United States Department of Agriculture

Natural Resources Conservation Service

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Subject: Geophysical Assistance -- Archaeological

Date: 14 April 2000

To: Margo L. Wallace
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Purpose:
To assist Connecticut NRCS Staff, the Connecticut State Archaeologist, and local historians assess the alleged burial of statues at the Long Hill Estate in Middletown, Connecticut. In addition, geophysical techniques were used to assess the locations of gravesites within an abandoned cemetery associated with the former Wethersfield Prison.

Participating Agencies:
Arthur Basto Archaeological Society (ABAS)
Connecticut State Museum of Natural History
Friends of the Office of State Archaeology (FOSA)
USDA-Natural Resources Conservation Service

Participants:
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ACTIVITIES:
All field activities were completed on 10 April 2000.

Background:
Town officials and managers are interested in recovering buried of statues at the Long Hill Estate (formerly Wadsworth Mansion) in Middletown, Connecticut. A nun and former resident at the estate had contended that the statues were buried in an area located to the left of the tennis court. If this account is true, the town of Middletown, Connecticut, has expressed interested in recovering these statues.

Wethersfield Town Official, local historians and archaeologist are interested in learning more about two former cemeteries that were associated with the former state prison in Wethersfield, Connecticut. The two cemetery sites adjoin one another. Historic records mention that one cemetery, partially enclosed by a stonewall, contained marked gravesites. The other cemetery, located outside the stonewall contained unmarked graves dating back to the 1800's.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-2000 consists of a digital control unit (DC-2000) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. This system is backpack portable and, with an antenna, typically requires two people to operate. Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. A 400 mHz antenna was used in this study. The scanning time was 50 nanoseconds (ns); the scanning rate was 32 scan/second. The radar data were stored on disc and printed in the field on a model T-104 printer.

A GEM300 sensor, manufactured by Geophysical Survey Systems, Inc., was used in this study.[1] Geophysical Survey Systems, Inc, (1998) has described the principles of operation for the GEM300 sensor. The GEM300 sensor is configured to simultaneously measure up to 16 frequencies between 330 and 20,000 Hz with a fixed intercoil spacing of 1.6 m. The sensor records both inphase and quadrature measurements. Output is the mutual coupling ratio in parts per million or apparent conductivity (mS/m).

Field Procedures:
Survey grids were established at each site. At Long Hill Estate, a 40 by 50 foot grid was set up across a suspected area that was located to the left of the tennis court. The grid intervals were 10 (east-west) and 5 (north-south) feet. Survey flags were inserted in the ground at each grid intersection and served as reference points. The antenna was pulled along each of the eleven, east-west trending grid lines. The GPR provides a continuous profile of the subsurface. As the radar antenna was pulled passed each flag, the operator impressed a vertical mark on the radar record. The vertical marks identified the reference points (flagged positions). The reference points provide a horizontal scale and identify relative locations along each traverse line.

Two grids were set up at the Wethersfield site. A 60 by 80 foot grid was established over the known location of a former cemetery. This cemetery had been partially enclosed with a stonewall. The western-most corner of the wall served as the grid's origin. Another grid was established over an area that purportedly contains unmarked graves dating back to the early 1800's. The dimensions of this grid were 40 by 70 feet. For both grids, the grid intervals were 10 (north-south) and 5 feet (east-west). Survey flags were inserted in the ground at each grid intersection and served as reference points. Pulling the antenna along each of the thirty, north-south trending grid lines completed the GPR survey.

At the Wethersfield site, an EMI survey was also completed. Measurements were taken with the GEM300 sensor held at hip-height in the vertical dipole orientation. Inphase, quadrature phase, and conductivity data were recorded with the GEM-300 sensor at three different frequencies (11730, 14630, and 18030 Hz).

Results:
Long Hill Estate, Middletown, Connecticut
The GPR worked well at this site providing suitable observation depths and resolution of subsurface features. Figure 1 is a representative radar profile from this site. Along the left-hand border of the radar profile is a depth scale. The depth scale is based on a tabled dielectric permittivity of 14 (for moist coarse-loamy soils). The depth scale is expressed in meters. The short vertical lines at the top of the radar profile represent flagged reference points spaced at 10 ft (3.05 m) intervals.

