in use since the 19th century. EM, magnetometer and GPR were used to map the cemetery. These datasets were then normalized and combined to make a grave probability map for the present populations to use when they are looking for appropriate burial locations. The article focuses on survey design and best practices for a practical report product.

Date Added 5/25/2016, 3:11:21 PM

Modified 8/29/2016, 4:07:59 PM

Tags:

electromagnetic induction, New Zealand, Historic Cemetery, Pre-contact cemetery, GPR, Magnetometer

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Geophysical Techniques for Forensic Investigation

Type Book Section
Author Peter J. Fenning
Author Laurance Donnelly
Editor Kenneth Pye
Editor Debra J. Croft
Series Special Publications
Place London, England
Publisher Geological Society
Pages 11-20
Date 2004
Series Number 232
Abstract Provides a general outline of geophysical instruments and their applicability towards forensic investigations, and illustrates these with three case studies. A large variety of geophysical instruments are discussed, although the authors note that many of them have not been tested successfully in forensic cases. The case studies include a successful location of burial vaults, an unsuccessful survey for Napoleonic graves, and a large scale metal detector survey looking for secondary forensic evidence. The authors conclude with recommendations about when to use geophysics in forensic cases: primarily to consider the search area and environmental conditions, and to look for indirect evidence. This article discusses slightly outdated equipment and methods, but the conclusions are still relevant.
Book Title Forensic Geoscience: Principles, Techniques and Applications
Date Added 5/27/2016, 10:35:12 AM
Modified 6/9/2016, 8:57:56 AM

Tags:

Modern Cemetery, electrical resistivity, General Reference, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Historic Cemetery, United Kingdom, Forensics, induced polarization, GPR, seismic, Magnetometer

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Geophysics and Burials: Field Experience and Software Development

Type Book Section
Author M. Watters
Author J.R. Hunter
Editor Kenneth Pye
Editor Debra J. Croft
Series Special Publications 232
Place London, England
Publisher Geological Society
Pages 21-31
Date 2004
Abstract This book chapter outlines a theoretical and methodological approach to collecting and processing GPR data in forensic cases. The authors suggest both high resolution data collection methods and processing methods meant to optimize difficult and ephemeral data sets including,

perpendicular grid data sets, making time slices, and using ultra high frequency antennas to target small areas. They also pay particular focus to using an equipment operator who is trained in forensic geophysics and not engineering or geology. Emphasis is also placed on working iteratively with law enforcement and investigators. The paper concludes with thoughts on how GPR might be used to identify, image, and interpret mass graves.

Book Title Forensic Geoscience: Principles, Techniques and Applications
Date Added 5/27/2016, 10:42:13 AM
Modified 6/9/2016, 2:13:47 PM

Tags:

General Reference, United States, Mass Grave, Historic Cemetery, United Kingdom, New Hampshire, Forensics, GPR

Geophysics and the Search of Freshwater Bodies: A Review

Type Journal Article
Author Rachael Parker
Author Alastair Ruffell
Author David Hughes
Author Jamie Pringle
Volume 50
Pages 141-149
Publication Science and Justice
Date 2010
Abstract This review article explores the use of geophysics in freshwater to locate objects, specifically forensic evidence. The article outlines a variety of methods, explains how they work, and how they function in water. Methods include GPR (referred to as water penetrating radar), terrestrial magnetometer, seismic, CHIRP sub-bottom profiler, and side scan sonar. The authors then summarize case studies where geophysics were used to locate either forensic evidence or buried objects under water. They conclude that geophysics could be very useful under water, but unless there is metal present, WPR is the best method.
Date Added 5/27/2016, 10:55:13 AM
Modified 6/9/2016, 11:21:19 AM

Tags:

United States, Sweden, Oregon, side scan sonar, United Kingdom, Forensics, CHIRP Sub-Bottom Profiler, GPR, seismic, Ireland, Magnetometer

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GPR and Bulk Ground Resistivity Surveys in Graveyards: Locating Unmarked Burials in Contrasting Soil Types

Type Journal Article
Author James D. Hansen

Author James K. Pringle
Author Jon Goodwin
Volume 237
Pages 14-29
Publication Forensic Science International
Date 2014
Abstract The article reviews GPR and resistivity studies of three formal cemeteries. These studies identified unmarked graves and extra/missing individuals from parish records in a variety of burial styles, including brick-lined interments, stacked individuals, and isolated single graves. Two of the three case studies discussed were excavated and the authors compare the survey results to the excavation results, including the types of burial containers identified and their relative visibility in the geophysical data sets. The authors determined that GPR worked best in coarse soils, resistivity worked best in clay-rich soils, and both methods worked well in sandy and black earth soils. They outline specific collection parameters and the lessons learned on both instruments. The study also concluded that unmarked burials in a cemetery were very different from clandestine burials of murder victims. This article provides an excellent example of using geophysics in a historic cemetery context where excavations were possible. The authors also discuss geophysics as an important tool in the context of determining how many people are buried in a cemetery and where they are buried.
Date Added 5/25/2016, 2:30:12 PM
Modified 8/29/2016, 5:17:29 PM

Tags:

Modern Cemetery, electrical resistivity, Historic Cemetery, United Kingdom, Forensics, GPR

GPR in Forensic and Archaeological Work: Hits and Misses.

Type Journal Article
Author James S. Mellett
Pages 487-491
Publication 9th Environmental and Engineering Geophysical Society Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 1996
Abstract Mellett discusses successes and failures using GPR to prospect for modern homicide victims. He proposes that many of the failures are related to inaccurate witness testimony and no graves were ever present. He further notes that because graves change over time, practitioners need to consider the age of a grave when they are proposing to locate bodies.
Date Added 5/23/2016, 10:00:01 AM
Modified 6/9/2016, 10:43:31 AM

Tags:

Modern Cemetery, United States, Clandestine Graves, Historic Cemetery, Forensics, GPR

GPR Survey of Cemeteries in Georgia's Coastal Plain

Type Journal Article
Author Daniel T. Elliott
Volume 41
Issue 2
Pages 175-210
Publication Early Georgia
Date 2013
Abstract Over approximately 10 years, Elliot surveyed multiple historic cemeteries in Georgia’s coastal plain. The article summarizes 18 cemetery projects and discusses how GPR is an effective tool to use to map coastal plain cemeteries.
Date Added 5/10/2016, 10:31:48 AM
Modified 6/9/2016, 8:44:03 AM

Tags:

United States, Georgia, Historic Cemetery, GPR

Ground Penetrating Radar: Theory and Applications

Type Book
Author Harry Jol
Place Amsterdam, Netherlands
Publisher Elsevier
Date 2009
Abstract This textbook covers general GPR methods and theory. Consists of an edited volume with chapters on electromagnetic principles, soil properties, GPR system and design, antennas, processing and analysis, different environmental resources and conditions, engineering applications, unexploded ordinance applications, and archaeology. The archaeology chapter (authored by Dean Goodman, Salvatore Piro, Yasushi Nishimura, Kent Schneider, Hiromichi Hongo, Noriaki Higashi, John Steinburg, and Brian Damiata) covers general field and processing methods and a number of case histories dealing with prehistoric and historic archaeological sites from around the world. They include a historic Choctaw Cemetery and two Japanese burials mounds. The case studies are succinct and provide images of representative data.
Date Added 5/25/2016, 2:43:53 PM
Modified 6/9/2016, 10:15:33 AM

Tags:

General Reference, United States, Japan, Louisiana, Historic Cemetery, prehistoric archaeology, GPR, Burial Mound

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Ground Probing Radar for Historical Archaeology

Type Journal Article

Author Bruce W. Bevan
Author J. Kenyon
Volume 11
Pages 2-27
Publication MASCA Newsletter
Date 1975
Date Added 5/25/2016, 12:59:31 PM
Modified 6/8/2016, 1:52:20 PM

Tags:

General Reference, GPR

Ground Radar View of Japanese Burial Mounds

Type Journal Article
Author Dean Goodman
Author Yasushi Nishimura
Volume 67
Issue 255
Pages 349-354
Publication Antiquity
Date 1993
Abstract This article discusses a GPR survey of a Kofun era burial mound in Japan. The processing steps for the mound data are highlighted, including a detailed discussion of time slicing and modeling geophysical data. This is an early instances of using three dimensional data to analyze cultural features.
Date Added 5/24/2016, 8:01:59 AM
Modified 6/9/2016, 9:13:21 AM

Tags:

Japan, Historic Cemetery, GPR, Burial Mound

Ground-Penetrating Radar for Archaeology

Type Book
Author Lawrence Conyers
Place Walnut Creek, California
Publisher AltaMira Press
ISBN 978-0-7591-0772-4
Date 2004
Library Catalog Open WorldCat

Abstract This book was written specifically for the application of GPR to archaeology. It includes a detailed overview of GPR method and theory, equipment, velocity analysis, data processing, and basic data interpretation. A small section is devoted to the identification of graves.

# of Pages 230

Date Added 11/10/2011, 8:40:34 AM

Modified 8/29/2016, 5:37:41 PM

Tags:

Worldwide, General Reference, GPR

Ground-Penetrating Radar for Historical Archaeology

Type Journal Article

Author Bruce W. Bevan

Author Jeffrey Kenyon

Volume 11

Issue 2

Pages 2-7

Publication MASCA Newsletter

Date 1975

Abstract This article is an early example of using GPR for historic archaeology. The authors used an early GPR system to locate historic features at a house site. At the time this was a ground breaking study for the use of GPR to identify features at an archaeological site.

Date Added 6/8/2016, 11:12:45 AM

Modified 6/8/2016, 11:29:12 AM

Tags:

historic archaeology, United States, Pennsylvania, GPR

Ground-Penetrating Radar Profile Spacing and Orientation for Subsurface Resolution of Linear Features.

Type Journal Article

Author James E. Pomfret

Volume 13

Pages 151-153

Publication Archaeological Prospection

Date 2006

Abstract Discusses transect/profile spacing for GPR survey on two different sites in the Georgia Coastal Plain.

Date Added 12/21/2011, 11:28:59 AM

Modified 11/30/2017, 12:00:10 PM

Tags:

African American, cemetery, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Ground-Penetrating Radar Survey and Marker Map for Historic Graves at the Clarks Creek Cemetery (31MK1080) in the Hampton Place Subdivision, Mecklenburg, North Carolina

Type	Report
Author	Sarah Lowry
Author	Ellen Turco
URL	http://newsouthassoc.com/
Place	Stone Mountain, Georgia
Date	2016
Accessed	6/27/2016, 1:58:30 PM
Institution	New South Associates, Inc, Prepared for Mecklenburg County
Abstract	This archaeological report discusses a ground-penetrating radar (GPR) survey of a probable historic African American cemetery. The cemetery contained no formal markers and was only apparent from a series of collapsed grave depressions and field stone markers. The survey included a limited GPR survey and detailed site map. Together, these data sets were combined to create a cemetery boundary and to estimate the number of individuals interred.
Report Number	2584
Date Added	6/27/2016, 1:58:30 PM
Modified	8/29/2016, 5:16:00 PM

Tags:

United States, North Carolina, African American cemetery, GPR

Attachments

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Ground-Penetrating Radar Survey of Andersonville National Historic Site

Type	Presentation
Presenter	James E. Pomfret
Place	Austin, Texas
Date	2014
Meeting Name	Society for American Archaeology
Abstract	This conference presentation summarized a GPR survey for mass burials at the Andersonville National Cemetery, formerly a Civil War prison camp in Georgia. The author used archival evidence and geophysics to locate the grave trenches and draw conclusions about how they were buried. The burial methods changed throughout the war and the differences were apparent in the

GPR data.

Date Added 5/25/2016, 3:16:39 PM

Modified 8/29/2016, 5:11:25 PM

Tags:

United States, Civil War, Mass Grave, Georgia, Historic Cemetery, Civil War-Context, GPR

Ground-Penetrating Radar Survey of Old Natchez Trace Road at the Old Town Archaeological Site (40WM2), Williamson County, Tennessee

Type Report

Author Sarah Lowry

Author Shawn Patch

Place Stone Mountain, Georgia

Date 2014

Institution New South Associates, Inc.

Abstract This archaeological report discusses the results of a ground-penetrating radar (GPR) survey for prehistoric stone box graves. The survey results focus on the area where a paved road runs over the Middle Cumberland Mississippian mound site. The GPR survey results are discussed in detail, outlining a variety of features including prehistoric burials, prehistoric features, and modern features. The physical characteristics of stone box graves are discussed in conjunction with the GPR results.

Report Number New South Associates Technical Report 2356

Date Added 8/29/2016, 2:07:30 PM

Modified 8/29/2016, 3:43:45 PM

Tags:

Tennessee, United States, prehistoric, GPR

Ground-Penetrating Radar Survey to Prospect for Burials in the Snow Creek Cemetery, Iredell County, North Carolina

Type Report

Author Sarah Lowry

Place Stone Mountain, Georgia

Date 2014

Institution New South Associates, Inc.

Abstract This archaeological report outlines results from ground-penetrating radar of the Snow Creek Community Cemetery. This historic and modern community cemetery was suspected to have missing and displaced markers. Cemetery managers were concerned about accidently encountering unmarked graves in the process of using the cemetery. The GPR survey identified both marked and unmarked burials and included detailed mapping.

Report Number 2413

Date Added 3/19/2015, 12:44:44 PM
Modified 8/29/2016, 5:09:54 PM

Tags:

United States, North Carolina, Historic Cemetery, GPR

Ground-Penetrating Radar Surveys to Locate 1918 Spanish Flu Victims in Permafrost

Type Journal Article
Author Les J. Davis
Author J. Alan Heginbottom
Author A. Peter Annan
Author S. Rod Daniels
Author B. Peter Berdel
Author Tom Bergan
Author Kirsty E. Duncan
Author Peter K. Lewin
Author John S. Oxford
Author Noel Roberts
Author John J. Skehel
Author Charles R. Smith
Volume 45
Issue 1
Pages 68-76
Publication Journal of Forensic Science
Date 2000
Abstract This article discusses a search for victims of the Spanish Flu buried in permafrost. The goal of the study was to find the victims efficiently and non-destructively so that tissue samples could be taken to better understand the disease. GPR was successful in identifying the location of the bodies, finding the top of the permafrost, and identifying the depth to which dynamite could be used to loosen the ground.
Date Added 5/25/2016, 1:40:18 PM
Modified 6/9/2016, 8:38:53 AM

Tags:

Norway, Historic Cemetery, GPR

Ground-Penetrating Radar Techniques to Discover and Map Historic Graves

Type Journal Article
Author Lawrence Conyers
Volume 40

Issue 3
Pages 64-73
Publication Historical Archaeology
Date 2006
Abstract Conyers outlines how GPR can be used to map graves and makes an argument for GPR as an effective tool in cemetery research. He discusses the history of GPR, how GPR works, and the types of grave features GPR may be able to map in a general sense.
Date Added 12/21/2011, 9:59:01 AM
Modified 6/9/2016, 8:23:45 AM

Tags:

General Reference, graves, Historic Cemetery, GPR

Handbook of Geophysics and Archaeology

Type Book
Author Alan Witten
Place London, England; Oakville, Connecticut
Publisher Equinox Publishing
ISBN 978-1-904768-59-3
Date 2006
Library Catalog Open WorldCat
Abstract Highly detailed book that contains extensive information on theoretical basis for different geophysical methods, including magnetometry, EM induction, GPR, geotomography, and electrical resistance tomography (ERT). Several case studies are used for each method, but none include cemeteries. Useful book for understanding the underlying physics behind each instrument.
Date Added 12/21/2011, 10:43:37 AM
Modified 5/11/2016, 2:31:29 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Geophysics in archaeology, geophysical, electrical resistance tomography, GPR, Magnetometer

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Identification of Unmarked Graves at Two Historic Cemeteries in Georgia

Type Journal Article
Author Donald J. Thieme
URL http://ww2.valdosta.edu/~dmthieme/Cemeteries/Thieme_2013_EarlyGeorgia.pdf
Volume 41
Issue 2
Pages 257-273

Publication Early Georgia
Date 2013
Accessed 5/10/2016, 8:00:00 PM
Abstract This article discusses GPR use in the Sunset Hills Cemetery in Valdosta, Georgia and the Dickson-Rainey Burial Ground south of Macon, Georgia. GPR was effective in both cemeteries and comprises a tool to identify possible graves without disturbance.
Date Added 5/11/2016, 2:07:57 PM
Modified 6/9/2016, 1:59:05 PM

Tags:

United States, Georgia, Historic Cemetery, GPR

Imaging Skeletal Remains with Ground-Penetrating Radar: Comparative Results over Two Graves from Viking Age and Medieval Churchyards on the Stóra-Seyla Farm, Northern Iceland

Type Journal Article
Author Brian N. Damiata
Author John M. Steinberg
Author Douglas J. Boender
Author Guðný Zoëga
Volume 40
Pages 268-278
Publication Journal of Archaeological Science
Date 2013
Abstract This article discusses the GPR results of two graves in great detail and compares them to the excavation results. Assessment of the GPR data is also compared to modeled GPR results. The authors conclude that in one of the examples they mapped the actual skeleton. In the other example, preservation was poor and no skeleton was mapped, although a more faint reflection was produced by the stratigraphic truncation. This article focuses on small area survey and looks at burial preservation and how that affects the GPR results.
Date Added 5/25/2016, 1:34:49 PM
Modified 8/14/2017, 9:29:05 AM

Tags:

Medieval, Iceland, historic archaeology, Historic Cemetery, Viking, GPR

Integrated Seismic Tomography and Ground-Penetrating Radar (GPR) for the High-Resolution Study of Burial Mounds (Tumuli)

Type Journal Article
Author E. Forte

Author E. Pipan
Volume 35
Pages 2614-2623
Publication Journal of Archaeological Science
Date 2008
Abstract This article discusses using both seismic tomography and GPR to investigate burial mounds where the height of the mound prohibits a simple GPR survey for detecting burial chambers. The GPR data imaged the top portions of the mound, providing stratigraphic data. The seismic tomography located the tomb below the depth penetration of the GPR. This case provides examples of topographic correction and innovative methods.
Date Added 5/25/2016, 2:15:54 PM
Modified 6/9/2016, 9:02:12 AM

Tags:

Italy, prehistoric archaeology, GPR, seismic, Bronze Age

Interpreting Ground-Penetrating Radar for Archaeology

Type Book
Author Lawrence Conyers
Place Walnut Creek, California
Publisher Left Coast Press
Date 2012
Abstract This book focuses specifically on interpreting GPR data from a range of archaeological sites, settings, and conditions. Chapter 8, Graves and Cemeteries, has information on the general challenges encountered in cemeteries and case studies. Conyers addresses differences in cultural practices, variation in burial depth, pattern recognition, and need to carefully evaluate individual profiles in conjunction with amplitude slice maps. The entire book provides a comparative basis for interpreting a wide variety of GPR data sets.
Date Added 1/23/2013, 9:58:24 AM
Modified 8/29/2016, 6:06:03 PM

Tags:

Worldwide, General Reference, Historic Cemetery, prehistoric archaeology, GPR

Locating and Characterizing Burials Using 3D Ground-penetrating Radar (GPR) and Terrestrial Laser Scanning (TLS) at the Historic Mueschke Cemetery, Houston, Texas

Type Journal Article
Author Azie S. Aziz
Author Robert R. Stewart
Author Susan L. Green
Author Janet B. Flores

URL http://dx.doi.org/10.1016/j.jasrep.2016.06.035
Volume 8
Pages 392-405
Publication Journal of Archaeological Science: Reports
Date 2016
Abstract Terrestrial laser scanning (LiDAR) and ground-penetrating were integrated at the Historic Mueschke Cemetery in Houston, Texas. LiDAR was used to identify surface depressions and mounds that correlated with known wooden coffin and concrete vault burials. These findings were then used to identify depressions without an associated gravestone, which were predicted to be unmarked, pre-1940 burials. This led to the implementation of GPR, which successfully located burials in those locations.
Date Added 8/11/2017, 3:48:52 PM
Modified 8/11/2017, 3:51:55 PM

Tags:

GPR, Cemeteries, LiDAR, Terrestrial Laser Scanning, Texas, United States, Unmarked burials

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Locating Unmarked Graves in Historic Cemeteries Using Ground Penetrating Radar.

