United States Department of Agriculture | **Natural Resources Conservation Service** | **11 Campus Boulevard Suite 200 Newtown Square, PA 19073**

Subject: -- Geophysical Assistance **Date:** 12 July 2005

To: Donald W. Gohmert
State Conservationist
USDA-NRCS
3737 Government Street
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Purpose:
Geophysical assistance was provided to volunteers and stewards of the Camp Moore Confederate Museum and Cemetery in Tangipahoa, Louisiana. The purpose of this investigation was to locate the graves of soldiers who died at Camp Moore during the Civil War.

Participants:
Wayne Cosley, President of the Board, Camp Moore Confederate Museum & Cemetery, Tangipahoa, LA
Jerry Daigle, State Soil Scientist, USDA-NRCS, Alexandria, LA
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA

Activities:
All activities were completed on June 27 and 28, 2005.

Results:
Geophysical investigations using electromagnetic induction (EMI) and ground-penetrating radar (GPR) failed to disclose the location of burials within the cemetery at Camp Moore. The absence of subsurface reflectors or anomalies suggest that the soldiers were buried in body bags or coffins that have weathered away and the interred materials lack sufficient contrast and size to be detected with these tools. Under subtropical conditions, soil processes have advance to the extent that no indications of grave shafts were evident on the radar records.

It was my pleasure to work in Louisiana and to offer assistance to the volunteers and stewards of the Camp Moore Confederate Museum and Cemetery in Tangipahoa. The field assistance and organizational help of Jerry Daigle were greatly appreciated.

With kind regards,

James A. Doolittle
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cc:
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Background:
During the Civil War, Camp Moore was the largest Confederate training camp in Louisiana. The camp was named for Louisiana Governor Thomas Overton Moore. A cemetery, believed to contain between 200 and 800 men who died of disease while stationed at Camp Moore, is located within this historic park. The exact location of the cemetery and number of burials is unknown. Descriptions and maps provide some information as to the approximate location of the cemetery. Based on this information, a monument was dedicated in 1905 within the supposed former grounds of the cemetery (see Figure 1, view is from the northwest). From photographs and descriptions, the bulk of the graves are believed to be located south of the monument. Graves were aligned in a southeast to northwest orientation. In the mid-1990s, 90 headstones were erected to the north of the monument to memorialize the site (see foreground in Figure 1). These headstones are engraved with the names of men known to have died at Camp Moore. The headstones are arranged in rows, but do not mark gravesites. The entrance and a portion of the low masonry wall that surrounds the cemetery are seen in Figure 1. The purpose of this investigation was to locate the graves of soldiers who had died at Camp Moore during the Civil War.

Figure 1. View of the entrance to the Camp Moore Cemetery showing headstones and monument. View is towards the southeast.

Study Sites:
Camp Moore is located about 78 miles north of New Orleans and about one half mile north of Tangiphoa,

Louisiana. The former military camp was bounded on the west by the Jackson and Great Northern Railroad (currently the Illinois Central Gulf Railroad), on the south by Beaver Creek, and on the east by the Tangipahoa River. Figure 2 is a topographic map that shows the cemetery and a large portion of Camp Moore. In Figure 2, the Illinois Central Gulf Railroad line and US Highway 51 can be seen running north-south across the center of the map. Beaver Creek is the unnamed stream that meanders in an easterly direction across the central portion of this map. The Tangipahoa River is just evident in the northeast (upper right-hand) corner of this map. The location of the cemetery has been labeled.

The study site is located in a grassed area of Fluker silt loam (map unit Fu). Figure 3 is a soil map that includes Camp Moore. The somewhat poorly drained Fluker soil formed in a mantle of silty sediments that overlies loamy sediments. Surface layers contain less than 18 percent clay while the subsoil contains 18 to 33 percent clay. A subsurface horizon having a higher bulk density than the solum above, seemingly cemented when dry, but showing moderate to weak brittleness when moist, develops at a depth of 18 to 40 inches. Reaction ranges from extremely acid to medium acid throughout the solum. Fluker series is a member of the fine-silty, siliceous, active, thermic Aquic Fraglossudalfs family.