Two conspicuous subsurface reflectors are evident in Figure 1. Depths to these features ranged from about 18 to 26 inches. Ground-truth observations revealed that the buried linear feature (see B in Figure 1) consisted of layers of buried ash. The strong subsurface reflector evident in the left-hand portion of this profile represents a buried concrete wall (see A in Figure 1). No other subsurface features were identified within the surveyed area. At completion of this survey, one of the estate's administrators speculated that the account of the buried statues was perhaps a falsehood. Further GPR investigations were halted and the survey was moved to Wethersfield, Connecticut.

Cemetery Sites, Old Wethersfield Prison, Wethersfield, Connecticut
GPR Survey:
Once again, the GPR worked well and provided appropriate observation depths and resolution of subsurface features. Figure 2 is a representative radar profile from this site. Along the left-hand border of the radar profile is a depth scale. The depth scale is based on a tabled dielectric permittivity of 14 (for moist coarse-loamy soils. The depth scale is expressed in meters. The short vertical lines at the top of the radar profile represent flagged reference points spaced at 10 ft (3.05 m) intervals.

[1] Trade names have been used in this report to provide specific information. Their use does not constitute endorsement.

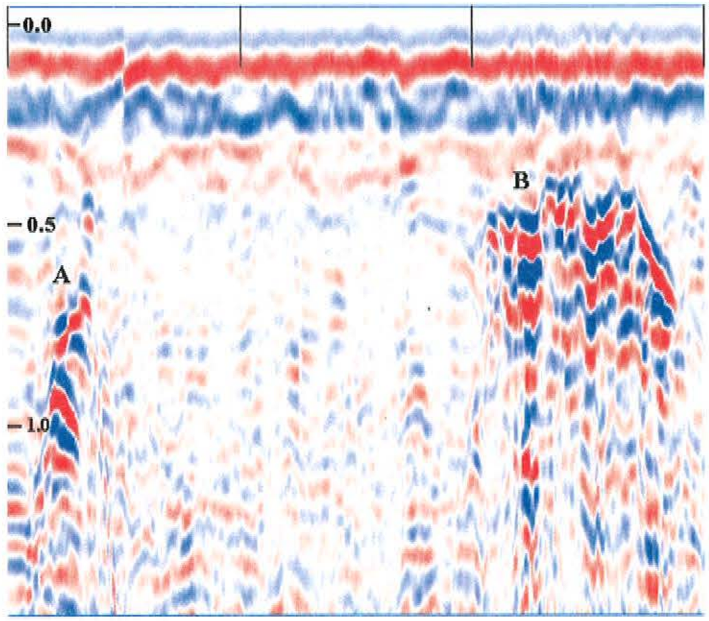


Figure 1. Representative radar profile from Long Hill Estate, Middletown, Connecticut

Several prominent point anomalies (A) are evident in the upper part of the radar profile shown in Figure 2. Most are clearly defined, but appear too shallow to represent possible burials. Two more deeply buried anomalies have been identified (see B and C in Figure 2). As no ground-truth excavations were carried out, the identity of these anomalous features remains unknown. Evidence of soil disturbance is absence above these point anomalies. Bevan (1991) noted that it is more likely that GPR will detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials that directly surrounds a burial rather than the bones themselves. Killam (1990) believes that most bones are too small and not directly detectable with GPR. This author observed that the disruption of soil horizons makes most graves and some cultural features detectable. However, in soils that lack contrasting horizons or geologic strata, the detection of a grave shaft is improbable. In addition, with the passage of time, natural soil-forming processes erase the signs of disturbances.

