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by
Steven L. De Vore
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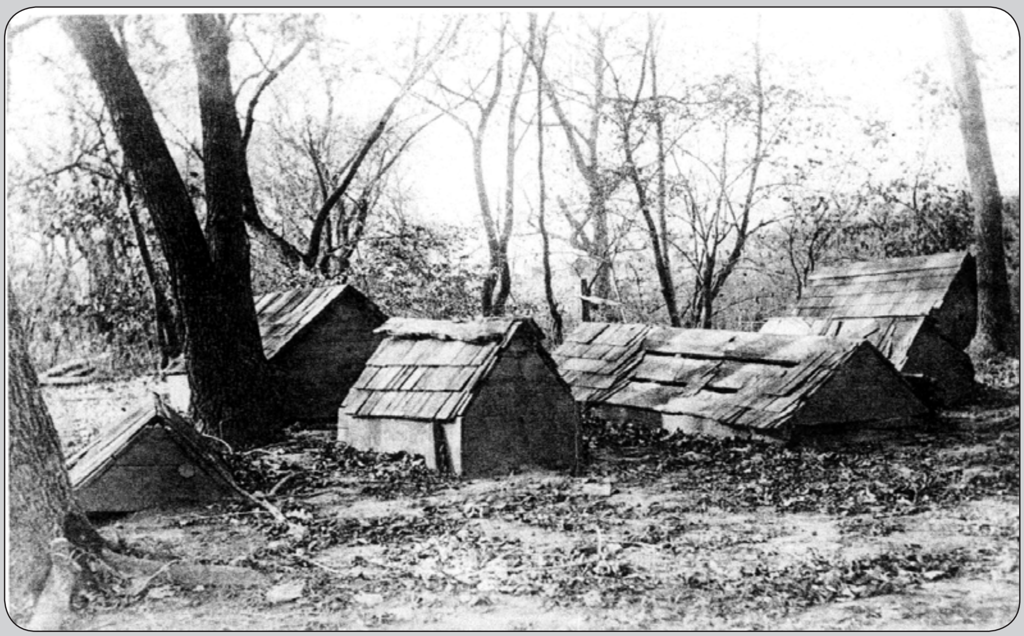
Midwest Archeological Center
Technical Report No. 98



NATIONAL PARK SERVICE
Midwest Archeological Center

Cover: Sac and Fox Indian Cemetery, East of Margrove Ranch, taken in 1907, reprinted in 1968, located in Richardson County, Nebraska (Courtesy of Sac and Fox Nation of Missouri Museum, Reserve, Kansas).

This report has been reviewed against the criteria contained in 43CFR Part 7, Subpart A, Section 7.18 (a) (1) and, upon recommendation of the Midwest Regional Office and the Midwest Archeological Center, has been classified as

Available

Making the report available meets the criteria of 43CFR Part 7, Subpart A, Section 7.18 (a) (1).

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United States Department of the Interior
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Midwest Archeological Center
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SAC AND FOX MULTIPLE FAMILY CEMETERY

ABSTRACT

The geophysical investigations of a tribal/multiple family cemetery (25RH122) in Richardson County, Nebraska, were initiated by the National Park Service in response to a request from the Sac and Fox Nation of Missouri tribal council. A meeting and site tour were held with the tribal council secretary, Midwest Archeological Center Archeological Assistance and Partnership Program archeologists, and private consultant on November 18, 2002. This visit was to assess the feasibility of the application of geophysical techniques to the identification and evaluation of the tribal/multiple family cemetery. During the month of November 2003, MWAC archeologist and Site Sensors private consultant conducted geophysical investigations at the cemetery (25RH122). Geophysical investigations, including magnetic gradient, conductivity, and ground-penetrating radar surveys, were conducted at the cemetery location identified by the Sac and Fox Nation tribal council secretary. A two day workshop was also held in conjunction with the cemetery investigations.

During the investigations, 1,520 square meters were surveyed with a Geoscan Research FM36 fluxgate gradiometer, the Geonics EM38 ground conductivity meter, and a Sensors and Software Noggins^{Plus} smart cart ground-penetrating radar system and 250 mHz antenna. The survey resulted in the identification of subsurface magnetic gradient anomalies, conductivity anomalies and ground penetrating radar anomalies. A series of anomalies identified in the three complementary data sets in the west central part of the geophysical grid suggested the location of graves associated with the cemetery. Other anomalies represented fence lines and more recent agricultural related metal objects.

This report provides an analysis of the geophysical data collected during four days at the site. Since 25RH122 represents a known historic cemetery, it is not recommended that any additional archeological investigations in the form of excavations be conducted at these sites at the present time. Should there be any development on or near these sites, then a research design needs to be developed for the implementation of archeological excavations to determine the nature and extent of this cemetery.

ACKNOWLEDGEMENTS

The authors would like to thank the members of the Sac and Fox Nation of Missouri for their support and hard work completing the geophysical investigation phase of the project. Edmore Green (tribal council secretary) and Deanne Bahr (NAGPRA coordinator) provided unlimited enthusiasm for the project and knowledge about the cemetery in southeastern Nebraska. We would also like to extend our gratitude to the participants in the two day geophysical workshop for their support and enthusiasm.

At MWAC, a number of people deserve credit for helping us complete this project. These include Dr. Mark Lynott, Dr. Ralph Hartley, and Thomas Thiessen. Production of this manuscript is attributed to Allan Weber and Carrol Moxham for production oversight and to John Andresen for his diligent editorial skills. Bonnie Farkas and Linda Clarke should also be commended for all of their hard work addressing the various fiscal and personnel issues related to the project.

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1. INTRODUCTION

Geophysical investigations of a historic Sac and Fox tribal/multiple family cemetery (25RH122) were initiated by the National Park Service (NPS) in response to a request from the Sac and Fox Nation of Missouri in October 2002. A preliminary visit to the cemetery was conducted on November 18, 2002 (De Vore 2002a). A formal request was submitted to the Midwest Archeological Center (MWAC) by the Sac and Fox Nation of Missouri in September 2003 (Bahr 2003). The tribal members requested that the Center provide technical assistance to help locate the historic tribal/multiple family cemetery in southern Richardson County, Nebraska. Tribal members were interested in identifying the extent of the cemetery. They were also hoping that the geophysical techniques would provide conclusive evidence of grave locations and provide an accurate count of individuals buried in the cemetery. It was pointed out to them by the authors that the geophysical techniques may possibly provide the information that they were seeking but the conditions had to be ideal. Both authors have been involved in several geophysical surveys across the country and in specific cemetery projects similar to the present one in the Midwest and Western United States. Funding was provided by the Sac and Fox Nation of Missouri through an Intergovernmental Personnel Act assignment agreement with the Midwest Archeological Center for the geophysical investigations of the cemetery. The Sac and Fox Nation of Missouri also contracted with Robert K. Nickel, a private consultant (Site Sensors) from Lincoln, Nebraska, to conduct the ground penetrating radar survey.

Between November 6 and 7, 2003, MWAC archeologist Steven L. De Vore and Site Sensors consultant Robert K. Nickel conducted magnetic, ground conductivity, and ground-penetrating radar surveys at the cemetery location identified by Sac and Fox Nation of Missouri tribal members. The project location was in the SW ¼ of the SW ¼ of the SW ¼ of Section 36, Township 1 North, Range 17 East in Richardson County, Nebraska (Figure 1). The cemetery was used by members of one family or social group dating to the late 1800s and early 1900s. This small family burial plot was located in a wooded area near a small stream in southeastern Nebraska. At the time of the geophysical survey, only a single tree was present and was located several meters east of the 2003 survey grid. The investigators also conducted a two-day geophysical workshop for approximately 20 individuals from the Sac and Fox Nation, as well as, other representatives from tribes in the Midwest. Completion of the site mapping and conductivity surveying occurred on November 17 and 21, respectively.

Non-invasive instruments certainly cannot be expected to identify individuals interred at specific locations, and in many cases, it is impossible to detect unmarked historic graves with geophysical instruments. The goal of this project was to try to delimit the extent of the area used for burials. For the graves to be identified by the geophysical techniques employed during the present project (i.e., magnetic, conductivity, and ground-penetrating radar), there needs to be sufficient contrasts in the measured physical property of the earth. Several factors contribute to the success or lack of success of the geophysical search for graves. Without significant contrasts in soil moisture, compaction, texture, structure, it would be impossible to identify specific grave locations. The lack of coffins, grave goods, and associated permanent stone or metal markers also make the search more difficult. The size and depth of the grave shaft are important to the overall success of the geophysical investigations. If the graves are hurriedly excavated and shallow, there may not be enough mixing of the excavated soil matrix as it was returned to the grave excavation. The lack of coffins would mean that there would be minimal collapse of the grave fill for the formation of a depression over the buried body. Any combination of these factors could spell disaster for positive grave identification in the geophysical investigations.

Although the soils may have high clay content that would make a ground-penetrating radar (GPR) survey impractical, none of the techniques has been applied to this type of cultural resource investigation in the project area. It is possible that the ground-penetrating radar could still identify the sides and bottom of the grave shaft. It is doubtful that the radar would detect coffin remains if those were present, and it will not identify individual human bones. The magnetometer can identify the presence on magnetic materials such as iron or steel artifacts (e.g., coffin hardware, nails, buckles, and other artifacts as well as disturbances to the natural soil matrix resulting from the mixing of topsoil and subsoil in the excavation and refilling of the grave). The conductivity meter can detect changes in the soil resulting from disturbances caused by excavation of a grave shaft. Conductivity data can also indicate the presence of conductive metals buried in the ground.

2. ENVIRONMENTAL SETTING

The present project is located in the glaciated region of southeastern Nebraska (Sautter and Kuhl 1974:67). The region is part of the dissected till plains section of the Central Lowlands Province of the Interior Plains (Fenneman 1938:588-605). During the Kansas glacial episode, the region was covered by a continental ice sheet (Fenneman 1938:594-595). As the ice sheet advanced into this region, the existing stream valleys were scoured and the uplands were leveled throughout the drift plain.

The thick deposits of glacial till, outwash, and loess conceals the cuesta-type topography of the underlying Pennsylvanian and Permian formations (Fenneman 1938:595-596). Erosion of the glacial deposits has left the region with rolling hills on the interstream divides. These divides are mantled by loess. The land becomes more dissected as it approaches the major stream valleys. Flat, wide floodplains with steep walls characterize the major stream valleys. The Pennsylvanian and Permian formations outcrop extensively in the region along the stream valleys. Interbedded limestone and shale are the primary sources for the soil parent material. Exposures of bedrock may be found along the valley walls.