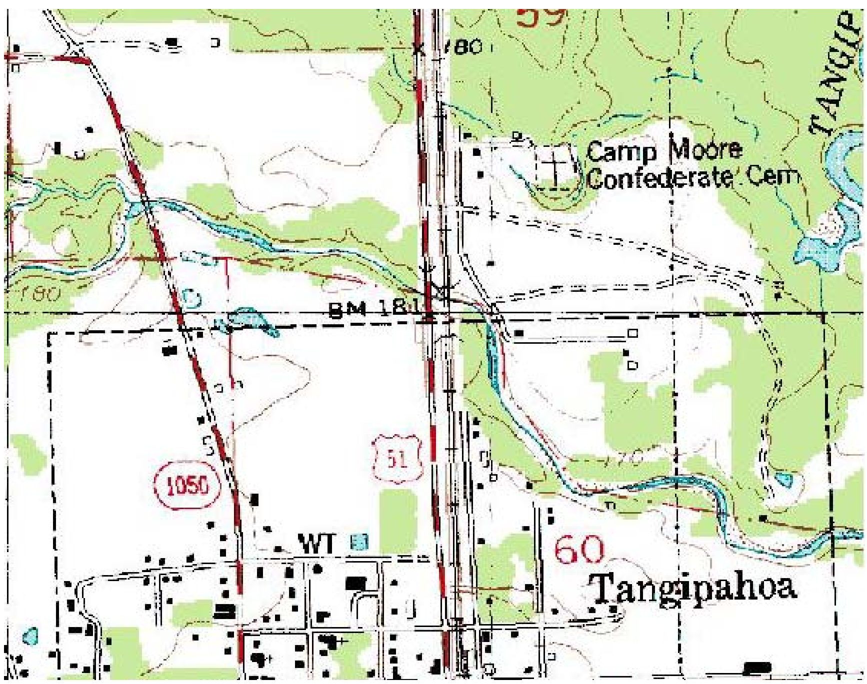

Figure 2. Topographic map showing the general area that surrounds Camp Moore.

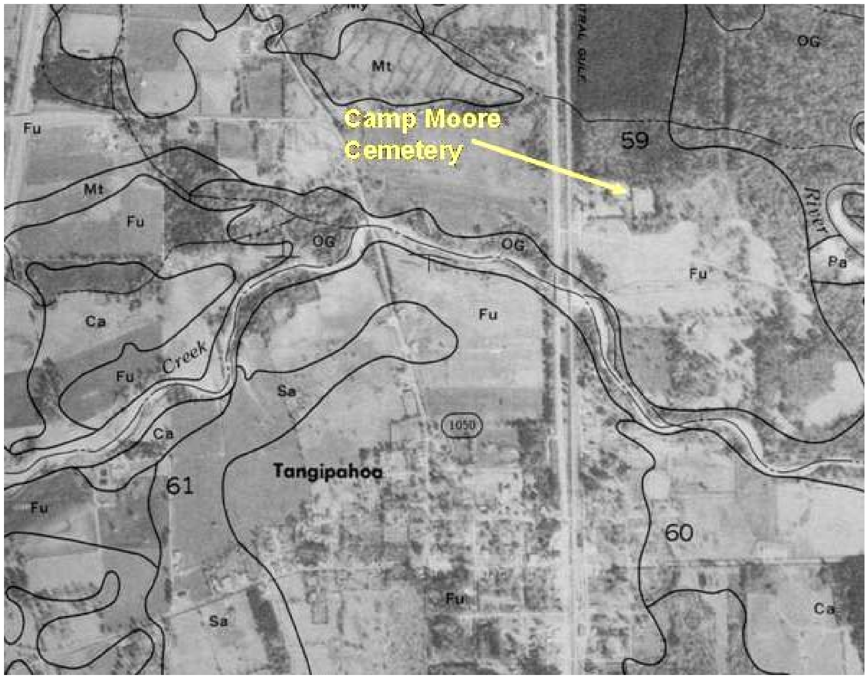

Figure 3. Soil map showing the general area that surrounds Camp Moore.

The cemetery has been enclosed with a low masonry wall. In some areas, layers of fill materials have been apparently added to level the surface immediately within this masonry wall. With the exception of the mound that was raised to support the monument, the grounds of the cemetery are level (see Figure 1). Although descriptions of the cemetery suggest mounded graves, no indications of mounds are evident within the demarcated grounds.

Equipment:

Electromagnetic induction (EMI) and ground-penetrating radar (GPR) are complimentary geophysical tools. Each tool has strengths and weaknesses. Electromagnetic induction was used as a rapid reconnaissance tool to cover most of the grounds enclosed by the masonry wall. It was anticipated that once the underlying factors for the spatial patterns appearing on plots of EMI data were identified, GPR surveys would be conducted over selected, smaller areas to provide high-resolution subsurface data.

