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GEOPHYSICAL DETECTION OF GRAVES – BASIC BACKGROUND AND CASE HISTORIES FROM HISTORIC CEMETERIES

By
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Abstract

The identification of graves is an important issue at many historical cemeteries. Time and vandalism have often obliterated the trace of burials and the operator of the cemetery may not know where empty plots may still be available. Land development encroaching on an historical cemetery may also have to be careful about disturbing unmarked graves. In the extreme case where a cemetery needs to be relocated because of development, it is important to make sure that unmarked graves are not overlooked. As excavation is seldom a desirable solution to locating unmarked graves, methods of detecting burials from the ground surface can have an obvious benefit.

This presentation reviews the three most commonly applied geophysical techniques and presents several case histories documenting the detection of graves. The main physical basis for grave detection is that grave shafts represent a disruption to the natural layering of the ground. Disruptions to soil layers can often be detected with GPR. Grave shafts represent a mixing of the soil types excavated, so there is usually a physical contrast of the grave fill with natural soil. Graves are often manifested by magnetic lows because they disrupt the natural fabric of soil magnetization and are also often delineated by resistivity lows, primarily because grave fill is not as dense as natural soil and can therefore retain higher moisture content. The basic conclusion is that grave detection is difficult, but usually achievable, especially when multiple techniques are applied.

Introduction

Many old cemeteries have "lost" graves that can prove to be problems if they are accidentally disturbed. In many or most cases church or family records are not precise in terms of knowing conclusively who is buried where. Assuming that massive excavations are not a good idea, the application of non-destructive means to locate unmarked graves can be clearly advantageous.

The most commonly applied remote sensing technique for the detection of unmarked graves is dowsing. Dowsing, also known as rhabdomancy or divining, traditionally uses a forked stick

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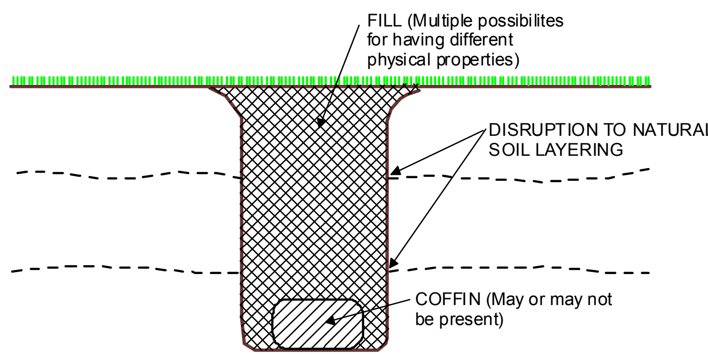
(although there are many variations including the use of coat hangers) and movements of the stick can indicate the presence of graves, or virtually any other buried object of interest. The mechanism behind the detection is believed to depend on energy fields unknown to science. Nearly everyone has met a person who at least claims to have some proficiency in the field of dowsing, although if asked to explain scientifically how the process works, they have no idea, but they know that it works for them. This subject is mentioned because a simple internet search will reveal that it is just as easy (and possibly easier) to find a "specialist" in dowsing than a geophysicist specializing in the detection of graves. The problem is that few things capture a curious mind more easily than the unproven and esoteric, as described in May/June 2003 Archaeology in the Special Section entitled *Seductions of Pseudoarchaeology*. Dowsing falls into the same category, even though there are certainly more followers of this form of pseudoscience than specialized geophysicists. As noted by the Romans: *Homo vult decipi; decipiatur* [Man wishes to be deceived; deceive him].

Returning to the realm of real science, geophysics can have potential success in detecting unmarked graves because of some general characteristics of grave shafts:

- Grave shafts disrupt natural soil layering. Techniques sensitive to mapping the continuity of soil horizons such as GPR can be effective.
- Fill in a grave shaft is usually an average of the physical properties of intact soil horizons, which means that if there are vertical soil changes, the fill will probably have some physical contrast with the natural ground.
- Grave fill can sometimes represent a disturbance to the magnetic fabric of natural soil and be manifested by a magnetic low.
- Grave fill is often of a lower density, higher porosity and higher moisture content than natural soil, and can be detected as a resistivity low, primarily because of the higher moisture content.