Soils in southeastern Nebraska are dominated by soils of the Argiudoll great group of the Udoll suborder of the Mollisol order (Foth and Schafer 1980:116-125), although the young alluvial soils of the floodplains are primarily Entisols and Inceptisols (Forth and Schafer 1980:37,63). Alfisols are found under forest vegetation (Forth and Schafer 1980:143). These soils have a relatively thin argillic horizon. The soils are more or less freely drained with udic soil moisture and mesic soil temperature regimes. Parent materials are primarily glacial till with some thick or moderately thick deposits of loess. Soils are generally deep to shallow, black or very dark brown silt loams, clay loams, and silty clay loams (Foth and Schafer 1980:118). The loessial soils on the uplands and the alluvial sediments in the valleys provide rich soils for the growth of cultivated crops and other edible and usable plant species (Kindscher 1987, 1992). These resources provide the basis for aboriginal subsistence of prehistoric times and the historic and modern farming economy. The project area is within the Kennebec-Judson-Wabash soil association (Sautter and Kuhl 1974:3-4). Soils within the association are “deep, nearly level to gently sloping, well-drained, silty soils and poorly drained, clayey soils in Nemaha River bottom lands and foot slopes” (Sautter and Kuhl 1974:3). The soils in the immediate project area are described as silty alluvial land (Sautter and Kuhl 1974:26). This flood plain soil (0 to 1 percent slopes) occurs on narrow tracts of land adjacent to meandering streams. In the immediate project area, the soil lies on the flood plain of the channalized Noharts Creek, a tributary of the Big Nemaha River. The area is subject to periodic flooding.

The project area also lies within the Illinoian biotic province (Dice 1943:21-23). The alternating forest and prairie in the western part of the province was highly dependent on local soil conditions and slope exposures. Native vegetation consisted of trees, shrubs, annual weeds, and grasses. Grasses dominated the landscape (Brown et al. 1998:29; Reichenbacher et al. 1998; Shelford 1963:334). The tall grass bluestem prairie extended across uplands throughout southeastern Nebraska (Nebraska State Historic Preservation Office 1990:6). Prairie vegetation occurred in dense stands of tall and medium grasses. Dominant grasses included big bluestem, little bluestem, switchgrass, and indiangrass (Brown 1985:45). Forbs varied in height from short to very tall and affected the physiognomy of the prairie. Forbs were dominated by the legumes and composites, which added color to the vast sea of grasses (Brown 1985:36). Trees were most commonly found along streams and on north-facing slopes (Shelford 1963:309-313). The upland forest communities contained many of the plant species common to the northeastern oak-hickory deciduous forest (Brown et al, 1998:29; Reichenbacher et al. 1998; Shelford 1963:17-55). These forests consisted of medium tall multilayered broadleaf deciduous species. Dominate species included the bitternut hickory, shagbark hickory, white oak, red oak, and black oak. Along the floodplains, the deciduous forests were dominated by hackberry, cottonwood, peachwood willow, black willow, and American elm (Shelford 1963:309-313). Other minor forest species included walnut, sycamore, hazel, linden, box elder, mulberry, cedar, dogwood, and prickly ash. Persimmon, elderberry, serviceberry, chokeberry, wild plum, wild grapes, and mushrooms were some of the resources used by prehistoric inhabitants of the region, as well as, the historic settlers. These forests may have well developed undergrowth vegetation communities of small trees, shrubs, and fords, including redbuds, hornbeam, pawpaw, hawthorn, gooseberry, sumac, deerberry, sweet haw, blackberry, raspberry, jack-in-the-pulpit, bloodroot, mayapple, wild asters, goldenrods, chenopods, ragweeds, and smartweed (Brown 1985:43-44,52-53; Shelford 1963:23-35,94-99,118-119,334-344). They were often interrupted by freshwater marshes and prairie communities. A common marsh plant species was the prairie cordgrass (Shelford 1963:89-119).

In the tall grass region, bison and pronghorn antelope roamed the open plains until the mid to late 1800s (Shelford 1963:334-335). Deer were present in the timbered areas along streams and slopes, along with bear, squirrel, and cottontail rabbits. Jackrabbits were common along with coyotes, badgers, mink, bobcats, and foxes. Wolves were also important predators until exterminated from the region in the late 1800s. Numerous other mammals and rodents also inhabited the region. Numerous species of birds inhabited the grasslands, the shrublands, and wooded areas of the region (Brown 1985:26-28; Shelford 1963:26-35,336). Wild turkey, quail, ruffed grouse, and prairie chicken represented some of the regional game birds, which also included several species of migratory waterfowl, in both prehistoric and historic times. Numerous grassland and forest species of songbirds were present. Reptiles included several species of lizards, turtles, and snakes. Amphibians were found in the prairies, forests, and wetlands. Fish, including catfish, carp, and bass, and fresh water mussels were found in the streams throughout the region. Numerous insects and other invertebrates commonly occurred throughout the region with the grasshopper being one of the most abundant insect groups (Shelford 1963:337-339).

The region has a typical continental climate characterized by large daily and annual variations in temperature (Blair 1941:967-978; Myers 1974:68-69). The project area lies within the moist subhumid climatic zone (Thornthwaite 1948). Winters are cold and the summers are warm. The average annual maximum temperature is 40° C with an average annual minimum temperature of –24.4° C. The average daily maximum temperature in January is 2.2° C with an average daily minimum of –8.9° C (Myers 1974:69). The lowest recorded (1889) winter temperature is –34.4° C. The average daily maximum temperature in July is 32.2° C with an average daily minimum of 18.9° C (Myers 1974:69). The highest recorded (1934) summer temperature is 46.1° C. Annual precipitation in the county is 90.42 cm. The majority of the precipitation falls between April and September. Tornadoes and severe thunderstorms occur occasionally. Although these are generally local in extend and of short duration, the resulting damage can be severe. Hail may occur with these in the warmer months. Snowfall averages 2.54 cm during the winter months and seldom remains on the ground for long periods of time (Myers 1974:69). Droughts may occur anytime throughout the year, but are most damaging in July and August. The average frost-free period in the county is 166 days (Blair 1941:970). Sunshine averages 68 percent for the year (Blair 1941:978). The prevailing winds are from the south or southeast from May through September. During the rest of the year, they are out of the northwest (Edwards 1917:38).

SAC AND FOX MULTIPLE FAMILY CEMETERY

3. HISTORICAL BACKGROUND

Following a French attack in the early eighteenth century, the Sacs and Foxes maintained a close confederation throughout their contact with the encroaching Euroamericans into modern times (Bushnell 1919:12, 1922:37; Hagan 1958:5). On November 3, 1804, the united tribes of the Sac and Fox signed a treaty with the United States ceding lands on both sides of the Mississippi River in Illinois, Wisconsin, eastern Iowa, and eastern Missouri (Culter 1883; Kappler 1972:74-77). During the War of 1812, the "peace group" of the Sac moved south to the Missouri River in central Missouri where they remained neutral (Sultzman 1999). The Foxes also maintained their neutrality during the conflict. Following the War of 1812, a treaty was held with the Sac and Fox residing in Missouri in September 1815 (Culter 1883; Hagan 1958:80-81; Kappler 1972:120-122). The Foxes and a small portion of the Sacs (i.e., the Missouri Sac) residing in Missouri reconfirmed the Treaty of 1804 and vowed to remain separate from the Rock River Sacs. This treaty also officially named the Sac and Fox of Missouri as a distinct tribe (Sac&Fox Casino 2004). They were moved from Iowa and Illinois to northeast Missouri. This also formed a breach between the two Sac groups that existed for several years in the remaining portion of the nineteenth century. In August 1824, the Sacs and Foxes of Missouri ceded additional lands between the Mississippi and Missouri Rivers and were moved to the Platte River valley northwest of the Missouri (Culter 1883; Kappler 1972:207-208; Sac&Fox Casino 2004). In 1836, the Sac and Fox of Missouri along with the Iowa received 400 sections of land on the south side of the Missouri River (Figure 2) between the Kickapoo reservation and the Big Nemaha River and from the Missouri River westward (Culter 1883; Edwards 1917:63; Kappler 1972:468-470,473-478). The land was divided equally between the Iowa and the Sac and Fox. In 1837, the Missouri Sac and Fox gave up all rights to the land between the Mississippi and Missouri Rivers and moved to into Kansas to the Great Nemaha Reservation in Doniphan and Brown Counties (Kappler 1972:497-498). The remaining group of Sac and Fox in Iowa were removed to Kansas after they ceded their Iowa holdings in the Treaty of 1842 (Kappler 1972:546-549). They were moved to the Osage River Agency (Hagan 1958:231). The Treaty of 1854 resulted in the cession of over half of the land given to the Sac and Fox of Missouri back to the United States government (Kapper 1972:631-633; Sac&Fox Casino 2004). They were left with fifty sections in the western part of the reservation (Edwards 1917:64). The land was selected after the official General Land Office survey by deputy surveyor John Leonard (Figure 3). The Sac and Fox of Missouri were again forced to cede additional reservation land in the Treaty of 1861 (Kappler 1972:811-814). In 1867, the main group of the Sac and Fox at the Osage River Agency ceded their lands in Kansas for land in Oklahoma (Kappler 1972:951-956). The treaty also allowed for willing Missouri Sac and Fox to join them in Oklahoma (Sultzman 1999). In 1887, Congress passed the General Allotment Act commonly referred to as the Dawes Act (Indian Lands Working Group 2003). The act called for the division and allotment of tribal reservation land to individual owners. The purpose was to accelerate the civilization and assimilation of Native Americans into the larger Anglo-American society by making them private landholders and farmers. Individual tribal members were allotted 40, 80, and 160-acre parcels. The remaining reservation lands declared surplus and sold to the Anglo-Americans. The 1896 plat of Rulo Township illustrated the landownership in Section 36 (Everts 1896:22). The area on the right bank of the Great Nemaha River (also called the Big Nemaha River) was identified as the Iowa Indian Reservation. The land on the left bank of the river was divided among several land owners, including M. R. Edgecomb, L. Forbes, J. A. Randolph, T. F. Plumb, Wm A. Margrove, Jno. Huss, and H. Riegons. Loss Creek was also shown on the plat. By 1913, the Margrove family, including Earl I. and W. A. Margrove, had acquired several acres on the right bank of the Big Nemaha River within the original boundary of the reservation lands (Ogle 1913:39). The area of the cemetery was still held by the tribe or tribal members. The General Allotment period finally ended in 1934 (Indian Lands Working Group 2003). The Sac and Fox Nation of Missouri (Figure 4) have retained 453 acres of tribal land and 44.60 acres of allotted land (Mni Sose Intertribal Water Rights Coalition 1998).