The electromagnetic induction sensor used in this study is the EM38DD meter manufactured by Geonics Limited (Mississauga, Ontario).[1] The meter is portable and requires only one person to operate. Lateral resolution is equal to the intercoil spacing. The EM38DD meter has a 40-inch intercoil spacing. When placed on the soil surface, the EM38DD meter provides theoretical penetration depths of 30 and 60 inches in the horizontal and vertical dipole orientations, respectively.

The Geonics DAS70 Data Acquisition System was used to record and store both EMI and GPS data.[1] The acquisition system consists of an EM38DD meter, an Allegro field computer, and a Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack).[1] With the acquisition system, the EM38DD meter is keypad operated and measurements are automatically triggered.

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

To help summarize the results of the EMI survey, the SURFER for Windows (version 8.0) software, developed by Golden Software, Inc. (Golden, Colorado), was used to construct a two-dimensional simulation.[1] Grids were created using kriging methods with an octant search.

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc. (North Salem, New Hampshire).[1] The SIR System-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. The 200 and 400 MHz antennas were used in this investigation.

Radar records contained in this report were processed with the RADAN for Windows (version 5.0) software program (Geophysical Survey Systems, Inc).[1] Processing included setting the initial pulse to time zero, color transformation, marker editing, distance normalization, horizontal stacking, background removal, migration, and range gain adjustments. Radar records were processed into three-dimensional images using the 3D QuickDraw for RADAN Windows NT software (Geophysical Survey Systems, Inc).[1] Once processed, arbitrary cross sections and time slices were viewed and selected images attached to this report.

Survey Procedures:
Prior to field work, the cemetery grounds were walked and appraised. It was decided that a reconnaissance survey of the cemetery grounds with EMI would be completed first. The EM38DD meter was operated in the continuous mode with measurements recorded at 1-sec intervals. The EM38DD meter was held about 2 inches above the ground surface with its long axis parallel to the direction of traverse. Walking at a fairly brisk and uniform pace, in a random back and forth pattern across the cemetery grounds completed the EMI survey. Following the EMI survey, a plot of EMI data was reviewed. Because of the absence of "cultural anomalies" on this plot, it was decided to restrict the GPR survey to the portion of the cemetery that was believed to contain a majority of the gravesites.

To expedite GPR field work, two equal length (115-ft) and parallel lines were established across the selected portion of the cemetery. Along each of these two lines, survey flags were inserted in the ground at intervals of 20 inches. These two parallel lines defined a 115 ft^2 (35 m^2) grid area. For positional accuracy, GPR traverses were completed along a reference line, which was stretched and sequentially moved between similarly numbered flags on the two parallel grid lines. Figure 4 shows the GPR grid area and the reference line stretched between the two parallel lines. In Figure 4, some of the evenly spaced survey flags are evident along each of the two parallel lines.

Calibration trials were completed with both the 200 and 400 MHz antennas. Based on these trials, the 400 MHz antenna was found to provide the best balance of penetration depth and resolution of subsurface features. As a consequence, the 400 MHz antenna was selected for use in this survey.

Pulling the 400 MHz antenna along the reference line completed a GPR traverse. Along the reference line, marks were spaced at intervals of about 40 inches. As the antenna was towed passed each reference point, a vertical mark was impressed on the radar record. Walking, in a back and forth manner, along the reference line, which was moved sequentially between similarly numbered flags on the two parallel survey lines, completed the GPR survey. This procedure resulted in 71, 115-ft long GPR traverse line records.

Figure 4. General view of the GPR survey grid area showing the reference lines stretched between similarly numbered flags on the two parallel lines.

Calibration of GPR:
Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., boundary of soil materials with artifact) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (D), two-way pulse travel time (T), and velocity of propagation (V) are described in the following equation (after Daniels, 2004):

$$V = 2D/T \qquad [1]$$

The velocity of propagation is principally affected by the relative dielectric permittivity (E_r) of the profiled material(s) according to the equation:

$$E_r = (C/V)^2 \qquad [2]$$

Where C is the velocity of propagation in a vacuum (about 0.3 m/nanosecond). Velocity is expressed in meters per nanosecond (m/ns). A nanosecond is one billionth of a second. The amount and physical state (temperature dependent) of water have the greatest effect on the E_r of earthen materials.