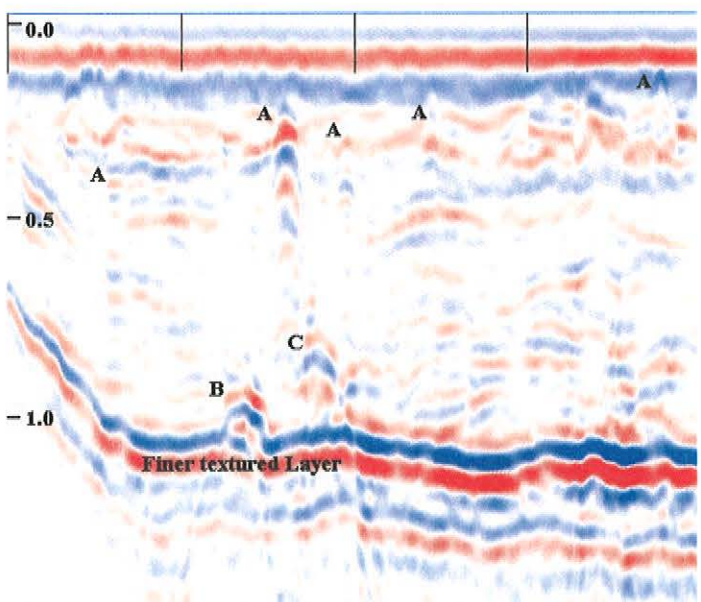


Figure 2. Cemetery Sites, Old Wethersfield Prison, Wethersfield, Connecticut

Locations and Depths of Point Anomalies
Detected with GPR
Wethersfield Cemetery

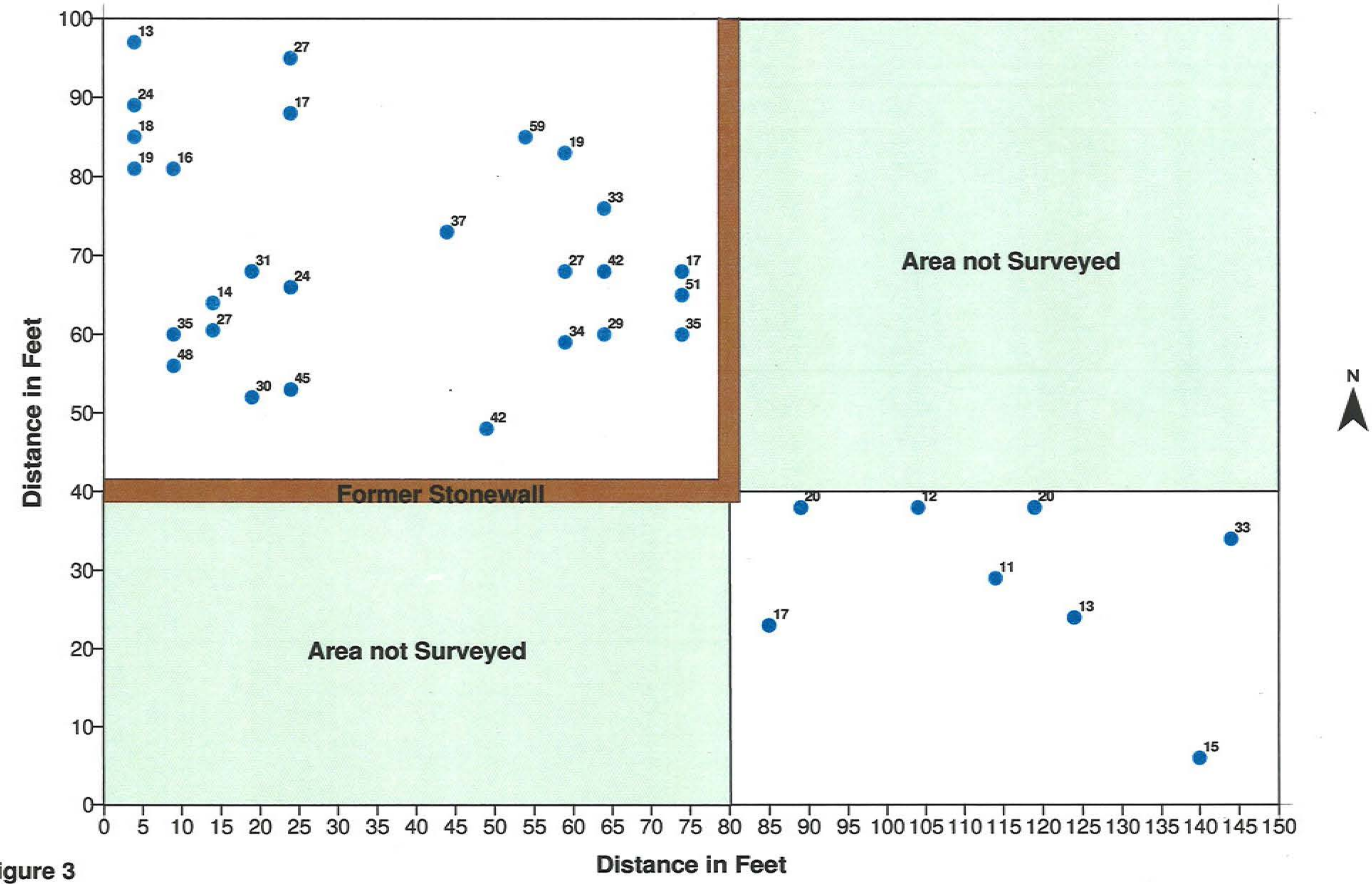


Figure 3

The strong continuous subsurface reflector apparent in the lower part of Figure 2 represents the contact between contrasting soil materials. Weaker planar reflections are apparent in the upper part of the radar profile. These reflections represent strata within the overlying materials.

A two-dimensional plot of the surveyed areas is shown in Figure 3. In Figure 3, the locations and depths of conspicuous subsurface point anomalies detected with GPR are shown. All depths are in inches. The survey area located in the northwest corner of this plot covers the former site of the known cemetery. The survey area located in the southeast corner of this plot covers a portion of the site that is believed to contain several unmarked graves. Depths to most point anomalies are considered too shallow to represent gravesites. These features may represent rock fragments, roots, animal borrows, or buried artifacts.

Electromagnetic Induction (EMI) Survey:

Electromagnetic induction is a noninvasive geophysical tool that can be used for detailed site investigations. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Results from an EMI survey are interpretable in the field. This geophysical method can, in a relatively short time, provide the large number of observations that are needed to comprehensively cover sites. Maps prepared from correctly interpreted EMI data provide the basis for assessing site conditions, planning further investigations, and locating exploratory test pits.

Electromagnetic induction measures vertical and lateral variations in magnetic and/or electrical fields associated with induced subsurface currents. Data is expressed as inphase, quadrature phase, or apparent conductivity. The inphase and quadrature phase responses represent the ratio of the secondary magnetic field at receiver coil to the primary magnetic field at receiver coil. Inphase refers to the part of the signal that is in phase (has zero phase shift) with the primary or reference signal. The inphase signal is sensitive to buried metallic objects and has been referred to as the "metal detection" mode. The magnitude of the inphase signal is proportional to the cube of a buried metallic object's surface area and is inversely proportional to its depth raised to the sixth power (Greenhouse et al., 1998). Quadrature phase refers to the part of the signal that is 90 degrees out of phase with the primary signal. The quadrature phase response is linearly related to the ground conductivity. Some highly conductive targets with small cross-sections, such as pipes, may show up better in the quadrature phase because of the channelization of current. With the GEM300 sensor, inphase and quadrature phase data are expressed in parts per million (ppm).