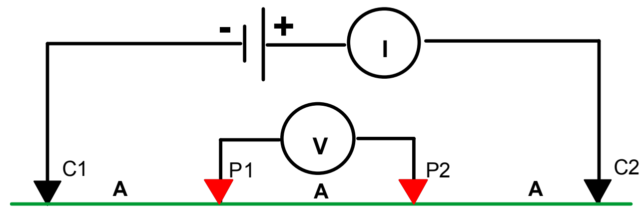


A grave as a geophysical target

Three geophysical techniques have the greatest potential application in detecting unmarked graves: electrical measurements, ground penetrating radar (GPR) and magnetic measurements. The following sections review these techniques.

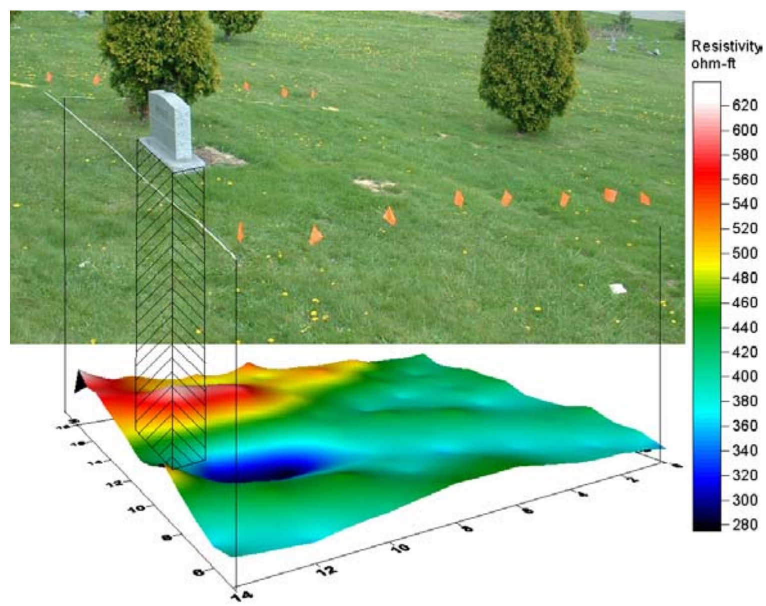
DC Resistivity

The purpose of DC electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the soil or rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations, but the use of this method has been recently increased due to improvements in both data acquisition and processing technologies.



Wenner electrode configuration – for the Old Stone Church cemetery experiment, the equipment consisted of two Radio Shack multimeters, batteries, a switch, steel rods used as electrodes and connecting wire

An example of a simple experiment to image a grave was obtained from the Old Stone Church historical cemetery in Monroeville, Pennsylvania. For this experiment, a simple four electrode system with the Wenner configuration was used with a constant 3-foot "a" spacing on a grid over a known, isolated grave. The grave was clearly imaged as an area of low resistivity, probably because the soil in the grave shaft had a higher porosity and corresponding moisture content than the surrounding natural residual soil.



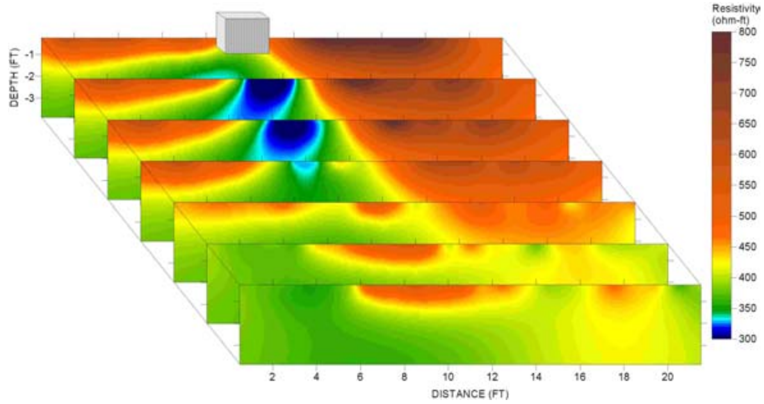
Results of simple experiment at the Old Stone Church cemetery presented as a color-coded surface with the Surfer 8 program

Multi-electrode systems have greatly improved the efficiency of data acquisition, as measurements can now be made automatically. Until recently, the DC resistivity method was limited by the need to perform complex calculations to model subsurface electrical properties. With the development of high-speed PC computer systems and improved 2D and 3D processing software, however, this limitation has been greatly reduced and the technique has seen increased application, including for the detection of graves.