Based on the measured depth to a buried (about 19-in or 48-cm) metallic reflector, the velocity of propagation through the upper part of the soil profile was an estimated 0.1248 m/ns. This velocity results in an E_r of 5.7. With a scanning time of 35 ns and a velocity of 0.1248 m/ns, equation [1] estimates that the maximum depth of penetration is about 7.2 ft (2.2 m) with the 400 MHz.

Results:
<u>EMI Survey</u>
Electromagnetic induction (EMI) has been used to locate and define archaeological features (Bevan, 1983; Frohlich and Lancaster, 1986; and Dalan, 1991). Studies have demonstrated the utility of EMI for locating, identifying, and

determine the boundaries of various types of large cultural features such as buried structures, tombs, filled fortification ditches, and earthen mounds. The detection of buried cultural features is affected by the electromagnetic gradient existing between the buried artifact and the soil. The greater and more abrupt the difference in electrical properties between the buried artifact and the surrounding soil matrix, the more likely the artifact will be detected with EMI. Buried cultural features with electrical properties similar to the surrounding soil matrix are often difficult to discern.

Electromagnetic induction measures the apparent conductivity, EC_a, of the soil. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). Variations in EC_a are produced by changes in the electrical conductivity of earthen materials. Interpretations of EMI data are based on the identification of spatial patterns within data sets.

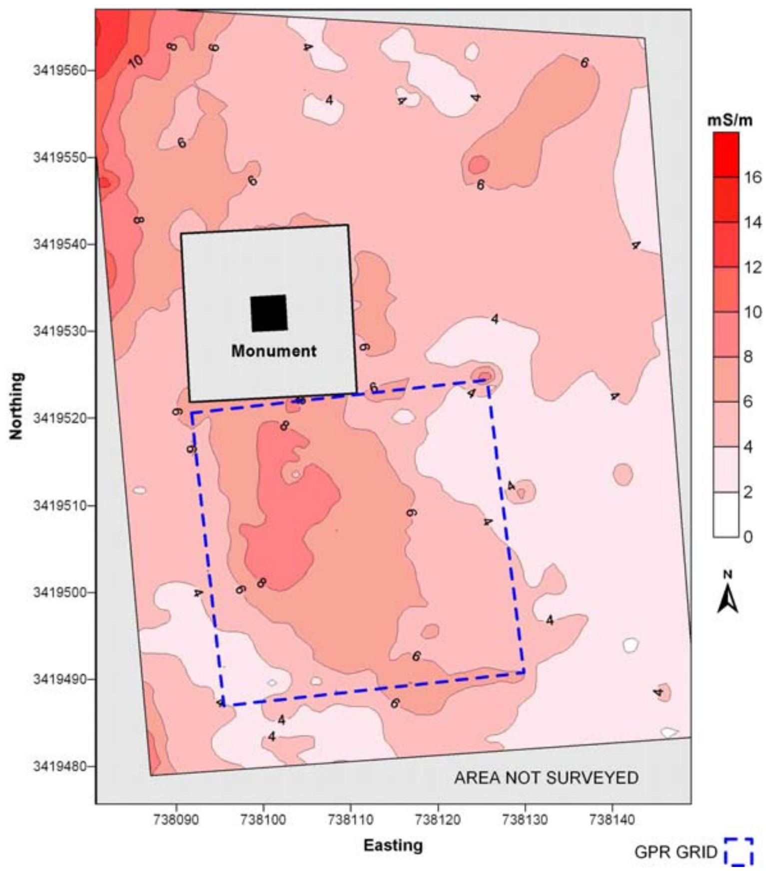

Figure 5. Plot of ECa data collected with the EM38-DD meter in the vertical dipole orientation.

Soils were exceeding dry and inherently electrically resistive. A total of 1513 EC_a measurements were made across the grounds of the cemetery with the EM38DD meter in both dipole orientations. In the shallower-sensing (0 to 30 inches) horizontal dipole orientation, EC_a ranged from -15.1 to 17.8 mS/m. Apparent conductivity averaged 2.5 mS/m with a standard deviation of 3.4 mS/m. The EC_a of one-half the measurements were between 0.0 and 4.6 mS/m. Measurements made in the horizontal dipole orientation were exceedingly low and often negative. These measurements were suspected of system errors and observed to be more susceptible to interference from cultural sources. As a consequence, measurements made in the horizontal dipole orientation were considered inaccurate.

In the deeper-sensing (0 to 60 inches) vertical dipole orientation, EC_a ranged from 0.4 to 14.2 mS/m. Apparent conductivity averaged 5.2 mS/m with a standard deviation of 1.8 mS/m. The EC_a of one-half the measurements were between 4.0 and 6.2 mS/m.