Traditionally, EMI data are expressed as apparent conductivity. The GEM300 sensor automatically converts quadrature phase data into apparent conductivity data. Values of apparent conductivity are expressed in milliSiemens per meter (mS/m). Apparent conductivity is a weighted, average measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity are caused by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the volumetric water content, type and concentration of ions in solution, temperature and phase of the soil water, and amount and type of clays in the soil matrix (McNeill, 1980). The apparent conductivity of soils increases with increases in soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

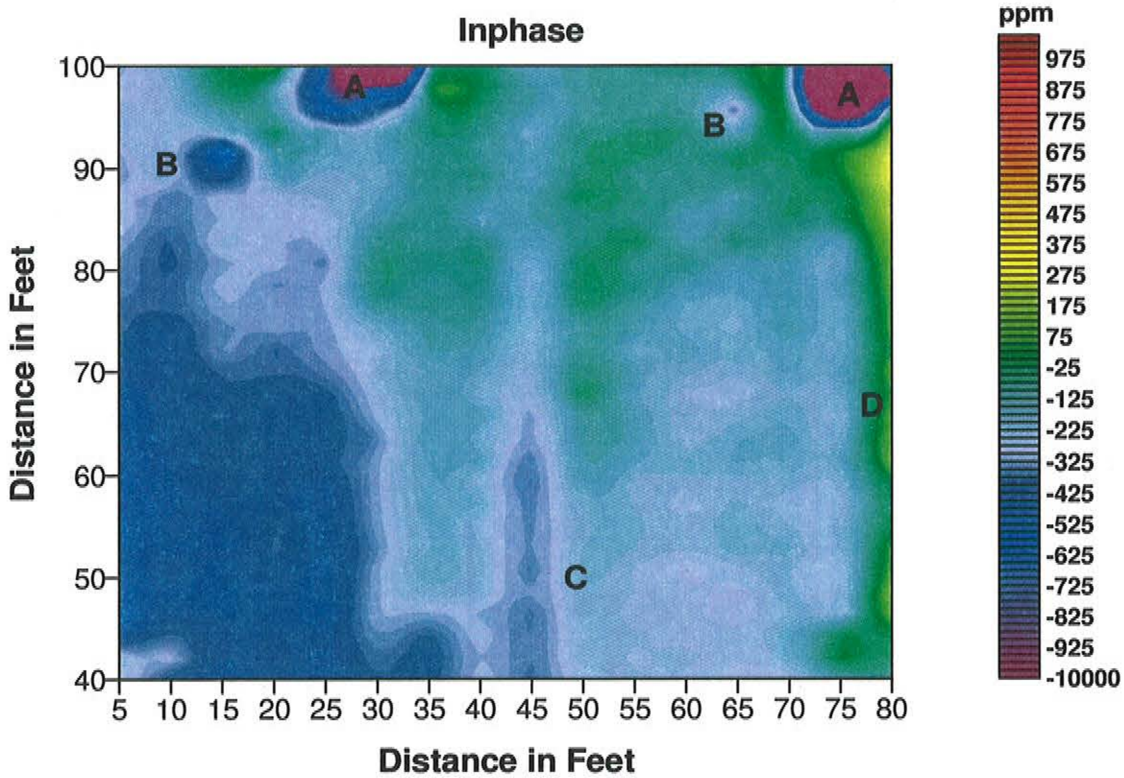
Values of apparent conductivity are seldom diagnostic in themselves, but lateral and vertical variations in these measurements can be used to infer changes in soils and soil properties and the locations of buried artifacts. Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, computer simulations are normally used.

Data collected with the GEM300 sensor at different frequencies were similar. Figures 4 and 5 contain plots of EMI data collected at the site of the former cemetery and the site suspected to contain several unmarked graves, respectively. Data shown in Figure 4 was collected at a frequency of 18030 Hz. Data shown in Figure 5 was collected at a frequency of 14610 Hz. In each figure, inphase and apparent conductivity data are shown in the upper and lower plots, respectively. These image maps use different colors to represent the data. Colors are associated with percentage values (in relation to the minimum and maximum values).

Several features are evident in the data collected over the site of the former cemetery (Figure 4). In the plot of the inphase response (upper plot), the two conspicuous point anomalies (see "A" in Figure 4) apparent in the upper part of the survey area represent large metallic objects. Several more weakly expressed features (B) and a linear feature suspected to represent a subsurface drainage tile (C) are evident in this plot of the inphase data. The linear feature (D) located along the right-hand margin of this plot represents the response from the former wall.

