USE OF PRECISION MAPPING AND MULTIPLE GEOPHYSICAL METHODS AT THE HISTORIC REESE CEMETERY IN MUNCIE, INDIANA

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Abstract

Many privately owned historical cemeteries are found throughout the countryside in the United States. One such cemetery, known as the Reese Cemetery, dates back to the pioneer settlement of Indiana in the early 1800's, and is located near Muncie, Indiana. As is often the case, documentation of the individual graves is often incomplete or even non-existent, and as a result many of the oldest graves become lost because they are either completely unmarked or have illegible or broken headstones. The cemetery association responsible for the care of the Reese Cemetery determined that it was necessary to map the entire cemetery and find as much out as practical about the locations of unmarked graves. Because of strict regulations regarding the disturbance of historic cemeteries, it was deemed necessary to locate the unmarked graves, buried headstones, etc. using non-intrusive methods whenever possible.

In July 2002, a detailed mapping project was performed on this one-acre (0.4-hectare) cemetery. Precision survey mapping of topography and individual headstones, written and photographic documentation of each headstone, and the completion of a geophysical survey were all performed to provide a lasting record of the cemetery. The techniques used included ground penetrating radar, terrain conductivity, and metal detection. This approach provided value both in terms of preserving the identity and locations of the graves and in offering insight into the locations of some unmarked graves. Ground penetrating radar amplitude mapping appears to have provided the single greatest insight and level of detail pertaining both to graves containing metallic objects (vaults and caskets) and graves retaining little more than disrupted soil strata and human remains.

Introduction

Indiana, like other locations around the world, contains practically innumerable small, privately owned cemeteries, many of which are found in remote or isolated rural locations. Many of these cemeteries have relatively long histories, often spanning back to the early days of Indiana statehood in 1816, or even to prior years when it was in the Indiana Territory (1800 to 1816) and Northwest Territory (1787 to 1800) before that. Many of the individuals buried in these cemeteries were early settlers and some were participants in the American Revolution, War of 1812, Civil War, and more recent conflicts. Native Americans are represented as well. As a result, many of these cemeteries represent a rich treasury of historical information that is valued by archeologists, anthropologists, descendants of the deceased, and those preservation-minded individuals who value the history of their state.

The Reese Cemetery is one such cemetery located in Indiana, near Muncie in central Delaware County (Figure 1). Graves in this historical cemetery are known to range from 1819, early in Indiana's statehood, to as recent as the year 2000, which was the last burial to occur in this

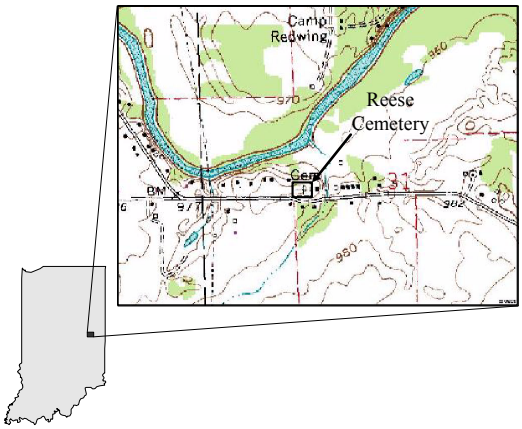

Figure 1. Location of Reese Cemetery in east-central Indiana, in Delaware County just southeast of Muncie.

cemetery. The Reese Cemetery Association was founded to care for and maintain this historical cemetery for future generations. Although active measures are being taken to repair or replace damaged or missing headstones, prior years of lesser care and maintenance and the natural processes of decay over time have resulted in the loss of valuable information regarding those buried, the number of graves present, particularly older ones, and the locations of missing graves in general. Our firm was retained by the Reese Cemetery Association to assist them in documenting the existing marked graves (approximately 490 total), accurately mapping the marked graves using modern surveying techniques, and utilizing geophysical methods for identifying potential unmarked graves, most of which would be presumed to be some of the oldest graves. Because of time and budgetary constraints, for all practical purposes, this investigation was restricted to the use of surface observations, surveying, and geophysical methods due to Indiana laws and regulations (IC 14-21-1), which restrict any activities that disturb the ground in privately owned cemeteries containing those who died prior to 1940. As can be seen in Figure 2, the majority of the marked burials occurred prior to 1950, clearly making the Reese Cemetery subject to the restrictive regulations (in fact 88% of the 303 marked and legible graves date prior to 1940). Under Indiana regulations, geophysical surveys are fully permissible, but ground-truthing the geophysical findings would not be possible without a pre-approved Archeological Plan. In addition, the Reese Cemetery Association, out of respect for the families of the deceased, did not wish to carry out excavation activities, regardless of the standards established by the state. Greater emphasis is therefore shifted to the outcome of the geophysical survey as essentially the sole means for identifying the locations of unmarked graves.

