Final Report on the Geophysical Survey at the Kitchen Branch site (41CP220)

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Introduction

Based on consultation with the excavation team archeologists, surveys using multiple geophysical methods were conducted in order to identify potential Caddo archeological features at the Kitchen Branch site (41CP220). A detailed geophysical survey were conducted using a GeoScan Research RM15 resistivity meter, a Bartington Grad 601-2 dual sensor fluxgate gradiometer, and a GSSI SIR-2000 Ground Penetrating Radar (GPR) with a 400 MHz dipole antenna. Using density maps of prehistoric artifacts, the distribution of Zone 2 sediments, and feature locations based on the results from previous test excavations at the site (Perttula et al 2005), archeologists from Archaeological & Environmental Consultants, LLC and Hicks & Company assigned the locations of excavation blocks for their data recovery investigations. The geophysical survey (425 square meters, see Figure 1) included the proposed block excavation area, but extended over a larger area to examine areas outside the block that would be eventually be machine-scraped to look for cultural features. Thus, the geophysical investigations were performed to supplement the information gained during the site’s testing (as well as the data recovery work to come) not to guide the excavations.

Figure 1. Geophysical Collection areas at the Kitchen Branch Site. Each of the three geophysical instruments covered slightly different areas due to the presence of open excavation units and trees.
Summary of Technical Information

Archeo-geophysics employs a range of techniques for the non-destructive prospecting of archeological deposits. These techniques have been developed for a range of applications, mostly geological in nature, but have been adapted for specific use in archeology through rigorous field collection techniques and unique data processing programs specifically developed for archeo-geophysics.

In general, all geophysical techniques map, record, or sense different variables or properties of the soil and the objects contained within the soil. The geophysical instruments are differentially affected by variables such as moisture, metal trash or debris, and transmission of signals such as cell phones and transmission lines. Data collection is also impacted differently for each of the geophysical instruments by physical impediments such as trees, pavement, fences, and vegetation.

Archeologists have found the first line of defense against this complex matrix of variables is to come to the field prepared to collect data with several different instruments. The “multiple-technique” not only increases the likelihood of success in the ability to detect archeological features of interest, but can often enhance the visibility of the archeological targets that may be present and preserved at archeological sites (Kvamme et al. 2006:251; Kvamme 2006a:57-58). Archeogeophysical data has a long history of success in helping to focus archeological excavations to specific locations within sites and under the right conditions can be used as a primary source of archeological data (Kvamme 2003).

Magnetometer

Magnetometer and gradiometer surveys are non-invasive and passive and measure slight variations in the magnetic properties of soil. Magnetometers have become the primary tool for archaeo-geophysicists working on Caddo sites, as well as on other sites in Texas, in part due to the fact that data can be collected and processed rapidly and efficiently, and when conditions are right due to the properties of specific soils, magnetometers have proven useful in locating negative relief features such as pits and post holes as well as thermally-altered features such as fire hearths and burned structures (Bruseth and Pierson 2004; Creel et al. 2005; Frederick and Abbott 1992; Schambach 2001, 2002; Schambach and Lockhart 2003; Walker and Perttula 2007a; Walker and Schultz 2006; Walker et al. 2003).

Magnetometers record the minute fluctuations that sediments and objects have on the earth’s magnetic field. This is known as induced magnetism because the object does not maintain its own magnetic field. If the effects of this induced magnetism are strong enough compared to the surrounding soil matrix, pit features or post holes can be identified or resolved in the geophysical data. A second type of magnetism called remnant magnetism is created when an object maintains its own magnetic field. In prehistoric archeology examples, this occurs when objects are thermally altered, thus creating a magnetic state called thermoremanent magnetism (Kvamme 2006b:207). The specific magnetometer used in the current study is detailed by Bartington and Chaman (2004).

Electrical Resistance

This technique has proven to be one of the most successfully and widely employed methods used by archeo-geophysicists (Bevan 1998:7, Somers 2006:109-110). Resistance surveys measure the resistance to the flow of electric currents through the ground (Gaffney and Gater 2003:26). Resistance surveys can record differences in soil compaction, moisture content, and locations of highly resistant features such as stone (as in stone walls or foundations). Depending on local site and soil conditions, in North American prehistoric archeological sites most features recorded with resistance will be negative resistance features, meaning that they
fall below the background resistivity of the site (Somers 2006:112). This is due to the fact that most prehistoric features in North American archeological sites will take the form of some sort of negative relief feature composed mainly of, at varying degrees, soil disturbance.