Type Journal Article
Author E. Torgashov
Author N. Anderson
Pages 125
Publication Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 2002
Abstract GPR surveys were conducted at several historic cemeteries in south-central Missouri to locate unmarked graves. At each study site, GPR profiles were acquired along closely-spaced traverses using a single 400 MHz antenna. The locations of known graves, trees, tree roots, utilities, and small surface depressions were carefully noted. The latter were of particular interest because they can indicate graves, where degradation of the coffin/contents and the collapse of the overlying soil have caused the surface to recede. Each acquired GPR profile was interpreted to identify the hyperbolic reflections/diffractions that characterize buried coffins. These interpretations were superimposed on base maps to identify patterns that were consistent with 6-foot long, 2-foot wide coffins buried at depths of between one and three feet. Additionally, plan view amplitude slice maps based on depth slices at 2 feet with various width windows were generated for each GPR data set. Most known graves and suspected graves appeared on the amplitude slice maps as 2-ft by 6-ft areas of anomalously high summed reflection amplitude (mostly reflection/diffractions signal).
Date Added 5/11/2016, 2:21:26 PM
Modified 6/9/2016, 2:11:07 PM

Tags:

United States, Missouri, Historic Cemetery, GPR

Location and Assessment of an Historic (150-160 years old) Mass Grave Using Geographic and Ground Penetrating Radar Investigations, NW Ireland

Type	Journal Article
Author	Alastair Ruffell
Author	Alice S. McCabe
Author	C. Donnelly
Author	B. Sloan
Volume	54
Issue	2
Pages	382-294
Publication	Journal of Forensic Sciences
Date	2009
Abstract	This article discusses the identification of mass graves using a combination of aerial imagery, metal detecting, and GPR. The GPR used 100 and 200MHz antennae for full survey, then 400Mhz antenna for better resolution of individual anomalies. Discrepancies between surface expressions, metal detector hits, and GPR data indicated that no single method was identifying all graves. Distributions of metal artifacts suggested Catholic graves in one location were separated from Protestant graves in another.
Date Added	5/25/2016, 3:35:21 PM
Modified	6/9/2016, 12:00:46 PM

Tags:

Aerial imagery, Metal Detector, Mass Grave, United Kingdom, GPR, Ireland

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Location of Human Remains with Ground-Penetrating Radar

Type	Book Section
Author	James S. Mellett
Editor	Pauli Hanninen
Editor	Sini Autio
Series	Special Paper 16
Place	Rovaniemi, Finland
Publisher	Geological Survey of Finland
Pages	359-365
Date	1992
Abstract	This is a general review article about using GPR to locate human remains. The article begins with a series of case studies where GPR was used in historic cemeteries, a prehistoric burial, a modern cemetery, and a forensic case. The second part of the article discusses why burials are visible in GPR, here the author discusses physical and chemical properties of bones that may reflect radar energy. There is a diagram of a skeleton showing GPR profiles at different locations on the skeleton, which could be a useful tool in understanding how skeletal remains could be visible in GPR results.
Book Title	In Fourth International Conference on Ground Penetrating Radar June 8-13, 1992
Date Added	5/25/2016, 3:00:50 PM

Modified 8/29/2016, 4:06:29 PM

Tags:

New Jersey, United States, New York, Maryland, Clandestine Graves, Historic Cemetery, Forensics, Vermont, prehistoric archaeology, GPR

Location of Human Remains with Ground-Penetrating Radar

Type	Book Section
Author	Robert Ruppe Unterberger
Editor	Pauli Hanninen
Editor	Sini Autio
Series	Special Paper 16
Place	Rovaniemi, Finland
Publisher	Geological Survey of Finland
Pages	351-357
Date	1992
Abstract	This article discusses the use of GPR to identify soil changes that correspond with burials. It addresses the general conditions of disturbed earth and how it appears in GPR data.
Book Title	In Fourth International Conference on Ground Penetrating Radar June 8-13, 1992
Date Added	6/6/2016, 4:52:22 PM
Modified	6/9/2016, 2:11:57 PM

Tags:

United States, Clandestine Graves, Historic Cemetery, Forensics, GPR

Locations of Mohegan Burial Grounds Using GPR

Type	Journal Article
Author	Roelof Versteeg
Author	Jeffrey Bendremer
Author	John Lane
Pages	493-498
Publication	9th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date	1996
Abstract	This article outlines a GPR survey to prospect for historic Native American graves on tribal land where the tribes wish to avoid ground disturbance. The authors identified possible unmarked graves in slice maps, although they noted they may have not collected a large enough grid. Their main conclusion is that slice maps helped their interpretations.
Date Added	5/24/2016, 3:05:29 PM
Modified	6/9/2016, 2:13:27 PM

Tags:

Connecticut, United States, Historic Cemetery, prehistoric archaeology, GPR

Looking for Lost Graves

Type	Journal Article
Author	William James Johnson
Author	Donald Johnson
Author	Marcella G. Johnson
Volume	20
Issue	2
Pages	20-31
Publication	FastTIMES the Environmental and Engineering Geophysical Society
Date	2015
Abstract	Updates a 2003 conference presentation with new case studies. Reports GPR, magnetometer, and electrical resistance studies from Pennsylvania, Ohio, and Kentucky. Concluded that GPR was the best method for identifying individual graves, but multiple instruments were recommended. Magnetometry and resistance are more suitable for defining overall cemetery context because of interference and lack of contrasts sufficient for individual grave detection.
Date Added	5/10/2016, 11:05:02 AM
Modified	6/9/2016, 10:07:20 AM

Tags:

electrical resistivity, United States, Kentucky, Pennsylvania, Ohio, Historic Cemetery, GPR, Magnetometer

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Mapping Anthropogenic Fill with GPR for Unmarked Grave Detection: a Case Study from a Possible Location of Mokar's Grave, Albany, Western Australia

Type	Journal Article
Author	Paul Bladon
Author	Ian Moffat
Author	David Guilfoyle
Author	Alice Beale
Author	Jennifer Milani
Volume	42
Pages	249-257
Publication	Exploration Geophysics
Date	2011
Abstract	The authors did a small GPR survey prospecting for the grave of a significant Noongar figure, Mokare. The tomb was historically recorded as a distinctive size and shape and was not relocated in this survey. Instead, the authors found an anthropogenic fill deposit after topographically correcting their data.

Date Added 5/9/2016, 3:45:45 PM
Modified 6/8/2016, 1:58:40 PM

Tags:

Historic Cemetery, Australia, Pre-contact cemetery, GPR

Mapping Social Relations: Geophysical Survey of a Nineteenth-Century Slave Cemetery

Type Journal Article
Author Daniel P. Bigman
Volume 6
Pages 17-30
Publication Archaeological and Anthropological Science
Date 2014
Abstract A single section of a known cemetery was surveyed for unmarked graves with GPR, EM, and magnetic susceptibility because it was thought to contain unmarked slave burials. Multiple graves were identified with GPR and magnetic susceptibility and some were tested with a probe. Bigman concludes by making the argument that because the identified possible graves are in an orderly row next to the cemetery the planter family had a more progressive attitude to the slave than was typical at the time.
Date Added 8/6/2015, 1:44:26 PM
Modified 6/8/2016, 1:56:17 PM

Tags:

United States, electromagnetic induction, Slave Cemetery, Georgia, Historic Cemetery, GPR

Moisture and Soil Differences as Related to the Spatial Accuracy of GPR Amplitude Maps at Two Archaeological Test Sites.

Type Presentation
Presenter Lawrence Conyers
Place The Netherlands
Date 2004
Meeting Name Tenth International Conference on Ground Penetrating Radar
Abstract This conference paper discusses a controlled archaeological study where the author did a GPR survey in two different geographic locations (with very different soils). The controlled site had packed earth floors, burned floors, timber, beams, wall trenches, post holes, and burials. The areas were surveyed both before and after a heavy precipitation and the results were compared. The interpreted results found that some features were more visible when saturated with water. Others were less visible based on how much water they absorbed, and the type of surrounding soils. The study also looked at RDP values of soils and found that even a small amount of water can dramatically raise the RDP. The principles discussed in this article are important to both cemetery and non-cemetery GPR studies as moisture retention differences could potentially drastically change the visibility of graves in geophysical data sets.

Date Added 12/21/2011, 9:55:57 AM
Modified 8/29/2016, 4:04:54 PM

Tags:

General Reference, United States, Washington, Illinois, GPR

Monitoring Controlled Graves Representing Common Burial Scenarios with Ground Penetrating Radar

Type Journal Article
Author John J. Schultz
Author Michael M. Martin
Volume 83
Pages 74-89
Publication Journal of Applied Geophysics
Date 2012
Abstract This article outlined the results of a controlled study of the effectiveness of GPR for forensic work. The study involved using pig cadavers buried at varying depths in conditions commonly found at forensic scenes, including wrapped with various materials, covered in stones, and with no treatment. Two control burials of different depths were also created. A 250 MHz and 500 MHz antenna were used monthly over the graves and climate data was recorded. The author concluded that moisture improved the resolution of all graves. Wrapped cadavers or those in which items were included with the burials were easier to identify, and deeper graves were generally more visible. Both antennae provided resolution of graves throughout the study periods, but the 500 MHz yielded slightly more detail, while the 250 MHz provided better depth penetration. The lower frequency also had less clutter in the data. The authors suggested using both antennae if time allows. Finally, they recommend generating both profiles and slice maps for forensic work. This study was well controlled and concisely provided information about GPR and its use for detecting modern burials.
Date Added 5/27/2016, 11:06:10 AM
Modified 6/9/2016, 12:27:11 PM

Tags:

United States, Florida, Clandestine Graves, Forensics, GPR

Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations

Type Book Section
Author Don H. Heimmer
Author Steven L. De Vore
Editor Ray A. Williamson
Editor Paul R. Nickens

Series Advances in Archaeological and Museum Science
Volume 4
Place New York, New York
Publisher Springer US
Pages 53-73
Date 2000
Abstract This book chapter outlines basic geophysical methods as they can be applied to archaeological resource management. It discusses general methods and emphasizes the use of an experienced operator.
Book Title Science and Technology in Historic Preservation
Date Added 5/23/2016, 11:38:53 AM
Modified 6/9/2016, 9:31:13 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation

Type Report
Author Kenneth L. Kvamme
Author Eileen G. Ernenwein
Author Michael L. Hargrave
Author Thomas Sever
Author Deborah Harmon
Author Fred Limp
Place Fayetteville, Arkansas.
Date 2006
Institution Center for Advanced Spatial Technologies, University of Arkansas
Abstract Comprehensive technical report focusing on the application of geophysical methods to four archaeological sites (prehistoric and historic) in different regions of the U.S. Includes information on field survey parameters, overviews of magnetometry, electrical resistivity, EM induction, and GPR, as well as data processing steps for each. One of the few publications to focus specifically on data fusion and interpretation of geophysical data. No discussion specific to cemeteries, although the principles are applicable.
Date Added 10/25/2012, 9:22:06 AM
Modified 6/9/2016, 10:37:03 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

Nondestructive Geophysical Surveys for Delineating Buried Tombs and Identifying their Environmental Status.

Type Journal Article
Author Mohamed G El-Behiry
Pages 399-407
Publication Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems 2000
Date 2000
Abstract This article discusses the use of EM conductivity and supporting resistivity and GPR to identify tombs in the Cairo suburbs. The study was undertaken due to development pressures. The author also discusses data processing and problems associated with complex, urban interference. The geophysical methods were successful at locating graves.
Date Added 5/23/2016, 9:32:09 AM
Modified 6/7/2016, 7:49:28 AM

Tags:

Egypt, electrical resistivity, electromagnetic induction, Historic Cemetery, Cairo, GPR

Preliminary Results of Sequential Monitoring of Simulated Clandestine Graves in Colombia, South America, using Ground Penetrating Radar and Botany

Type Journal Article
Author Carlos Martin Molina
Author James K. Pringle
Author Miguel Saumett
Author Orlando Herńandez
Volume 248
Pages 61-70
Publication Forensic Science International
Date 2015
Abstract This article discusses the preliminary results for a simulated clandestine burial in Colombia. The burials simulated common scenarios found in Colombia using both freshly killed pigs and skeletonized human remains. GPR was used to monitor the burials over nine months, and found that it became less effective over time. Temporal changes in vegetation species were also noted. Analysis of soil data found that moisture content was almost double those reported from more temperate climates.
Date Added 5/27/2016, 9:53:53 AM
Modified 6/9/2016, 11:00:42 AM

Tags:

Mass Grave, Colombia, Forensics, GPR

Preservation of McVicker Family Cemetery, Jonesboro, Georgia

Type Journal Article
Author Gail Tarver
Author Daniel P. Bigman
Volume 41
Issue 2
Pages 211-241
Publication Early Georgia
Date 2013
Abstract This article outlines the steps taken to preserve the McVicker family cemetery beginning with a multi-instrument geophysics survey and concluding with restoration of the cemetery stones and fencing. The geophysics identified two possible graves outside of the cemetery that were determined not related to it.
Date Added 5/25/2016, 3:56:05 PM
Modified 6/9/2016, 1:57:42 PM

Tags:

electrical resistivity, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Radar Investigations of Ancient Dutch Cemetery in Southern Thailand

Type Journal Article
Author A. Phattanaviriyapisarn
Author W. Lohawijarn
Author T. Srisuchat
Pages 727-730
Publication 4th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 1998
Abstract This brief article outlines a GPR survey to prospect for the graves of Dutch settlers in Thailand. GPR was chosen because it was judged the most effective at detecting the lime coffins from the surrounding sand matrix. The survey successfully located graves and the researchers concluded this method would be useful in the future to target archaeological excavations.
Date Added 5/23/2016, 1:39:11 PM
Modified 6/9/2016, 11:25:14 AM

Tags:

Holland, Thailand, Historic Cemetery, GPR

Reconstruction of Lost Burial Plots Records with Ground Penetrating Radar

Type Journal Article
Author Cameron S. Ross
Author Miguel Merino
Author Laura Sherrod
Pages 1042-1050
Publication 22nd Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 2009
Abstract This article presents a GPR survey of a Michigan cemetery used from approximately 1800 to the 1950s. The burial records were lost and the cemetery subsequently closed, but empty spaces were thought to represent unmarked graves. GPR was used to make interpretations of burial history. The authors established a tiered system of interpretation certainty using GPR profiles. The survey covered five acres with transects spaced five feet apart. While no slice maps were produced, the final interpretive plots indicated nearly all of the surveyed area contained graves.
Date Added 5/24/2016, 1:13:19 PM
Modified 6/9/2016, 11:55:58 AM

Tags:

United States, Historic Cemetery, Michigan, GPR

Remote Sensing Applications in Forensic Investigations

Type Journal Article
Author G. Clark Davenport
Series Archaeologists as Forensic Investigators
Volume 35
Issue 1
Pages 87-100
Publication Historical Archaeology
Date 2001
Abstract This article outlines remote sensing methods used in forensic investigations and discusses the attributes of each type of instrument. Includes an overview of unique circumstances in forensic cases, discussion of methods/techniques that were commonly used at that time, limitations, and special considerations (e.g., results scrutinized in courts, evidence procedures, proper training). The article then briefly describes three case studies where thermal imaging and geophysics were used to assist in forensic cases. The technical sections are dated with respect to equipment advances, making them largely irrelevant, but the general emphasis on choosing the right equipment with the right resolution is remains important.
Date Added 8/6/2013, 4:18:35 PM
Modified 6/9/2016, 8:35:34 AM

Tags:

electrical resistivity, United States, electromagnetic induction, Remote Sensing, Thermal Imaging, Forensics, Grave Detection, GPR, Magnetometer

Remote Sensing in Archaeology: an Explicitly North American Perspective

Type Book
Editor Jay K. Johnson
Place Tuscaloosa, Alabama
Publisher University of Alabama Press
ISBN 978-0-8173-5343-8
Date 2006
Library Catalog Open WorldCat
Abstract Edited volume intended for operators and managers with chapters from leading geophysical practitioners in the United States. The book includes background on the development and application of geophysics in North America. The bulk of the book is devoted to chapters on methods (EM conductivity, electrical resistance, GPR, magnetic susceptibility, magnetometry, data processing), and the benefits of multiple methods and ground truthing.
Short Title Remote sensing in archaeology
Date Added 9/27/2011, 1:05:25 PM
Modified 6/9/2016, 10:05:54 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, Canada, Remote Sensing, Mexico, GPR, Magnetometer

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Revealing the Buried Past: Geophysics for Archaeologists

Type Book
Author Chris Gaffney
Author John Gater
Place Briscombe Port Stroud, United Kingdom
Publisher Tempus Publishing Ltd.
ISBN 978-0-7524-2556-6
Date 2003
Library Catalog Open WorldCat
Abstract One of the first major publications to address archaeological geophysics. Includes background on development of field, theoretical principles, discussion of most common methods (electrical resistance, magnetic gradiometry, GPR, EM conductivity, metal detecting, magnetic susceptibility), survey logistics, data processing, and case studies. Includes some discussion of burials specific to the UK, but nothing on cemeteries as a unique site type.
Short Title Revealing the buried past
Date Added 12/21/2011, 10:37:51 AM
Modified 6/9/2016, 9:06:21 AM

Tags:

Worldwide, electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Metal Detector, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Searching for Concealed Human Remains Using GPR Imaging of Decomposition

Type Journal Article
Author Michelle L. Miller
Author Robert S. Freeland
Author Steven K. Koppenjan
Volume Proceedings of SPIE Volume 4158
Pages 539-544
Publication Ninth International Conference on Ground-Penetrating Radar. 30 April to 2 May 2002, Santa Barbara, California
Date 2004
Abstract This article discusses the variables involved in using GPR to detect forensic remains. The complexity of GPR results is largely dependent on surrounding soils and the decomposition of the body. Using geophysical principles and the chemistry of decomposition, the article discusses how bodies decompose and how that process can affect GPR results. The authors further discuss a test site in Tennessee where they are studying human cadavers in mock burials.
Date Added 5/25/2016, 3:08:17 PM
Modified 6/9/2016, 10:47:46 AM

Tags:

Tennessee, United States, Clandestine Graves, Forensics, GPR

Searching for Graves Using Geophysical Technology: Field Tests with Ground Penetrating Radar, Magnetometry, and Electrical Resistivity.