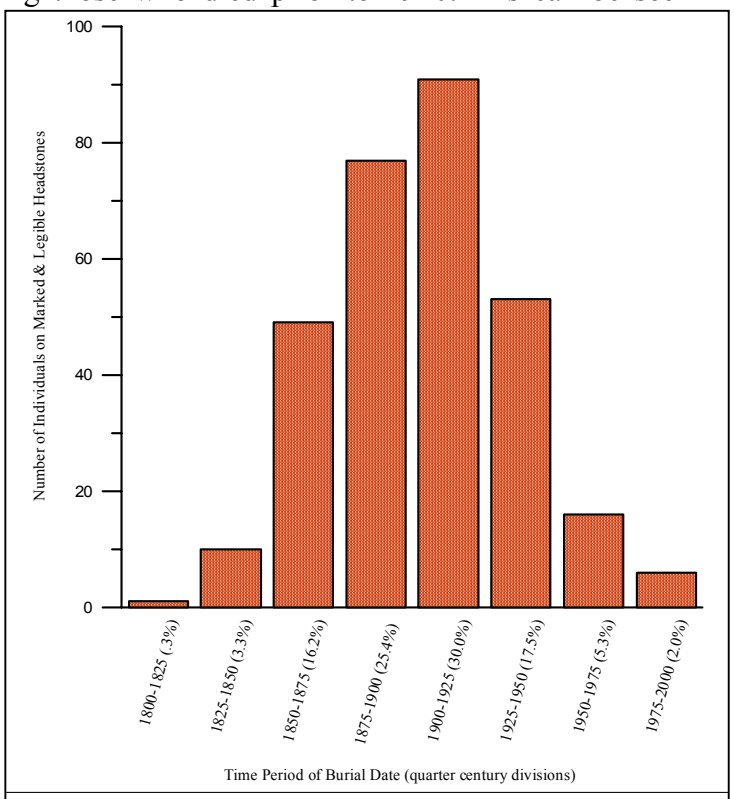

Figure 2. Distribution of burials over time for the Reese Cemetery based on legible headstones. The earliest marked and legible grave is from 1819 and the last grave was in 2000. There are a total of approximately 490 marked graves, but only 303 of the headstones are legible. It is apparent that the majority of the illegible headstones are older graves, most likely pre-1900. The unmarked graves are also likely to be some of the oldest graves.

Based on the documented efforts and findings of other workers in mapping historic cemeteries using geophysical means (for example Bevan, 1991; Bauman et al., 1995; and Nobes, 1999), in the order of relative effectiveness, ground penetrating radar, metal detection, and electromagnetic conductivity were selected *a priori* as the suite of geophysical methods believed to be potentially effective for use at Reese Cemetery.

The choice of methods has a sound basis. Bevan (1991), in one of the earliest contemporary papers on the subject, indicated that graves might be identified by several potentially distinguishing characteristics including the following.

- Disturbed soil in the filled excavation, which may result in higher or lower electrical conductivity and magnetic susceptibility than undisturbed soils – these effects may be long-lasting.
- Although nothing but bones may remain in old graves, the decay of human remains may alter the chemical composition of the soils in the grave.

- If a coffin is still partially intact, there could be an air-filled void present.
- Although coffin nails are probably undetectable, some larger metallic coffin fittings, metallic coffin frames, or metallic (iron or lead) coffins may be present, resulting in metallic object detection with magnetics, electromagnetic conductivity, and metal detection.
- If a burial vault made of stone or brick is present, there could be an air cavity and the stone or brick may be moderately magnetic.
- Settlement of the soil in the grave shaft may lead to a surface depression, and adjacent soils may have washed into the depression, resulting in a lense of topsoil, which may be detectable.
- Metallic objects or head or footstones, now buried, may be found near the grave.

Bevin (1991) concluded that ground penetrating radar had the greatest success in locating unmarked graves in the eight sites investigated. He further concluded that the best conditions are where soil conditions are not complex, and where there is little or no stratification. Nobes (1999) found that clayey conditions can greatly reduce the effectiveness of ground penetrating radar. Because graves are customarily elongated east-west in most western cultures, east-west elongation of grave anomalies can be one of the most distinguishing features. Bevin (1991) found that electrical conductivity measurements have been associated with high conductivity graves in some cases, and low conductivity graves in others. Nobes (1999) developed a scheme for creating a composite scoring system by combining electrical conductivity, magnetic, and ground penetrating radar data anomalies. This system was developed to deal with his observation that graves were associated with both positive and negative conductivity anomalies and magnetics anomalies and did not always have a corresponding ground penetrating radar anomaly.

The subject survey at the Reese Cemetery provided an opportunity to evaluate commonly applied geophysical mapping techniques in a controlled setting. The wide range of grave ages and likely range of burial methods has resulted in a field trial which can suggest which method or combinations of methods are more likely to yield useful results regarding the locations of both marked and unmarked graves. There is interest in locating unmarked graves in situations including:

- historic preservation and documentation, such as the case at the Reese Cemetery;
- accidental or unintentional discovery of old, undocumented or poorly marked cemeteries (often found during construction activities);
- intentional search for known, but poorly marked or unmarked cemeteries with the intent of memorializing or even moving the cemetery; and
- existing cemetery owners with an interest in finding and marking older, unmarked graves in existing cemeteries with the goal of more efficiently utilizing the available space.

Site History and Geological Background

Site Description

The Reese (also spelled Rees) Cemetery is located in a scenic rural setting about 2 miles southeast of Muncie, Delaware County, Indiana (Figure 1). It lies on the north side of County Road 350S between County Road 400E and Burlington Pike. The center of the site has geographic coordinates of W85º19.462', N40º8.517'. It was placed on a slight topographic rise, as cemeteries often are, with about 40 feet (12 meters) of relief and it overlooks the West Fork of the White River to the north. The size of the Reese Cemetery is approximately one acre (0.4 hectare), and contains graves spanning at least a 181-year period from 1819 to 2000 as shown in Figure 2. Figure 3 depicts the cemetery's topographic surface, which was mapped as a part of this project. This map also shows the locations of the visible headstone markers, about 490 total, and those that have legible dates are grouped into date ranges as shown.