In 1906, plans were developed for the channelization of the Great or Big Nemaha River near its confluence with the Missouri River (Figure 5). The project was initiated by Drainage District No. One, a private water district in southeastern Richardson County. The plans were developed by A.M. Munn, Engineer, W. F. Rantsma, Assistant Engineer, and O. N. Munn, Assistant Engineer (Note: The original plans are located in the Richardson County Surveyor's Office in Falls City, Nebraska). The plans indicated the changes or rectification to the Big Nemaha River. The project was to improve the outlet of the river and to lessen the affects of future flooding. The map also showed the original channel of the Big Nemaha River and its tributary, Loss Creek (Note: Loss Creek was renamed Noharts Creek sometime after 1927). In 1906, the landowners of the southwest quarter of the southwest quarter section of Section 36 where the cemetery was located included W^{m} Wahpeconian and Mary Murphy. Earl Margrave owned the eighty acres immediately north of the present project area. The plans, however, do not show the straightening of Loss Creek. According to Ron Hazard, Richardson County Surveyor (personal communications, 2004), the project began construction in 1907 and was completed by the end of 1913, including the construction of the Loss Creek lateral. The lateral was illustrated on the 1927 plat of Drainage District No. 1 by Carl Shildneck and J. F. Reif, Engineers (Figure 6). The 1927 plat also illustrated the old channels of the Big Nemaha River and Loss Creek. According to the plat map, the land had been divided into lots and was owned by the Provident Loan and Investment Company. In 2003, John R. Teale of Midland Survey compiled a survey of the area and plated the survey results on an aerial photograph (Figure 7). The 2003 plat provided the most recent view of the cemetery project area. The old meander scars of the Noharts Creek and the Big Nemaha River were clearly visible.

In 1907, a photograph was taken of the Sac and Fox cemetery by an unidentified photographer (Note: The copy of the photograph is on file at the Sac and Fox of Missouri Tribal Museum in Reserve, Kansas). The photograph caption identified the picture as the Sac and Fox Indian cemetery, east of Margrave Ranch, taken in 1907 reprinted in 1968 (Figure 8). Six spirit houses are present in the foreground of the photograph. There also appears to be a recent interment near the center of the left side of the photograph. The grave consists of a mound of earth surrounded by planking. The wooden structures ranged in size and were composed of planking for the sidewalls. Planking was also used for the gable style roofs, which was covered with wooden shake shingles. Buildings associated with the Margrave ranch were visible in the background. On January 15, 1827, Thomas Forsyth observed a Sac and Fox burial ceremony near St. Louis (Bushnell 1927:14):

> …The Sauk and Fox bury their dead in the ground and sometimes have them transported many miles to a particular place of interest. The grave is dug similar to that of white people, but not so deep, and a little bark answers for a coffin…After which the grave is filled up with earth, and in a day or two afterwards a kind of cabin is made over the grave with split boards something like the roof of a house, if the deceased was a brave a post is planted at the head of the grave, on which is painted with vermilion…, distinguishing the sexes…

Although the context of the burial ceremony reported by Thomas Forsyth was different from the activities of the Sac and Fox Nation of Missouri in Nebraska a half a century or more later, the use of the spirit houses at the cemetery in Richardson County exhibited a continuity in the traditional ways of the Sac and Fox Nation of Missouri tribal members. Euroamerican concepts were also being incorporated into the lives of the tribal members through their contact with the Christian missionaries during the nineteenth century. Edmore Green of the tribal council indicated that family members had uncovered a grave stone in the early 1990s but had recovered it in the field where the cemetery was located (Edmore Green, personal communications, 2003). The cemetery was recorded with the Archeology Division at the Nebraska State Historical Society in March 1997. It was recorded as Site 25RH122 based on information supplied by Curtis Gilfillan of Reserve, Kansas. According to oral histories from tribal members (Deanne Bahr, personal communications 2004), the cemetery contained individuals from at least three families including the Connell, Green, and Robidoux families (Table 1).

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4. AERIAL PHOTOGRAPHS

During the Great Depression, several farm programs were instituted to help the farm community. Consequently, farmers needed a way to accurately measure their farmlands. Precise measurement continued to use surveyor's chains, which had to be carried around the fields. The resulting map continued to be drawn by hand. Due to the large number of acres numbering in the millions needing to be measured and mapped, the government sought a way to more quickly and cheaply map the agricultural acreage of the Nation. In 1935, the United States Department of Agriculture (USDA) instituted the rectified-to-scale aerial photography program. The program allowed a more efficient method to measure farm acreage. Vertical imagery was used for and continues to be used for rectified aerial photography. The camera was mounted on an airplane so it pointed straight down. Due to wind currents, changing elevation, and camera motion during flight, the resulting photographs were often at an angle rather than truly vertical. The resulting tilt of the photograph was corrected by a system of analytical triangulation which measured points on the photograph and mathematically computed the scale and tilt data to correct the accurate scale photographs. The primary format for the aerial photographs was the 9x9-inch film negative. Most of the conterminous United States has been covered.

During the first several decades, the aerial photographs taken by the USDA Agricultural Stabilization and Conservation Service (ASCS) were black-and-white panchromatic negative film at a scale of 1:20,000. In 1978, several Federal agencies combined their efforts to provide consistent and systematic aerial photographic coverage of the United States. The National High Altitude Program (NHAP) collected two different scales of photography simultaneously. Black-and white panchromatic film was used for the 1:80,000 scale while color infrared film was collected at a scale of 1:58,000. The NHAP was replaced in 1987 with the National Aerial Photography Program (NAPP), which was to acquire uniform coverage of the conterminous United States every 5 to 7 years at a scale of 1:40,000. Color infrared or black-and-white film was used based on the project requirements. In 2001, the National Agriculture Imagery Program (NAIP) was implemented to replace the existing compliance imagery program. NAIP imagery may be delivered at 1 meter to 2-meter resolution in natural color or color infrared imagery. USDA aerial photography acquired since 1955 is available from the Field Service Agency's Aerial Photography Field Office in Salt Lake City, Utah. Aerial photographs acquired before 1955 have been transferred to the National Archives and Records Administration in the Nation's capitol. Other agencies, such as the USDA Forest Service, the U.S. Geological Survey, U.S. Army Corps of Engineers, and the National Aeronautics and Space Administration, also acquire aerial photographs and satellite imagery. Aerial photographs of the project area were obtained from the National Archives and Records Administration and the Aerial Photography Field Office.

Aerial photo interpretation involves the evaluation of several factors in the identification of features on vertical photographs. Major factors include the shape of the object, the size of the object, photographic tone, spatial pattern or arrangement of the objects, shadows cast by the object, the object's relative topographic location, association with other objects, site location, and the degree of coarseness or texture (Avery 1977:23-24; Avery and Berlin 1985:52-57). Although it may be feasible to use only one vertical photograph for the identification and classification of specific features, the method only allows for the perception of two dimensions (i.e., length and width). It leaves out depth perception used for stereoscopic vision (Avery 1977:26-28; Avery and Berlin 1985:58-59). Two photographs of the same object are taken at slightly different positions during the flight are required in order to obtain stereoscopic images. Aerial photographs are collected by overlapping consecutive photographs taken by the airplane flying horizontally over the project area. In addition to overlapping consecutive photographs along the single flight line, adjacent flights lines must also overlap along the sides of the area photographed. The aerial camera stations are spaced to provide a 60 percent forward overlap along each flight line and a 20 to 30 percent sidelap for adjacent lines (Avery and Berlin 1985:59-60).

The instrument used to view a stereo pair of aerial photographs is the stereoscope. The stereoscope is used to deflect converging lines of sight so each eye views a different image. It produces a sharply defined, although exaggerated or distorted, three-dimensional image. Three general types of stereoscopes exist: 1) lens or pocket stereoscopes, 2) mirror or reflecting stereoscopes, and 3) zoom stereoscopes (Avery 1977:29-31; Avery and Berlin 1985:60-62). The analysis of the stereo pairs of aerial photographs obtained for the present project was conducted with a Topcon MS-3 mirror stereoscope (Topcon 1994).

Stereo pairs of aerial photographs must be arranged in the position they were taken along the flight line (Avery 1977:33-35; Avery and Berlin 1985:63; Topcon 1994:3-6). The principal point or optical center is identified and marked on the two photographs (Note: Marking the point may be accomplished by placing a small pinhole at the location). This is the point at the intersection of the imaginary line connecting the top and bottom and the left and right fiducial marks at the edges of the photographs. The next step is to identify and mark the conjugate principal point. The conjugate principal point is the location of the principal point from the other photograph. The flight line is represented by a line connecting the principal and conjugate principal points of the two aerial photographs. The aerial photographs are mounted on a magnetic photo panel to keep them from moving while viewing them with the stereoscope. The stereoscope is placed over the photographs and aligned with the imaginary flight line. The separation between the two photographs is approximately 260 mm between the principal point on one photograph and its conjugate principal point on the second photograph. This provides approximately 14 cm of common viewing area. Viewing the set of aerial photographs should produce a 3-D of the area of interest. Normally, objects viewed in stereo have their vertical heights exaggerated with respect to the horizontal distances (Avery and Berlin 1985:64-66). The binocular eyepieces on the stereoscope provide the largest viewing area measuring 180mm-x 240 mm at 1x magnification. The stereoscope also has a set of built-in magnifiers for observing a wide area of 170 mm x 230 mm at a higher magnification of 1.8x. The stereoscope also comes with two detachable binocular viewers for precision measurements of height when used with the accessory stereometer. The 3x magnification viewer provides a 70 mm diameter field of vision while the 6x magnification viewer provides a 30 mm diameter field of vision. The detachable binocular eyepieces are also adjustable for the pupillary distance of an individual's eyesight.

Aerial photographs for the project area were obtained from the National Archives and the Aerial Photography Field Office (Table 2). The first set of ASCS aerial photographs for the project area was flown in 1937 (Figure 9). The immediate geophysical project area appears to be vegetated with pasture grasses with a small stand of trees in the lower southwest corner adjacent to the Loss (Noharts) Creek lateral. Near the middle of the project area and to the east, the field is mixed trees and grasses. A fence line appears to run north-south along the western edge of the trees. Several farm buildings are located on the Margrave ranch west of the lateral; however, none of the spirit houses from the 1907 photograph are visible on the aerial photograph. This may be due to the relative short height of the houses or the deterioration of the houses. The 1940 aerial photograph shows the encroachment of the trees into the triangular portion of the project area west of the fence line. Most of the trees are relatively small except in the extreme southwester corner next to the lateral. The fence line is indicated by the relative height of the trees noted in the 1937 photograph. They are approximately twice as tall as the smaller trees. The project area changes little over the next seven years. The 1947 photograph shows the project area covered with trees. In 1955, there is some thinning of the trees along the interior fence line but most of the project area is still covered with a dense growth of trees. By 1959, additional thinning of the trees in the project area has occurred. A small area along the southern fence line adjacent to the road is devoid of trees. By 1965, the trees have been removed from the property with the exception of two large trees near the center of the project area (Figure 10). Economic strategies have changed by 1971. A large portion of the project area is under cultivation. The two large trees in the center of the project area are present. By 1979, the entire field is under cultivation and the trees have been removed. The field continues to be under modern farming practices throughout the 1980s and 1990s as noticed in the aerial photographs from 1982, 1989, 1993, and 1999 (Figure 11).