Type Journal Article
Author Sabrina C. Buck
Volume 48
Issue 1
Pages 1-7
Publication Journal of Forensic Science
Date 2003
Abstract This article outlines field experiments using various configurations of GPR, magnetometry, and electrical resistivity to look for historic and forensic burials. The studies stated goal was to review the utility of these methods for finding human burials. The author had limited success identifying human remains and concluded that the technology methods and user skills need development. Notably, she did much of her processing in the field and used technology that would be considered outdated today.
Date Added 12/21/2011, 9:22:25 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, Magnetometry in archaeology, geophysical, Historic Cemetery, Forensics, GPR, Magnetometer

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Searching for the IRA "Disappeared": Ground-Penetrating Radar Investigations of a Churchyard Burial Site, Northern Ireland

Type	Journal Article
Author	Alastair Ruffell
Volume	50
Issue	6
Pages	1430-1435
Publication	Journal of Forensic Sciences
Date	2005
Abstract	This article follows the investigation of a cemetery plot thought to contain the clandestine burial of a "disappeared" person adjacent to a known burial. The investigator used two frequencies of GPR antennae to survey a small plot containing a 1970's burial and that was thought to also contain a clandestine burial. The survey located the 1970's burial, including the stepped platform used to dig the grave, but it did not find the clandestine burial. The author concluded that the clandestine burial as not in this plot, and it was later recovered elsewhere. This article is follows a common theme seen in forensic case studies where generated tips are explored most often resulting in negative findings.
Date Added	5/25/2016, 3:30:00 PM
Modified	8/29/2016, 4:29:29 PM

Tags:

Modern Cemetery, Clandestine Graves, United Kingdom, Forensics, GPR, Ireland

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Seeing Beneath the Soil: Prospecting Methods in Archaeology

Type	Book
Author	Anthony Clark
URL	http://books.google.com/books/about/Seeing_Beneath_the_Soil.html?id=YRGI_E3-yvgC
Place	London, England
Publisher	B.T. Batsford, LTD
Date	1996
Accessed	1/3/2012, 10:59:42 AM
Abstract	Among the first textbooks dedicated to remote sensing/geophysics and still widely cited. It provides detailed information on the most common instruments, data collection parameters, data processing, and interpretation. The focus is almost entirely on case studies in the United Kingdom. There are two brief references to graves. The first dealt with the identification of Saxon warrior burials and associated weaponry using magnetometry. The second discussed a poor response from known graves to electrical resistance that was attributed to chalky soils in

the backfill.

Date Added 1/3/2012, 10:59:42 AM

Modified 6/8/2016, 4:50:35 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Sequential Monitoring of Burials Containing Large Pig Cadavers Using Ground-Penetrating Radar

Type Journal Article

Author John J. Schultz

Author Mary E. Collins

Author Anthony B. Falsetti

Pages 607-616

Publication Journal of Forensic Sciences

Date 2006

Abstract This article discussed the results from a long term GPR study using pig cadavers. The cadavers were buried in shallow graves in sandy soils and deep graves that reached to the clay stratum. The graves were surveyed with GPR over 12 months and 21 months, after which they were partially excavated to determine decomposition. The shallow graves within the sand were easiest to identify, even after the pig carcasses had skeletonized. The deeper graves became increasingly difficult to identify, despite better preservation than the shallow specimens, although they could still be identified from the stratum breaks. The authors also discuss general best forensic practices for processing data and field methods. This article provides an excellent technical background for understanding how burials decompose differently in different conditions and provides a detail analog for human remains.

Date Added 5/25/2016, 3:47:12 PM

Modified 8/29/2016, 4:27:40 PM

Tags:

United States, Florida, Clandestine Graves, Forensics, GPR

Sequential Monitoring of Burials Containing Small Pig Cadavers Using Ground Penetrating Radar

Type Journal Article

Author John J. Schultz

Volume 53

Pages 279-287

Publication Journal of Forensic Sciences

Date 2008

Abstract GPR test cases on 12 pig cadavers in Florida. Six were buried in sand at depths between 0.5-0.6 meters and six were buried at a depth of 1.0-1.1 meter, where the sand met the clay horizon. The burials were monitored for 12-13 or 21-21.5 months and then excavated. Cadavers in sand were easily located even after 21 months and complete skeletonization. Detection was much more difficult with burials in clay. Soil type had the greatest effect on whether or not a cadaver was detected. The control grave demonstrated that GPR reflections in sand came from body/skeleton itself, not disturbed soil.

Date Added 5/25/2016, 3:44:59 PM

Modified 6/9/2016, 12:36:12 PM

Tags:

United States, Florida, Clandestine Graves, Forensics, GPR

Situating Remote Sensing Anthropological Archaeology

Type Journal Article

Author Victor D. Thompson

Author Philip J., III Arnold

Author Thomas J. Pluckhahn

Author Amber M. Vanderwarker

Volume 18

Pages 195-213

Publication Archaeological Prospection

Date 2011

Abstract This article argues that many geophysical or remote sensing projects are not integrated fully into research designs. By developing research questions that incorporate geophysics, archaeologists can address more complex anthropological questions. The authors outline a series of landscape, temporal, and construction related problems they think can be considered using geophysical data sets. They provide examples from prehistoric sites in Mexico, Georgia, and Florida to illustrate this argument. The focus is on a theoretical approach based on the analysis of “persistent places within a regional context” rather than specific case study details.

Date Added 5/23/2016, 3:47:25 PM

Modified 8/29/2016, 4:03:16 PM

Tags:

electrical resistivity, historic archaeology, United States, Florida, Georgia, Mexico, electrical resistance tomography, prehistoric archaeology, GPR, Magnetometer

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Still Searching for Graves: An Analytical Strategy for Interpreting Geophysical Data Used in the Search for “Unmarked” Graves

Type Journal Article

Author Chris Gaffney

Author C. Harris
Author F. Pope-Carter
Author J. Bonsall
Author R. Fry
Author A. Parkyn
Volume 13
Pages 557-569
Publication Near Surface Geophysics
Date 2015
Abstract This article discusses a multi-instrument survey of a historic cemetery. The authors used magnetometer, resistivity (multiple arrays), three dimensional (multiple antenna) GPR, and EM induction. They then compared their results with the historic burial plots. The argument is that no single method identified all of the graves, and that more techniques may equate with greater success. Additionally, better integration strategies will increase interpretive ability. It should be noted that the integration strategies appeared largely computer based using the ArcGIS intersection tool.
Date Added 5/24/2016, 2:47:54 PM
Modified 6/9/2016, 9:07:58 AM

Tags:

electrical resistivity, electromagnetic induction, Historic Cemetery, United Kingdom, GPR, Magnetometer

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Techniques for Locating Burials, with Emphasis on the Probe

Type Journal Article
Author Douglas W. Owsley
Volume 40
Issue 5
Pages 735-740
Publication Journal of Forensic Sciences
Date 1995
Abstract This article discusses how probing can be a superior grave detection method in smaller, expedient surveys and in areas where geophysical survey would be impossible. The author summarizes geophysical methods and their use in forensic applications. He then discusses the application of probing in a forensic setting. The article provides a series of case studies illustrating successful uses of probes. The examples include modern forensic cases in environments unsuited to geophysics and two small historic cemetery studies requiring expedient methods. Probing does need a skilled operator and systematic methods, but the cost is considerably lower.
Date Added 6/6/2016, 4:32:34 PM
Modified 6/9/2016, 11:14:43 AM

Tags:

electrical resistivity, United States, Texas, Clandestine Graves, Virginia, Historic Cemetery, Forensics, Probe, GPR, Magnetometer

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Testing for Unmarked Graves

Type	Conference Paper
Author	Bruce W. Bevan
Series	Micellaneous Paper GL-92-40
Place	Vicksburg, Mississippi
Publisher	Department of the Army, Corps of Engineers
Pages	34-38
Date	1992
Conference Name	Government Users Workshop on Ground Penetrating Radar Applications and Equipment 26-27 March 1992
Abstract	This paper is provides a general outline of GPR use in historic cemeteries and discusses some advantages and disadvantages of the method. Bevan presents some methodological suggestions as well as a discussion of field time use. The information provided is very briefly presented, the technology is dated, and there are two example profiles.
Proceedings Title	Proceedings of the Government Users Workshop on Ground Penetrating Radar Applications and Equipment
Date Added	5/31/2016, 10:43:35 AM
Modified	5/31/2016, 11:09:09 AM

Tags:

United States, Historic Cemetery, prehistoric archaeology, GPR

The Application of Geophysics to Archaeologic Mapping of Prehistoric, Protohistoric, and Historic Sites in Western Canada

Type	Journal Article
Author	Paul Bauman
Author	Rod Heitzmann
Author	Jack Porter
Pages	359-373
Publication	9th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date	1995
Abstract	This article outlines a study done at two fur trading posts, native campsites, and historic cemeteries in Alberta. The survey consisted of GPR, magnetometer, and EM conductivity. Because the fort was burned after abandonment, the magnetometer was most effective at mapping post holes. The GPR was effective at locating cellars and clearly pinpointed several burial sites. The article argues that multiple instruments are important in geophysical survey. Notably, this is an early article and equipment and software has improved significantly since this

was published.

Date Added 5/25/2016, 9:29:21 AM

Modified 6/8/2016, 1:51:49 PM

Tags:

historic archaeology, electromagnetic induction, Canada, protohistoric archaeology, Alberta, Historic Cemetery, prehistoric archaeology, GPR, Magnetometer

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The Application of GPR in Florida for Detecting Forensic Burials

Type Journal Article

Author Steven K. Koppenjan

Author John J. Schultz

Author Anthony B. Falsetti

Author Mary E. Collins

Author Sashi Ono

Author Hua Lee

Pages 635-649

Publication 16th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems.

Date 2003

Abstract This paper discusses the application of GPR for detecting forensic graves. The authors constructed a test site with 24 pig cadavers and monitored them monthly for 21 months with regular data collection. Cadaver size was chosen to simulate adult and child bodies and they were buried at different depths. Results showed that anomalies representing graves became less distinct over time due to body decomposition and settling of backfill in the grave shaft. Soil type was identified as a major factor and deeper targets in clay were more difficult to detect over time, while targets in sand remained distinct for the duration of the study.

Date Added 5/26/2016, 1:47:13 PM

Modified 6/9/2016, 10:35:54 AM

Tags:

United States, Florida, Clandestine Graves, Forensics, GPR

The Detection of Human Remains

Type Book

Author Edward W. Killam

Edition Second Edition

Place Springfield, Illinois

Publisher Clarence C. Thomas, Publisher, LTD

Date 2004

Abstract This updated reference for forensic investigators is intended as a guide for locating human remains by law enforcement, archaeologists, and other investigators. Methods include ground contact, proximate, geophysical, and aerial remote sensing. Includes general overview of theory and applicability of each method. Geophysical methods can be used as principal means of location/identification, or to refine, corroborate, or eliminate certain areas. No single method is best for all situations.

Date Added 5/25/2016, 2:48:24 PM

Modified 6/9/2016, 10:32:45 AM

Tags:

electrical resistivity, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Forensics, Probe, GPR, Magnetometer

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The Effectiveness of Ground-Penetrating Radar Surveys in the Location of Unmarked Burial Sites in Modern Cemeteries

Type Journal Article

Author Sabine Fiedler

Author Bernhard Illich

Author Jochen Berger

Author Matthias Graw

Volume 68

Pages 380-385

Publication Journal of Applied Geophysics

Date 2009

Abstract This article outlines a controlled study on a modern cemetery in Germany. The study determined that GPR was an effective method for locating the graves with relative accuracy, but was not effective to study the decay of the graves.

Date Added 7/12/2013, 4:43:07 PM

Modified 5/31/2016, 1:44:15 PM

Tags:

Modern Cemetery, Germany, Forensics, GPR

The Reliability of Geophysical Surveys at Historic-Period Cemeteries: An Example from the Plains Cemetery, Mechanicsville, Maryland.

Type Journal Article

Author Julia A. King

Author Bruce W. Bevan

Author Robert J. Hurry

Volume 27

Issue 3
Pages 4-16
Publication Historical Archaeology
Date 1993
Date Added 5/10/2016, 1:29:41 PM
Modified 8/14/2017, 1:33:36 PM

Tags:

United States, Maryland, Historic Cemetery, GPR, Magnetometer

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The Search for "Yvonne": A Case Example of the Delineation of a Grave Using Near-Surface Geophysical Methods

Type Journal Article
Author David C. Nobes
Volume 45
Issue 3
Pages 715-721
Publication Journal of Forensic Sciences
Date 2000
Abstract This article outlines a search for the remains of a homicide victim. The searchers had a reasonable idea about where the victim might be, but needed a more certain target. They covered a large area with EM and a smaller area with GPR. The area was heavily disturbed by forestry operations and there were a number of anomalous readings due to metal debris and tree roots. An isolated EM anomaly on the edge of the grid located the body and GPR was of minimumal use due to the complexity of the subsurface.
Date Added 5/25/2016, 3:14:13 PM
Modified 6/9/2016, 11:08:15 AM

Tags:

electromagnetic induction, New Zealand, Clandestine Graves, Forensics, GPR

The Search for Graves

Type Journal Article
Author Bruce W. Bevan
Volume 56
Issue 9
Pages 1310-1319
Publication Geophysics
Date 1991

Abstract One of the first publications to deal specifically with cemeteries. Bevan used GPR and EM conductivity at nine different cemeteries in the U.S (diverse environmental settings). GPR tends to detect the bottom of the grave or the shaft. EM tends to detect grave shafts and/or metal (if in sufficient quantities in detectable range). Bevan concluded that there is no guarantee of success because of false positives and not detecting marked graves in certain cases. Although dated, this is an important article because it contains a range of cemetery types and has technical information assessing the results and it still holds relevance.

Date Added 8/6/2013, 1:45:00 PM

Modified 6/8/2016, 1:54:13 PM

Tags:

Cemetery Survey, Modern Cemetery, United States, electromagnetic induction, Slave Cemetery, New York, Maryland, Rhode Island, Ohio, Historic Cemetery, Pauper Cemetery, Minnesota, GPR, Viriginia

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The Search for Graves with Ground-Penetrating Radar in Connecticut

Type Journal Article

Author James A. Doolittle

Author Nicholas F. Bellantoni

Volume 37

Pages 941-949

Publication Journal of Archaeological Science

Date 2010

Abstract This general methods article discusses the use of GPR and specific issues and environmental settings in Connecticut for both forensic and historic purposes. The article discusses problems with soil clutter, burial decomposition, and the amount of acceptable uncertainty. Under ideal conditions some graves will be missed. The authors do discuss the use of slice maps in GPR to improve identification of unmarked graves and suggest that the method be employed strategically.

Date Added 5/24/2016, 11:13:01 AM

Modified 5/25/2016, 1:53:37 PM

Tags:

Connecticut, Modern Cemetery, United States, Historic Cemetery, Forensics, GPR

The Tulsa Race Riot of 1921: A Geophysical Study to Locate a Mass Grave

Type Journal Article

Author Alan Witten

Author Robert Brooks

Author Thomas Fenner

Volume 20

Pages 655-660

Publication The Leading Edge

Date 2001

Abstract This short article discusses the search for a mass grave of the African American victims of the Tulsa Race Riot of 1921. Magnetometer and electromagnetic induction were used in an area where an eye witness recalled seeing crates of bodies. Two specific anomalies identified with magnetic instruments were tested with GPR and one anomaly with trench-like features was isolated for further testing. The article was written prior to testing.