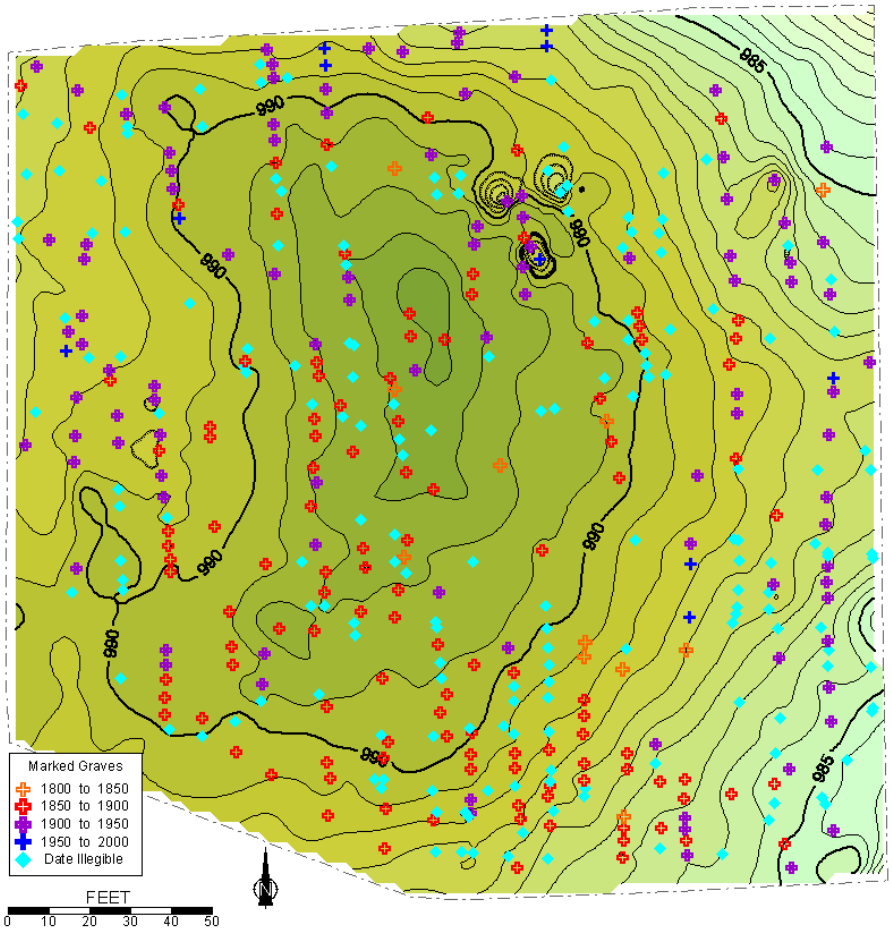

Figure 3. Topographic contour map of the Reese Cemetery created using precision surveying via Total Station. Perimeter of map is bounded by a metal fence (dashed line). Elevation contours are in feet above mean sea level, contour interval is 0.5 feet (15.24 cm). Also shown are the approximately 490 marked graves, subdivided by half-century divisions.

Reportedly, one of the last Native American settlements in the area was found near the cemetery, and some of the cemetery's occupants are Native Americans including a highly revered individual

known as “Indian Jim”, i.e., James Musco, who died in 1875 at the age of 69. A commemorative monument and statue have been erected in his honor (Figure 4).

Figure 4. Commemorative plaque and hand carved wooden statue at entrance to Reese Cemetery (left). Memorial to James Musco, “Indian Jim”, who was highly regarded by the local residents.

Site Geology

The Reese Cemetery is underlain by about 90 feet (27 meters) of Pleistocene glacial deposits, which lie unconformably on Silurian limestone bedrock. The uppermost glacial deposit consists of Wisconsinan glacial till associated with the Tipton Till Plain, a region characterized by nearly level to moderately rolling ground moraine. This physiographic region is characterized by flat to gently rolling terrain, the result of continental glaciation during which glacial till and outwash were deposited as the ice advanced and melted from Indiana more than eight times. Occasional terminal moraines, knolls, and kames are present, with esker remnants and meltwater drainageways entrenched in the till. Sediments borne by the ice sheets were deposited as till (an unsorted mixture of sand, silt, clay and boulders) when the glaciers advanced into Indiana and as outwash sand and gravel when the ice melted. The soils at this site were developed by weathering of the parental glacial till materials and tend to be relatively impermeable, silty and/or clayey, and dense. There is generally little stratification visible in these soils other than the vertical transition from top soils (O, A, and E horizons) to oxidized parental material (B horizon) to unweathered glacial till (C horizons).

Field Investigation

Survey Grid and Topographic and Headstone Mapping

A 10 foot by 10 foot control grid was initially surveyed within the confines of the fenced area of the cemetery. A Topcon GTS-300 total station equipped with an electronic data logger was used to survey the positions and elevations of each of the approximately 415 grid nodes. In addition, 490 headstone locations and elevations were also recorded. This data set was used to contour the surface elevation at a 0.5 foot contour interval as shown on Figure 3. Each of the headstone markers was also photographed, and was entered into a log book containing names and date of death.

The distribution of headstones shown on Figure 3 suggests that there is a pattern to the arrangement of graves by date of burial. Figure 5 is a contour map of the earliest date of death marked on legible headstones, contoured in quarter-century subdivisions. In general, it appears that the oldest graves are found in the topographically highest, central portion of the cemetery and increasingly more recent graves are found on the flanks of the cemetery to the west, north, and east.