Resistivity surveys are controlled by constant variables including electric current, voltage, and the geometry of the resistivity probe array. The most common probe configuration is known as the Twin Probe Array, and it was developed specifically for archeological purposes (Gaffney and Gater 2003:27-34; Somers 2006:112-115). This array uses a set of mobile probes, one injecting the current and one recording the reading (which is an average of the resistance in the area between the two probes), usually spaced with a 0.5 m separation. Probe spacing can be changed to resolve geophysical data to different depths. The 0.5 m separation has proven to be the most useful in electrical resistance for shallow archeological deposits (Gaffney and Gater 2003:60), as at the Kitchen Branch site. A set of probes are placed off the collection grid at a distance 30 times the mobile probe separation from any point on the grid (thus 15 m off the grid when using a 0.5 m separation).

**Ground Penetrating Radar (GPR)**

GPR is an active, non-invasive technique that uses a shielded surface antenna to transmit pulses of radar energy, generally high-frequency electromagnetic (EM) waves, that reflect off buried objects, features, or geological bedding contacts and are detected using a receiving antenna (Conyers 2004:23-28). The waves detected by the receiving antenna are recorded in nano seconds (ns) that reflect the two-way travel time of the radar energy. Fairly accurate approximations of depth of recorded anomalies can be determined through velocity analysis (Conyers and Lucius 1996).

While GPR is one of the more widely used techniques in archeological geophysics, its success, like that of the other archeological geophysics techniques, is largely based on such site conditions as soil type, sediment mineralogy, and moisture content (Conyers 2004; Kvamme 2003). For example, ideal soil types for GPR include dry homogenous soils with minimal clay. On the other extreme, radar energy will become attenuated more quickly in more conductive mediums such as clay and poorly drained soils or in mediums with high magnetic permeability (Conyers 2004).

**Field Methods**

Three geophysical collection areas were laid out using tapes, consisting of one 15 x 15 m grid, a 10 x 15 m grid, and one 5 x 10 m collection grid (see Figure 2); the somewhat irregular shape of the complete grid was necessary to cover the available open area within the proposed right-of-way at the Kitchen Branch site. One side of each grid was staked out and the two opposite corners were triangulated in to achieve square corners. After corner stakes were in place, stakes were placed every 1 m on the north and south sides of each grid. North-south ropes marked every 1 m were placed on 1 m intervals. These ropes were placed to guide the archæogeophysicist during the geophysical survey. Hicks and Company, Inc. later recorded coordinates of the outside corners of the collection areas with a total data station.

Geophysical data are collected in a series of grids, when possible measuring 20 x 20 m in size. The specific settings used for the instruments differ greatly; however, there are a few general concepts of data collection that apply to all three technologies used in this geophysical survey at the Kitchen Branch site. The density of the dataset is controlled by two factors: (1) traverse interval—the distance between the passes the instrument makes as it zigs zags back and forth across the collection area; and (2) sample interval—the distance between readings the instrument records as it passes along each traverse. There are standard starting points for
these settings, but ultimately this depends on many factors, including the size and depth of the targets of interest (i.e., archeological features), the nature of the sediment matrix, land use of the collection area, duration of the survey, as well as the investigative scope of the overall project research design.

Magnetic data was collected using a 0.5 m traverse interval and a 0.125 m (8 readings per meter) sample interval. Resistance data was collected using a twin probe array with a 0.5 m probe separation. A 0.5 m traverse interval and 0.5 m sample interval was used. Radar data was collected at a 0.5 m traverse interval and 32 samples per m were recorded. All instruments were passed over the grids in a bi-directional pattern.

**Data Processing**

The data collection techniques discussed above have dramatically different workflows for post-collection data processing. All data were processed and filtered to remove extraneous false readings (spikes and drop-outs). Processing levels the datasets so adjacent grids can be combined into a single image with no “grid lines.” Datasets were processed to enhance the visibility of any target features through statistical manipulation of the recorded data as well as through image processing of the image file output.