Date Added 5/24/2016, 9:24:25 AM

Modified 5/24/2016, 9:26:04 AM

Tags:

United States, electromagnetic induction, Mass Grave, Historic Cemetery, Oklahoma, Forensics, GPR, Magnetometer

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The Use of Geoscience Methods for Terrestrial Forensic Searches

Type Journal Article

Author James K. Pringle

Author Alastair Ruffell

Author John R. Jervis

Author L. Donnelly

Author J. McKinley

Author J. Hansen

Author R. Morgan

Author D. Pirrie

Author M. Harrison

Volume 114

Pages 108-123

Publication Earth-Science Reviews

Date 2012

Abstract This review article surveys geoscientific methods for locating clandestine graves. It starts with broad searching techniques and then focuses on reconnaissance, where seismology, conductivity, resistivity, GPR, magnetometry, probing, geomorphology, among other techniques. Each method is described briefly along with examples and citations of its use. The post-search section discusses topsoil removal, trenches, and excavations. The authors emphasize that there is no method that works every time, success is largely dependent on environmental conditions and the type of burial.

Date Added 5/25/2016, 3:22:08 PM

Modified 6/9/2016, 11:45:53 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Metal Detector, Clandestine Graves, Forensics, GPR, seismic, Magnetometer

The Usefulness of Ground Penetrating Radar in Locating Burials in Charity Hospital Cemetery, New Orleans

Type Thesis
Author Monique Tashell Mitchell
URL http://scholarworks.uno.edu/td/686/
Place New Orleans, Louisiana
Date 2008
Accessed 5/10/2016, 8:00:00 PM
University University of New Orleans
Abstract The Charity Hospital Cemetery in New Orleans, Louisiana, was used as a potter's field for over 150 years. When Charity Hospital considered selling a portion of the property, ground penetrating radar (GPR) and thermal infrared (TIR) data were collected in the cemetery to locate unmarked graves. The TIR data became unavailable before the study ended, leaving the GPR data as the sole source of subsurface information. GPR anomalies were used to guide excavation in three areas, which produced bones and hospital supplies. Only very limited analyses were possible on the analog GPR data. The study involved digitizing data and conducting a more thorough analysis of map patterns to determine whether GPR data could be used reliably to locate burials in the cemetery. The study's result indicated that GPR is a reliable source for burial detection and other anomalies below the surface.
Date Added 5/11/2016, 11:53:27 AM
Modified 6/9/2016, 10:56:15 AM

Tags:

United States, Louisiana, Historic Cemetery, GPR

Time-Lapse Geophysical Investigations over a Simulated Urban Clandestine Grave

Type Journal Article
Author James K. Pringle
Author John Jervis
Author John P. Cassella
Author Nigel J. Cassidy
Volume 53
Issue 6
Pages 1405-1416
Publication Journal of Forensic Science
Date 2008
Abstract This article discusses a study of the usefulness of geophysical instruments in locating a clandestine burial site in an urban environment. For the study a cadaver mannequin was buried along with animal organs and fluids. The area was examined over three months with multiple geophysical instruments. As a control, the study area was also tested with all instruments prior to installing the simulated grave. The resistivity was best at resolving the grave location, while electrical resistance tomography (ERT) and GPR were better for providing spatial information. The authors suggest that resistivity surveys be conducted prior to collecting GPR and ERT data

in forensic search conditions.

Date Added 5/27/2016, 10:26:18 AM

Modified 6/9/2016, 11:41:23 AM

Tags:

electrical resistivity, electromagnetic induction, Clandestine Graves, United Kingdom, Forensics, electrical resistance tomography, GPR, Magnetometer

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Use of Precision Mapping and Multiple Geophysical Methods at the Historic Reese Cemetery in Muncie, Indiana

Type Journal Article

Author Gregory B. Byer

Author John A. Mundell

Pages 68-79

Publication 16th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems.

Date 2003

Abstract This article outlines a program of geophysical research at a historic cemetery in Indiana. This cemetery could not be excavated due to both regulatory and ethical concerns but was known to contain unmarked burials. The survey team used EM metal detector, EM conductivity, and GPR. The EM metal detecting was of limited utility and the EM conductivity was somewhat more useful. The GPR provided the most data about marked and unmarked graves including the more subtle, older graves.

Date Added 5/23/2016, 2:17:15 PM

Modified 6/8/2016, 2:31:13 PM

Tags:

United States, Indiana, electromagnetic induction, Metal Detector, Historic Cemetery, GPR

Using 3D GPR to Determine the Extent of Possible 17th and 18th Century Graves Beneath a Concrete Driveway: Bridgetown Synagogue, Bridgetown, Barbados

Type Journal Article

Author Brian M. Whiting

Author Steven Hackenberger

Pages 475-478

Publication Proceedings of the 10th International Conference on Ground Penetrating Radar. 21-24 June 2004, Delft, The Neatherlands

Date 2004

Abstract This article outlines a GPR survey done on a drive built over a seventeenth through eighteenth-century Jewish cemetery. The driveway was constructed after the cemetery fell into disrepair and likely covered burials. The authors did not locate any graves under the driveway. They used a

900 MHz antenna, which they determined to have insufficient depth penetration for imaging the grave due to their depth below the subsurface. It was determined that further GPR would be useful with a 500 or 250 MHz antenna. The article title references 3D GPR, in this case the authors mean traditional slice maps and profiles. They did not use a multi-antenna three-dimensional system.

Date Added	5/26/2016, 4:40:08 PM
Modified	6/9/2016, 2:31:04 PM

Tags:

Barbados, Historic Cemetery, GPR

Using Geophysics to Locate Unmarked Graves to Aid in Remediation Design and Construction at an NPL Site

Type	Journal Article
Author	Joseph M. Parish
Pages	399-405
Publication	21st Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date	2008
Abstract	A drainage culvert associated with a Superfund site was planned adjacent to a historic cemetery where coffins had previously been exposed through erosion. The authors performed a GPR and electromagnetic conductivity survey over a known portion of the cemetery with marked graves to calibrate the instruments. They then directed their efforts to the area where the culvert was planned. They identified 14 graves, four of which were unmarked and the culvert was located and installed with no incident. This survey was apparently done by non-archaeologists or forensic specialists and little or no possibility for error is discussed.
Date Added	5/24/2016, 11:42:35 AM
Modified	6/9/2016, 11:17:14 AM

Tags:

United States, Texas, Historic Cemetery, GPR

Using Ground-Penetrating Radar to Locate Clandestine Graves of Homicide Victims: Forming Forensic Archaeology Partnerships with Law Enforcement

Type	Journal Article
Author	John J. Schultz
Volume	11
Issue	1
Pages	15-29
Publication	Homicide Studies
Date	2007

Abstract This article describes the use of GPR to law enforcement investigators. Key points include the importance of variables such as buried remains, disturbed ground, and non-biological items that may have been used to wrap the body. Human remains can be detected with GPR during various stages of decomposition and possibly when skeletonized. Most law enforcement agencies do not own their own equipment and must rely on outside experts. Operator experience is probably the most important factor and data collection should follow archaeological practice. One example is provided of a successful forensic case.

Date Added 5/25/2016, 3:43:14 PM

Modified 6/9/2016, 12:30:10 PM

Tags:

United States, Florida, Clandestine Graves, Forensics, GPR

Utilizing Ground Penetrating Radar for the Location of a Potential Human Burial Under Concrete

Type Journal Article

Author Michael S. Billinger

Volume 42

Pages 200-209

Publication Canadian Society of Forensic Science Journal

Date 2009

Abstract The author outlines a case where GPR was used on a concrete basement floor to locate a possible clandestine burial. There were indications that there was a grave present, which turned out to be false. This leads the author to caution others about false positives in GPR results.

Date Added 6/2/2016, 1:37:28 PM

Modified 6/8/2016, 1:57:09 PM

Tags:

Canada, Alberta, Clandestine Graves, Forensics, GPR

Velocity Analysis in Archaeological Ground Penetrating Radar Studies

Type Journal Article

Author Lawrence Conyers

Author Jeffery Lucius

Volume 3

Issue 1

Pages 25-38

Publication Archaeological Prospection

Date 1996

Abstract This article discusses ways to calculate the accurate conversion of the two-way travel time of electromagnetic energy to depth through velocity calculation. Methods include various reflective-wave methods and direct-wave methods. The authors recommend multiple types of velocity testing for optimal accuracy. This article is a classic methodological study that is still useful today.

Date Added 12/21/2011, 10:07:56 AM

Modified 11/30/2017, 12:00:10 PM

Tags:

General Reference, GPR

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LiDAR


Source: Weitman 2012

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Automated Detection of Prehistoric Conical Burial Mounds from LiDAR Bare-Earth Digital Elevation Models

Type	Thesis
Author	Melanie A. Riley
Place	Maryville, Missouri
Date	2009
Type	Master of Arts
Language	English
University	Northwest Missouri State University
Abstract	A feature detection tool was developed to be used in ArcGIS to locate conical burial mounds in LiDAR bare-earth digital elevation models. The research was implemented in Iowa, where ninety percent of field verified mounds were located. Some mounds were not detected, and there were many false positives. This tool may be used to location conical burial mounds in LiDAR imagery, though field verification is necessary.
# of Pages	124
Date Added	8/11/2017, 2:08:26 PM
Modified	8/11/2017, 2:10:53 PM

Tags:

Middle Woodland, Iowa, United States, LiDAR, conical burial mounds

LiDAR for Archaeological Research and the Study of Historical Landscapes

Type	Book Section
Author	Adrian S. Z. Chase
Author	Diane Z. Chase
Author	Arlen F. Chase
Editor	Nicola Masini
Editor	Francesco Soldovieri
Publisher	Springer International Publishing
Pages	89-100
Date	2017
Abstract	This chapter details the different types of LiDAR, how they work, and how they have been used by archaeologists. LiDAR has allowed archaeologists to produce models, and visualize, survey, and analyze the landscape in new ways. Previously unidentified archaeological features that may have no visible surface expression may be discovered in LiDAR data. The authors provide many other examples of how LiDAR has been used in archaeology.
Book Title	Sensing the Past

Date Added 8/14/2017, 2:58:56 PM
Modified 8/14/2017, 3:05:45 PM

Tags:

Archaeology, Landscape, LiDAR

LiDAR-Derived Local Relief Models-a New Tool for Archaeological Prospection

Type Journal Article
Author Ralf Hesse
Volume 17
Pages 67-72
Publication Archaeological Prospection
Date 2010
Abstract Local Relief Models from LiDAR-derived high-resolution Digital Elevation Models were used to detect archaeological features of Baden-Wurttemberg, Germany. This method allowed for small-scale positive and negative elevation differences to be discerned, resulting in the identification of archaeological features, including many potential burial mounds. The author notes that burial mounds can often be misidentified, since small hills, wood piles, and unfiltered patches of low vegetation can appear similarly in the model. However, LRMs can be useful for archaeological prospection and the identification of potential burial mounds.
Date Added 8/11/2017, 10:59:19 AM
Modified 8/11/2017, 11:01:33 AM

Tags:

Germany, Bronze Age, Burial Mounds, Iron Age, LiDAR, Local Relief Models, Paleolithic, Roman

Medieval

LiDAR-guided Archaeological Survey of a Mediterranean Landscape: Lessons from the Ancient Greek Polis of Kolophon (Ionia, Western Anatolia).

Type Journal Article
Author Benedikt Grammer
Author Erich Draganits
Author Martin Gretscher
Author Ulrike Muss
Issue 9999
Publication Archaeological Prospection

Date 2017

DOI 10.1002/arp.1572

Abstract By combining LiDAR interpretations with ground-observations, archaeological sites were detected in the Ancient Greek Polis of Kolophon. Features in the high-resolution LiDAR imagery were recognized and categorized based on a number of attributes. These were then assessed through a ground-observation survey, whereby 89 of 131 potential archaeological features were verified. The vast majority of objects identified were burial mounds and grave terraces, primarily because of the comparatively large size of those types of features.

Date Added 8/11/2017, 11:48:10 AM

Modified 8/11/2017, 11:52:02 AM

Tags:

Archaid Period, Burial Mounds, Geometric Period, Grave Terraces, Hellenistic, LiDAR, Turkey, Western Anatolia

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Locating and Characterizing Burials Using 3D Ground-penetrating Radar (GPR) and Terrestrial Laser Scanning (TLS) at the Historic Mueschke Cemetery, Houston, Texas

Type Journal Article

Author Azie S. Aziz

Author Robert R. Stewart

Author Susan L. Green

Author Janet B. Flores

URL http://dx.doi.org/10.1016/j.jasrep.2016.06.035

Volume 8

Pages 392-405

Publication Journal of Archaeological Science: Reports

Date 2016

Abstract Terrestrial laser scanning (LiDAR) and ground-penetrating were integrated at the Historic Mueschke Cemetery in Houston, Texas. LiDAR was used to identify surface depressions and mounds that correlated with known wooden coffin and concrete vault burials. These findings were then used to identify depressions without an associated gravestone, which were predicted to be unmarked, pre-1940 burials. This led to the implementation of GPR, which successfully located burials in those locations.

Date Added 8/11/2017, 3:48:52 PM

Modified 8/11/2017, 3:51:55 PM

Tags:

GPR, Cemeteries, LiDAR, Terrestrial Laser Scanning, Texas, United States, Unmarked burials

Robust Extraction of Ancient Burial Mounds in Brushland from Laser Scanning Data

Type	Journal Article
Author	Tsutomu Kakiuchi
Author	Hirofum Chikatsu
Volume	37
Issue	5
Pages	341-346
Publication	The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences
Date	2008
Language	English
Abstract	The village of Moroyama, Japan, has over 80 ancient burial mounds that are concealed by dense brushland. By filtering airborne laser scanner (LiDAR) data, the authors successfully identified all known mounds regardless of size and shape. This method also identified eleven new mounds, one of which was found to be a natural topographic feature that fit the dimensions of a burial mound.
Date Added	8/11/2017, 12:11:58 PM
Modified	8/11/2017, 12:15:16 PM

Tags:

Japan, Burial Mounds, Laser Scanning, LiDAR, Tumulus Period

Surface Prospection of Burial Grounds and New Research Tools (on the Example of the Study of Changes in Cemetery Boundaries)

Type	Journal Article
Author	Anna Majewska
Volume	7
Issue	1
Pages	60-69
Publication	Journal of Geography, Politics and Society
Date	2017
DOI	10.4467/24512249JG.17.008.6207
Language	English

Abstract This article provides examples of integrating LiDAR elevation models and terrain observations to study changes in the boundaries of burial sites. The changing boundaries of Christian and Jewish cemeteries in Poland were defined. Evidence of historic fences, ditches, earthworks, trenches, and roads all contributed to the identification of historic cemetery boundaries.

Date Added 8/11/2017, 9:38:48 AM

Modified 8/11/2017, 9:46:53 AM

Tags:

Cemeteries, Christianity, Judaism, LiDAR, Modern Historic Period, Poland

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Using Archaeological Methods in Cemetery Surveys with Emphasis on the Application of LiDAR

Type Thesis

Author Sarah L. Weitman

Place Statesboro, Georgia

Date 2012

Type Master of Social Sciences

Language English

University Georgia Southern University

Abstract This study was conducted for the purpose of determining the most comprehensive method of gathering gravestone data and mapping cemeteries. A total station, a handheld GPS, and LiDAR were used to map two Historic Period cemeteries. Gravestones were accurately mapped with LiDAR, with the exception of slab gravestones, which were indiscernible. The LiDAR data were also used to produce 3D images of gravestones in the cemeteries.

# of Pages 185

Date Added 8/11/2017, 3:12:18 PM

Modified 8/11/2017, 3:15:33 PM

Tags:

Cemeteries, Georgia, United States, LiDAR, South Carolina, United States

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Using LiDAR Data to Locate a Middle Woodland Enclosure and Associated Mounds, Louisa County, Iowa

Type Journal Article

Author Melanie A. Riley

Author Joseph A. Tiffany
URL http://dx.doi.org/10.1016/j.jas.2014.07.018
Volume 52
Pages 143-151
Publication Journal of Archaeological Science
Date 2014
Language English
Abstract Mortuary mounds belonging to the Middle Woodland enclosure of the McKinney site in Louisa County, Iowa, were first reported in 1841, but had not been detected since the nineteenth-century. The authors used LiDAR to locate these mounds. They report that they were able to do so, but their findings must be verified through ground observations.
Date Added 8/11/2017, 1:38:57 PM
Modified 8/11/2017, 1:41:28 PM

Tags:

Middle Woodland, Iowa, United States, LiDAR, Mortuary Mounds, Mounds

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Using LiDAR, Aerial Photography, and Geospatial Technologies to Reveal and Understand Past Landscapes in Four West Central Missouri Counties

Type Thesis
Author R. Zane Price
Place Lawrence, Kansas
Date 2012
Type Doctor of Philosophy in the Department of Geography
Language English
University University of Kansas
Abstract The author compared LiDAR and aerial photography to historical plat book and a Geographic Names Information System to study the ways that cemeteries in Missouri appeared in those data sets. LiDAR detected large monuments, large cemetery stones, or groups of stones in cemeteries. It was not found to reveal information that was not part of existing data sets.
# of Pages 525
Date Added 8/11/2017, 1:07:51 PM
Modified 8/11/2017, 1:11:06 PM

Tags:

Cemeteries, Historic Period, LiDAR, Missouri, United States

Using Pattern Recognition to Search LiDAR Data for Archaeological Sites

Type	Conference Paper
Author	Arjan De Boer
Volume	XXXIII
Pages	245-254
Date	2005
Conference Name	Computer Applications in Archaeology
Language	English
Abstract	LiDAR data pattern recognition techniques were used to identify registered and potential burial mounds in forested areas of the Netherlands. A template-based technique to identify Neolothic-Iron Age burial mounds was developed and implemented. This resulted in most registered mounds having high correlations, and the identification of many potential burial mounds. These potential mounds will need to be verified through field surveys.
Proceedings Title	The World is in Your Eyes
Date Added	8/11/2017, 10:18:59 AM
Modified	8/11/2017, 10:22:14 AM

Tags:

Bronze Age, Burial Mounds, Copper Age, Iron Age, LiDAR, Neolothic, Netherlands

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Magnetometer

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A Little Slice of Heaven: Investigations at Rincon Cemetery, Prado Basin, California

Type	Journal Article
Author	James Brock
Author	Steven J. Schwartz
Volume	25
Issue	3
Pages	78-90
Publication	Historical Archaeology
Date	1991
Abstract	This article discusses investigations at an unmarked twentieth-century California cemetery. Initial investigations were conducted with a proton magnetometer and those results were used to target limited excavations along with surface depressions. The results of excavations confirmed the interpretations of the magnetometer data and detailed map of possible graves was generated. There is an extensive discussion of California burial practices and the information generated from excavations.
Date Added	5/31/2016, 11:16:03 AM
Modified	6/8/2016, 2:07:59 PM

Tags:

United States, Historic Cemetery, California, Magnetometer

A Multidisciplinary Approach to the Detection of Clandestine Graves

Type	Journal Article
Author	D.L. France
Author	T.J. Griffin
Author	J.G. Swanburg
Author	J.W. Lindemann
Author	G. Clark Davenport
Author	V. Tranunell
Author	C.T. Armbrust
Author	B. Kondratieff
Author	A. Nelson
Author	K. Castellano
Author	D. Hopkins
Volume	37
Issue	6
Pages	1445-1458
Publication	Journal of Forensic Sciences
Date	1992

Abstract This article discusses a forensic research team assembled in Colorado. The multidisciplinary team buried pig carcasses and evaluated various techniques that included GPR, magnetics, and electromagnetics for their ability to locate the graves. Of the geophysical methods tested, GPR was the most effective. The article further recommends that law enforcement seek out a multidisciplinary approach to forensic work.