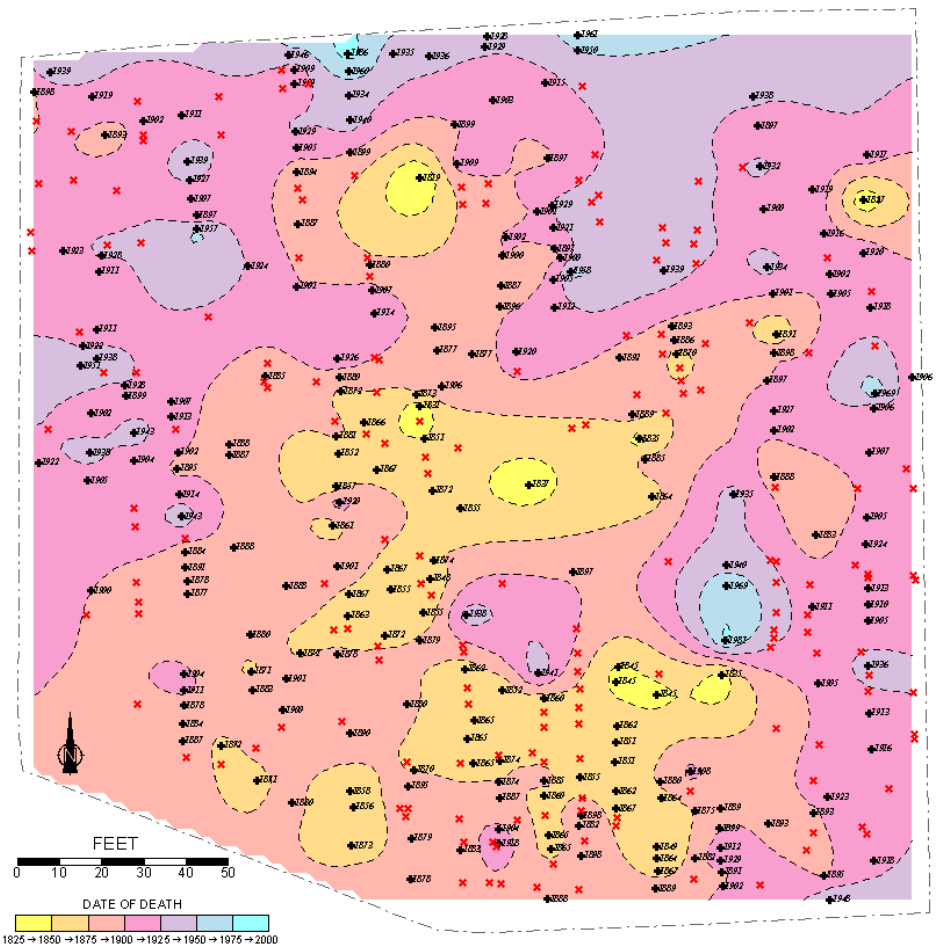

Figure 5. Contour map of the date of death by quarter century on those headstones that were legible (black symbols with date shown). Illegible markers are shown as red Xs. Note that most of the oldest graves appear to be near the center at the high topographic points.

Electromagnetics Mapping

Two types of electromagnetics surveys were carried out over the entire gridded area. The data collection lines were oriented north-south and were spaced 5 feet (1.5 meters) apart (every other line interpolated by the operator between grid flags). First, a Geonics EM-61 metal detector (1 meter by 1 meter coil size) was used to characterize the distribution of buried metallic objects. Generally, it was assumed that the EM-61 would reveal the locations of graves by detecting ferrous and non-ferrous metals contained in reinforced concrete or metal burial vaults, metal grave liners, metal caskets or metal-reinforced caskets or coffins[1]. The EM-61 is a high-sensitivity, time-domain metal detector whose transmitter generates a pulsed primary magnetic field, inducing eddy currents in nearby metallic objects. The subsequent decay of these induced currents is measured by a pair of vertically-separated receiver coils at a relatively long time after termination of the primary pulse. In so doing, the recorded response is nearly independent of the effects of soil conductivity. Both the individual signal strengths and the differential signal strength between the two coils are recorded by this instrument, allowing for depth estimation and suppression of near-surface noise cause by smaller, shallow objects. The advantages that