Figure 5 is a choropleth map that shows the spatial distribution of EC_a measured with the EM38DD meter in the vertical dipole orientation (0 to 60 inch depth). This plot was constructed from 1513 EC_a measurements. In Figure 5, color variations have been used to help show the distribution of EC_a. The color interval is 2 mS/m. The locations of the monument, monument mound, and GPR survey grid area have been shown in this plot. In Figure 5, spatial patterns of EC_a are broad and inferred to principally reflect variations in soils and soil properties. A few small, contrasting anomalies, which suggest possible cultural features, are evident in the plot. Near the northeast corner of the GPR grid area, a rebar post was approached too closely with the EM38DD meter, resulting in a small anomalous pattern. Midway along the eastern border of the GPR grid area, a small point anomaly can be seen immediately adjacent to the GPR survey area. Other than these anomalies, the EMI survey provided no information concerning the locations of possible artifacts or gravesites.

<u>GPR Grid Survey:</u>
A favorable feature of GPR is its ability to detect soil disturbances and the intrusion of foreign materials. GPR has therefore been a useful tool for locating burials (Vaughan, 1986; Bevan, 1991; King et al., 1993; Gracia et al., 2000; and Davenport, 2001). Ground-penetrating radar has been used to locate unmarked graves (Bevan, 1991; Mellett, 1992; Unterberger, 1992; Miller, 1996; Nobes, 1999 and 2000; Davis et al., 2000; and Dittmer, 2004). However, results vary with soil conditions. In some soils, rates of signal attenuation are so severe that GPR cannot profile to the required depths. Even under favorable site conditions (i.e. dry, coarse-textured soils) the detection of a burial is never guaranteed with GPR. The detection of burials is affected by the electromagnetic gradient existing between the feature and the soil; the size, depth, and shape of the buried feature; and the presence of scattering bodies within the soil (Vickers et al., 1976).

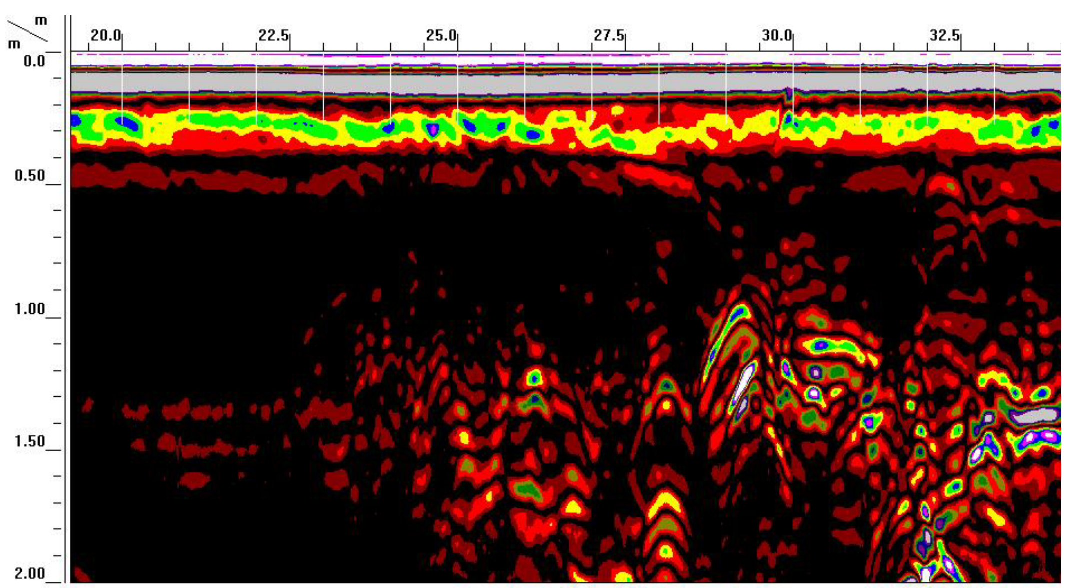

Figure 6. This representative radar record is from the GPR survey area at Camp Moore.