Date Added 5/20/2016, 3:49:53 PM

Modified 6/9/2016, 9:03:09 AM

Tags:

Modern Cemetery, United States, electromagnetic induction, Clandestine Graves, Forensics, Colorado, GPR, Magnetometer

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Archaeological Geophysics for DOD Field Use: A Guide for New and Novice Users

Type Report

Author Eileen Ernenwein

Author Michael L. Hargrave

URL https://www.researchgate.net/publication/228554161_Archaeological_Geophysics_for_DoD_Field_Use_a_Guide_for_New_and_Novice_Users

Place Fayetteville, Arkansas

Date 2009

Accessed 5/9/2016, 8:00:00 PM

Institution Center for Advanced Spatial Technologies, University of Arkansas and The U.S. Army Corps of Engineers, Engineer Research and Development Center Construction Engineering Research Laboratory

Abstract Demonstrates the validity of multi-sensor approach for detecting and characterizing sub-surface deposits at archaeological sites. Includes review of electrical resistance, electrical conductivity, magnetic susceptibility, magnetometry, and GPR. Good focus on determining site suitability, instrument selection, field implementation, estimating time and cost, and expectations. Includes very brief assessment of graves as part of discussion on detectable features and instrument selection.

Date Added 5/10/2016, 10:34:19 AM

Modified 6/9/2016, 8:52:27 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Comparisons of Magnetic and Electrical Resistivity Surveys Over Simulated Clandestine Graves in Contrasting Burial Environments

Type Journal Article

Author Alanna Juerges

Author James K. Pringle

Author John R. Jervis

Author Peter Masters
Volume 8
Pages 529-539
Publication Near Surface Geophysics
Date 2010
Abstract This article discusses a controlled pig cadaver study where magnetics and resistivity were tested in conjunction to evaluate their usefulness for detecting clandestine graves. Multiple site types were tested and the study evaluated how these instruments worked over a year. The magnetometer was deemed to be the most effective method, but both instruments working in conjunction were ultimately determined to be preferable. The study also tested the instruments at a medieval monastery where known graves have been identified.
Date Added 5/23/2016, 4:30:05 PM
Modified 6/9/2016, 10:20:00 AM

Tags:

electrical resistivity, Clandestine Graves, Historic Cemetery, United Kingdom, Forensics, Magnetometer

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Complementary Geophysical Survey Techniques: Why Two Ways are Always Better than One

Type Journal Article
Author R. Berle Clay
Volume 20
Issue 1
Pages 31-44
Publication Southeastern Archaeology
ISSN 0734-578X
Date 2001
Abstract This article discusses using two different geophysical instruments to complement each other during archaeological survey. The author used magnetic gradiometer and EM conductivity on a variety of historic and prehistoric sites. The results of each instrument are discussed with the emphasis on how different types of data support each other for interpretive purposes. The article stresses that different geophysical instruments can only work within their limitations but produce complementary results and that practioners should focus on why survey instruments produce results in a specific circumstance when others do not.
Date Added 5/31/2016, 11:06:20 AM
Modified 6/8/2016, 5:00:47 PM

Tags:

historic archaeology, General Reference, United States, electromagnetic induction, Kentucky, Mississippi, Ohio, prehistoric archaeology, Magnetometer

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Confederate Guns in the Graveyard

Type	Journal Article
Author	Jessica Cook Hale
Author	Sheldon Skaggs
Volume	41
Issue	2
Pages	243-255
Publication	Early Georgia
Date	2013
Abstract	Archaeologists responded to a local legend of two cannons buried in a cemetery in Rome, Georgia during the Confederate retreat. They conducted a GPR and gradiometer survey and identified an unknown anomaly that was too small to be a cannon but they did not think it was a grave. Excavation revealed it was an iron coffin. The article also goes into detail about managing public expectations and the press.
Date Added	5/25/2016, 1:25:32 PM
Modified	6/9/2016, 8:28:03 AM

Tags:

historic archaeology, Civil War, Georgia, Historic Cemetery, GPR, Magnetometer

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Detecting Buried Human Remains Using Near-Surface Geophysical Instruments

Type	Journal Article
Author	Kathryn Powell
Volume	35
Pages	88-92
Publication	Exploration Geophysics
Date	2004
Abstract	This article discusses the use of geophysics to identify graves in an Australian environment. The author used a controlled grave site containing human cadaver, pig, and kangaroo remains. GPR was successful in locating the pigs than the kangaroo. The author also queried local police and found that searches for forensic remains with geophysics had a poor success rate. Finally, a historic burial was located with resistivity, demonstrating the application of this technique to locate historic graves.
Date Added	5/25/2016, 3:19:13 PM
Modified	6/9/2016, 11:31:35 AM

Tags:

electrical resistivity, Clandestine Graves, Australia, Forensics, GPR, Magnetometer

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Effect of Grain Size on the Geophysical Responses of Indigenous Burial Sites

Type	Conference Paper
Author	David C. Nobes

Place Istanbul, Turkey
Publisher Near Surface
Pages 1-5
Date 2007
Conference Name 13th European Meeting of Environmental and Engineering Geophysics
Abstract This is paper discusses grave detection in clay, loess, and sand using five Maori cemeteries from New Zealand using magnetics, EM, and GPR. The results show burials in clay and loess can be identified but burials in sand do not always show responses. Different results are likely due to depositional setting. Clay and loess are usually deposited as layers or massive beds, and therefore disturbances are clear, while fluvial and Aeolian sand contain sedimentary structures that can mask geophysical responses.
Proceedings Title Near Surface
Date Added 5/31/2016, 2:56:53 PM
Modified 8/29/2016, 5:47:53 PM

Tags:

electromagnetic induction, New Zealand, Historic Cemetery, Pre-contact cemetery, GPR, Magnetometer

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Forensic Archaeology: Advances in Theory and Practice

Type Book
Author J. Hunter
Author M. Cox
Place London, England
Publisher Routledge
Date 2005
Abstract This book discusses forensics from an archaeological perspective. It contains a chapter that specifically addresses using geophysics for forensic applications, and case studies using geophysics are discussed. The book also summarizes how each instrument functions. This a textbook-style work that addresses many aspects of forensics and discusses the integration of geophysics with other forensic methods.
Date Added 5/25/2016, 2:33:18 PM
Modified 6/9/2016, 9:37:45 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Clandestine Graves, Forensics, GPR, Magnetometer

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Forensic Geoscience: Applications of Geology, Geomorphology and Geophysics to Criminal Investigations

Type Journal Article
Author Alastair Ruffell

Author Jennifer McKinley
Volume 69
Pages 235-247
Publication Earth-Science Reviews
Date 2005
Abstract This review article summarizes the history of and the modern application of forensic geosciences. "Forensic geoscience" is a broad classification and includes everything from geophysics to geochemistry. The authors begin with a discussion of the discipline's history and finish with an overview of available literature that pertains to each method, including GPR, magnetics, resistivity, and ERT. This discussion extends to cover large scale landforms and microscopic particle forensic studies. The authors conclude with a suggestion that more is being done in the discipline outside of journal publication.
Date Added 6/2/2016, 8:17:45 AM
Modified 6/9/2016, 12:03:30 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Forensics, electrical resistance tomography, GPR, Magnetometer

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Forensic Methods: Excavation for the Archaeologist and Investigator

Type Book
Author Melissa A Connor
Place Lanham, Maryland
Publisher AltaMira Press
Date 2007
Abstract This book is a thorough overview of forensic archaeology, including preparation, fieldwork, soils, taphonomy of forensic sites, locating and excavating buried remains, evidence, documentation, and professionalization of the discipline. Methods for identifying graves include probing, cadaver dogs, test trenches, aerial photographs, and geophysical methods (metal detectors, GPR, EM, electrical resistance, and magnetometers). Includes a geophysical case study and summary of strengths/weaknesses of various methods.
Date Added 6/6/2016, 10:20:10 AM
Modified 6/8/2016, 5:02:47 PM

Tags:

electrical resistivity, electromagnetic induction, Metal Detector, Clandestine Graves, Cadaver Dogs, Forensics, Probe, GPR, Magnetometer

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Geophysical Detection of Graves - Basic Background and Case Histories from Historic Cemeteries

Type Conference Paper

Author William James Johnson
URL http://www.archaeology-geophysics.com/PDF%20papers/Geophysical%20Detection%20of%20Graves%202014.pdf
Place Charleston, West Virginia
Date 2003
Accessed 5/9/2016, 8:00:00 PM
Conference Name Council for West Virginia Archaeology Spring Workshop
Abstract This conference paper describes geophysical methods used to identify graves in cemeteries. Discusses a case study involving a historic cemetery in Pennsylvania located adjacent to a possibe Revolutionary War training camp. The geophysical survey identified a number of graves, although did not quantify marked or unmarked grave numbers, along with possible prehistoric and historic features. The author concludes that GPR was the best technique, but other methods may help.
Date Added 5/10/2016, 11:00:08 AM
Modified 6/9/2016, 10:11:39 AM

Tags:

electrical resistivity, United States, Civil War, electromagnetic induction, Revolutionary War, Pennsylvania, Historic Cemetery, GPR, Magnetometer

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Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration

Type Report
Author Bruce W. Bevan
Place Lincoln, Nebraska
Date 1998
Institution United States Department of the Interior, National Park Service, Midwest Archaeological Center
Abstract One of the first attempts to produce a comprehensive overview of geophysical methods for archaeology. This report includes detailed discussions of resistivity, magnetometry, conductivity (EM), and GPR. Examples focus exclusively on work at Petersburg Battlefield, with nothing specific to cemeteries. It was written before the advent of major advances in computer power and software development.
Report Number Special Report No. 1.
Date Added 1/3/2012, 11:17:14 AM
Modified 6/8/2016, 1:55:11 PM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, GPR, Magnetometer

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Geophysical Investigations at a Potential Mass Grave Site in Bethlehem, PA

Type Presentation
Presenter Charles Messler

Presenter Laura Sherrod
Presenter James Higgins
URL http://www.earthdoc.org/publication/publicationdetails/?publication=53081
Place Charleston, South Carolina
Date 2011
Accessed 5/9/2016, 8:00:00 PM
Type Poster Presentation
Meeting Name Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Abstract This poster outlines efforts to locate Spanish Influenza victims in a pauper's cemetery where mass burial was thought to have occurred. It includes a three dimensional data set.
Date Added 5/23/2016, 4:50:18 PM
Modified 6/9/2016, 10:43:59 AM

Tags:

Modern Cemetery, United States, Pennsylvania, Historic Cemetery, GPR, Magnetometer

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Geophysical Mapping of Historic Cemeteries

Type Journal Article
Author Geoffrey Jones
Volume 3
Pages 25-28
Publication Technical Briefs in Historical Archaeology
Date 2008
Abstract This article focuses on best practice methods and methodologies for geophysics in cemeteries. Proposes a multiple method approach as well as careful consideration of site conditions and burial practices. The article suggests sampling strategies that account for site settings and research goals. The integration of historical, archeological, environmental, and other data is discussed along with new remote technologies including EM conductivity, thermal infrared imaging, and penetrometers. The Wyandotte County Cemetery in Kansas is used as a case study, where electrical resistance and magnetic gradiometer were used in conjunction with testing to help establish the cemetery boundary. This is an example where the magnetometer and resistance are successfully used in a historic cemetery.
Date Added 12/21/2011, 11:07:29 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, electromagnetic induction, Magnetometry in archaeology, geophysical, Historic Cemetery, Thermal Imaging, Probe, GPR, Kansas, Magnetometer

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Geophysical Survey in Archaeological Field Evaluation, Second Edition.

Type Book
Author Andrew David
Author Neil Linford
Author Paul Linford
Place Swindon, United Kingdom
Publisher Historic England
Date 2008
Abstract This manual, produced bv Historic England (formerly English Heritage), outlines geophysical techniques (magnetometery, GPR, electrical resistance, EM induction), their optimal use, basic field configurations, and data processing steps. It is set up to provide specific guidelines for geophysical work done in England and has matrices to assist planners with selecting appropriate instruments based on site-specific conditions. The manual contains a small section on cemeteries, but is extremely cautious in their recommendation to use geophysics in cemeteries.
Date Added 5/23/2016, 11:29:29 AM
Modified 6/9/2016, 8:37:06 AM

Tags:

electrical resistivity, historic archaeology, General Reference, electromagnetic induction, Metal Detector, United Kingdom, prehistoric archaeology, GPR, Magnetometer

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Geophysical Surveys at the West End Cemetery, Townsville: An Application of Three Techniques

Type Journal Article
Author Ross Stanger
Author David Roe
Volume 65
Pages 44-50
Publication Australian Archaeology
Date 2007
Abstract This article discusses the application and results of resistance, GPR, and magnetometer survey of the E Block section of the Townsville cemetery in Queensland, Australia. The goal was to examine the cultural and/or ethnic association of the graves and apply geophysical instruments to this section of the country. Resistance and GPR were inconclusive due to environmental factors, but magnetometer produced excellent results. Because of metal grave markers, 65 individuals were identified and confirmed through limited excavations. The authors could then correlate the burial records with the markers to address social research questions. Magnetometer may be the best method in this region for two reasons: 1) the widespread use of metal markers and 2) environmental limits on detecting grave shafts and burial containers.
Date Added 8/9/2013, 10:34:30 AM
Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, Resistivity, Historic Cemetery, Australia, Grave Detection, GPR, Magnetometer, Unmarked Graves

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Geophysical Surveys of Burial Sites: A Case Study of the Oaro Urupa

Type Journal Article
Author David C. Nobes
Volume 64
Issue 2
Pages 357-367
Publication Geophysics
Date 1999
Abstract The article outlines a survey in a Maori cemetery in use since the 19th century. EM, magnetometer and GPR were used to map the cemetery. These datasets were then normalized and combined to make a grave probability map for the present populations to use when they are looking for appropriate burial locations. The article focuses on survey design and best practices for a practical report product.
Date Added 5/25/2016, 3:11:21 PM
Modified 8/29/2016, 4:07:59 PM

Tags:

electromagnetic induction, New Zealand, Historic Cemetery, Pre-contact cemetery, GPR, Magnetometer

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Geophysical Techniques for Forensic Investigation

Type Book Section
Author Peter J. Fenning
Author Laurance Donnelly
Editor Kenneth Pye
Editor Debra J. Croft
Series Special Publications
Place London, England
Publisher Geological Society
Pages 11-20
Date 2004
Series Number 232
Abstract Provides a general outline of geophysical instruments and their applicability towards forensic investigations, and illustrates these with three case studies. A large variety of geophysical instruments are discussed, although the authors note that many of them have not been tested successfully in forensic cases. The case studies include a successful location of burial vaults, an unsuccessful survey for Napoleonic graves, and a large scale metal detector survey looking for secondary forensic evidence. The authors conclude with recommendations about when to use geophysics in forensic cases: primarily to consider the search area and environmental conditions,

and to look for indirect evidence. This article discusses slightly outdated equipment and methods, but the conclusions are still relevant.

Book Title	Forensic Geoscience: Principles, Techniques and Applications
Date Added	5/27/2016, 10:35:12 AM
Modified	6/9/2016, 8:57:56 AM

Tags:

Modern Cemetery, electrical resistivity, General Reference, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Historic Cemetery, United Kingdom, Forensics, induced polarization, GPR, seismic, Magnetometer

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Geophysics and the Search of Freshwater Bodies: A Review

Type	Journal Article
Author	Rachael Parker
Author	Alastair Ruffell
Author	David Hughes
Author	Jamie Pringle
Volume	50
Pages	141-149
Publication	Science and Justice
Date	2010
Abstract	This review article explores the use of geophysics in freshwater to locate objects, specifically forensic evidence. The article outlines a variety of methods, explains how they work, and how they function in water. Methods include GPR (referred to as water penetrating radar), terrestrial magnetometer, seismic, CHIRP sub-bottom profiler, and side scan sonar. The authors then summarize case studies where geophysics were used to locate either forensic evidence or buried objects under water. They conclude that geophysics could be very useful under water, but unless there is metal present, WPR is the best method.
Date Added	5/27/2016, 10:55:13 AM
Modified	6/9/2016, 11:21:19 AM

Tags:

United States, Sweden, Oregon, side scan sonar, United Kingdom, Forensics, CHIRP Sub-Bottom Profiler, GPR, seismic, Ireland, Magnetometer

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Ground-Penetrating Radar Profile Spacing and Orientation for Subsurface Resolution of Linear Features.