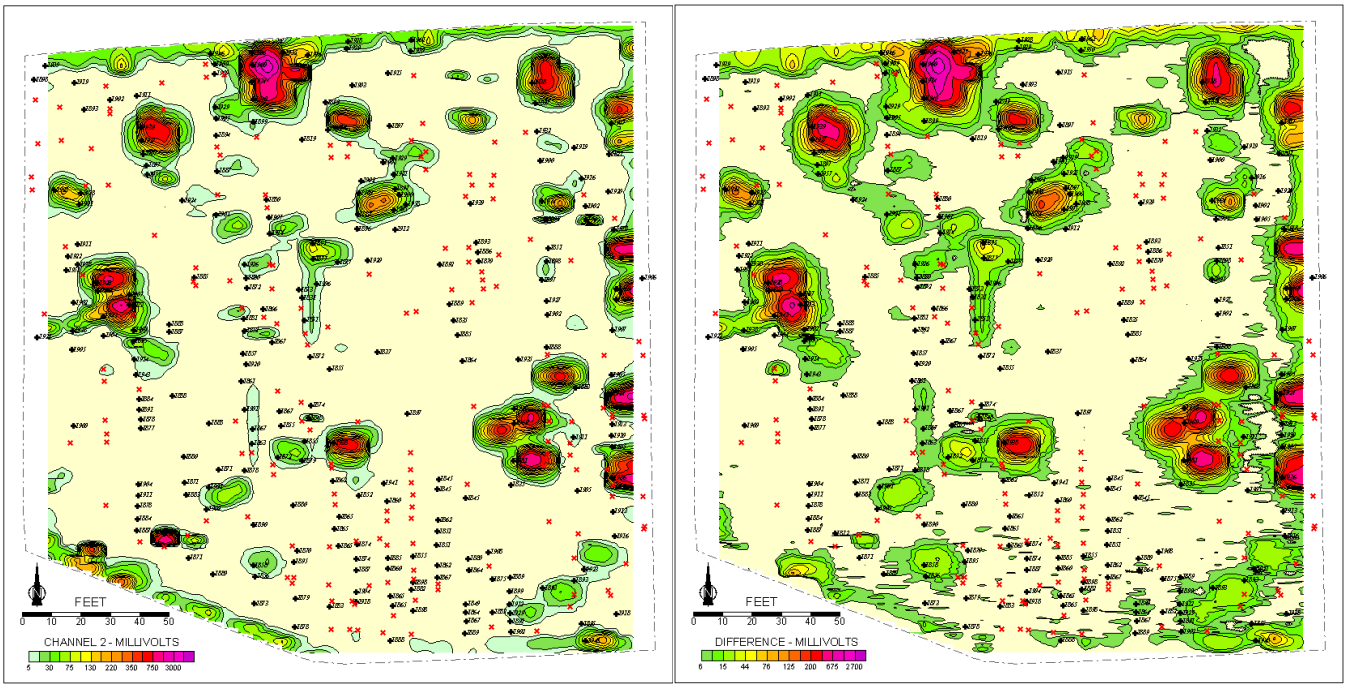

Figure 6. Geonics EM-61 maps of the Reese Cemetery. Lines were at a 5 foot (1.5 meter) separation and oriented north-south. Bottom coil (channel 2) is shown on the left, and the channel difference is shown on the right. The strongest responses were recorded for graves, which probably contain reinforced concrete or metal vaults as well as metal, or metal reinforced caskets. Most of these graves are 100 years old or younger.

the EM-61 has over magnetometers in this application are twofold. First, the EM-61 detects both ferrous and non-ferrous metals, and second, the response curve is a single, well-defined, easily interpreted peak. Generally both the shallow response (bottom coil or channel 2) and the deep response provided by the coil difference (i.e., top minus bottom or channel 1 minus channel 2) are plotted for interpretive purposes. Figure 6 is a contoured map of the EM-61 bottom coil (channel 2) response (left) and coil difference (right).

[1] According to www.funeralplan.com, the average length of a casket is 84 inches, width 28 inches, and height 23 inches. There is a difference between a casket and a coffin. A coffin is the six-sided box often used in vampire movies—it's wider at the shoulders and tapers down towards the feet. Coffins are still used occasionally, but they're more of a specialty item now. A casket is the standard four-sided box most often used for modern burials.

The second electromagnetic instrument used was a Geonics EM-38 terrain conductivity meter to map soil conductivity. This instrument was used primarily to quantify variations in soil conductivity with the assumption that, in addition to the metallic objects sensed by the EM-61, the EM-38 would possibly respond to disturbances in the soil caused by the excavation and backfilling of graves. The EM-38 is a shallow, frequency-domain conductivity meter. It operates at a single frequency of 14.6 kilohertz and has a fixed intercoil spacing of 1 meter. It can be operated in either the horizontal or vertical dipole orientation. In this particular case, the EM-38 was held in the vertical dipole orientation only. Figure 7 is a contour map of electrical conductivity (right) developed from the EM-38 vertical dipole data, and the EM-61 bottom coil map is provided for comparison (left) since a significant amount of the site is underlain by metal objects.