The 400 MHz antenna provided a satisfactory penetration depth and resolution of subsurface features. Figure 6 is a 15-m portion of the radar record from traverse line Y = 0 meters. In Figure 6, all units are in meters. The left-hand portion (19 to 24 m) of the radar record provides little subsurface information. In this portion of the radar record there are no meaningful subsurface signal returns, either because the radar energy was more completely attenuated or the soil materials are more homogenous and contain no highly contrasting reflective interfaces. The parallel intermittent bands at depths of 1.3 to 1.6 m (4.3 to 5.2 ft) represent low frequency noise. Unfortunately, this portion of the radar record typified most of the grid area. In Figure 6, numerous point and planar reflectors are evident in the right-hand portion (25 to 34 m) of the radar record. Although some of these features suggest possible soil disturbances and burials, their aggregate reflection patterns suggest a stratigraphic layer of contrasting coarser-textured materials. Point reflectors in the upper part of the radar record (see Figure 6) are believed to represent ant mounds, tree roots, or artifacts.

On radar records such as the one shown in Figure 6, the depth, shape, size, and location of subsurface features may be used as clues to infer burials. In the past, reflections could only be identified and correlated on two-dimensional radar records such as seen in Figure 6. The recent development of sophisticated signal-processing software has enabled signal enhancement and improved pattern-recognition on radar records. Today, three-dimensional (3D) imaging techniques are commonly used to reduce interpretation uncertainties and aid identification of potential targets on radar records. Three-dimensional interpretations of GPR data have been used to identify burials, middens, and other cultural features (Conyers and Goodman, 1997; Whiting et. al, 2000; Goodman et al., 2004).

In recent years, an advanced type of GPR data manipulation, known as *amplitude slice-map analysis*, has been used in archaeological investigations (Conyers and Goodman, 1997). For this analysis, a 3D image of a survey site is constructed from the computer analysis and synthesis of a series of closely-spaced, two-dimensional radar records. Amplitude differences within the 3-D image are analyzed in "*time-slices*" that examine changes within specific depth intervals in the ground (Conyers and Goodman, 1997). In this process, the reflected radar energy is averaged horizontally between adjacent, parallel radar records and in specified time (or depth) windows to create a time-slice (or depth-slice) image. Each amplitude time-slice shows the spatial distribution of reflected wave amplitudes, which are indicative of changes in soil properties or the presence of buried features.

A three-dimensional image of the grid area within the cemetery was developed using *amplitude slice-map analysis* techniques. Figures 7 thru 10 are 3D time-sliced diagrams of the GPR grid area. In each figure, units are expressed in meters. The origin of each plot is located in the northwest corner of the grid area (see Figure 5) and is identified by an orange circle. In each plot, north is to the left. Horizontal “time-slices” were made across the 3D cube of the grid area at the depths specified in each figure caption. These depths are based on an assumed signal propagation velocity of 0.1248 m/ns through the soil. The width of each time-slice is about 12 inches. A gray-scale color table has been used in these images.

Figure 7 is an amplitude time-sliced map for the soil surface. Across most of the grid area, reflections are of low amplitudes. Higher amplitude reflections are apparent in the northeast (upper left-hand) portion of the grid. These patterns are broad and gradational suggesting natural changes in soil properties. Along the northern boundary (left-hand boundary) of the grid, between lines 10 and 21 m (Y-axis), the embankment of the monument’s mound was crossed producing slightly higher amplitude signals. While broad and irregular spatial patterns of low signal amplitudes are evident all over this time-sliced image, no cultural significance or meaning can be attached to these patterns.

Figure 8 is an amplitude time-sliced map from a depth of about 24 inches. This image is characterized by the absence of contrasting materials and consequently, the inferred presence of homogenous soil conditions.

Figure 9 is an amplitude time-sliced map from a depth of about 48 inches. Prominent spatial patterns of high amplitude reflections are evident in the northeast (upper left-hand) and southwest (lower right-hand) corners of the grid area. Within these areas, reflectors are haphazardly arranged into crescent or linear stripes consisting of point reflectors of variable sizes and shapes. While the approximate sizes of some of these reflectors (1 to 2 m) do suggest potential burials, these reflectors probably represent dissimilar sediments. This interpretation is supported by the portion of the radar record shown in Figure 6, which is from GPR traverse line Y = 0 meters.

Figure 10 is an amplitude time-sliced map from a depth of about 72 inches. Prominent spatial patterns of high amplitude reflections continue to dominate the northeast (upper left-hand) portion of the grid area. Reflections of lower amplitudes are also apparent in the southwest (lower right-hand) and southeast (upper right-hand) corners of the grid area. These patterns are too broad, irregular, and poorly defined to suggest burials.