SAC AND FOX MULTIPLE FAMILY CEMETERY

5. GEOPHYSICAL PROSPECTION TECHNIQUES

Various geophysical instruments have been used by archeologists to locate evidence of past human activity. Magnetometers and soil resistance meters were initially employed on Roman sites in England during the late 1940s and early 1950s (Aitken 1961), and their use was the focus of considerable research in the 1960s and 1970s. During this period the archeological applications of additional instruments were explored (Aitken 1974, Clark 2000, Scollar et al. 1990, Tite 1972). While many of the early studies in England and Europe were very successful, it was some time before improvements in detector sensitivity and data processing techniques allowed a wide range of New World sites to be mapped. Virtually all the instruments used in non-invasive mapping of historic sites originated as prospecting devices for geological exploration. In general, cultural resource applications using geophysical instruments focus on weaker anomalies or smaller anomalies. It is important to emphasize that instruments employed in archeological geophysical surveys do not respond only to the desired cultural targets, and consequently feature detection depends greatly on the recognition of patterns that match the anticipated form of the cultural target. The challenge in archeological geophysics is to recognize the anomalies produced by the target features and sort them out from the "noise" produced by the responses from the surrounding matrix. The amount of data collected in any given area and the method of collection both affect one's ability to recognize the specific anomaly type or "signature" of the feature being sought.

Geophysical prospection techniques available for archeological investigations consist of a number of techniques that record various physical properties of the earth, typically in the upper couple of meters; however, deeper prospection can be utilized if necessary. Geophysical techniques are divided between passive techniques and active techniques. Passive techniques are ones that measure inherently or naturally occurring local or planetary fields created by earth related processes under study (Heimmer and De Vore 1995:7,2000:55; Kvamme 2001:356). The primary passive method utilized in archeology is magnetic surveying. Other passive methods with limited archeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground (Heimmer and De Vore 1995:9,2000:58-59; Kvamme 2001:355-356). The interaction of these signals and buried materials produces alternated return signals that are measured by the appropriate geophysical instruments. Changes in the transmitted signal of amplitude, frequency, wavelength, and time delay properties may be observable. Active methods applicable to archeological investigations include electrical resistivity, electromagnetic conductivity (including ground conductivity and metal detectors), magnetic susceptibility, and ground penetrating radar. Active acoustic techniques, including seismic, sonar, and acoustic sounding, have very limited or specific archeological applications.

Passive Geophysical Prospection Techniques

A magnetic survey is a passive geophysical prospection technique used to measure the earth's total magnetic field at a point location. Magnetometers depend upon sensing subtle variation in the strength of the earth's magnetic field in close proximity to the archeological features being sought. Variation in the magnetic properties of the soil or other buried material induces small variations in the strength of the earth's magnetic field. Its application to archeology results from the local effects of magnetic materials on the earth's magnetic field. These anomalous conditions result from magnetic materials and minerals buried in the soil matrix. Iron based materials have very strong effects on the local earth's magnetic field. Historic iron artifacts, modern iron trash, and construction material like metal pipes and fencing can produce such strong magnetic anomalies that nearby archeological features are not detectable. Other cultural features, which affect the earth's local magnetic field, include fire hearths, and soil disturbances (e.g., pits, mounds, wells, pithouses, and dugouts), as well as, geological strata.

Magnetic field strength is measured in nanoteslas (nT; Sheriff 1973:148). In North America, the earth's magnetic field strength ranges from 40,000 to 60,000 nT with a inclination of approximately 60° to 70° (Milsom 1996:43; Weymouth 1986:341). The project area has a magnetic field strength of approximately 55,900 nT with a inclination of approximately 69° (Sharama 1997:72-73). Magnetic anomalies of archeological interest are often in the ±5 nT range, especially on prehistoric sites. Target depth in magnetic surveys depends on the magnetic susceptibility of the soil and the buried features and objects. For most archeological surveys, target depth is generally confined to the upper one to two meters below the ground surface with three meters representing the maximum limit (Clark 2000:78-80; Kvamme 2001:358). Magnetic surveying applications for archeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects (Bevan 1991; Breiner 1973; Clark 2000:92-98; Gaffney et al 1991:6; Heimmer and De Vore 1995:13; Heimmer and De Vore 2000:55-56; Weymouth 1986:343).

Two modes of operation for magnetic surveys exist: the total field survey and the gradient survey. The instrument used to measure the magnetic field strength is the magnetometer (Bevan 1998:20). Three different types of magnetic sensors have been used in the magnetometer: 1) proton free precession sensors, 2) alkali vapor (cesium or rubidium) sensors, and 3) fluxgate sensors (for a detailed description of the types of magnetometers constructed from these sensors see Aitken 1974; Clark 2000:66-71; Milsom 1996:45-47; Scollar et al. 1990{450-469; Weymouth 1986:343-344).

The total field magnetometer is designed to measure the absolute intensity of the local magnetic field. This type of magnetometer utilizes a single sensor. Due to diurnal variation of the earth's magnetic field, the data collected with a single sensor magnetometer must be corrected to reflect these diurnal changes. One method is to return to a known point at regular intervals during the survey to take a series of readings that can be used to correct the diurnal variation. A second method is to use two magnetometers with one operated at a fixed base station collecting the diurnal variation in the magnetic field. The second roving magnetometer is used to collect the field data in the area of archeological interest. Common magnetometers of this types used in archaeological investigations include the proton precession magnetometer, the Overhauser effect magnetometer (a variation of the proton precession magnetometer), and the cesium magnetometer.

The gradient magnetic survey is conducted with a gradiometer or a magnetometer with two magnetic sensors at a fixed vertical distance apart. The instrument measures the magnetic field at two separate heights. The top sensor reading is subtracted from the bottom sensor reading. The resulting difference is recorded. This provides the vertical gradient or change in the magnetic field. Diurnal variations are automatically canceled. This setup also minimizes long range trends. The gradiometer provides greater feature resolution and potentially provides better classification of the magnetic anomalies. Two commonly used gradiometers in archeological investigations are the cesium gradiometer and the fluxgate gradiometer. They are capable of yielding 5 to 10 measurements per second at an accuracy resolution of 0.1 nT (Kvamme 2001:358). Cesium gradiometers record the absolute total field values like the single sensor magnetometers. The fluxgate sensors are highly directional, measuring only the component of the field parallel to the sensor's axis (Clark 2000:69). They also require calibration (Milsom 1996:46-47). Both cesium and fluxgate gradiometers are capable of high density sampling over substantial areas at a relatively rapid rate of acquisition (Clark 2000:69-71; Milsom 1996:46-47).

Active Geophysical Prospection Techniques

The active geophysical prospection techniques used during the project included conductivity, resistivity, and ground-penetrating radar (GPR). As indicated above, active techniques transmit electrical, electromagnetic, or acoustic signals into the ground. The interaction of these signals and buried materials produces an altered return signal, which is measured by the appropriate geophysical instrument. The ground-penetrating radar and ground conductivity meter utilize electromagnetic signals. The resistivity meter injects an electric current into the ground.

Electromagnetic Conductivity Surveys

The capacity of soil to conduct electrical currents has led to the use of soil conductivity and soil resistivity meters in cultural resource management (Heimmer and De Vore 1995:29-41). Both resistivity and conductivity represent active geophysical techniques. Soil resistivity meters used in archeological surveys typically involve four metal probes placed in contact with the soil. A small alternating current is normally applied to two of the probes and the voltage difference between the other two probes is measured. Variations in soil moisture, chemistry, and structure affect the electrical resistance of the soil. Soil resistivity surveys are particularly well suited to locating high resistance material (e.g. stone or brick) in relatively conductive soil (e.g. clay). Soil conductivity meters provide another method of measuring the soil's ability to conduct electrical current. This survey technique measures the soil conductivity. Theoretically, conductivity represents the inverse of resistivity. High conductivity equates to low resistivity and vice versus. The electromagnetic ground conductivity meter induces an electromagnetic field into the ground through a transmitting coil (see Bevan 1998:29-43; Clark 2000:34-37; and Heimmer and De Vore 1995:35-41 for more details of conductivity surveys). The induced primary field causes an electromagnetic wave flow in the earth similar to the electrical current in a resistivity survey. The materials in the earth create secondary eddy current loops, which are picked up by the instrument's receiving coil. The interaction of the generated eddy loops or electromagnetic field with the earthen materials is directly proportional to terrain conductivity within the influence area of the instrument. The receiving coil detects the response alteration (secondary electromagnetic field) in the primary electromagnetic field. This secondary field is out of phase with the primary field (quadrature of conductivity phase). The in-phase component of the secondary signal is used to measure the magnetic susceptibility of the subsurface soil matrix. Only the quadrature or conductivity phase data were collected during the present project. Contrasts result from electrical and magnetic properties of the soil matrix. Changes are caused by materials buried in the soil, differences in soil formation processes, or soil disturbances from natural or cultural modifications to the soil. Electromagnetic conductivity instruments are also sensitive to surface and buried metals. Due to their high conductivity, metals show up as extreme values in the acquired data set. On occasion, these values may be expressed as negative values since the extremely high conductivity of the metals cause saturation of the secondary coil. The apparent conductivity data were recorded in units of millisiemens per meter (mS/m). The electrical conductivity unit or siemens represents the reciprocal of an ohm-meter or the unit for resistivity (Sheriff 1973:197). The relationship between conductivity and resistivity is represented by the following formula (Bevan 1983; McNeil 1980): mS/m = 1000/ohm/m.

Its application to archeology results from the ability of the instrument to detect lateral changes on a rapid data acquisition, high resolution basis, where observable contrasts exist. Lateral changes in anthropogenic features result from compaction, structural material changes, buried metallic objects, excavation, habitation sites, and other features affecting water saturation (Heimmer and De Vore 1995:37). Since the conductivity meter has no direct contact with the soil, this permits the conductivity meter to be moved more rapidly than a resistivity meter and a greater area can be surveyed in a shorter period of time. The instrument has been used to identify areas of compaction and excavation as well as buried metallic objects. It has the potential to identify cultural features that are affected by the water saturation in the soil (Clark 2000:36; Heimmer and De Vore 1995:36-37). In the present project, the investigations are looking for changes in the electromagnetic conductivity between the natural soil surrounding the grave and the disturbed soil within the grave. Conductivity meters are also susceptible to interference from metal including gas or water pipes and wires. Metallic trash in the topsoil can degrade conductivity signals.