The general goal of data processing is to lessen the effects of background “noise” and to enhance the quality of the “signal” or “target” in the geophysical data. In field geophysics in general, and archeogeophysics in particular, the term noise is used to discuss any return that is not a direct result of the object under investigation, this being referred to as the “target” or “signal.” Hence, in some cases what is discussed as noise can in another case become the signal or target (Milsom 2005:13-14). Accuracy of the geophysical readings are not as important for resolving targets in the geophysical data as is the contrast between the target and its surrounding matrix.

The major data processing techniques are discussed in this section (for more detail on data processing consult the ArchaeoSurveyor or GPR Slice user manuals), with details on the specific data processing workflow applied to each collection grid. The general approach to data processing follows Kvamme (2006c:236), namely computer process the geophysical data to identify regular and culturally interpretable patterns using pattern recognition principles: “In general, anomalies exhibiting regular geometric shapes (lines, circles, squares, rectangles) tend to be of human origin” (Kvamme 2006c:236). After each processing step the results are closely compared to their previous processed state to assure that data manipulation is not in fact decreasing the clarity and quality of the data, and thus avoiding the creation of processed images that are primarily products of the data processing.

GPR data was processed using GPR Slice 5.0 written by Dean Goodman. Amplitude slice-maps are a three-dimensional tool for viewing differences in reflected amplitudes across a given surface at various depths. Amplitude slice-maps are generated through a comparison of reflected amplitudes between raw vertical profiles. Amplitude variations are analyzed at each location in a grid where there is a recorded reflection. The individual profiles are combined into a data cube and the amplitudes of all traces are compared to the amplitudes of all nearby traces. This database or data cube can then be “sliced” horizontally and displayed to show the variation in reflection amplitudes at a sequence of depths in the ground.

Fairly accurate approximations of the depths of recorded anomalies can be determined through velocity analysis (Conyers and Lucius 1996). When travel times of energy pulses are measured, and their velocity through the ground is known, distance (or depth in the ground) can be accurately measured (Conyers and Lucius 1996). The geometry of hyperbolic reflections can be used to calculate the relative dielectric permittivity of the ground and in turn this can be used to calculate the velocity of the signal then employed to
calculate the various depths of objects or individual amplitude slice maps. A velocity of 0.083 m/ns was recorded for the GPR data from the Kitchen Branch site.

Magnetometer and resistivity data from the Kitchen Branch site were both processed using ArchaeoSurveyor 2.0 by DW Consulting. A 21 x 21 Gaussian high pass filter was run on the resistivity data (Table 1). High pass filters are used to remove high frequency components in a geophysical survey. A high pass filter calculates the mean of a window of a specified size, then subtracts this mean from the center value. One of the most common applications of the high pass filter is to remove the geological background from resistivity data (Somers 2006:118-119). This filter was used with caution and close attention was made to their resulting effects, thus assuring that no processing artifacts were created and no significant anomalies removed as a result of their application (Kvamme 2006c).

Table 1. Data processing steps for resistivity data at the Kitchen Branch site (41CP220).

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<th>Step</th>
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<td>1 Base Layer</td>
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<tr>
<td>2 High pass Gaussian filter: Window: 21 x 21</td>
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Magnetometer data was first de-striped (Table 2). Destriping is a process used to equalize the underlying differences between grids caused by instrument drift, inconsistencies during setup, delays between surveying adjacent grids, or heading error from magnetic instruments. The Mean, Mode, or Median of each grid or traverse is subtracted from the grid or traverse, effectively zeroing the mean, mode, or median. When the mean is used, thresholds are set to exclude extreme data points. For the Kitchen Branch site, the median value was used to zero each traverse.

Table 2. Data processing steps for magnetometer data at the Kitchen Branch site.

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<th>Step</th>
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<tbody>
<tr>
<td>1 Base Layer</td>
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<tr>
<td>2 DeStripe Median Traverse: Grids: All</td>
</tr>
<tr>
<td>3 Clip to =/- 10 nT</td>
</tr>
<tr>
<td>4 Low pass Gaussian filter: Window: 3 x 3</td>
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Next the data was clipped to =/- 10 nT (nanoTeslas). Clipping replaces all values outside a specified minimum and maximum range. These minimum and maximum values are specified in either absolute values or ± Standard Deviations (SD). This process is used to remove extreme data point values and aids in normalizing the histogram of the data. Archeological details are subtle, and having a normal distribution of geophysical data allows the fine detail to show through with clarity.