Type	Journal Article
Author	James E. Pomfret
Volume	13

Pages	151-153
Publication	Archaeological Prospection
Date	2006
Abstract	Discusses transect/profile spacing for GPR survey on two different sites in the Georgia Coastal Plain.
Date Added	12/21/2011, 11:28:59 AM
Modified	11/30/2017, 12:00:10 PM

Tags:

African American, cemetery, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Handbook of Geophysics and Archaeology

Type	Book
Author	Alan Witten
Place	London, England; Oakville, Connecticut
Publisher	Equinox Publishing
ISBN	978-1-904768-59-3
Date	2006
Library Catalog	Open WorldCat
Abstract	Highly detailed book that contains extensive information on theoretical basis for different geophysical methods, including magnetometry, EM induction, GPR, geotomography, and electrical resistance tomography (ERT). Several case studies are used for each method, but none include cemeteries. Useful book for understanding the underlying physics behind each instrument.
Date Added	12/21/2011, 10:43:37 AM
Modified	5/11/2016, 2:31:29 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Geophysics in archaeology, geophysical, electrical resistance tomography, GPR, Magnetometer

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Looking for Lost Graves

Type	Journal Article
Author	William James Johnson
Author	Donald Johnson
Author	Marcella G. Johnson
Volume	20
Issue	2
Pages	20-31

Publication FastTIMES the Environmental and Engineering Geophysical Society
Date 2015
Abstract Updates a 2003 conference presentation with new case studies. Reports GPR, magnetometer, and electrical resistance studies from Pennsylvania, Ohio, and Kentucky. Concluded that GPR was the best method for identifying individual graves, but multiple instruments were recommended. Magnetometry and resistance are more suitable for defining overall cemetery context because of interference and lack of contrasts sufficient for individual grave detection.
Date Added 5/10/2016, 11:05:02 AM
Modified 6/9/2016, 10:07:20 AM

Tags:

electrical resistivity, United States, Kentucky, Pennsylvania, Ohio, Historic Cemetery, GPR, Magnetometer

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Magnetic Ghosts: Mineral Magnetic Measurements on Roman and Anglo-Saxon Graves

Type Journal Article
Author Neil T. Linford
Volume 11
Pages 167-180
Publication Archaeological Prospection
Date 2004
Abstract The article discusses finding graves with magnetics and discusses the challenges associated with the magnetic identification of graves. The author discusses two case studies which both identified graves, one using the magnetometer and the other using magnetic susceptibility. The study also assessed the magnetic properties of the soils and discusses the biogenic enhancement of soils due to decomposing organic materials.
Date Added 5/25/2016, 2:54:08 PM
Modified 6/9/2016, 10:37:56 AM

Tags:

electromagnetic induction, Historic Cemetery, United Kingdom, Magnetometer

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Magnetometry for Archaeologists

Type Book
Author Arnold Aspinall
Author Chris Gaffney
Author Armin Schmidt
Place New York, New York
Publisher Rowman Altamira
ISBN 978-0-7591-1348-0
Date 2008
Library Catalog Google Books

Abstract This book is a detailed overview of magnetic gradiometry as applied to archaeology and includes theory, method, instrumentation, practical applications, and limited case studies but there is no mention of cemeteries.

# of Pages 232

Date Added 9/28/2011, 12:03:47 PM

Modified 6/8/2016, 1:48:37 PM

Tags:

Social Science / Anthropology / General, Worldwide, General Reference, Social Science / Archaeology, Magnetometry in archaeology, Science / Geophysics, Magnetometer, Science / Magnetism

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Merging Cultures and Curriculums: Enriching Heritage and Education With Applied Geophysics.

Type Journal Article

Author Tate Meehan

Author Timothy S. De Smet

Author Charles Stanford

Volume 20

Issue 2

Pages 61-70

Publication FastTIMES the Environmental and Engineering Geophysical Society

Date 2015

Language 2015

Abstract Discusses blending of geophysical survey with community outreach involving a historical African American cemetery in Texas. The authors created a high-precision topographic map and conducted magnetic and EM surveys of the cemetery. GPR was not suitable because of ground conditions. The community wanted to know precise grave locations but there was ambiguity with interpretations.

Date Added 5/10/2016, 1:54:54 PM

Modified 6/9/2016, 10:40:36 AM

Tags:

African American, United States, electromagnetic induction, Texas, Historic Cemetery, Magnetometer

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Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations

Type Book Section

Author Don H. Heimmer

Author Steven L. De Vore

Editor Ray A. Williamson

Editor	Paul R. Nickens
Series	Advances in Archaeological and Museum Science
Volume	4
Place	New York, New York
Publisher	Springer US
Pages	53-73
Date	2000
Abstract	This book chapter outlines basic geophysical methods as they can be applied to archaeological resource management. It discusses general methods and emphasizes the use of an experienced operator.
Book Title	Science and Technology in Historic Preservation
Date Added	5/23/2016, 11:38:53 AM
Modified	6/9/2016, 9:31:13 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

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New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resource Identification and Evaluation

Type	Report
Author	Kenneth L. Kvamme
Author	Eileen G. Ernenwein
Author	Michael L. Hargrave
Author	Thomas Sever
Author	Deborah Harmon
Author	Fred Limp
Place	Fayetteville, Arkansas.
Date	2006
Institution	Center for Advanced Spatial Technologies, University of Arkansas
Abstract	Comprehensive technical report focusing on the application of geophysical methods to four archaeological sites (prehistoric and historic) in different regions of the U.S. Includes information on field survey parameters, overviews of magnetometry, electrical resistivity, EM induction, and GPR, as well as data processing steps for each. One of the few publications to focus specifically on data fusion and interpretation of geophysical data. No discussion specific to cemeteries, although the principles are applicable.
Date Added	10/25/2012, 9:22:06 AM
Modified	6/9/2016, 10:37:03 AM

Tags:

electrical resistivity, historic archaeology, General Reference, United States, electromagnetic induction, prehistoric archaeology, GPR, Magnetometer

Preservation of McVicker Family Cemetery, Jonesboro, Georgia

Type Journal Article
Author Gail Tarver
Author Daniel P. Bigman
Volume 41
Issue 2
Pages 211-241
Publication Early Georgia
Date 2013
Abstract This article outlines the steps taken to preserve the McVicker family cemetery beginning with a multi-instrument geophysics survey and concluding with restoration of the cemetery stones and fencing. The geophysics identified two possible graves outside of the cemetery that were determined not related to it.
Date Added 5/25/2016, 3:56:05 PM
Modified 6/9/2016, 1:57:42 PM

Tags:

electrical resistivity, United States, electromagnetic induction, Georgia, Historic Cemetery, GPR, Magnetometer

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Remote Sensing Applications in Forensic Investigations

Type Journal Article
Author G. Clark Davenport
Series Archaeologists as Forensic Investigators
Volume 35
Issue 1
Pages 87-100
Publication Historical Archaeology
Date 2001
Abstract This article outlines remote sensing methods used in forensic investigations and discusses the attributes of each type of instrument. Includes an overview of unique circumstances in forensic cases, discussion of methods/techniques that were commonly used at that time, limitations, and special considerations (e.g., results scrutinized in courts, evidence procedures, proper training). The article then briefly describes three case studies where thermal imaging and geophysics were used to assist in forensic cases. The technical sections are dated with respect to equipment advances, making them largely irrelevant, but the general emphasis on choosing the right equipment with the right resolution is remains important.
Date Added 8/6/2013, 4:18:35 PM
Modified 6/9/2016, 8:35:34 AM

Tags:

electrical resistivity, United States, electromagnetic induction, Remote Sensing, Thermal Imaging, Forensics, Grave Detection, GPR, Magnetometer

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Remote Sensing in Archaeology: an Explicitly North American Perspective

Type Book
Editor Jay K. Johnson
Place Tuscaloosa, Alabama
Publisher University of Alabama Press
ISBN 978-0-8173-5343-8
Date 2006
Library Catalog Open WorldCat
Abstract Edited volume intended for operators and managers with chapters from leading geophysical practitioners in the United States. The book includes background on the development and application of geophysics in North America. The bulk of the book is devoted to chapters on methods (EM conductivity, electrical resistance, GPR, magnetic susceptibility, magnetometry, data processing), and the benefits of multiple methods and ground truthing.
Short Title Remote sensing in archaeology
Date Added 9/27/2011, 1:05:25 PM
Modified 6/9/2016, 10:05:54 AM

Tags:

electrical resistivity, General Reference, United States, electromagnetic induction, Canada, Remote Sensing, Mexico, GPR, Magnetometer

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Revealing the Buried Past: Geophysics for Archaeologists

Type Book
Author Chris Gaffney
Author John Gater
Place Briscombe Port Stroud, United Kingdom
Publisher Tempus Publishing Ltd.
ISBN 978-0-7524-2556-6
Date 2003
Library Catalog Open WorldCat
Abstract One of the first major publications to address archaeological geophysics. Includes background on development of field, theoretical principles, discussion of most common methods (electrical resistance, magnetic gradiometry, GPR, EM conductivity, metal detecting, magnetic susceptibility), survey logistics, data processing, and case studies. Includes some discussion of burials specific to the UK, but nothing on cemeteries as a unique site type.
Short Title Revealing the buried past
Date Added 12/21/2011, 10:37:51 AM
Modified 6/9/2016, 9:06:21 AM

Tags:

Worldwide, electrical resistivity, General Reference, electromagnetic induction, Magnetometry in archaeology, Metal Detector, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Search for the Grave of the Hanged Texas Gunfighter, William Preston Longley

Type	Journal Article
Author	Brooks B. Ellwood
Author	Douglas W. Owsley
Author	Suzanne H. Ellwood
Author	Patricia A. Mercado-Allinger
Volume	28
Issue	3
Pages	94-112
Publication	Historical Archaeology
Date	1994
Abstract	This article details a search for the Longley grave in a Texas cemetery. The authors started with historic records and informant interviews, and then used resistivity and magnetometry to locate the grave. When both methods were less conclusive than hoped for due to modern debris and soil moisture conditions, probing and augering were used to identify multiple graves. Following those tests, a number of areas were tested using a backhoe. Many unmarked graves were tested, unfortunately they were all unlikely to be Longley due to sex, racial, or temporal distinctions. The authors concluded that their search hampered by the number of unmarked graves in the cemetery and the possibility they may have been looking in the wrong location. The technology has improved for both methods since this survey was conducted, but the authors of this study still used a robust research design for combining archival work, geophysics, and testing.
Date Added	8/5/2013, 11:54:16 AM
Modified	6/9/2016, 8:46:32 AM

Tags:

Cemetery Survey, electrical resistivity, United States, Texas, Historic Cemetery, Magnetometer, Unmarked Graves

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Searching for Graves Using Geophysical Technology: Field Tests with Ground Penetrating Radar, Magnetometry, and Electrical Resistivity.

Type	Journal Article
Author	Sabrina C. Buck
Volume	48
Issue	1
Pages	1-7
Publication	Journal of Forensic Science
Date	2003

Abstract This article outlines field experiments using various configurations of GPR, magnetometry, and electrical resistivity to look for historic and forensic burials. The studies stated goal was to review the utility of these methods for finding human burials. The author had limited success identifying human remains and concluded that the technology methods and user skills need development. Notably, she did much of her processing in the field and used technology that would be considered outdated today.

Date Added 12/21/2011, 9:22:25 AM

Modified 11/30/2017, 12:00:10 PM

Tags:

electrical resistivity, cemetery, United States, Magnetometry in archaeology, geophysical, Historic Cemetery, Forensics, GPR, Magnetometer

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Seeing Beneath the Soil: Prospecting Methods in Archaeology

Type Book

Author Anthony Clark

URL http://books.google.com/books/about/Seeing_Beneath_the_Soil.html?id=YRGI_E3-yvgC

Place London, England

Publisher B.T. Batsford, LTD

Date 1996

Accessed 1/3/2012, 10:59:42 AM

Abstract Among the first textbooks dedicated to remote sensing/geophysics and still widely cited. It provides detailed information on the most common instruments, data collection parameters, data processing, and interpretation. The focus is almost entirely on case studies in the United Kingdom. There are two brief references to graves. The first dealt with the identification of Saxon warrior burials and associated weaponry using magnetometry. The second discussed a poor response from known graves to electrical resistance that was attributed to chalky soils in the backfill.

Date Added 1/3/2012, 10:59:42 AM

Modified 6/8/2016, 4:50:35 PM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Geophysics in archaeology, geophysical, United Kingdom, GPR, Magnetometer

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Situating Remote Sensing Anthropological Archaeology

Type Journal Article

Author Victor D. Thompson

Author Philip J., III Arnold

Author Thomas J. Pluckhahn

Author Amber M. Vanderwarker

Volume 18
Pages 195-213
Publication Archaeological Prospection
Date 2011
Abstract This article argues that many geophysical or remote sensing projects are not integrated fully into research designs. By developing research questions that incorporate geophysics, archaeologists can address more complex anthropological questions. The authors outline a series of landscape, temporal, and construction related problems they think can be considered using geophysical data sets. They provide examples from prehistoric sites in Mexico, Georgia, and Florida to illustrate this argument. The focus is on a theoretical approach based on the analysis of "persistent places within a regional context" rather than specific case study details.
Date Added 5/23/2016, 3:47:25 PM
Modified 8/29/2016, 4:03:16 PM

Tags:

electrical resistivity, historic archaeology, United States, Florida, Georgia, Mexico, electrical resistance tomography, prehistoric archaeology, GPR, Magnetometer

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Still Searching for Graves: An Analytical Strategy for Interpreting Geophysical Data Used in the Search for "Unmarked" Graves

Type Journal Article
Author Chris Gaffney
Author C. Harris
Author F. Pope-Carter
Author J. Bonsall
Author R. Fry
Author A. Parkyn
Volume 13
Pages 557-569
Publication Near Surface Geophysics
Date 2015
Abstract This article discusses a multi-instrument survey of a historic cemetery. The authors used magnetometer, resistivity (multiple arrays), three dimensional (multiple antenna) GPR, and EM induction. They then compared their results with the historic burial plots. The argument is that no single method identified all of the graves, and that more techniques may equate with greater success. Additionally, better integration strategies will increase interpretive ability. It should be noted that the integration strategies appeared largely computer based using the ArcGIS intersection tool.
Date Added 5/24/2016, 2:47:54 PM
Modified 6/9/2016, 9:07:58 AM

Tags:

electrical resistivity, electromagnetic induction, Historic Cemetery, United Kingdom, GPR, Magnetometer

Techniques for Locating Burials, with Emphasis on the Probe

Type Journal Article
Author Douglas W. Owsley
Volume 40
Issue 5
Pages 735-740
Publication Journal of Forensic Sciences
Date 1995
Abstract This article discusses how probing can be a superior grave detection method in smaller, expedient surveys and in areas where geophysical survey would be impossible. The author summarizes geophysical methods and their use in forensic applications. He then discusses the application of probing in a forensic setting. The article provides a series of case studies illustrating successful uses of probes. The examples include modern forensic cases in environments unsuited to geophysics and two small historic cemetery studies requiring expedient methods. Probing does need a skilled operator and systematic methods, but the cost is considerably lower.
Date Added 6/6/2016, 4:32:34 PM
Modified 6/9/2016, 11:14:43 AM

Tags:

electrical resistivity, United States, Texas, Clandestine Graves, Virginia, Historic Cemetery, Forensics, Probe, GPR, Magnetometer

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The Application of Geophysics to Archaeologic Mapping of Prehistoric, Protohistoric, and Historic Sites in Western Canada

Type Journal Article
Author Paul Bauman
Author Rod Heitzmann
Author Jack Porter
Pages 359-373
Publication 9th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems
Date 1995
Abstract This article outlines a study done at two fur trading posts, native campsites, and historic cemeteries in Alberta. The survey consisted of GPR, magnetometer, and EM conductivity. Because the fort was burned after abandonment, the magnetometer was most effective at mapping post holes. The GPR was effective at locating cellars and clearly pinpointed several burial sites. The article argues that multiple instruments are important in geophysical survey. Notably, this is an early article and equipment and software has improved significantly since this was published.
Date Added 5/25/2016, 9:29:21 AM
Modified 6/8/2016, 1:51:49 PM

Tags:

historic archaeology, electromagnetic induction, Canada, protohistoric archaeology, Alberta, Historic Cemetery, prehistoric archaeology, GPR, Magnetometer

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The Detection of Human Remains

Type	Book
Author	Edward W. Killam
Edition	Second Edition
Place	Springfield, Illinois
Publisher	Clarence C. Thomas, Publisher, LTD
Date	2004
Abstract	This updated reference for forensic investigators is intended as a guide for locating human remains by law enforcement, archaeologists, and other investigators. Methods include ground contact, proximate, geophysical, and aerial remote sensing. Includes general overview of theory and applicability of each method. Geophysical methods can be used as principal means of location/identification, or to refine, corroborate, or eliminate certain areas. No single method is best for all situations.
Date Added	5/25/2016, 2:48:24 PM
Modified	6/9/2016, 10:32:45 AM

Tags:

electrical resistivity, electromagnetic induction, Gravity Survey, Metal Detector, self potential, Forensics, Probe, GPR, Magnetometer

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The Reliability of Geophysical Surveys at Historic-Period Cemeteries: An Example from the Plains Cemetery, Mechanicsville, Maryland.