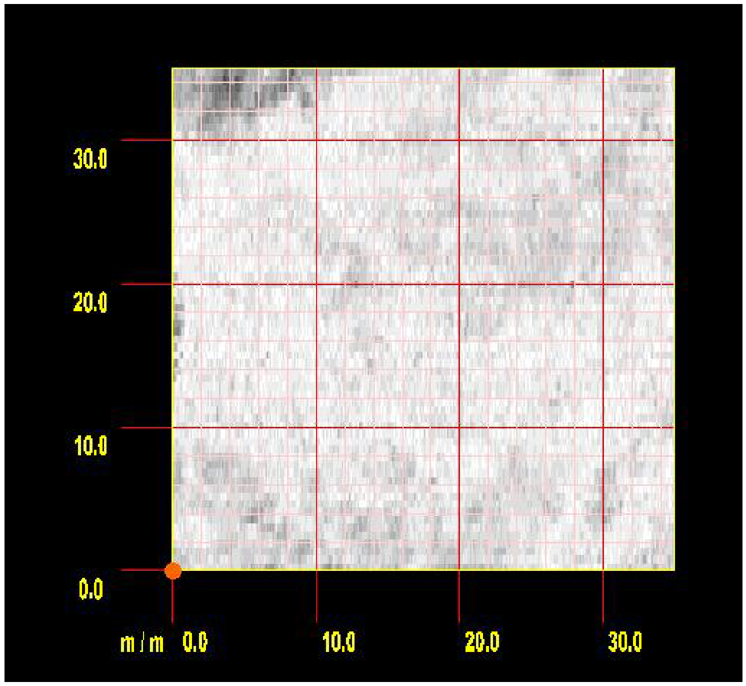

Figure 7. Time sliced image of the GPR survey area. Depth is 0 inches.

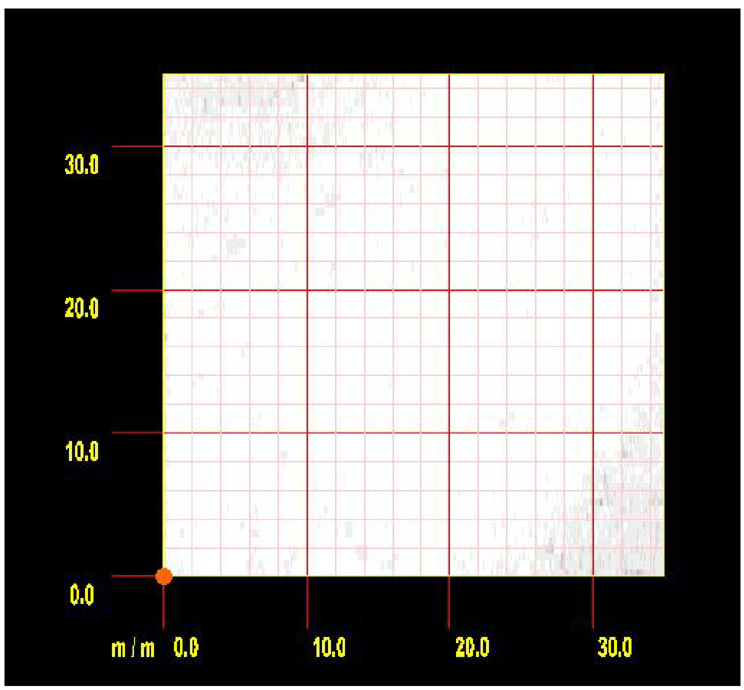

Figure 8. Time sliced image of the GPR survey area. Depth is 24 inches.