Ground-penetrating Radar Survey

Ground-penetrating radar is an active method that has recently achieved popularity in cultural resource management applications (see Bevan 1998:43-57; Clark 2000:118-120; Conyers and Goodman 1997; and Heimmer and De Vore 1995:41-47 for more details of ground-penetrating radar surveys). Although Bruce Bevan pioneered the archeological use of GPR a quarter-century ago (Bevan 1977; Bevan and Kenyon 1975), the cost of equipment and problems dealing with the massive amount of data produced by GPR surveys limited the number of archeological applications. Recently, Conyers and Goodman (1997) have published an introduction to GPR for archeologists, and Bevan (1998) has provided an excellent comparison of various radar antennae as applied to a consistent group of archeological features. Reductions in the cost of equipment and improvements in the software available for processing the voluminous data have helped to make GPR surveys more affordable and analysis more efficient.

Ground-penetrating radar uses pulses of radar energy (i.e., short electromagnetic waves) that are transmitted into the ground through the surface transmitting antenna. A short burst of radio energy is transmitted and then the strength of the signal received from reflectors a few nanoseconds after the pulse's transmission is recorded by the receiving antenna. The combination of time after transmission and strength of reflected signal provides the data used to create plan maps and profiles. The radar wave is reflected off buried objects, features, or interfaces between soil layers. These reflections result from contrasts in electrical and magnetic properties of the buried materials or reflectors. The contrasts are a function of the dielectric constant of the materials (Sheriff 1973:51). The depth of the object or soil interface is estimated by the time it takes the radar energy to travel from the transmitting antenna and for its reflected wave to return to the receiving antenna. The depth of penetration of the wave is determined by the frequency of the radar wave. The lower the frequency, the deeper the radar energy can penetrate the subsurface; however, the resulting resolution, or the ability to distinguish objects, features, and soil changes, decreases. These low frequency antennas generate long wavelength radar energy that can penetrate several tens of meters under certain conditions, but can only resolve larger targets or reflectors. The higher the radar wave frequency, the higher the resulting resolution but the depth penetration decreases. High frequency antennas generate much shorter wavelength energy, which may only penetrate a meter into the ground. The generated reflections from these high frequency antennas are capable of resolving objects or features with maximum dimensions of a few centimeters. A resulting tradeoff exists between subsurface resolution and depth penetration: the deeper the penetration then the resulting resolution is less or the higher the resolution then the resulting depth penetration is much shallower.

As the radar antenna system (transmitting and receiving antennas) is moved along the survey line, a large number of subsurface reflections are collected along the line. The various subsurface materials affect the velocity of the radar waves as they travel through the ground (Conyers and Goodman 1997:31-40). The rate at which these waves move through the ground is affected by the changes in the physical and chemical properties of the buried materials through which they travel. The greater the contrast in electrical and magnetic properties between two materials at the interface results in a stronger reflected signal. As each radar pulse travels through the ground, changes in material composition or water saturation, the velocity of the pulse changes and a portion of the energy is reflected back to the surface where it is detected by the receiving antenna and recorded by ground-penetrating radar unit. The remaining energy continues to pass into the subsurface materials where it can be reflected by deeper reflectors until the energy finally dissipates with depth. In a uniform soil, there would be little energy reflected (except at the air/soil interface), and the bulk of the energy would be absorbed within a short distance. Objects included in the soil or strata with contrasting electrical properties may result in reflection of enough energy to produce a signal that can be detected back at the antenna. The radar system measures the time it takes the radar pulse to travel to a buried reflector and return to the unit. If the velocity of the pulse is known, then the distance to the reflector or the depth of the reflector beneath the surface can be estimated (Conyers and Lucius 1996).

Actual maximum depth of detection also depends upon the electrical properties of the soil, the frequency of the antenna, and the contrast between the target and its matrix. Plan maps present the average signal strength across the grid during the selected time interval (e.g. 7.2 to 14.4 ns). Because these time intervals correspond with horizontal layers or slices of soil, they are called either time-slices or depth-slices. The analyst can set the span of the time-slice and consequently the thickness of the depth-slice. GPR profiles illustrate a cross section through the soil with the ground’s surface at the top of the image. The profile images are conceptually similar to what one would see when looking at the side of an excavated trench. The vertical scale used on the profiles can be marked in nanoseconds (ns) indicating the amount of time between the transmission of the radar pulse and the receipt of the reflected signal or in units indicating depth below the ground surface. The earlier reflections are received from targets nearer the surface and the later reflections are received from deeper levels or features. The velocity can be measured directly in the field in some cases, calculated from the size and shape of strong hyperbolic reflections, or estimated by using values of similar soils. The plots used in this report were calculated using a value of ca. 0.1 m/ns.

The success of the survey is dependent on soil and sediment mineralogy, clay content, ground moisture, depth of burial, and surface topography and vegetation. The ground-penetrating radar signal can be lost or attenuated (i.e., quickly dissipated) in soils that have high moisture content, high electrical conductivity, highly magnetic materials, or high clay contents. Dry soils and sediments, especially those with low clay content, represent the best conditions for energy propagation. The soils at the project sites do contain a relatively high clay content and were relatively moist during the survey. A ground-penetrating radar survey, with its capability for estimating the depth and shape of buried objects, may be an extremely valuable tool in the search of grave shafts. At times, radar cannot profile deep enough or the strata may be so complex as to render the graves indistinguishable from the surrounding soil profile. Selection of the appropriate antenna frequency is also important in providing a good compromise between the depth penetration and resolution.

6. GEOPHYSICAL SURVEYS OF HISTORIC CEMETERIES

The search for unmarked graves includes both modern forensic applications and more traditional archeological applications. Forensic applications have some similarities to archeological ones but there are also distinct differences. Forensic problems typically involve little time between burial and the attempted detection, and typically presume that the burial was not intended to be discovered. Most historic graves were intended to be recognized but many have become lost with the passage of considerable time. Some grave markers were never installed, some decayed through time, and some have been removed for one reason or another. Many attempts have been made to map historic cemeteries with the goal of detecting unmarked graves. In some cases, where sites are threatened with destruction or encroachment, excavation is used to evaluate the results. More often, most results must be evaluated based on more circumstantial evidence. The main question in geophysical studies of historic cemeteries is whether the geophysical devices will yield readings over known graves that differ from readings in areas devoid of graves. Do the geophysical anomalies detected correspond with burial monuments or depressions? Are the anomalies of appropriate size? Can the anomalies be reasonably attributed to soil changes that one would expect to result from the excavation of a grave or to grave inclusions?

With the exception of graves that contain iron caskets or reinforced vaults, grave contents are rarely detected directly. Human skeletal elements are not expected to produce significant anomalies. Geophysical instruments in common use do not have the capability to detect human remains. Successful results can more often be attributed to the detection of soil changes that result from the excavation and refilling of the grave shaft. A geophysical survey of a historic cemetery normally includes known graves that should yield a "signature" or typical data measurements of a refilled grave, as well as, background readings of the undisturbed soils. With these two opposing data sets, one can then model the response from unmarked graves by predicting the nature of the anticipated anomalous readings based on the soil's physical properties and expected differences between backfilled grave excavations and the unexcavated natural soil matrix. In other words, the ability to identify unmarked graves is greatly increased when one has comparative geophysical signatures from known graves in a cemetery survey. It is expected that in the more recent cemeteries will have a greater differentiation between disturbed grave fill and adjacent natural soil matrix. In small and abandoned burial plots, where documentation is poor and visible markers are missing or non-existent, it is more difficult to reliably detect graves with a given geophysical instrument and to determine typical background values for undisturbed soils.

Dr. Bruce W. Bevan (1991) reported on the results of several geophysical surveys in cemeteries. His study sites ranged from Minnesota to New England. At various sites he used ground-penetrating radar, magnetometers, and a ground conductivity meter. At the Burton Parish church in Williamsburg, Virginia, the results of the radar were clear and unambiguous (Bevan 1991:1313-1314, Figure 5). The same site resulted in low values of conductivity (high resistivity) and high magnetic readings in the vicinity of a grave. At the other sites the results were much less clear with some graves clearly detected and others only a few meters away showing no clear signature (Bevan 1991:1311, Figure 1).

Two years later, Bevan contributed to another test of geophysical techniques at an historic cemetery at which extensive test excavations were used to confirm the geophysical data (King et al. 1993). At this site, the magnetic data were disappointing although the poor results were attributed primarily to iron debris not associated with the graves. About half of the potential graves identified in the radar data were confirmed. The rest of the radar reflections appeared to have resulted from shallow near-surface sources not associated with graves. In these two studies, Bevan identified several attributes of graves that can result in successful detection. These included air pockets in intact coffins, a metal coffin or framework, loose fill in a collapsed coffin and disturbed stratigraphy in the grave shaft. He also noted that troublesome features included large rocks, animal dens, tree roots, naturally occurring lenses of contrasting soil and other complex natural stratigraphy. In some cases, the distribution of excess soil around the area of a grave made it difficult to precisely locate the actual grave shaft.

The geophysical survey of the Middlecoff and Perschbacher pioneer family cemeteries on Scott Air Force Base, St. Clair County, Illinois, produced mixed results on the location of the graves (De Vore and Bevan 1995). Magnetic, conductivity, resistivity, and ground-penetrating radar survey techniques were employed at the pioneer cemeteries. At the Middlecoff cemetery, four stones marked grave locations. It was expected that the burials would be on the east side of these stones. The geophysical survey found no clear indications of the burials in these locations. Data from five separate locations surrounding the known grave locations indicated the possibility of unmarked graves. At the Perschbacher cemetery, the ground-penetrating radar evidence was not as clear as that from the Middlecoff cemetery. The ground conductivity survey data at the Perschbacher cemetery were closely associated with the topographic contours of the cemetery area. Tree roots and naturally occurring lenses of contrasting soil also created spurious readings. The multi-instrument geophysical survey was not a reliable predictor of grave locations although portions of or complete gravestones were *in situ*.

A geophysical survey of the Kane Cemetery in Bighorn National Recreational Area, Wyoming was conducted in order to determine the location of unmarked graves and to determine if known graves were correctly marked (De Vore 2002b). Ground-penetrating radar and ground conductivity surveys were conducted over the enclosed cemetery. The GPR survey provided positive data concerning the known grave locations. The radar data did not indicate the presence of stacked graves or unmarked graves beyond the known marked graves. The ground conductivity survey identified several anomalies associated with metal markers at known grave locations. A few high conductivity anomalies may suggest the location of broken metal markers at the location of unmarked graves. Overall, the radar survey proved to be best suited to meet the park's objectives for the project.

GEOPHYSICAL SURVEYS OF HISTORIC CEMETERIES

At the Nez Perce Mission Cemetery at Spalding, Idaho, the geophysical investigations utilized a multi-instrument survey to examine portions of the cemetery (Nickel 2000a). The magnetic, soil resistance, and ground-penetrating radar surveys were about equally successful at detecting subtle anomalies associated with existing stone grave markers. Similar anomalies were recorded at most of the shallow depressions and several comparable anomalies were detected in areas without surface evidence of graves. Weak near-surface GPR anomalies, as well as, deeper and stronger anomalies were detected and associated with the marked and unmarked graves in the single cemetery.