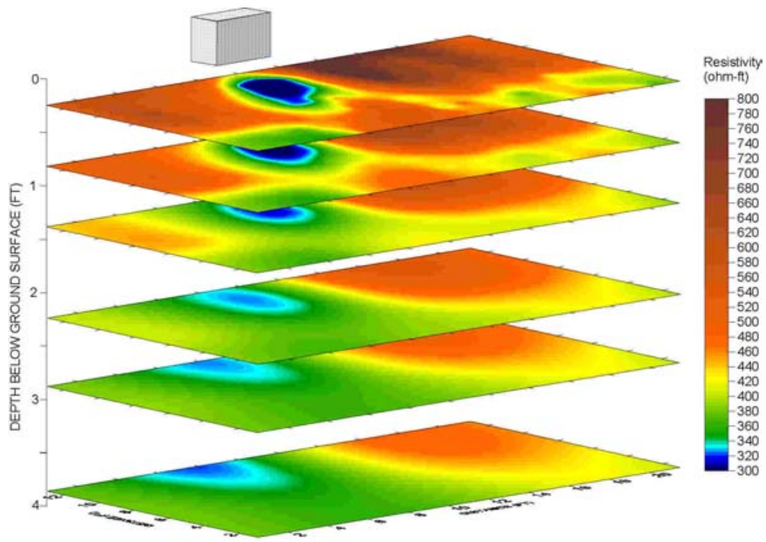
The same area surveyed with the simple survey was also surveyed with a commercial, multi-electrode system and the data processed as both 2D profiles and as a 3D block. The results of this more comprehensive survey confirm the accuracy of the simple survey, but provide significant additional detail regarding the variations of shallow electrical properties in the area of the grave.

Ground Penetrating Radar (GPR)

GPR offers the highest resolution of any geophysical method. In many cases, the time required for the acquisition of GPR profiles is minimal and subsurface profiles can be obtained in real time, making this tool very cost-effective. GPR works best in non-conductive soils, such as dry sand or sand saturated with fresh water. The least favorable condition occurs when the soils consist of wet, saturated clay, although this is not a major concern at the shallow depths associated with most burials. GPR surveys are most often conducted as 2D profiles, but newer systems and software allow for the processing of GPR data in three dimensions, similar to the example of DC resistivity. Nevertheless, for locating graves, the 3D imaging of graves is difficult and frequently not practical because of the variability in the amplitude of reflections from graves.



Results of 3D resistivity survey over the same ground as the simple survey depicted as a series of vertical sections produced as a result of the RES3DINV program