No additional information is provided in the plot of the apparent conductivity data from this site (see Figure 4, lower plot). Once again, two conspicuous point anomalies are apparent in the upper part of the survey area. No other conspicuous point

EMI SURVEY
GEM300 SENSOR
18030 HZ



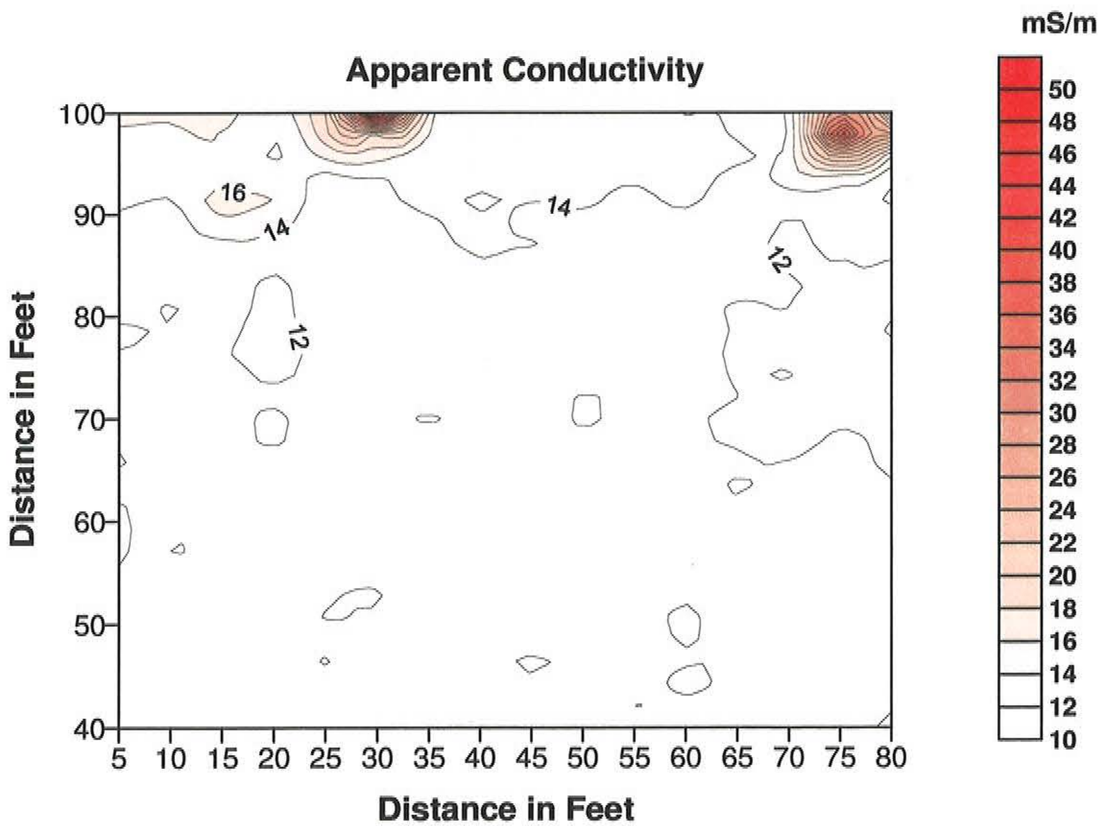
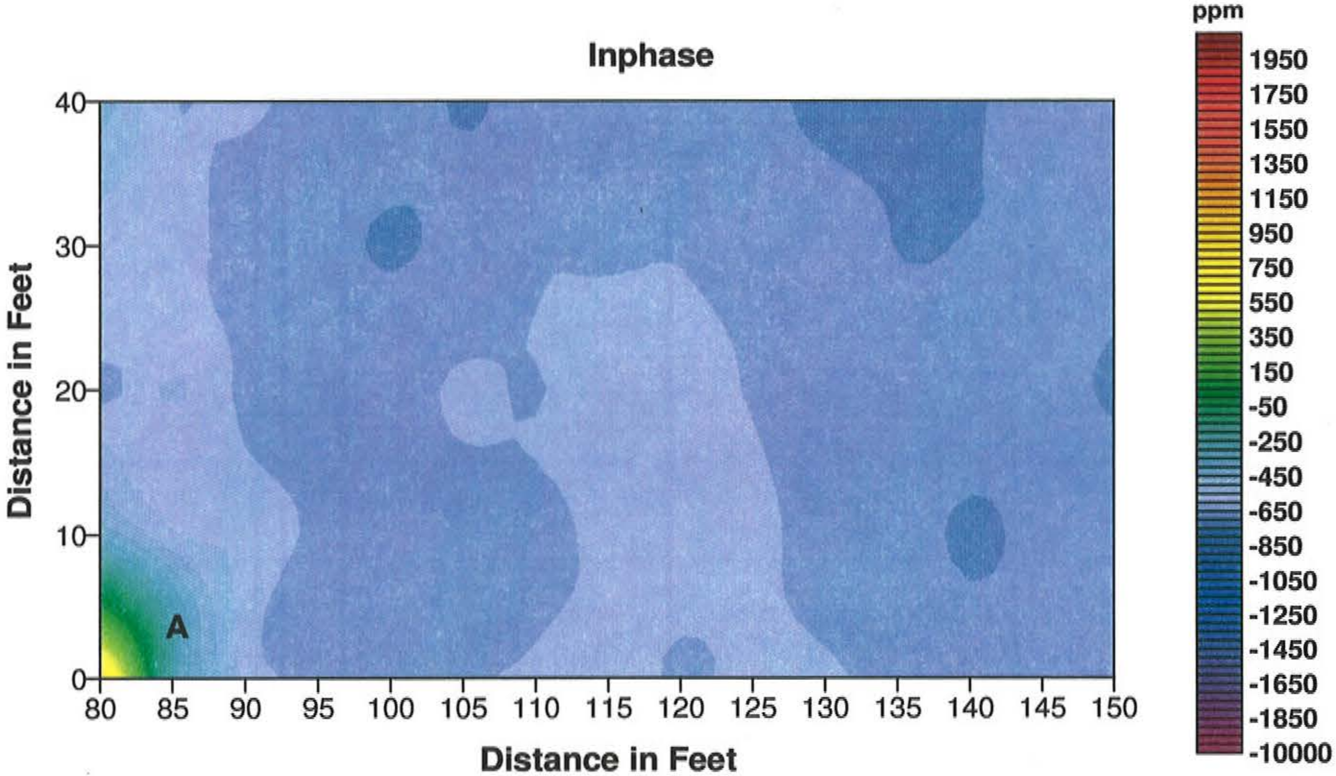