The geophysical survey of the Moses Carter family cemetery at George Washington Carver National Monument in Missouri utilized magnetic, soil resistance, and ground-penetrating radar survey techniques (Nickel 2000b). The magnetic and soil resistance surveys recorded considerable variation over relative small distances. This made it extremely difficult to detect a typical “grave signature” that could be used throughout the cemetery. The results did not predictably correspond to known grave locations. Of the three geophysical techniques, the GPR appeared to be partially successful in detecting known graves.

Investigations of known cemeteries and suspected grave locations along the Oregon and California trails in Kansas (De Vore and Nickel 2003) also illustrated the difficulty of detecting historic graves. Ground penetrating radar, magnetic, resistivity, and conductivity techniques were utilized during the investigations. Gravestones were present at 14MH323 and the Cholera cemetery, 14PO312. At the Cholera cemetery, detectable radar anomalies were observed on multiple traverses over the marked graves. It was hoped that such a pattern would be noticeable in the rest of the survey area; however, that was not to be the case. The geophysical data failed to indicate the presence of any more graves in an area where at least fifty people were known to have been buried at the cemetery. The multiplexer resistance data did suggest the presence of a few graves. At Site 14MH323, the known grave did not produce an anomaly, which could be associated with the burial or any other graves at the cemetery. The investigations at the remaining two sites, 14MH322 and 14PO406, were even more problematic since it was not known if the features were associated with pioneer graves. The geophysical techniques provided a non-invasive, non-destructive avenue of investigations at the cemetery sites. The investigations were successful as far as the operation of the instruments and the collection of data measuring the sites’ physical properties; however, the techniques did not provide clear indications for the presence of graves. Two possible explanations exist: 1) there was a lack of sufficient contrast in the measured physical properties associated with the graves, or 2) there were no graves in the areas of investigation.

In applying geophysical techniques to archeological problems, one is challenged with the detection and recognition of anomalous conditions caused by human alteration of natural soil properties. There is no unique interpretation of substantial geological or anthropogenic anomalies that can be used to identify similar features at different site settings (Breiner 1973:18-19). Many different geological or pedological configurations of buried material (e.g., soils, rocks, or other substances) can produce an individual anomaly. The challenge is to identify the most probable or realistic model. Similar problems occur in archeological interpretations of geophysical anomalies, but on a much smaller scale than those encountered in geological anomalies (Nickel 2000b:10). For grave identification, there needs to be a contrast in the physical property being measured by the geophysical instrument between what is in the grave and the surrounding natural soil matrix. If the displaced soil from the excavation of the grave is piled to the side of the grave as the shaft is being dug and then replaced over the body in the reverse order with the deeper soil on the top of the pile shoveled back into the grave first, there may not be any differentiation between the displaced soil and the surrounding unexcavated soil. If the soil is not compacted during its replacement, there may be no contrast in compaction between the surrounding soil matrix and the displaced soil. These factors would affect the ability of the geophysical instruments to detect the change between the surrounding soil matrix and the disturbed excavated soil of the grave. If the soil moisture levels between the disturbed and undisturbed soil matrices are approximately the same, then the geophysical instruments may not be able to detect any contrasts. Depending on how the individual was buried (e.g., in a coffin, blanket/shroud, or clothes), there may be metal objects on the body or in the coffin furniture that could be detected by a magnetic, conductivity, or ground-penetrating radar survey. The ability of the geophysical instruments to detect a grave is based on the presence of significant changes in the property being measured by the instrument. If there is no contrast or very little contrast in magnetic properties, conductivity, resistance, dielectric constant, the geophysical instruments will not register a contrast in the data and the grave will be indistinguishable from the surrounding natural/undisturbed soil matrix.

Several attributes of graves can result in successful detection (Bevan 1991; King et al. 1993). These include air pockets in intact coffins, a metal coffin or framework, loose fill in a collapsed coffin, and disturbed stratigraphy in the grave shaft. Troublesome features include large rocks, animal dens, tree roots, naturally occurring lenses of contrasting soil and other complex natural stratigraphy. In some cases, the distribution of excess soil around the area of a grave may make it difficult to precisely locate the actual grave shaft. One thing is clear: it is difficult to predict the success of any geophysical technique on the basis of work in other depositional contexts or with other cultural traditions. Certainly one should not be surprised if similar features (graves) produce quite different anomaly patterns in different areas or even within different soil types in a local area.

7. FIELD SURVEY PROCEDURES

The survey scope-of-work for the Sac and Fox Nation cemetery (25RH122) project called for magnetic, resistivity/conductivity, and ground penetrating radar surveys of the area associated with known cemetery in order to identify the extent and location of possible graves (Figure 12). It also called for the possible use of a digital compaction meter if time permitted. The survey was to cover an area approximately 40 meters by 40 meters in the general location of the cemetery as identified by tribal members and oral history. The geophysical grids were laid out at the project location with a portable Ushikata S-25 Tracon surveying compass (Ushikata n.d.) and 100 meter tape. The surveying compass was used to sight in the two perpendicular base lines and grid corners. Wooden hub stakes were placed at the 20-meter grid corners or at 10-meter midpoints. A datum point was established at the southwest grid corner.

Once the geophysical grid was established, a Nikon DTM-730 electronic field station (Nikon 1993) was positioned over the site datum or mapping station. Arbitrary values were assigned to the Northing (N) or y coordinate , Easting (E) or x coordinate, and elevation (Z coordinate) of the mapping station (Note: these values were North 500 meters and East 500 meters with an elevation of 500 meters). The backsight reference point for the project was aligned on magnetic north. The site features, geophysical grid points, and topography were mapped with the field station, prism, and prism pole. The data were stored on the memory card of the DTM-730 and subsequently downloaded into a laptop computer. Initially the coordinate data (i.e., survey codes, northing coordinates, easting coordinates, and elevation) and raw field data (i.e., survey codes, horizontal angle, vertical angle, slope distance) files were transferred from the field station to the laptop computer with the Transit software package (Nikon 1996). These data files for each site were then transferred to the WordStar 5.5 software package (MicroPro 1989). The extraneous information in the coordinate data files were removed leaving the northing (Y) coordinates, easting (X) coordinates, elevations (Z coordinates), and point descriptions. This locational information was then converted to an XYZ data (dat) file for processing in the SURFER 8 mapping software (Golden Software 2002).

Once in SURFER 8, a grid file was created from the data file (Golden Software 2002:89-161). The data columns were identified. Column B contained the X values or the East coordinates. Column A contained the Y values or North coordinates. Column C contained the Z or elevation values. Column D contained the description of the individual points. The grid line geometry was set for minimum and maximum values in both the X and Y directions. These values formed the corner points for the generated contour maps. The data were gridded using the Kriging algorithm (Golden Software 2002:17-121). The generated grid file was then smoothed (Golden Software 2002:383-387). The spline smoothing routine was selected to eliminate the angular contours by rounding the edges using a cubic spline interpolation over the gridded data. The grid file defined the XY locations of each grid node over the extent of the map and the interpolated Z value at each node. Finally, a blanking file was created and the blanking routine was run over the topographic data set. (Golden Software 2002:403-405). The blanking routine removed grid mode data from the area of the grid that did not contain any original data in order to eliminate contour lines in that area.

A contour map was then created from the grid file (Golden Software 202:197-230). The contour map consisted of several components, which defined the appearance of the contour map (Figure 13). These included the contour level, which defined the interval between contour lines. The line component determined the appearance of the contour lines, including type, thickness, and color. The area between the contour lines could be filled with a gradually changing spectrum of colors. The labeling feature allowed for the placement of the contour value on the contour lines. This component controlled the text properties, numeric format, spacing, and interval of the labels. Hachures or small tick marks could also be placed along the contour lines to indicate the direction of slope. These were generally not used in the generation of the topographic or feature maps, but were used for indicating negative values in the geophysical data. The contour lines were drawn as a series of smoothed line segments between adjacent grid lines. Feature maps were generated and labeled for each site. A map posting the location of the individual feature points was also generated (Golden Software 2002:241-258) and overlain (Golden Software 2002:373-380) on the contour map. The points were used to draw objects including lines, polygons, and points; to label specific features; to change the appearance of the objects; and to assign unique symbols to classes of objects (Golden Software 2002:467-492). A scale bar and north arrow were added to the finished contour map. The project area's natural and cultural features were also labeled.

Before the start of the geophysical survey, yellow nylon ropes were laid out on the grids. These ropes served as guide ropes during the actual data acquisition phases of the project. Twenty-meter ropes were placed along the top and bottom base lines connecting the grid corners. These ropes formed the boundaries of each grid during the data collection phase of the survey. Additional traverse ropes were placed a one-meter intervals across the grid at a perpendicular orientation to the base lines beginning with the line connecting the two wooden hubs on the left side of the grid unit. These ropes serve as guides during the data acquisition. These 20-meter lengths of ropes are divided into 0.5 meter increments by different colored tape. One color (blue) is placed every meter along the rope with a different colored (red) tape placed at half-meter intervals. The use of different colored tape on the ropes provides a simple way to maintain one's position within the geophysical survey grid unit as data are being collected. The geophysical data were therefore recorded in a series of evenly spaced parallel lines with measurements taken at regular intervals along each line resulting in a matrix of recorded measurements (Kvamme 2001:356; Scollar et al. 1990:478-488). Beginning in the lower left-hand corner of the grid, data collection occurred in a parallel (unidirectional) or zigzag (bi-directional) mode across the grid(s) until the survey was completed for each technique.

FIELD SURVEY PROCEDURES

Magnetic Survey Methodology

The magnetic survey was conducted with a Geoscan Research FM36 fluxgate gradiometer with a ST1 sample trigger (Geoscan Research 1987). MWAC archeologist and co-author Steven L. De Vore operated the instrument (Figure 14). The instrument is a vector magnetometer, which measures the strength of the magnetic field in a particular direction. The gradiometer consists of a control unit that contains the electronics, menu keyboard pad, power source, operating program, on-off switch, connector for the charger/ data output/external logger, analog output connector, LCD display screen, sounder outlet, balance control, and memory chips (Geoscan Research 1987:8-10). The tubular carrying handle connects the control unit to the vertical sensor housing tube that contains the two fluxgate sensors. N/S and E/W sensor alignment controls are located on the sensor tube.