Finally a 3 x 3 Gaussian low pass filter was used to remove low frequency components in the data set. A low pass filter calculates the mean of a window of a specified size, and replaces the center value with the mean. Either filters can use Uniform or Gaussian weighting. With Uniform weighting means, all values within the window are given equal weight. Gaussian weighting gives a higher weight to values closer to the center of the window. Low pass filters are commonly applied to lessen the effects of background noise. As with high pass filters, a low filter should be used with caution (cf. Kvamme 2006c:242).
Survey Results

Ground cover at the Kitchen Branch site was optimal for geophysical data collection. Before collection began, archaeologists from the excavation team cleared the site area of vegetation and swept the site with metal detectors. They also re-excavated the 2005 test units from previous excavations to remove any metal pin flags or other metal objects left in the units when they were originally backfilled. Unfortunately, it was raining during much of the geophysical data collection, but time constraints necessitated that the geophysical data collection proceed. This rain had a marked effect on both the GPR and resistivity data that were collected from the site.

Results of both the GPR (Figures 2 - 6) and resistance (Figure 7) data were limited due to the fact that the soil was over-saturated with water. In fact, the resistivity data was collected while it was raining. The soils at the Kitchen Branch site appear to be well drained; however, there was still too much water present to get reliable contrasts in either dataset. GPR amplitude slice maps are shown in 10 cm intervals (Figures 2-6). The red areas are high amplitude reflections which are more than likely due to the waterlogged soils, especially the upper 40 cm.

Any interpretations of either of these data sets should be made with extreme caution, but it appears that what these techniques essentially identified were only relative differences in the draining of sediments across the collection grids. Future geophysical projects would benefit from having more flexibility of scheduling during the fieldwork. Active geophysical instruments such as GPR, Resistance and Electromagnetic Induction are all effected by the relative amounts of moisture in the soil. It is difficult to assess the effects of soil saturation on the archaeological interpretations of the data from these instruments. However, work on Caddo (and other Native American sites) would benefit from waiting until conditions are optimal due to the ephemeral nature of the archaeological deposits.

The magnetometer data from the Kitchen Branch site was originally discussed in a preliminary report submitted directly following the fieldwork (Walker 2007). The preliminary report discussed an area of magnetic enhancement and two possible Caddo structures (Walker 2007 figures 9 and 10). This report incorrectly suggested that the area of magnetic enhancement was associated with the Caddo occupation at the site. The strong dipolar signatures in the magnetometer data are the results of metal debris (Figures 8 and 9). The preliminary report also discussed two possible Caddo Structures. Given the high number of metal historic artifacts recovered from the site it is highly possible that these magnetic patterns are the result of metal debris and not prehistoric Caddo archaeological features. The magnetic data from the Kitchen Branch site is extremely noisy due to the high concentrations of metal artifacts. This makes any prehistoric interpretation of the data questionable.
Figure 2. GPR Amplitude Slice Map showing 0 - 10 cm below surface.
Figure 3. GPR Amplitude Slice Map showing 10 - 20 cm below surface.
Figure 4. GPR Amplitude Slice Map showing 20 - 30 cm below surface.
Figure 5. GPR Amplitude Slice Map showing 30 - 40 cm below surface.
Figure 6.  GPR Amplitude Slice Map showing 40 - 50 cm below surface.
Figure 7. Resistance Data from the Kitchen Branch site.
Figure 8. Magnetometer Data from the Kitchen Branch site.
Figure 9. Magnetometer Data from the Kitchen Branch site with distributions of metal artifacts.
Acknowledgments

Mark Walters, Tim Perttula, and James Harrison helped with the data collection. Both the Archeological & Environmental Consultants, LLC and Hicks and Company, Inc. crews cleared the site before geophysical collection and scanned the collection areas with metal detectors prior to data collection. Tim Perttula edited earlier versions of this report.

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