Type	Journal Article
Author	Julia A. King
Author	Bruce W. Bevan
Author	Robert J. Hurry
Volume	27
Issue	3
Pages	4-16
Publication	Historical Archaeology
Date	1993
Date Added	5/10/2016, 1:29:41 PM
Modified	8/14/2017, 1:33:36 PM

Tags:

United States, Maryland, Historic Cemetery, GPR, Magnetometer

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The Tulsa Race Riot of 1921: A Geophysical Study to Locate a Mass Grave

Type	Journal Article
Author	Alan Witten
Author	Robert Brooks
Author	Thomas Fenner
Volume	20
Pages	655-660
Publication	The Leading Edge
Date	2001
Abstract	This short article discusses the search for a mass grave of the African American victims of the Tulsa Race Riot of 1921. Magnetometer and electromagnetic induction were used in an area where an eye witness recalled seeing crates of bodies. Two specific anomalies identified with magnetic instruments were tested with GPR and one anomaly with trench-like features was isolated for further testing. The article was written prior to testing.
Date Added	5/24/2016, 9:24:25 AM
Modified	5/24/2016, 9:26:04 AM

Tags:

United States, electromagnetic induction, Mass Grave, Historic Cemetery, Oklahoma, Forensics, GPR, Magnetometer

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The Use of Geoscience Methods for Terrestrial Forensic Searches

Type	Journal Article
Author	James K. Pringle
Author	Alastair Ruffell
Author	John R. Jervis
Author	L. Donnelly
Author	J. McKinley
Author	J. Hansen
Author	R. Morgan
Author	D. Pirrie
Author	M. Harrison
Volume	114
Pages	108-123
Publication	Earth-Science Reviews
Date	2012
Abstract	This review article surveys geoscientific methods for locating clandestine graves. It starts with broad searching techniques and then focuses on reconnaissance, where seismology, conductivity, resistivity, GPR, magnetometry, probing, geomorphology, among other techniques. Each method

is described briefly along with examples and citations of its use. The post-search section discusses topsoil removal, trenches, and excavations. The authors emphasize that there is no method that works every time, success is largely dependent on environmental conditions and the type of burial.

Date Added 5/25/2016, 3:22:08 PM

Modified 6/9/2016, 11:45:53 AM

Tags:

electrical resistivity, General Reference, electromagnetic induction, Metal Detector, Clandestine Graves, Forensics, GPR, seismic, Magnetometer

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Time-Lapse Geophysical Investigations over a Simulated Urban Clandestine Grave

Type Journal Article

Author James K. Pringle

Author John Jervis

Author John P. Cassella

Author Nigel J. Cassidy

Volume 53

Issue 6

Pages 1405-1416

Publication Journal of Forensic Science

Date 2008

Abstract This article discusses a study of the usefulness of geophysical instruments in locating a clandestine burial site in an urban environment. For the study a cadaver mannequin was buried along with animal organs and fluids. The area was examined over three months with multiple geophysical instruments. As a control, the study area was also tested with all instruments prior to installing the simulated grave. The resistivity was best at resolving the grave location, while electrical resistance tomography (ERT) and GPR were better for providing spatial information. The authors suggest that resistivity surveys be conducted prior to collecting GPR and ERT data in forensic search conditions.

Date Added 5/27/2016, 10:26:18 AM

Modified 6/9/2016, 11:41:23 AM

Tags:

electrical resistivity, electromagnetic induction, Clandestine Graves, United Kingdom, Forensics, electrical resistance tomography, GPR, Magnetometer

Other Instruments

(Thermal Imagery, Side Scan Sonar, Seismic, Self Potential, Remote Sensing, Metal Detector, Induced Polarization, Gravity Survey, Electrical Resistance Tomography, CHIRP Sub-Bottom Profiler)

Intentionally Left Blank

Establishing Forensic Search Methodologies and Geophysical Surveying for the Detection of Clandestine Graves in Coastal Beach Environments

Type	Journal Article
Author	James K. Pringle
Author	Claire Holland
Author	Katie Szkornik
Author	Mark Harrison
Volume	219
Pages	e29-e36
Publication	Forensic Science International
Date	2012
Abstract	This article addresses the detection of burials in coastal environments. In this study, mannequins were buried in the sand in three locations in the dunes and foreshore. The study then used a metal detector, GPR, electrical resistivity, and magnetic susceptibility to locate the mannequin with mixed results. The metal detector was ineffective (likely due to depth penetration limitations). The GPR was only effective in the dry dunes. Resistivity was effective, but not recommended in very dry sand. The magnetic susceptibility was entirely effective, but the instrument was not suitable for collecting large areas. The authors suggested a targeted approach where the specific environment is considered prior to instrument selection.
Date Added	11/27/2017, 10:16:22 AM
Modified	11/27/2017, 10:16:22 AM

Tags:

Clandestine Graves, electrical resistivity, electromagnetic induction, Forensics, GPR, Metal Detector, United Kingdom

Forensic Geoscience: Applications of Geology, Geomorphology and Geophysics to Criminal Investigations

Type	Journal Article
Author	Alastair Ruffell
Author	Jennifer McKinley
Volume	69
Pages	235-247
Publication	Earth-Science Reviews
Date	2005

Abstract This review article summarizes the history of and the modern application of forensic geosciences. "Forensic geoscience" is a broad classification and includes everything from geophysics to geochemistry. The authors begin with a discussion of the discipline's history and finish with an overview of available literature that pertains to each method, including GPR, magnetics, resistivity, and ERT. This discussion extends to cover large scale landforms and microscopic particle forensic studies. The authors conclude with a suggestion that more is being done in the discipline outside of journal publication.

Date Added 11/27/2017, 10:16:24 AM

Modified 11/27/2017, 10:16:24 AM

Tags:

electrical resistance tomography, electrical resistivity, electromagnetic induction, Forensics, General Reference, GPR, Magnetometer

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Forensic Methods: Excavation for the Archaeologist and Investigator

Type Book

Author Melissa A Connor

Place Lanham, Maryland

Publisher AltaMira Press

Date 2007

Abstract This book is a thorough overview of forensic archaeology, including preparation, fieldwork, soils, taphonomy of forensic sites, locating and excavating buried remains, evidence, documentation, and professionalization of the discipline. Methods for identifying graves include probing, cadaver dogs, test trenches, aerial photographs, and geophysical methods (metal detectors, GPR, EM, electrical resistance, and magnetometers). Includes a geophysical case study and summary of strengths/weaknesses of various methods.

Date Added 11/27/2017, 10:16:25 AM

Modified 11/27/2017, 10:16:25 AM

Tags:

Cadaver Dogs, Clandestine Graves, electrical resistivity, electromagnetic induction, Forensics, GPR, Magnetometer, Metal Detector, Probe

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Geophysical Mapping of Historic Cemeteries

Type Journal Article

Author Geoffrey Jones
Volume 3
Pages 25-28
Publication Technical Briefs in Historical Archaeology
Date 2008
Abstract This article focuses on best practice methods and methodologies for geophysics in cemeteries. Proposes a multiple method approach as well as careful consideration of site conditions and burial practices. The article suggests sampling strategies that account for site settings and research goals. The integration of historical, archeological, environmental, and other data is discussed along with new remote technologies including EM conductivity, thermal infrared imaging, and penetrometers. The Wyandotte County Cemetery in Kansas is used as a case study, where electrical resistance and magnetic gradiometer were used in conjunction with testing to help establish the cemetery boundary. This is an example where the magnetometer and resistance are successfully used in a historic cemetery.
Date Added 11/27/2017, 10:16:05 AM
Modified 11/27/2017, 10:16:05 AM

Tags:

cemetery, electrical resistivity, electromagnetic induction, geophysical, GPR, Historic Cemetery, Kansas, Magnetometer, Magnetometry in archaeology, Probe, Thermal Imaging, United States

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Geophysical Survey in Archaeological Field Evaluation, Second Edition.

Type Book
Author Andrew David
Author Neil Linford
Author Paul Linford
Place Swindon, United Kingdom
Publisher Historic England
Date 2008
Abstract This manual, produced bv Historic England (formerly English Heritage), outlines geophysical techniques (magnetometery, GPR, electrical resistance, EM induction), their optimal use, basic field configurations, and data processing steps. It is set up to provide specific guidelines for geophysical work done in England and has matrices to assist planners with selecting appropriate instruments based on site-specific conditions. The manual contains a small section on cemeteries, but is extremely cautious in their recommendation to use geophysics in cemeteries.
Date Added 11/27/2017, 10:16:11 AM
Modified 11/27/2017, 10:16:11 AM

Tags:

electrical resistivity, electromagnetic induction, General Reference, GPR, historic archaeology, Magnetometer, Metal Detector, prehistoric archaeology, United Kingdom

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Geophysical Techniques for Forensic Investigation

Type	Book Section
Author	Peter J. Fenning
Author	Laurance Donnelly
Editor	Kenneth Pye
Editor	Debra J. Croft
Place	London, England
Publisher	Geological Society
Pages	11-20
Date	2004
Abstract	Provides a general outline of geophysical instruments and their applicability towards forensic investigations, and illustrates these with three case studies. A large variety of geophysical instruments are discussed, although the authors note that many of them have not been tested successfully in forensic cases. The case studies include a successful location of burial vaults, an unsuccessful survey for Napoleonic graves, and a large scale metal detector survey looking for secondary forensic evidence. The authors conclude with recommendations about when to use geophysics in forensic cases: primarily to consider the search area and environmental conditions, and to look for indirect evidence. This article discusses slightly outdated equipment and methods, but the conclusions are still relevant.
Book Title	Forensic Geoscience: Principles, Techniques and Applications
Date Added	11/27/2017, 10:16:22 AM
Modified	11/27/2017, 10:16:22 AM

Tags:

electrical resistivity, electromagnetic induction, Forensics, General Reference, GPR, Gravity Survey, Historic Cemetery, induced polarization, Magnetometer, Metal Detector, Modern Cemetery, seismic, self potential, United Kingdom

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Geophysics and the Search of Freshwater Bodies: A Review

Type	Journal Article
Author	Rachael Parker

Author Alastair Ruffell
Author David Hughes
Author Jamie Pringle
Volume 50
Pages 141-149
Publication Science and Justice
Date 2010
Abstract This review article explores the use of geophysics in freshwater to locate objects, specifically forensic evidence. The article outlines a variety of methods, explains how they work, and how they function in water. Methods include GPR (referred to as water penetrating radar), terrestrial magnetometer, seismic, CHIRP sub-bottom profiler, and side scan sonar. The authors then summarize case studies where geophysics were used to locate either forensic evidence or buried objects under water. They conclude that geophysics could be very useful under water, but unless there is metal present, WPR is the best method.
Date Added 11/27/2017, 10:16:21 AM
Modified 11/27/2017, 10:16:21 AM

Tags:

CHIRP Sub-Bottom Profiler, Forensics, GPR, Ireland, Magnetometer, Oregon, seismic, side scan sonar, Sweden, United Kingdom, United States

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Handbook of Geophysics and Archaeology

Type Book
Author Alan Witten
Place London, England; Oakville, Connecticut
Publisher Equinox Publishing
ISBN 978-1-904768-59-3
Date 2006
Library Catalog Open WorldCat
Abstract Highly detailed book that contains extensive information on theoretical basis for different geophysical methods, including magnetometry, EM induction, GPR, geotomography, and electrical resistance tomography (ERT). Several case studies are used for each method, but none include cemeteries. Useful book for understanding the underlying physics behind each instrument.
Date Added 11/27/2017, 10:16:04 AM
Modified 11/27/2017, 10:16:04 AM

Tags:

electrical resistance tomography, electrical resistivity, electromagnetic induction, General Reference, geophysical, Geophysics in archaeology, GPR, Magnetometer, Magnetometry in archaeology

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Integrated Seismic Tomography and Ground-Penetrating Radar (GPR) for the High-Resolution Study of Burial Mounds (Tumuli)

Type	Journal Article
Author	E. Forte
Author	E. Pipan
Volume	35
Pages	2614-2623
Publication	Journal of Archaeological Science
Date	2008
Abstract	This article discusses using both seismic tomography and GPR to investigate burial mounds where the height of the mound prohibits a simple GPR survey for detecting burial chambers. The GPR data imaged the top portions of the mound, providing stratigraphic data. The seismic tomography located the tomb below the depth penetration of the GPR. This case provides examples of topographic correction and innovative methods.
Date Added	11/27/2017, 10:16:15 AM
Modified	11/27/2017, 10:16:15 AM

Tags:

Bronze Age, GPR, Italy, prehistoric archaeology, seismic

Location and Assessment of an Historic (150-160 years old) Mass Grave Using Geographic and Ground Penetrating Radar Investigations, NW Ireland

Type	Journal Article
Author	Alastair Ruffell
Author	Alice S. McCabe
Author	C. Donnelly
Author	B. Sloan
Volume	54
Issue	2
Pages	382-294
Publication	Journal of Forensic Sciences
Date	2009

Abstract This article discusses the identification of mass graves using a combination of aerial imagery, metal detecting, and GPR. The GPR used 100 and 200MHz antennae for full survey, then 400Mhz antenna for better resolution of individual anomalies. Discrepancies between surface expressions, metal detector hits, and GPR data indicated that no single method was identifying all graves. Distributions of metal artifacts suggested Catholic graves in one location were separated from Protestant graves in another.

Date Added 11/27/2017, 10:16:19 AM

Modified 11/27/2017, 10:16:19 AM

Tags:

Aerial imagery, GPR, Ireland, Mass Grave, Metal Detector, United Kingdom

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Remote Sensing Applications in Forensic Investigations

Type Journal Article

Author G. Clark Davenport

Volume 35

Issue 1

Pages 87-100

Publication Historical Archaeology

Date 2001

Abstract This article outlines remote sensing methods used in forensic investigations and discusses the attributes of each type of instrument. Includes an overview of unique circumstances in forensic cases, discussion of methods/techniques that were commonly used at that time, limitations, and special considerations (e.g., results scrutinized in courts, evidence procedures, proper training). The article then briefly describes three case studies where thermal imaging and geophysics were used to assist in forensic cases. The technical sections are dated with respect to equipment advances, making them largely irrelevant, but the general emphasis on choosing the right equipment with the right resolution is remains important.

Date Added 11/27/2017, 10:16:06 AM

Modified 11/27/2017, 10:16:06 AM

Tags:

electrical resistivity, electromagnetic induction, Forensics, GPR, Grave Detection, Magnetometer, Remote Sensing, Thermal Imaging, United States

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Remote Sensing in Archaeology: an Explicitly North American Perspective

Type Book
Editor Jay K. Johnson
Place Tuscaloosa, Alabama
Publisher University of Alabama Press
ISBN 978-0-8173-5343-8
Date 2006
Library Catalog Open WorldCat
Abstract Edited volume intended for operators and managers with chapters from leading geophysical practitioners in the United States. The book includes background on the development and application of geophysics in North America. The bulk of the book is devoted to chapters on methods (EM conductivity, electrical resistance, GPR, magnetic susceptibility, magnetometry, data processing), and the benefits of multiple methods and ground truthing.
Short Title Remote sensing in archaeology
Date Added 11/27/2017, 10:16:04 AM
Modified 11/27/2017, 10:16:04 AM

Tags:

Canada, electrical resistivity, electromagnetic induction, General Reference, GPR, Magnetometer, Mexico, Remote Sensing, United States

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Revealing the Buried Past: Geophysics for Archaeologists

Type Book
Author Chris Gaffney
Author John Gater
Place Briscombe Port Stroud, United Kingdom
Publisher Tempus Publishing Ltd.
ISBN 978-0-7524-2556-6
Date 2003
Library Catalog Open WorldCat
Abstract One of the first major publications to address archaeological geophysics. Includes background on development of field, theoretical principles, discussion of most common methods (electrical resistance, magnetic gradiometry, GPR, EM conductivity, metal detecting, magnetic susceptibility), survey logistics, data processing, and case studies. Includes some discussion of burials specific to the UK, but nothing on cemeteries as a unique site type.
Short Title Revealing the buried past
Date Added 11/27/2017, 10:16:05 AM
Modified 11/27/2017, 10:16:05 AM

Tags:

electrical resistivity, electromagnetic induction, General Reference, geophysical, Geophysics in archaeology, GPR, Magnetometer, Magnetometry in archaeology, Metal Detector, United Kingdom, Worldwide

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Situating Remote Sensing Anthropological Archaeology

Type	Journal Article
Author	Victor D. Thompson
Author	Philip J., III Arnold
Author	Thomas J. Pluckhahn
Author	Amber M. Vanderwarker
Volume	18
Pages	195-213
Publication	Archaeological Prospection
Date	2011
Abstract	This article argues that many geophysical or remote sensing projects are not integrated fully into research designs. By developing research questions that incorporate geophysics, archaeologists can address more complex anthropological questions. The authors outline a series of landscape, temporal, and construction related problems they think can be considered using geophysical data sets. They provide examples from prehistoric sites in Mexico, Georgia, and Florida to illustrate this argument. The focus is on a theoretical approach based on the analysis of "persistent places within a regional context" rather than specific case study details.
Date Added	11/27/2017, 10:16:11 AM
Modified	11/27/2017, 10:16:11 AM

Tags:

electrical resistance tomography, electrical resistivity, Florida, Georgia, GPR, historic archaeology, Magnetometer, Mexico, prehistoric archaeology, United States

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The Application Remote Sensing for Detecting Mass Graves: An Experimental Animal Case Study from Costa Rica

Type	Journal Article
Author	Margaret E. Kalacska
Author	Lynne S. Bell

Author	G. Arturo Sanchez-Azofeifa
Author	Terry Caelli
Volume	54
Issue	1
Pages	159-166
Publication	Journal of Forensic Sciences
Date	2009
Abstract	This article addresses the use of remote sensing to locate mass graves. The authors established an animal burial and an empty grave as a control. The authors used a variety of spectra over a 16-month period. They concluded that there were distinct differences between the animal burial and the control with the spectrometry and the airborne hyperspectral imagery. They also discussed how remote sensing can provide an objective way of observation.
Date Added	11/27/2017, 10:16:23 AM
Modified	11/27/2017, 10:16:23 AM

Tags:

Clandestine Graves, Costa Rica, Forensics, Mass Grave, Remote Sensing

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The Detection of Human Remains