The sensors are set at 0.5 meters apart from one another. The instrument is carried so the two sensors are vertical to one another. Height of the bottom sensor above the ground is relative to the height of the surveyor. In the carrying mode at the side of the body, the bottom sensor is approximately 0.30 meters above the ground. Two readings are taken at each point along the survey traverse, one at the upper sensor and one at the lower sensor. The difference or gradient between the two sensors is calculated (bottom minus top) and recorded in the instrument's memory. Each sensor reads the magnetic field strength at its height above the ground. The gradient or change of the magnetic field strength between the two sensors is recorded in the instrument's memory. This gradient is not in absolute field values but rather voltage changes, which are calibrated in terms of the magnetic field. The fluxgate gradiometer does provide a continuous record of field strength. With a built-in data logger, the gradiometer provides fast and efficient survey data collection. Typically, data across a 20m by 20m grid unit with sampling parameters of eight samples per meter and one-meter traverses in the zigzag mode of operation can be collected in 15 minutes. This amounts to 3,200 readings per survey grid. With eight samples per meter and one-half meter traverses in the zigzag mode, it takes approximately 30 minutes to complete a 20m by 20 m grid. This amounts to 6,400 readings per survey grid.

Prior to the start of the survey, the memory of the gradiometer is cleared and the menu settings are checked for the appropriately planned survey. The operator must be free of any magnetic metal. If any clothing or objects carried by the operator is slightly magnetic, there is a high probability that the survey results will be degraded due to presence of magnetic materials in close proximity to the sensors in the instrument. As one walks along the traverse, the presence of magnetic materials on the operator will resulting in a shift in the readings of 1 to 2 nT or greater. This will cause a stripe effect to the data. In the case of the present project at all four sites, the gradiometer is programmed for a resolution of 0.1nT, reading average off, log zero drift off, log interval at 0.25 m, baud rate of 2400, average period set to 16 readings, check offset off, and the encoder external trigger type. When the instrument is turned on, the initial LCD display indicates the current display resolution, the status of the log drift facility, and the battery status. The resolution display reading can be either positive or negative and with the instrument set to the 0.1 nT resolution mode, the maximum value recorded is 204.7 nT. Although some magnetic anomalies may be stronger in the positive and negative values, the instrument defaults to a program recognized value (2047.5) when these extremely strong values are observed. Generally such strong fields result from the close proximity of highly magnetic iron artifacts to the instrument. On the sample trigger, the samples/m knob is set to 8 samples/m and the rate knob is located at the 1 o'clock position. The toggle switch is set to the stop position. The grid size interval in the instrument and the traverse m knob on the sample trigger must be set to the same value. The value is set to 20 for the 20-m by 20-m grid unit size.

The sensors must be accurately balanced and aligned along the direction of the field component to be measured. The zero reference point was established at N520/E540 grid corner and the balancing and alignment procedures were oriented to magnetic north. This point was selected where there were no noticeable localized changes in the digital display or by raising the instrument above the ground with the use of a plastic step stool. The readings should vary less than 2 to 3 nT. The balance control on the instrument was adjusted first. The balancing the instrument was conducted in the 1 nT resolution range by first inverting the instrument and zeroing the instrument. The instrument was then rotated 180 degrees about the same horizontal plane of the axis of the handle. The trimming tool was inserted into the balance control slot on the side of the instrument and the reading in the digital display was reduced in half. The procedure was repeated until the reading in the upright and inverted positions was within a range of –1 to 1 nT. With the instrument held vertically at a height where the alignment controls were within easy reach, the two sensors were then aligned. At first, the bottom sensor was aligned. The instrument was pointed to magnetic north and the instrument was zeroed so that the display reading was zero. The instrument was then rotated around the sensor tube 180 degrees until it pointed south. The small aluminum wheel of the N-S alignment control at the bottom of the tube was used to adjust the sensor until the reading was half of the value first observed when it was rotated to the south. The instrument was rotated back 180 degrees until it pointed to magnetic north and rezeroed. The display reading was checked. If the north reading was within the range of –1 to 1 nT, the alignment was considered successful and the bottom sensor was aligned. If the north reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the bottom sensor was aligned, the top sensor was then aligned. The instrument was rotated 90 degrees until it faced east. The instrument was zeroed and then rotated 180 degrees until it faced west. The display reading was noted. The E-W alignment control wheel at the top of the sensor tube was adjusted until the reading was half of the observed reading. The instrument was then returned to its east facing position and rezeroed. If the east reading was within the range of –1 to 1 nT, the alignment was considered successful and the top sensor was aligned. If the east reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the top sensor was aligned, the top sensor was then aligned. As a final check, the instrument was rotated 360 degrees about the vertical tube axis. If the display reading stayed within the –1 and 1 nT range, the sensor alignment procedures were considered successful. If the observed display readings went over the acceptable range, the balancing and alignment procedures were repeated until successful. The instrument was returned to the 0.1 nT resolution operating range and then zeroed at arms length over the operator's head. The operator's manual (Geoscan Research 1987:29-31) illustrates the steps involved in preparing the instrument for actual field data collection.

The survey of each traverse was conducted in a zig-zag or bidirectional mode beginning in the southwest corner or lower left-hand corner of each grid unit. With the instrument on, the Enable Log button on the menu pad is pushed to initialize the logging display mode. The LCD screen displayed the starting Grid Number (G1), the Line Number (L1), and the Position Number (P1). The toggle switch on the sample trigger was moved to the start position and the operator began walking the traverse line. The instrument was carried along the traverse rope with control box facing magnetic north. The sample trigger on the instrument provided a series of clicks for every sample reading and the instrument signals a beep on every eighth sample reading. As each measurement was recorded, the logging display was advanced one position until reaching the end of the line and then the line number advanced. The grid number advanced when the end of the grid was reached. The geophysical investigator maintained a pace along the traverse in accordance with the audio beeps from the fluxgate gradiometer. This placed the eighth sample reading at the meter tape mark. At the end of the first traverse, the instrument stopped collecting and recording the data. The toggle switch was moved to the stop position. At the end of each line, the operator moved over to the next traverse, revered his direction of travel, and proceeded back down the next traverse line towards the starting edge of the grid unit. The zigzag mode of data acquisition was repeated over and over until the end of the grid was reached. At the end of the grid, the instrument was turned off. The operator maintained a constant vigilance of the tilt of the instrument throughout the survey. The gradiometer was maintained in a vertical position during data acquisition. Any rotation or tilt in the instrument could cause errors of shifts in the readings of 1 to 2 nT or more.

During the survey, data were collected at 8 samples per meter (0.125 m) along each traverse and at half-meter traverses across each individual grid unit resulting in 16 samples per square meter. A total of 160 magnetic measurements were recorded for each traverse in the memory of the Geoscan Research FM36 fluxgate gradiometer. For each complete 20- by 20-meter grid unit, a total of 6,400 measurements was recorded during the magnetic survey. The instrument's memory can hold data acquired from two grid units. At the end of the data acquisition of two grid units, the magnetic data from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research) on a laptop computer. It took approximately 26 minutes to download the data from the two complete 20 m by 20 m grid units. The grid files created in GEOPLOT were reviewed in the field prior to the clearing of the gradiometer's memory.

Ground-penetrating Radar Survey Methodology

The Noggin^{Plus} 250 Smart Cart System GPR unit produced by Sensors and Software (2001) is used for the Sac and Fox cemetery project. The GPR unit is operated and owned by Site Sensors consultant and co-author Robert K. Nickel (Figure 15). The Smart Cart System consists of the cart, an antenna, an odometer wheel, a Digital Video Logger (DVL), and a battery. The Noggin antenna used in the present project operates at a nominal frequency of 250 MHz (megahertz) and is mounted in a cart that records the location of the radar unit along a grid line. The antenna separation or spacing is 0.034 meters.

The DVL contains the operating Noggins^{Plus} software, and provides a visual display of the data, which allows the results to be viewed almost immediately as they are recorded. The DVL also stores the digital radar profile data. The DVL is connected to the battery and to the antenna by a Y-shaped sensor cable. Prior to the start of the GPR survey, the operating parameters are set in the DVL. For the present project, the depth unit is set to time in nanoseconds (ns) and the horizontal distance unit is in meters. A 50 ns time window is used for the present project. The data were recorded with "stacking" set at two, which means that two measurements were made for each trace location and their average was calculated and stored. Stacking is used to reduce undesirable minor variations from reading to reading. A stacking level of two is low. The interval between traces along each traverse was set at 2.5 cm (.96 inch). The Noggin 250 has a normal data trace of 5 centimeters. The trace is fixed distance interval (i.e., station interval) over which one vertical strip of data is recorded. Collecting several traces at each survey position and then averaging them into a single averaged trace is one way of increasing data quality and reduces random radio frequency noise or interference. The Noggin 250 antenna has an antenna separation of 0.3048 meters with a pulser voltage of 100 volts. The survey mode is reflection.

The odometer is set to active, which allows it to be used to collect data. As the cart moves, data is collected; however, if the cart stops, then the system stops collecting data. Without the activation of the odometer, the system operates continuously. The cart is pushed along each traverse in a forward direction.

GPR surveys often involve a trade-off between depth of detection and detail. Lower frequency antennae permit detection of features at greater depth but they cannot resolve objects or strata that are as small as those detectable by higher frequency antennae. Actual maximum depth of detection also depends upon the electrical properties of the soil. If one has an open excavation one can place a steel rod in the wall of the excavation at a known depth and use the observed radar reflection to calibrate the radar charts. When it is not possible to place a target at a known depth one can use values from comparable soils and achieve reasonable estimates of the velocity of the radar signal in the site's soil.

The data acquisition parameter for the GPR system is set to the grid mode. This allows the operator to set the grid dimensions, line spacing, grid type, and survey format. The Grid collection mode allowed for the collection of the radar profiles in an organized pattern over the project area. The grid parameter also allows for the production of a plan-view map of the grid. The grid type specifies the way data is collected along the traverses. The data lines or traverses run in the Y or north direction. The survey format specifies how the data in the lines are collected. The data are collected in a ziz-zag or bi-directional mode starting with 0 with the even numbered lines in the forward direction and the odd number lines in the reverse direction. The line spacing is 0.5 meters between the traverses or survey lines. The digital GPR data for each line in the grid is saved in the *.dt1 file format by line number and direction (Liney*.dt1). Information about the parameters of each line is also saved in a header file (Liney*.hd). The header file contains information on the program type (i.e., Noggin^{Plus}), the date, number of traces, number of points per trace, time zero at point, total window time, starting position, final position, step size used, position units, nominal frequency of antenna, antenna separation between transmitting and receiving antenna, pulser voltage, number of stacks, and survey mode. The data is transferred from the DVL to a laptop computer at the end of the day using the WinPXFER program designed by Sensors and Software (2001:87-90). Once the data are reviewed in the laptop computer, the data are then deleted on the DVL.