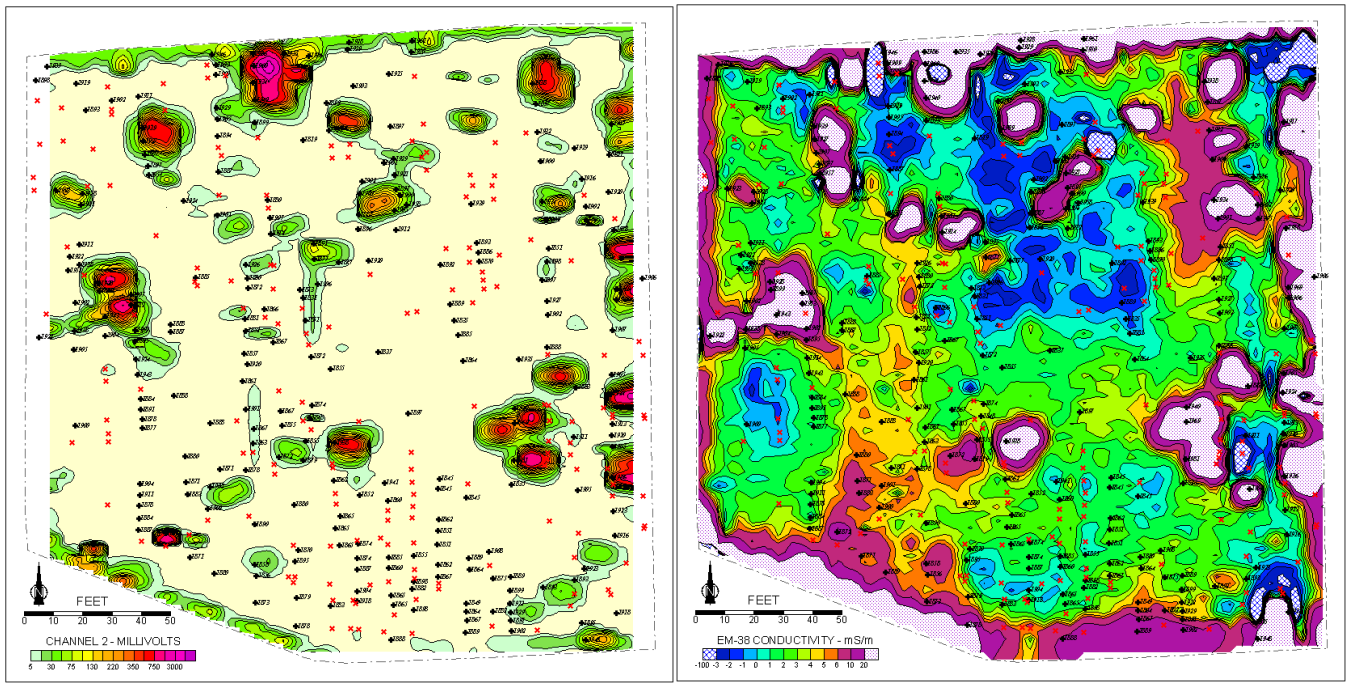

Figure 7. Map of apparent conductivity measured with a Geonics EM-38 (vertical dipole) shown on right. The EM-61 channel 2 map is shown on the left for comparison. The EM-38 clearly responds to most of the metallic objects found by the EM-61. In areas where metallic objects are not present, the conductivity of the soil spans about 7 mS/m. There is a distinctively low conductivity character in the north-central portion of the cemetery, which corresponds to a shady area dominated by a Silver Maple tree. There are also two high conductivity areas, one in the northeast and one in the southwest, which do not appear to correspond to metallic objects. These broad conductivity anomalies appear to be too large to mark individual graves. In general, aside from the high conductivity metallic anomalies, this map does not appear to effectively respond to individual graves (those not containing significant metal) in a consistent manner.

Ground Penetrating Radar

In addition to the electromagnetics mapping, a regular grid of ground penetrating radar (GPR) profiles was also gathered. The equipment used consisted of a Sensors & Software Noggin^{plus} SmartCart integrated GPR system. This system is a rugged, easily deployed integrated mobile system containing on-board long-life battery, wheel odometer, data logger with real time visual output (DVL), and sealed, shielded antennae, 250 megahertz in this instance.

The operating parameters were as follows. The nominal antenna frequency was 250 megahertz with a fixed antenna separation of 0.2794 meters. There were a total of 151 data points per trace resulting in a sampling interval of 0.4 nanoseconds. The nominal trace separation was 0.16 feet (4.9 centimeters). The number of data stacks was four.

Data were gathered in the north-south orientation at an approximate line separation of 5 feet (1.5 meters). Data were gathered from south to north with registration at the start and end points of each line. Some lines were broken or shifted east-west to avoid headstones, trees, etc. A total of 43 data lines were stored in the Noggin's DVL memory. The north-south line orientation was selected because the graves are oriented east-west.