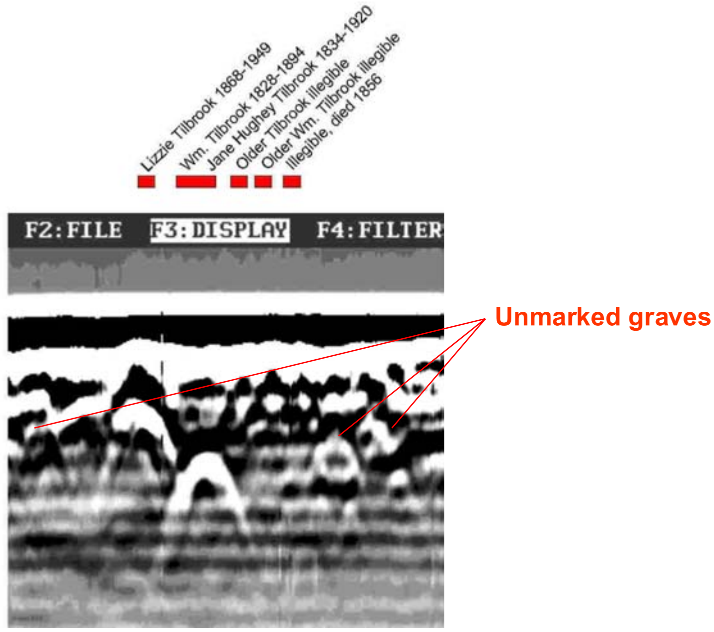


Results of 3D resistivity survey over the same ground as the simple survey depicted as a series of horizontal sections produced as a result of the RES3DINV program

Graves can be identified on the basis of the disruption of soil horizons by the grave shaft. This assumes that the natural soil has discrete horizons that can be identified by GPR reflections, which may not always be the case. An air-filled casket is usually an excellent target for GPR, if a casket is present. Although it is not possible to make guarantees, the GPR method is usually the most definitive technique in mapping unmarked graves.

Magnetics

The excavation of a grave shaft disturbs the magnetism that may be associated with natural soil, effectively reducing the magnetic susceptibility of the grave fill compared to the natural soil. A grave shaft can therefore sometimes be detected as a magnetic low. The main disadvantage to the magnetometer is the likely presence of other cultural interference, especially metal, commonly encountered in areas disturbed by man.



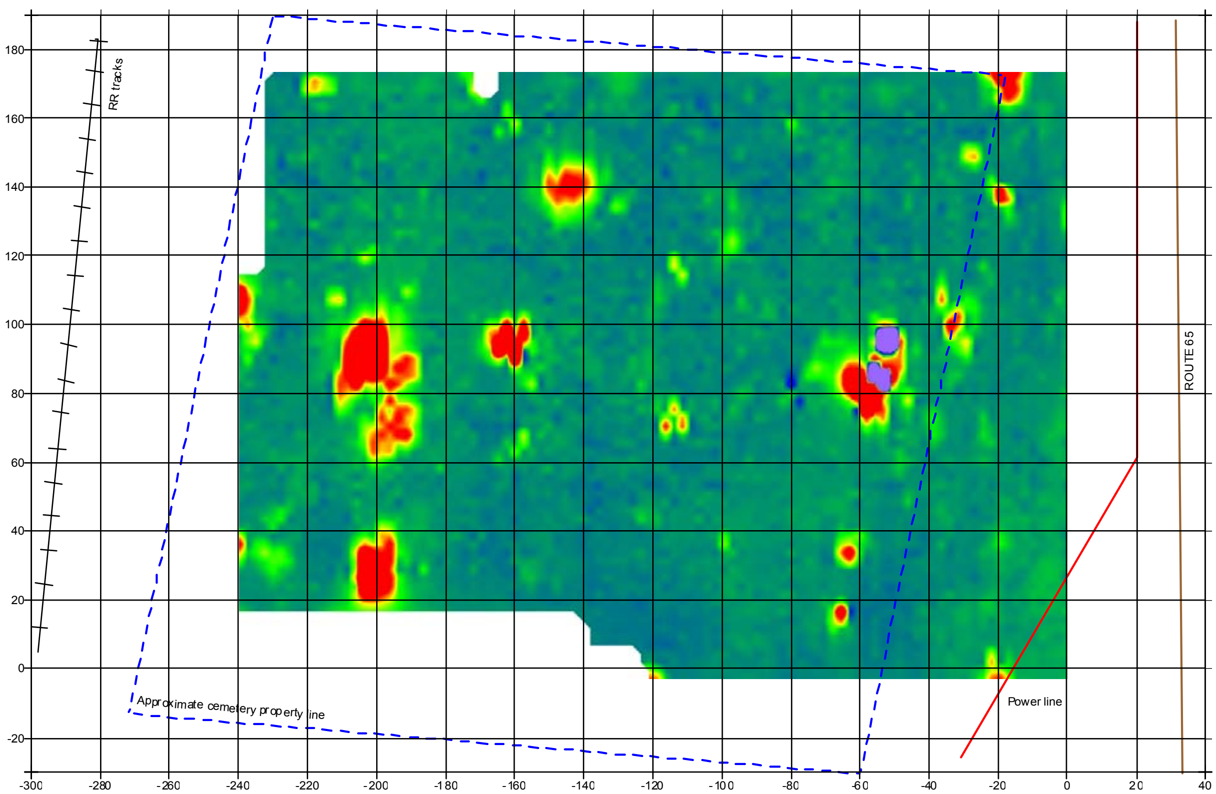
GPR profile over historic graves at the Old Stone Church cemetery – several reflections are from graves where headstones are not present