Figure 4

EMI SURVEY
GEM300 SENSOR
14610 HZ



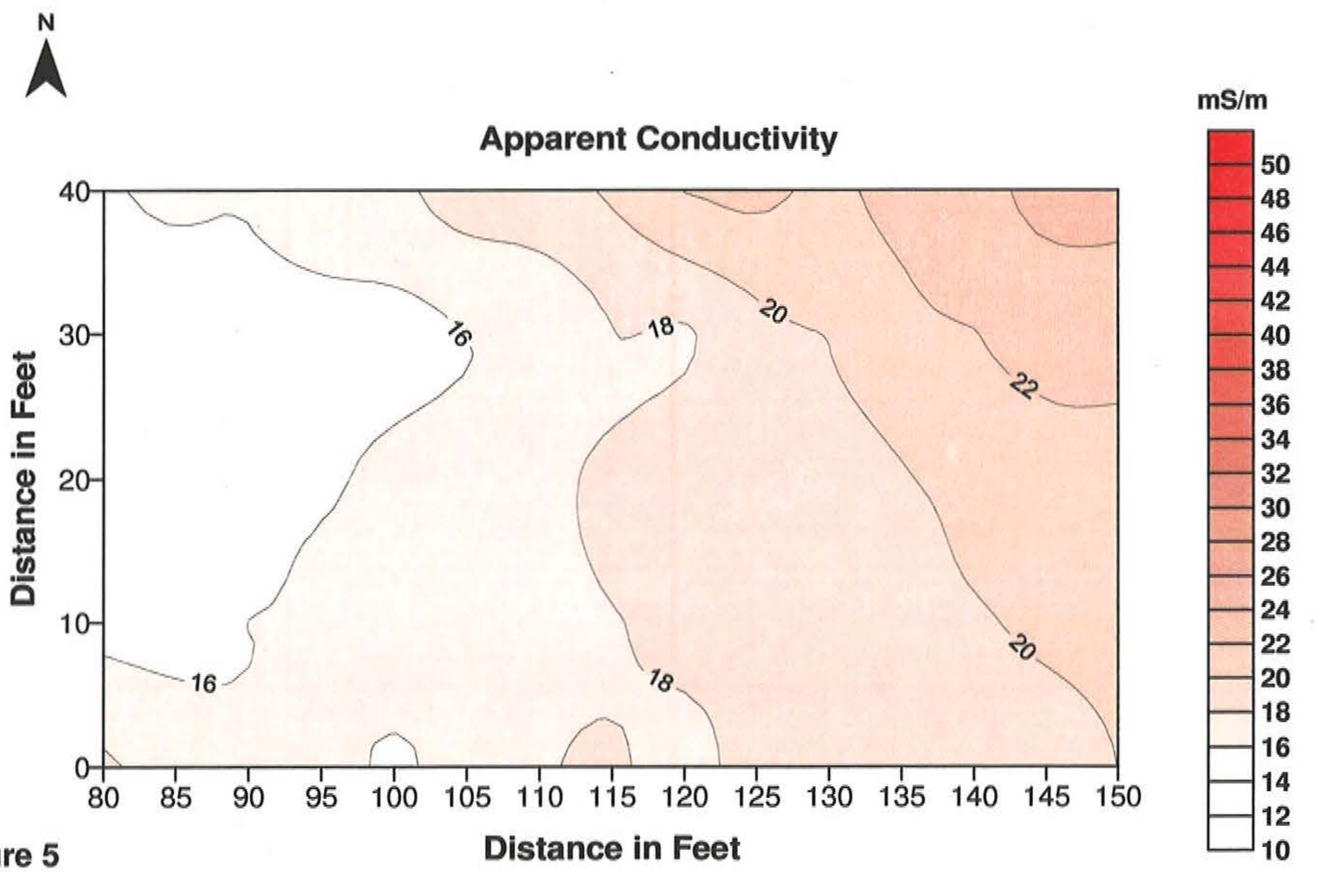


Figure 5

anomalies are apparent in the data. With the exception of these anomalies, apparent conductivity responses were invariable throughout the site and provided no indicative spatial patterns.

Figure 5 represents the data collected over the suspected burial site that contained the unmarked graves. The spatial patterns evident in both the inphase and conductivity plots are nondescript. In the plot of the inphase data, the response near "A" represents interference from a nearby vehicle. The patterns shown in the plot of apparent conductivity data reflect differences in soil properties. As the ground surface sloped towards the northeast, the higher apparent conductivity in the upper right-hand corner of the lower plot is believed to reflect soils with greater clay and moisture contents.

Conclusions:
Archaeologists have used geophysical techniques to facilitate excavation strategies, decrease field time and costs, and locate buried artifacts and archaeological features. However, even with favorable site conditions the detection of a buried cultural feature with geophysical techniques cannot be guaranteed. The detection of buried cultural features is affected by the electromagnetic gradient existing between a cultural feature and the soil, the size, shape, and orientation of the buried cultural feature, and the presence of scattering bodies within the soil (Vickers et al., 1976). In the search for buried cultural features with geophysical techniques, success is never guaranteed. Even under ideal site and soil conditions, buried cultural features will be missed. The usefulness of geophysical techniques for site assessment purposes depends on the amount of uncertainty or omission that is acceptable.

Interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. All interpretations made in this report should be verified by ground-truth observations.

It was my pleasure to be of assistance to you, your staff, and the State Archaeologist

With kind regards,

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