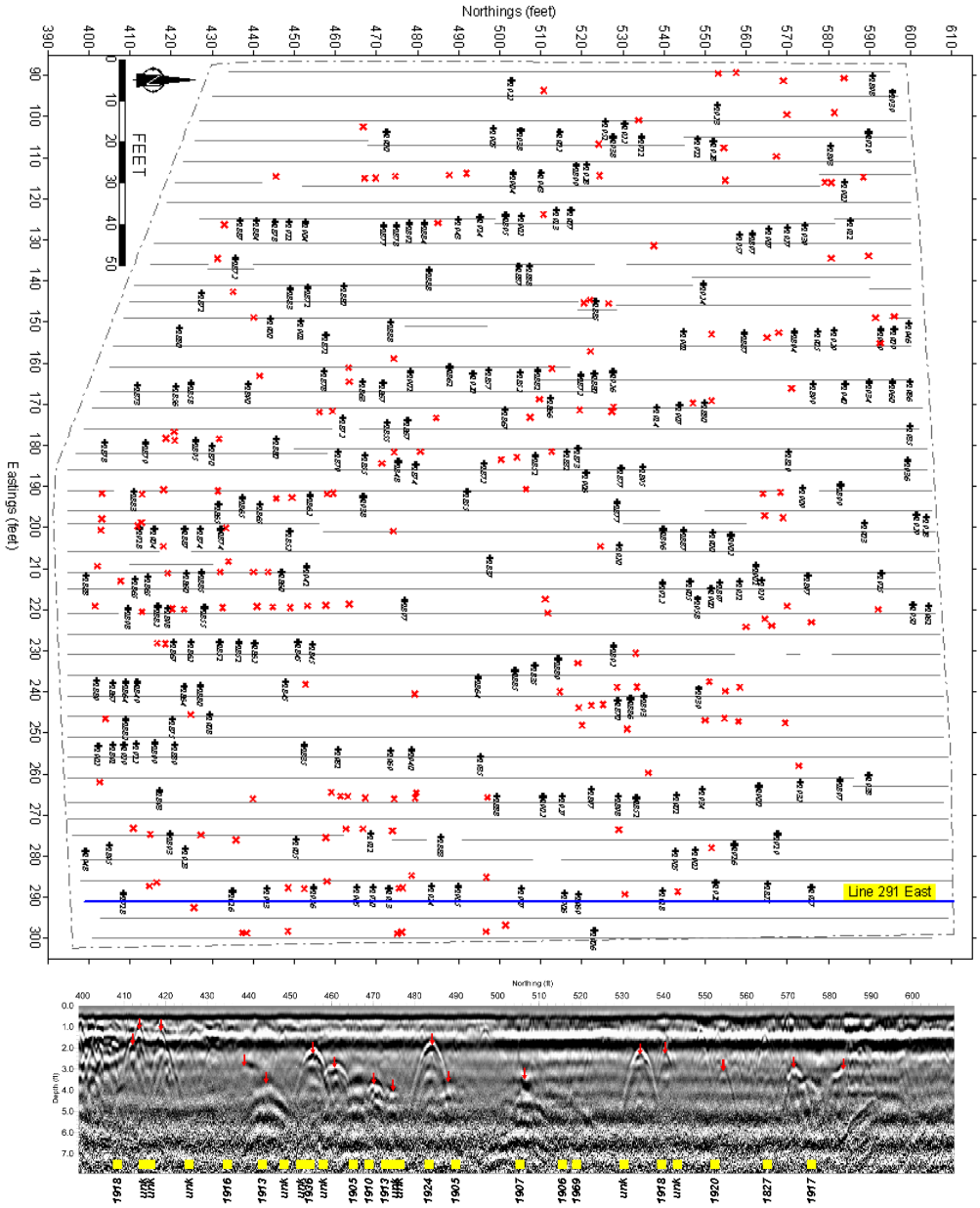

Figure 8. Map showing locations of 43 GPR lines collected with a Sensors & Software Noggin^{plus} 250. *Line 291 East* is highlighted and shown at the bottom of the figure. On *Line 291 East*, the yellow squares indicate positions of nearby headstones and the red + symbols indicate locations of possible or probably graves. Metallic vaults or caskets provide the clearest, high amplitude reflections.

Figure 8 shows the locations of the 43 GPR lines and highlights one specific line, *Line 291 East*, which is shown at the bottom of the figure. *Line 291 East* was "dewowed" and SEC gain was applied to

the data. The vertical exaggeration is 5:1. Based on analysis of diffractions, a velocity of 0.328 ft/ns (0.1 m/ns) was estimated and applied to the depth scale shown on *Line 291 East*.

Along *Line 291 East*, markers are shown where headstones are within 5 feet (1.5 meters) of *Line 291 East* (yellow squares). The date of death, if known, is also shown below the marker. Generally, it has been observed that the headstones are placed to the west of the grave (consistent with cultural norms). It is assumed that the graves associated with most of the headstones that lie a few feet west of *Line 291 East* are beneath *Line 291 East*. There are several obvious graves, probably vault or casket reflections, along *Line 291 East* which fall within a depth range of 1.5 to 3.5 feet – see anomalies at 455, 461, 470, 484, 506, 535, and 572. Red arrows have been placed on these anomalies that are likely to be graves along with additional anomalies that might be graves or objects such as headstones, tree roots, or naturally occurring boulders. Based on review of the 43 GPR lines, it was found that the graves with obvious high amplitude reflections, most of which were dated to within 100 years or less, generally fall between 1.5 and 5 feet depth.

Working with individual GPR lines does not provide the larger, site wide perspective that the other mapping techniques utilized in this project provided. To address this shortcoming, a GPR mapping program, Sensors & Software EKKO_Mapper Version 2, was used to create GPR amplitude depth slice maps at 1-foot (0.3 meter) intervals (e.g., 0 to 1, 1 to 2, etc.). Parameters included dewow, average envelope amplitude, and depth conversion using a velocity of 0.1 m/ns.