The preferred instrument for the shallow, high resolution measurements associated with historical cemeteries is the cesium vapor gradiometer, a special form of magnetometer that contains two sensors mounted on an aluminum rod and separated vertically by at least 0.5 meters. The magnetic intensity recorded at the upper sensor is subtracted from the intensity at the lower sensor to determine the vertical magnetic gradient at each measurement point. The gradiometer is more sensitive to the location of shallow objects than a conventional magnetometer because the response of the instrument falls off as the inverse fourth power of distance, whereas intensity falls off as the inverse third power. This means that the gradient field that a shallow object will produce is a response to very shallow subsurface conditions and for this reason is commonly measured for archaeological studies. Graves (and frequently old excavation units left over from archaeological investigations) can be imaged by magnetic gradient.

Application of Multiple Geophysical Techniques - Hill Historical Cemetery in Baden, Pennsylvania

GPR surveying at the Hill Historical Cemetery

The Hill historical cemetery in Baden, PA is located adjacent to a highway (Route 65) on a small hill on the eastern bank of the Ohio River about 21 miles downstream from Pittsburgh. The cemetery was created by the Hill family in the early 1800's, and contains the graves of many of the original settlers of Baden, including several veterans from the Revolutionary and Civil Wars. Due to several factors, including vandalism, many tombstones have been knocked over and several appear to be missing or mislocated. The scope of the geophysical investigation was twofold, to identify graves that are either unmarked or have inaccurate tombstone placement and also to delineate buildings and related structures associated with Legion Ville, a Revolutionary War training camp constructed by General Anthony Wayne in 1792 and suspected of encroaching on the cemetery. Another factor to be considered in the interpretation of the data was that the site is near Logstown, a well-known settlement of Native Americans that was the location of early contact with European traders. The possibility that there could be evidence of prehistoric occupation of the cemetery site also needed to be considered.