Type	Book
Author	Edward W. Killam
Edition	Second Edition
Place	Springfield, Illinois
Publisher	Clarence C. Thomas, Publisher, LTD
Date	2004
Abstract	This updated reference for forensic investigators is intended as a guide for locating human remains by law enforcement, archaeologists, and other investigators. Methods include ground contact, proximate, geophysical, and aerial remote sensing. Includes general overview of theory and applicability of each method. Geophysical methods can be used as principal means of location/identification, or to refine, corroborate, or eliminate certain areas. No single method is best for all situations.
Date Added	11/27/2017, 10:16:20 AM
Modified	11/27/2017, 10:16:20 AM

Tags:

electrical resistivity, electromagnetic induction, Forensics, GPR, Gravity Survey, Magnetometer, Metal Detector, Probe, self potential

The Use of Geoscience Methods for Terrestrial Forensic Searches

Type Journal Article
Author James K. Pringle
Author Alastair Ruffell
Author John R. Jervis
Author L. Donnelly
Author J. McKinley
Author J. Hansen
Author R. Morgan
Author D. Pirrie
Author M. Harrison
Volume 114
Pages 108-123
Publication Earth-Science Reviews
Date 2012
Abstract This review article surveys geoscientific methods for locating clandestine graves. It starts with broad searching techniques and then focuses on reconnaissance, where seismology, conductivity, resistivity, GPR, magnetometry, probing, geomorphology, among other techniques. Each method is described briefly along with examples and citations of its use. The post-search section discusses topsoil removal, trenches, and excavations. The authors emphasize that there is no method that works every time, success is largely dependent on environmental conditions and the type of burial.
Date Added 11/27/2017, 10:16:15 AM
Modified 11/27/2017, 10:16:15 AM

Tags:

Clandestine Graves, electrical resistivity, electromagnetic induction, Forensics, General Reference, GPR, Magnetometer, Metal Detector, seismic

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Time-Lapse Geophysical Investigations over a Simulated Urban Clandestine Grave

Type Journal Article
Author James K. Pringle
Author John Jervis
Author John P. Cassella
Author Nigel J. Cassidy
Volume 53

Issue 6
Pages 1405-1416
Publication Journal of Forensic Science
Date 2008
Abstract This article discusses a study of the usefulness of geophysical instruments in locating a clandestine burial site in an urban environment. For the study a cadaver mannequin was buried along with animal organs and fluids. The area was examined over three months with multiple geophysical instruments. As a control, the study area was also tested with all instruments prior to installing the simulated grave. The resistivity was best at resolving the grave location, while electrical resistance tomography (ERT) and GPR were better for providing spatial information. The authors suggest that resistivity surveys be conducted prior to collecting GPR and ERT data in forensic search conditions.
Date Added 11/27/2017, 10:16:22 AM
Modified 11/27/2017, 10:16:22 AM

Tags:

Clandestine Graves, electrical resistance tomography, electrical resistivity, electromagnetic induction, Forensics, GPR, Magnetometer, United Kingdom

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Use of Precision Mapping and Multiple Geophysical Methods at the Historic Reese Cemetery in Muncie, Indiana

Type Journal Article
Author Gregory B. Byer
Author John A. Mundell
Pages 68-79
Publication 16th Environmental and Engineering Geophysical Society Symposium on the Application of Geophysics to Engineering and Environmental Problems.
Date 2003
Abstract This article outlines a program of geophysical research at a historic cemetery in Indiana. This cemetery could not be excavated due to both regulatory and ethical concerns but was known to contain unmarked burials. The survey team used EM metal detector, EM conductivity, and GPR. The EM metal detecting was of limited utility and the EM conductivity was somewhat more useful. The GPR provided the most data about marked and unmarked graves including the more subtle, older graves.
Date Added 11/27/2017, 10:16:11 AM
Modified 11/27/2017, 10:16:11 AM

Tags:

electromagnetic induction, GPR, Historic Cemetery, Indiana, Metal Detector, United States

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APPENDIX B

Interview Summaries

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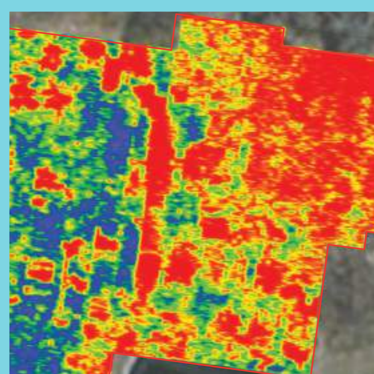
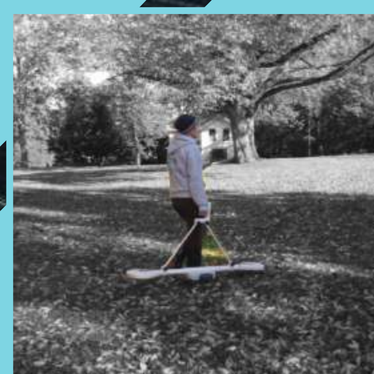
NCHRP Project 25-25(B) Task 98:

Practical Guide for Developing Effective SOWs for the Geophysical Investigation of Cemeteries: Interview Summaries





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NCHRP Project 25-25(B) Task 98: A Practical Guide for Developing Effective SOWs for the Geophysical Investigation of Cemeteries:

INTERVIEW SUMMARIES

Introduction

This appendix summarizes the responses to a detailed survey with experienced practitioners (Table 1). The survey was sent to 64 recipients in Academia (n=15), Industry (n=26), Agency (n=13), and Tribal positions (n=10). This group was chosen based on their professional involvement with geophysical methods, their management of cemetery geophysical projects, and/or their interest in geophysical methods. One important goal was to represent broad regional diversity, different cultural perspectives, various research interests, and management needs. The panel provided additional contacts and reviewed/approved the survey before it was sent.

Two formats were developed for the survey questions based on panel suggestions. The first was a Word document and the second was an online format using SurveyMonkey.com. Initial survey requests were sent on April 22, 2016 with a response deadline of June 15, 2016. At that time, requests were also included for references to publications such as books, journal articles, and technical briefs, and specific technical reports that highlighted an important case study or "best practice." Seven responses were received.

As a follow up to the initial request, a new request for an online format through SurveyMonkey.com was sent to 57 recipients on June 17, 2016, with a reminder email to 49 recipients on July 6, 2016. Eight additional responses were received.

Fifteen individuals responded, which resulted in 14 surveys because two individuals completed the survey on behalf of the same organization (Table 2). This represents a total response rate of 23.44 percent. Response rates by employment field varied considerably, with the highest rate from Agency staff (38.5%), followed by Industry (31%), Academia (13%), and Tribal staff (0%). Although somewhat lower than expected, there were sufficient responses to provide good information on the overall state of geophysical survey in cemeteries.

One disappointment with the survey was the lack of any additional references. Only one respondent (who did not complete the survey) provided any additional publications or technical reports beyond those identified in the literature summary (Appendix A). This was addressed in the follow up telephone interviews.

Telephone interviews were conducted with the following individuals: Jami Lockhart (Arkansas Archaeological Survey), Paul Mohler (North Carolina Department of Transportation), Geoff Jones (Archaeo-Physics, LLC), and Peter Leach and Dan Welch (GSSI). During those interviews, the themes of experience/qualifications, scoping, and reporting were discussed in detail. The themes of environmental and cultural variables, equipment and field survey, and data processing and analysis were more thoroughly answered in the initial survey. Each respondent was also asked what additional information that might like to see in the final guidebook (e.g., time/cost estimates, flow chart, decision matrix, etc.).

With a survey that requires written responses rather than "yes or no," it is very difficult to quantify the data. Analyses of responses for each theme are presented below.

Table 1

Last Name	First Name	Employer Category	Title	Employer
Conyers	Larry	Academia	Professor of Anthropology	University of Denver
DeVore	Steve	Agency	Geophysical Specialist/Archaeologist	Midwest Archaeological Service Center
Elliott	Dan	Industry	Geophysical Specialist/Archaeologist	LAMAR Institute
Gale	Sara	Industry	Program Manager	New South Associates, Inc.
Griswold	William	Agency	Geophysical Specialist/Archaeologist	National Park Service
Hammerstedt	Scott	Academia	Professor of Anthropology	Oklahoma Archaeological Survey
Johnson	Bill	Industry	Geologist and Geophysicist	Rhea Engineers and Consultants
Jones	Geoffrey	Industry	Geophysical Specialist/Archaeologist	Archaeo-Physics LLC
Leach	Peter	Industry	Technical Trainer	GSSI
Lockhart	Jamie	Agency	Research Archaeologist	Arkansas Archaeological Survey
Mohler	Paul	Agency	Archaeologist	North Carolina Department of Transportation
Mt. Joy	Kristen	Agency	Archaeologist	TXARNG
Peterson	Ryan	Industry	Geophysical Specialist/Archaeologist	AMEX Environmental
Sturm	Jennie	Industry	PhD Candidate/ Business Owner	University of New Mexico
Welch	Dan	Industry	Customer Support Manager	GSSI

Table 2. Interview Response Rates by Employment Field

Employment Field	No		Yes		Grand Total	
	Count	Percent (%)	Count	Percent (%)	Count	Percent (%)
Academia	13	86.67	2	13.33	15	100
Industry	18	69.23	8	30.77	26	100
Tribal	10	100.00	0	0.00	10	100
Agency	8	61.54	5	38.46	13	100
Grand Total	**49**	**76.56**	**15**	**23.44**	**64**	**100**

Experience

Interview respondents all agreed that experience was an important qualification to conducting geophysical work in cemeteries. There was also agreement that geophysical work in cemeteries should be done by an archaeologist with experience using geophysics and a strong background in how to interpret cultural features. During conversations with Jones and Lockhart, they both noted that utility locator specialists and geophysicists lacked an understanding of both the instrument parameters and data processing steps considered essential to identifying archaeological features. Formal training was brought up by several respondents and Lockhart suggested some combination of formal training and experience was the most desirable qualification. Mohler suggested that geophysical surveys should also meet the Secretary of Interiors Standards for an archaeologist. Jones, Leach, and Welch all suggested some sort of apprenticeship as one way to gain experience. There was some concern that if the qualifications were too strict they might be exclusionary, but also a strong agreement that a minimum level of background was needed to be successful conducting surveys, interpreting data, and reporting.

Scoping

Scoping questions elicited a varied range of answers from interview respondents. There was widespread agreement with the need to make sure client scopes aligned with the projects survey goals. Project goals and cemetery conditions all affect the scope and could mean that the geophysical survey required might be less intensive or more intensive. For example, if a client only needed a boundary defined they could limit the scope by not surveying the inside of the cemetery. During their interviews, Mohler, Jones, and Lockhart all mentioned the collection of non-geophysical data, including background historical research and marker mapping to aid in the interpretation of the geophysical data. Mohler, Leach, and Welch again discussed qualifications during the project scoping phase, particularly making sure that the proper geophysical equipment and/or instrumentation was used and that the practitioner was experienced in cemetery work.

Another common scoping theme was client communication and setting realistic expectations for survey results. Being honest about the limitations of geophysics was a common theme among respondents, with many people noting that it was important that a client be aware of the limitations of geophysics before a project started. Several people mentioned that sample reports should be shared. Jones specifically mentioned recommending against geophysical survey if he felt that the conditions would make the results unsuccessful. A few people mentioned dispelling popular culture perceptions of the accuracy of geophysics in cemeteries. All of the respondents agreed that no geophysical project can promise complete accuracy and those scoping projects should take that into account.

Environmental And Cultural Variables

The types of cemeteries in which survey respondents have worked was diverse and cemeteries were located within a variety of temporal periods and landscapes. A total of 64% (n=9) of the respondents have worked on prehistoric cemeteries and burials, but most indicated that it was less common than historic cemeteries, exclusively within the United States. One respondent noted that prehistoric burials are a complicated feature to interpret within geophysical results and the types of burials can vary widely depending on the way they were buried, the cultural context, age, and geography. There was consensus that these are sensitive features that can be identified with geophysical methods so they can be avoided by potential impacts.

Geophysical survey is most common in European- and African-American cemeteries in North American with dates typically ranging from the Seventeenth to Twentieth centuries. These surveys predominately include community, family, and church cemeteries. Respondents also mentioned ancient Greek, medieval England, African, Australian outback, and Native American cemeteries. One respondent noted that her work is often done in cemeteries containing "marginalized groups" and another brought up work conducted to prospect for mass graves and clandestine graves.

Respondents indicated that their cemeteries were located in a variety of physical settings, including sand and clay. It was pointed out that rules about the efficacy of geophysics in specific environments tend to over-generalize and that actual data collection needs to be conducted to determine if the equipment is suitable. Many respondents noted that they had seen cemeteries in diverse environmental and soil conditions, including environmentally marginal areas. The most commonly cited environmental concern was thick vegetation, physical obstacles, or topographic variation prohibiting adequate survey of the cemetery. Low moisture levels were a concern for resistivity data collection. Also, the presence of old or degraded graves, thus producing subtle geophysical results, was cited as a problem. The diversity of field conditions in cemeteries requires flexible analysis and collection parameters.

Equipment/Field Survey

Ground-penetrating radar (GPR), electrical resistance, and magnetic gradiometers are the most commonly used instruments. A few respondents also noted electromagnetic induction (EM), magnetic susceptibility, metal detectors, digital compaction meters, and LiDAR, but these are far less common. GPR is by far the primary instrument in most applications, with antenna frequencies of 400MHz, 500MHz, 800MHz, and 900MHz, depending on the manufacturer.

When asked about whether multiple instruments are used, 23 percent said “Yes, always,” 23 percent said “No, never,” and 54 percent said “Sometimes.” Again, GPR is typically the most common, but there are conditions under which it may not always be appropriate. Respondents tended to evaluate the need for multiple instruments depending on the context, research/management needs, and time/budget. It is not clear from the survey to what extent the availability of only a single instrument is an important variable.

Positional accuracy of survey locations was of critical importance. Approximately 83 percent of the respondents stated they collect geophysical data in a grid and 17 percent said grids were used “sometimes.” Cases where data might not be collected in a grid include determining presence/absence of graves with a few individual transects and/or surveying around individual plots rather then an entire cemetery. However, these situations would be determined by the overall project goals.

When asked about the strengths and limitations of particular instruments, most respondents identified GPR as the best method because of its ability to determine accurate depths. GPR also has the steepest learning curve and requires the most processing and interpretation. Limitations such as signal noise, dry soils, and highly conductive soils were noted for GPR and electrical resistance, and metallic interference for magnetometer and EM. Unsuitable surface conditions apply to all instruments.

Data collections and sampling intervals were highly variable and dependent on the conditions. In most cases, respondents indicated transect spacing of no more than 0.5-meter, with occasional higher density sampling spaced at 0.25-meter. One respondent indicated using single direction transects as opposed to bi-directional (zig-zag) to maximize accuracy. Regardless of the specifics, almost everyone agreed in general that higher density sampling is better, but there are always concerns about the costs in time/money. Data sampling intensity along transects depended on the specific instrument.

In terms of referencing cemetery features such as markers, coping, trees, and paths, everyone agreed that these need to be mapped in some way. However, the specifics included hand drawn sketch maps, total station, Real Time Kinematic (RTK) GPS, and drones, in addition to photographic documentation. Geophysical data are typically correlated with surface features through geographic information systems (GIS) overlays. Most respondents recognized the importance of accurate placement in real space.

Data Processing And Analysis

Software for data processing depends to a large extent on which manufacturer’s equipment is used. For GPR data, Radan (GSSI), Mala 3D, EkkoMapper, Ekko View Deluxe, Voxler (Sensors and Software), GPR viewer, and GPR Slice are common. For magnetometer and electrical resistance, TerraSurveyor and Geoplot are common. Surfer, ArcGIS, and IDRISI are used by many practitioners for presentation and spatial control.

Special steps/techniques/methods for cemeteries were noted by several respondents, including the need to orient transects perpendicular to graves, collect data over marked graves for comparative purposes, GPR profile analysis (2D), GPR amplitude slice maps (3D), and GPR target picking. Others noted that special considerations might be necessary but they are site-specific. One person stated that s/he followed the same procedures as other archaeological sites. It is also important that a few people recognized the need to consider burial practices, cultural, temporal, and economic factors, which might be identified in archival/historic research.

When asked about testing geophysical results with archaeology, almost all respondents said this occurs very rarely, is not typically allowed, and may only be done if there are definite impacts. A corollary to this finding is that many also acknowledge that it would be helpful for better interpretation of geophysical data, but there are practical limits. A typical approach would be to remove topsoil and identify grave shafts.

Reporting

When asked about reporting and managing client expectations, all respondents emphasized communication, detailed explanation of methodology, and setting realistic expectations of the results from the beginning. Particularly when asked about conveying negative results or false positives in cemeteries, communication and careful reporting were important themes. Because negative results do not necessarily mean the absence of graves or that the geophysical survey was a failure, communicating this to clients was emphasized. Lockhart specifically mentioned he would not trust a report that did not outline that there could be some missed or false positive grave identifications. Mohler pointed out he would prefer to have false positives rather than false negatives. Testing a possible grave and determining that it is not a grave is preferable than finding unknown graves during construction.

During follow up conversations, interviewees were asked to outline the components of a good geophysical report from a cemetery. All of the interviewees agreed that good visuals were the primary requirement, including maps (with underlying spatial data) and graphics. Aside from the visual data, Leach and Welch pointed out that the basic "who, what, when, why, and where" should be covered. They also discussed the inclusion of detailed technical and equipment specifications. Jones and Lockhart both discussed including information on how interpretations were made, specifically describing the geophysical results in detail. Jones suggested a ranking of results based on confidence levels (high, medium, low). Leach, Welch, and Mohler discussed using historic context information and connecting the cemetery to its historic origin. Mohler also suggested an understanding of how state, local, and federal regulations apply to cemeteries be included in the reporting. Finally, Jones suggested that a report should include both the raw and processed data for archival purposes.

Summary

The responses provided more clarity on geophysical survey in cemeteries. Although there are diverse perspectives on certain aspects such as instrument selection and data collection strategies, there is also widespread agreement regarding many common themes such as qualifications, effective scoping, and reporting.

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