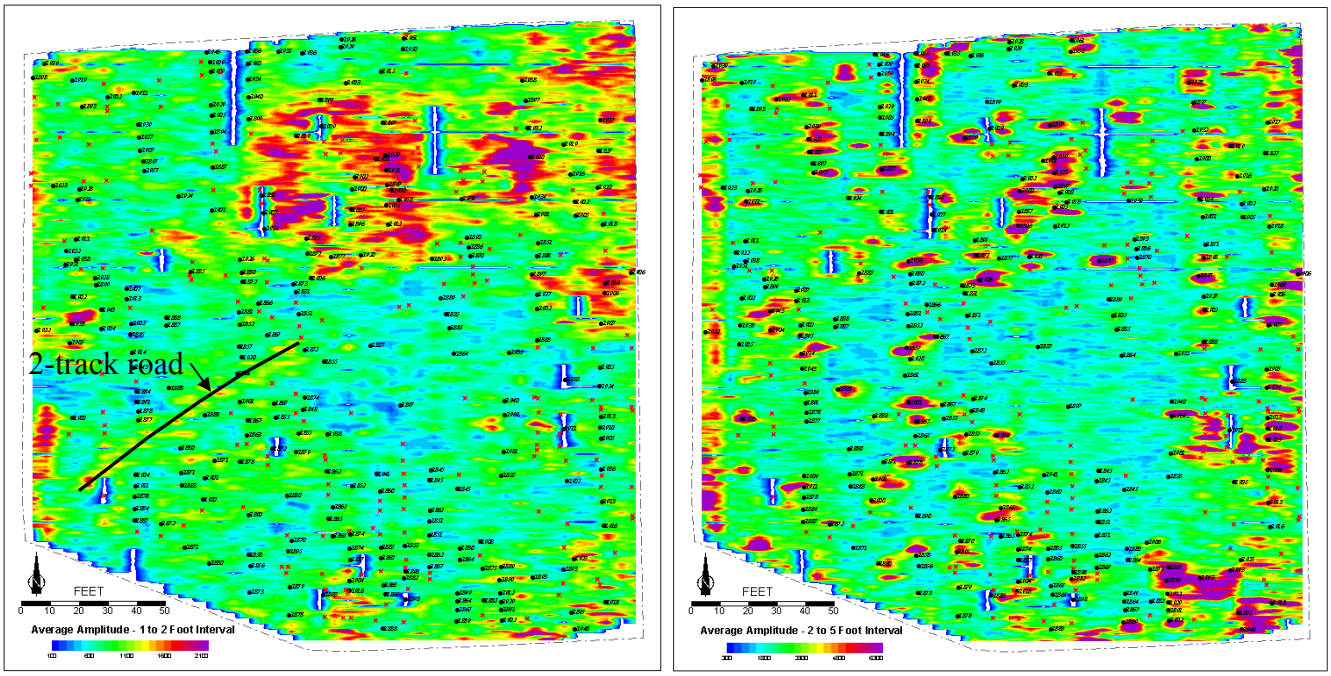

Figure 9. Average GPR amplitude maps for the 1 to 2 foot depth interval (left) and the 2 to 5 foot depth interval (right). On the 1 to 2 foot interval map the dominant high amplitude feature in the north and northeast portion of the map corresponds to the anomalous low and high conductivity anomalies observed with the EM-38. Black line indicates linear anomaly that corresponds to an old road no longer visible to the eye. Some of the small, high amplitude anomalies may correspond to lost headstones and tops of vaults or caskets. The 2 to 5 foot interval is a composite of three individual depth slices. The majority of the east-west, high amplitude anomalies appear to correlate well with graves. Graves tend to be found east of corresponding headstones. It is possible that some of the low amplitude (blue), east-west anomalies correspond to graves due to soil disturbances alone where soil strata are disrupted.

The map from the 1 to 2 foot interval is shown on the left side of Figure 9. To the right is a composite map of the intervals 2 to 3, 3 to 4, and 4 to 5 feet, inclusive. The deeper map was created as a composite because it was observed that the graves generally fell within the 2 to 5 foot interval, and since

the primary goal of this map was to concisely depict the grave locations, this map was selected as representative. The color scales, as shown, have been adjusted to provide similar relative amplitudes based on the mean amplitude for each map. These maps allow broad comparison between the various GPR lines at the differing levels.

On the 1 to 2 foot interval map (Figure 9, left side), the dominant high amplitude feature in the north and northeast portion of the map corresponds to the anomalous low- and high-conductivity anomalies observed with the EM-38. The black line indicates a linear anomaly, which is interpreted to correspond to an old road (two track) that is no longer visible. This is interesting in that it reveals the effects of soil densification on the GPR response. Some of the small, high amplitude anomalies may correspond to lost headstones and tops of vaults or caskets (see shallow anomalies also marked on *Line 291 East*, Figure 8).

The 2 to 5 foot interval (Figure 9, right side) is a composite of three individual depth slices, which are most representative of the zone where graves are found. The majority of the east-west elongated, high-amplitude anomalies appear to correlate well with graves. These anomalies are consistent with the orientation and dimensions of graves. Graves tend to be found east of their corresponding headstones. It is possible that some of the low amplitude (blue), east-west anomalies, particularly in the central portion of the cemetery where many of the oldest graves are present, correspond to graves revealing a lack of reflection where soil strata (soil horizons) are disrupted by the digging of graves.

Conclusions

It appears that the dominant feature revealed by each of the three geophysical methods corresponds to the presence of buried metallic objects, most likely to be vaults or caskets made of or containing metal. Although the EM-61 and EM-38 both respond strongly to the presence of metallic objects, they did not fair particularly well at resolving individual graves, but tended to merge the appearance of adjacent graves into larger anomalies. On the other hand, the GPR mapping appeared to provide a detailed image of individual graves (where metallic objects were present) based on the well-defined, high amplitude anomalies that corresponded well to the object dimensions. In addition, the GPR also produced a number of low amplitude anomalies, particularly in the older portions of the cemetery, which may correspond to locations where disrupted soil strata produced a *lack* of GPR reflections. Considering these results, the creation of multilevel GPR amplitude maps appears to hold the greatest promise in terms of mapping individual graves. Older graves are more likely to <u>not</u> contain intact metallic vaults or caskets, which do provide a strong response in both the electromagnetic and GPR data sets. As such, GPR is the only method that appears to have the potential for reliably locating graves in which the only remaining attribute is the presence of disrupted soil strata. Whereas electromagnetic metal detection does an excellent job of revealing metallic objects, conductivity mapping with a Geonics EM-38 provides equal insight into the presence of metallic objects *plus* it can provide potential insight into soil conductivity variations that may impact GPR data quality and may also reveal the presence of subtle graves in other soil types. Thus, conductivity mapping with a high resolution conductivity meter such as a Geonics EM-38 combined with gridded GPR mapping appears to be the best potential combination of methods for mapping unmarked graves.

References

1. Bauman, Paul, Rod Heitzmann, and Jack Porter (1995), "The Application of Geophysics to Archaeologic Mapping of Prehistoric, Protohistoric and Historic Sites in Western Canada",

Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Orlando, Florida, April 23-26, 1995, pp. 359-373.

2. Bevan, Bruce W. (1991), "The Search for Graves", *Geophysics, Vol. 56, No. 9, pp. 1310-1319.*
3. Nobes, David C. (1999), "Geophysical Surveys of Burial Sites: A Case Study of the Oaro Urupa", *Geophysics, Vol. 64, No. 2, pp. 357-367.*