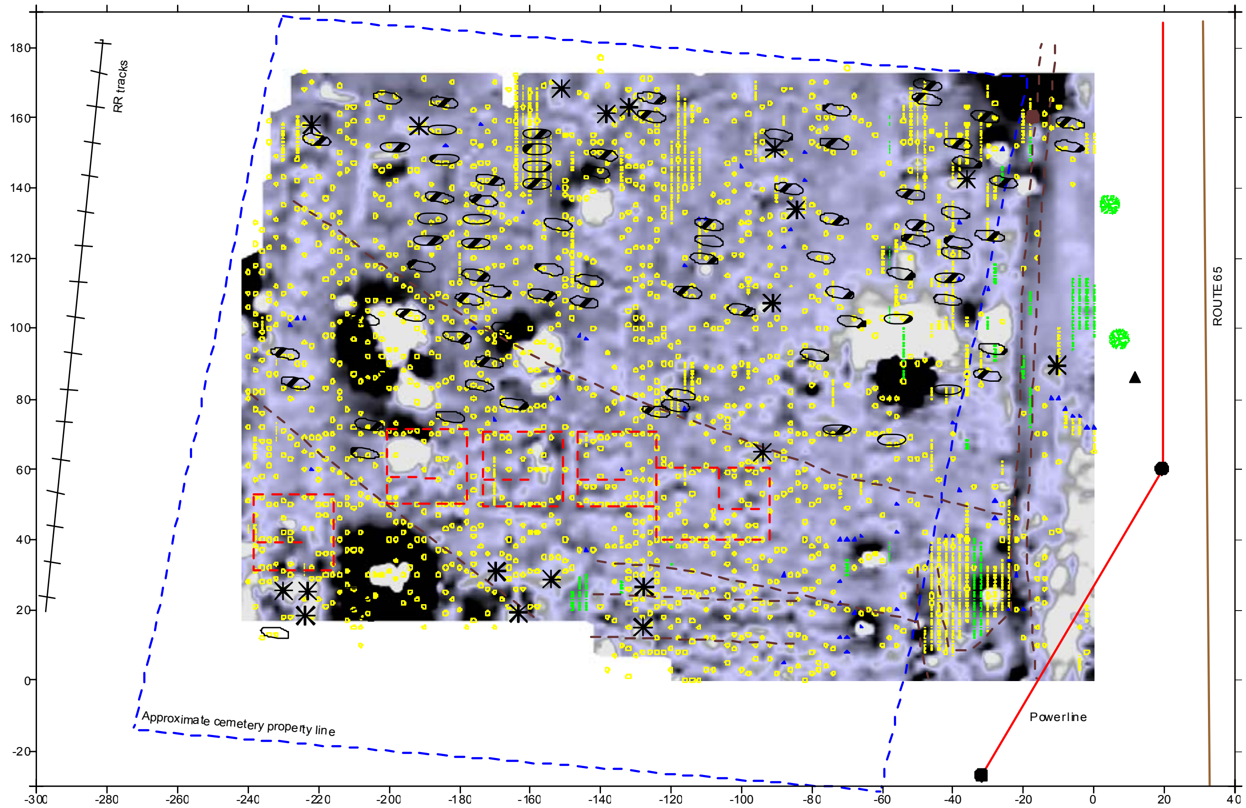


Distribution of metal at the Hill Historical Cemetery from EM61 measurements

Several geophysical techniques including a Geonics EM61 time-domain electromagnetic system for deep metal detection, magnetic gradiometry, and ground penetrating radar (GPR) were applied at the cemetery. The deep metal detection survey is not mentioned as a primary technique for identifying graves as metal is typically not a diagnostic feature of a grave. In this case, the metal detection was conducted to facilitate the interpretation of the magnetic data to distinguish which anomalies were due to metal and which could be interpreted in terms of a different cultural origin.

The survey was initiated with the time-domain metal detector. This determined a baseline from which the magnetic data could be interpreted. Magnetic data acquired with a Scintrex Smartmag cesium vapor gradiometer were interpreted in terms of subtle soil changes, such as associated with buried roads, graves, building foundations, or fire hearths. Finally, ground penetrating radar

(GPR) was conducted using a RAMAC system to identify graves based on images from the coffins or on the basis of disturbances to soil horizons. The GPR data also provided supplementary information regarding structures and building foundations.



Magnetic gradient and specific GPR anomalies at the Hill Historical Cemetery

The interpretation of the geophysical data sets proved to be a challenging process. The site has a complex history of occupation probably beginning in prehistoric times and including the Revolutionary War and the subsequent development of the Hill Cemetery. Each occupation left an imprint on subsurface conditions reflected in the geophysical results.