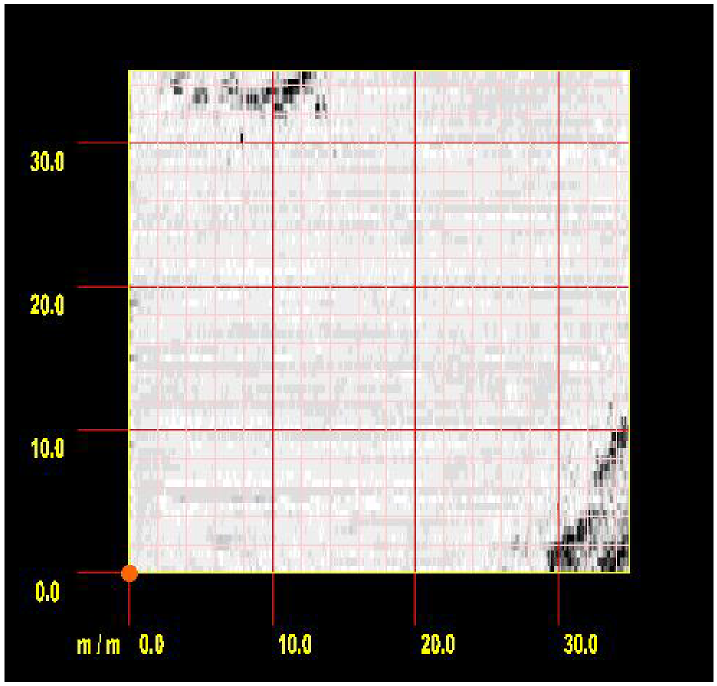

Figure 9. Time sliced image of the GPR survey area. Depth is 48 inches.

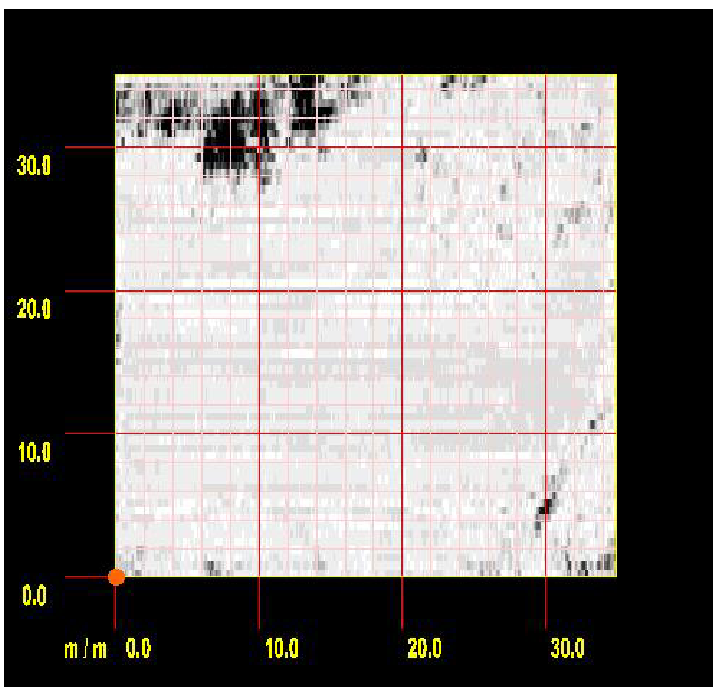

Figure 10. Time sliced image of the GPR survey area. Depth is 72 inches.

Why didn't GPR work at Camp Moore?

The amount of energy reflected back to an antenna from a burial is a function of the contrast in dielectric properties that exists between a buried feature and the soil. The greater and more abrupt the difference in electromagnetic properties between the buried feature and the soil, the greater the amount of energy that is reflected back to the antenna, and the more intense will be the amplitude of the reflection recorded on the radar record. The contrast between many buried objects and the soil materials is small resulting in lower chances of detection.

Large, electrically contrasting features reflect more energy and are easier to detect than small, less contrasting features. Small, deeply buried features are more difficult to discern on radar records. Bones are generally too small to be distinguished with GPR (Killam, 1990; Bevan, 1991). Remains may be buried in sacks, body bags, or in wooden, fiberglass, composite, or metal caskets. Metallic or lead coffins and burial vaults provided large and contrasting interfaces that produce strong, recognizable radar reflections. If a coffin is intact, an air-filled void exists, which can be detected with GPR. Bevan (1991) used GPR to detected intact coffins, but was not successful in detecting collapsed or soil-filled coffin, or bones alone. It is probable that the soldiers buried at Camp Moore were interred in body bags or wooden coffins that are no longer intact and detectable with GPR.

At many sites, the most distinctive feature of a grave is the disturbed soil materials that fill and cover the grave shaft (Bevan, 1991). Bevan (1991) noted that it is more likely for GPR to detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials, which directly surrounds a burial rather than the bones themselves. Refilled excavations contain disturbed soil materials that can have electrical properties that contrast with the surrounding, undisturbed soils (Bevan, 1991; Miller, 1996). Often, GPR operators rely on the presence of soil disturbance to identify burials. Because of the passage of time and the intense weathering associated with subtropical conditions, signs of disturbances at Camp Moore appear to have been erased by natural soil-forming processes.

In the search for burials with GPR, success is never guaranteed. Even under ideal site and soil conditions, burials will be missed with GPR. The usefulness of GPR for site assessment purposes depends on the amount of uncertainty or omission that is acceptable.

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