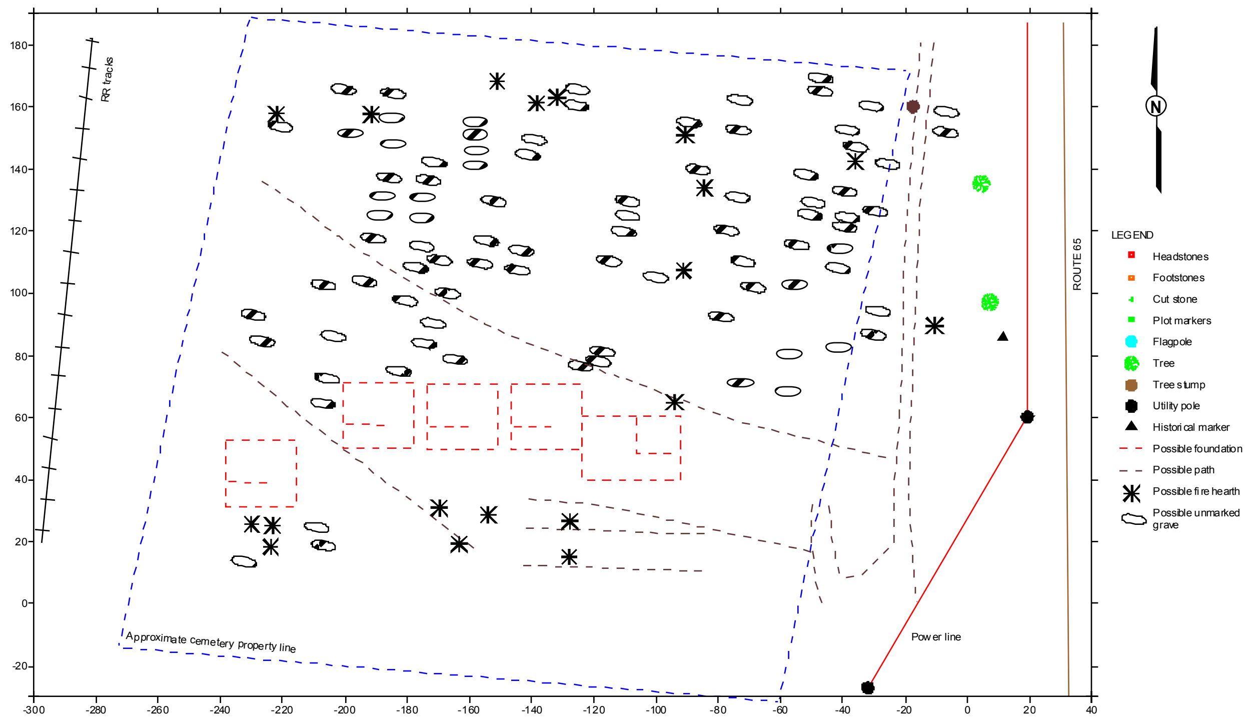
Interpretation of the geophysical data was categorized into probable features:

- *Possible prehistoric features* - Features that could be related to prehistoric occupation are fire hearths. Hot fires cause soil to become magnetic and are normally marked by magnetic highs. The interpretation is not entirely straightforward, however, as small amounts of metal could also produce similar magnetic anomalies. To be able to identify features that could be fire hearths, the magnetic results were compared with the distribution of metal from the EM-61 readings.
- *Possible Revolutionary War structures* - Prior to the survey, available information suggested that the cemetery could be the location of Redoubt No. 4. This part of the Legion Ville Camp was expected to be comprised of a blockhouse, probably with stone foundations, surrounded by a deep trench. This type of structure was not encountered. Nevertheless, the data

do define what appear to be building foundations, best depicted by the magnetic gradient data. The overall pattern of the apparent structures is not one of a redoubt, but could be associated with barracks or stables. The distribution of shallow metal suggests that one of the structures could have been a forge.

- *Roads and pathways* - A N-S trending road is present at the eastern edge of the property that is unrelated to modern Route 65. Other, more subtle alignments of magnetic anomalies and GPR reflections define the presence of other roadways or pathways crossing the cemetery diagonally.
- *Graves* - Over 50 locations of ground disturbance that have the appearance of graves not associated with headstones are present across the site. In many cases there is evidence of the presence of graves at the ground surface, but in other cases there is no surficial evidence. Generally speaking, where a headstone is present there appears to be an associated grave.

An archaeological investigation to verify the geophysical interpretation is pending.



Interpretation of geophysical data at the Hill Historical Cemetery

Conclusions

In most cases, the best technique for mapping graves is ground penetrating radar (GPR), but electrical and magnetic measurements can also be effective. Nevertheless, the identification of graves can be a complicated problem, depending on the age of the graves and soil conditions. Surface conditions, soil conditions, type and age of burial and condition of the coffins are all important factors in determining the effectiveness and costs of geophysical surveying. The most effective surveys will be multidisciplinary, where the geophysicist and archaeologist are teamed together to interpret the data.