Ground Conductivity Survey Methodology

The present survey utilizes a Geonics EM38 ground conductivity meter (Geonics Limited 1992). The instrument is operated by MWAC archeologist Steven L. DeVore. The instrument is lightweight and approximately one meter in length (Figure 16). The meter consists of the transmitting and receiving coils embedded in the case of the instrument, a 9 volt battery, horizontal and vertical digital displays, recorder connector, and control panel. The control panel contains the conductivity range switch with two settings (1000 millisiemens/meter and 100 millisiemens/meter), on/off/battery test switch, a fine and course inphase (I.P) zero controls, a phase adjustment knob, the quadrature phase (Q/P) zero control, and a toggle switch for Q/P and I/P modes. The transmitting and receiving coils are located at opposite ends of the meter with an intercoil spacing of one meter. It has an operating frequency of 14.6 kHz in the 100 mS/m range and 40.4 kHz in the 1000 mS/m range. The conductivity meter can collect conductivity data in the quadrature phase operating mode or magnetic susceptibility data in the in-phase operating mode. The present ground conductivity survey is operated in the quadrature phase. The EM38 ground conductivity meter has a depth of investigation of approximately 1.5 meters in the vertical dipole mode with optimum resolution at 0.6 meters. An adjustable tubular handle is attached to the meter for carrying during survey. The handle also contains the manual trigger button.

Prior to the start of data acquisition, the meter must be nulled and the battery checked for nominal operating voltage. The battery test is conducted at the beginning of the survey and start of each day or when the voltage is thought to be low. With the range switch in the 1000 mS/m position and the battery test switch to BATT, a good battery should have a display of over –720 units. The battery is replaced if the display is below -720. After the battery check, the instrument is nulled in the inphase mode and then zeroed in the quadrature phase mode. Nulling in conducted at the beginning of the survey at a single reference point. For the present project, the reference point used to null the EM38 is located at N520/E512. Since the EM38 measures ground conductivity by inducing very small electrical eddy currents into the ground and measuring the magnetic field that these currents generate, it is important to null the larger primary signal produced by the transmitting coil so that the electronic circuitry is not overloaded by the primary signal. All metal objects must be removed from the operator prior to beginning the initial inphase nulling operation. The range switch is set to the 1000 mS/m position. The instrument is positioned at a height of 1.5 meters above the reference point in the vertical dipole position (upright). The mode toggle switch is set to the I/P position. The meter is nulled by first adjusting the I/P course knob and then the fine I/P knob until the display reads zero. The range switch is then set to the 100 mS/m position and the procedures are repeated. The meter is successfully nulled when the meter reads approximately zero (±10 mS/m) on the 100 mS/m setting at 1.5 meters above the ground. The instrument is then zeroed. The instrument zeroing is conducted at the beginning of the survey and checked three to four times throughout the day. Using the same reference point and with the instrument at a height of 1.5 meters above the ground, the mode toggle switch is set to the normal Q/P position. With instrument in the horizontal dipole position (flat) and the range switch set to 100 mS/m, adjust the Q/P Zero Control until the meter reads 50 mS/m. This value is referred to as **H**. Without changing the instrument height rotate the EM38 about its long axis to the vertical dipole position. The value in this position is referred to as **V**. Regardless of any layering in the earth at a height of 1.5 meters, **V** should equal twice **H** (**V=2H**). If it doesn't, then the Q/P Zero is not set correctly. To adjust the Q/P Zero, one needs to calculate the correlation **C** value that affects **V** and **H** equally (**C=V-2H**). With the meter in either the horizontal or vertical dipole position, adjust the Q/P Zero Control by the correlation value. Turn the control in the direction of higher conductivity if the value is positive and lower conductivity if the value is negative. One repeats the adjustment of the vertical and horizontal dipole measurements until the instrument zero is set correctly. After the Q/P Zero is set, the instrument needs final inphase nulling before commencing the survey. The final inphase nulling is carried out as previously mentioned for the initial inphase nulling procedure, except the EM38 is placed on the ground in the vertical dipole position.

The meter is connected to the Omnidata DL720 Polycorder (Geonics 1998) for digital data acquisition after the nulling and zeroing procedures have been completed. Data were collected in the continuous mode and stored in the Polycorder's memory. The data stored in the Polycorder were downloaded into the laptop computer at the end of the day for processing in the Geonics DAT38 software (Geonics 1997). The polycorder contains the EM38 operating program along with BATTERY, CREATEDIR, FILE DIR, and DEMO programs. The EM38 program acquires and records the data from the EM38 ground conductivity meter. It also record field survey information (i.e., survey line number, starting station, survey increment, recorded phase component, survey comments, etc.). It is important to note that data files can not be appended. So if a mistake is made in the file setup or during the survey, or if the polycorder is turned off, one can not use the same file. A new one, including file name, must be created. The BATTERY program is used to check the voltage status of the polycorder's rechargeable battery pack. FILEDIR has to be present for the EM38 program to run. The CREATEDIR program creates a directory file FILEDIR if it is deleted by mistake or if the data files are erased manually. The DEMO program is used to examine the voltage output of any analog channel in the Polycorder. With the polycorder connected to the EM38 and the EM38 on and in the Q/P mode, the polycorder is turned on. At the mode prompt, 0 (zero) is selected to initiate the polycorder program setup. The EM38 program is then selected and executed. The polycorder prompt requires confirmation of the Polycorder clock setting. The digital instrument type is selected. The operator is then requested to provide a file name. The file name can be up to 8 alphanumeric characters in length. The Polycorder creates two files with this name, a header file and a data file. The operator is then prompted for the GPS option (global positioning system), which is answered with no. The operator then selects the survey phase type (Q for quadrature or conductivity; I for inphase or susceptibility; or B for both), the mode (V for vertical dipole; H for horizontal dipole; or B for both), and the number of orientations (1 or 2; can be in 0 and 90 degree rotation about the common axis or at two different heights about the ground). For the present survey, Q was selected for the survey phase type. V was selected for the vertical dipole position, and 1 was selected of the number of orientations. The operator can provide his or her name and additional comments in the operator and comment fields. The polycorder can be set to the automatic data collection mode or to the manual mode. The automatic collection mode was selected. The polycorder then prompts for the time interval in seconds between data readings which was set at 0.5 seconds. The polycorder then prompts the operator for the line number, line direction, start station, and increment in the positive or negative direction. After all the information requested for the file setup has been completed, EM38 program provides the ready prompt after which the operator presses the enter key to start the logging. From that point on, the data is automatically logged until the end of the line is reached. The enter key is pressed at the end of the line to stop further data collection. The line "L" key is pressed to end the collection of data along the traverse line to start the next line. The EM38 program then prompts for the new survey line number, direction, start station, and increment. All prompts must be answered before the operator starts the next line. Upon completion of the grid, the file is closed with the end option, and the operator is returned to file setup routine.

The ground conductivity survey was designed to collect 4 samples per meter along 0.5-meter traverses or 8 data values per square meter. The data were collected in a parallel fashion with the surveyor returning to the starting side of the grid and maintaining the same direction of travel for each traverse across the grid. A total of 12,360 data values were collected over the four grid units. The data were downloaded to a laptop computer for processing.

SAC AND FOX MULTIPLE FAMILY CEMETERY

8. DATA PROCESSING AND INTERPRETATION

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme 2001:365; Music 1995; Neubauer et al. 1996). Walker and Somers (2001) provide strategies, alternatives, and case studies on the use of several processing routines commonly used with the Geoscan Research instruments in the GEOPLOT software manual. Kvamme (2001:365) provides a series of common steps used in computer processing of geophysical data:

Concatenation of the data from individual survey grids into a single composite matrix;

Clipping and despiking of extreme values (that may result, for example, from introduced pieces of iron in magnetic data);

Edge matching of data values in adjacent grids through balancing of brightness and contrast (i.e., means and standard deviations);

Filtering to emphasize high-frequency changes and smooth statistical noise in the data;

Contrast enhancement through saturation of high and low values or histogram modification; and

Interpolation to improve image continuity and interpretation.

It is also important to understand the reasons for data processing and display (Gaffney et al. 1991:11). They enhance the analyst's ability to interpret the relatively huge data sets collected during the geophysical survey. The type of display can help the geophysical investigator present his interpretation of the data to the archeologist who will ultimately use the information to plan excavations or determine the archeological significance of the site from the geophysical data.

Processing Magnetic Data

Due to the limited memory capacity and changes in the instrument setup of the FM36 fluxgate gradiometer, the data were downloaded into a laptop computer after the completion of two grid units at the site. On the laptop computer, the GEOPLOT software was initialized and the download data routine was selected from the file menu (Geoscan Research 2001:4/1-4/27). The default input template was then selected. The selection of the gradiometer and FM36 were then made. The grid input template was displayed. For the gradiometer survey, the survey information was entered under the general category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 3). The next step required entering the grid names for downloading data from the FM36. In the grid names for downloading screen, the file names for each grid unit were entered into the laptop computer. The grid files contained the magnetic raw data obtained during the survey. The file names for the grid units included the grid number followed by the letter “g” for the gradiometer survey type (i.e., 1g, 2g, 3g, and 4g). The download instructions screen was displayed after the file names were checked for duplicate names in the laptop computer and entered into the laptop computer. The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The DUMP key on the FM36 keyboard was depressed and the download process was initiated. Downloading the magnetic data from a typical 20-m by 20-m grid unit at 8 samples/m and 0.5 m traverses required approximately 13 minutes to complete the download process. The FM36 was then switched off and disconnected from the laptop computer. The grid files were reviewed in the shade plot display under the graphics menu in the Geoscan Research GEOPLOT processing software (Geoscan Research 2001) for data transfer or survey errors. If no data transfer errors were observed, a composite of the grid files was created for further data processing. Generally, while in the field, the composite file was processed with the zero mean traverse routine and viewed on the laptop computer before the memory in the gradiometer was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. Grids actually consist of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the magnetic data, the grid files from the survey must be combined into a composite file. To construct a composite file containing all of the grid files collected at a site, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2001:5/2). The master grid file names screen is displayed and the grid files are entered into the mesh template by the grid position in the overall survey of the site. The mesh template defines how the grids fit adjacent to one another within the surveyed area. The grid files are entered into the mesh cells according to their position beginning in the upper left hand corner of the surveyed area. For grids that are in the line of travel or traverse direction (X direction on the template), the grid names are placed from left to right in the mesh cells on the screen display. Grids that are perpendicular to the traverse direction (Y direction on the template) are placed from the top cell to the bottom cell of the mesh template. The GEOPLOT survey directions have the display the line of travel along the traverse on the X axis and the movement across the grid along the Y axis. This format is also followed for the creation of the composite file. Once the grid files have been placed in the correct position in the mesh template, the composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file name included the field acronym for the site (sfc) and the letter "g" for the gradiometer survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite files for the magnetic data collected at each site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2001:5/2-5/3). In order to continue to analyze the data, the grid or composite files must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window with clip between a minimum value of –3, maximum value of 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Inspection of the background should show the data as bipolar and centered on zero. There should be a broad range in the archeological anomalies with weak anomalies less than 1 nT, typical 1 nT to 20 nT anomalies, strong anomalies greater than 20 nT. If the anomalies are weak then reset the clip plotting parameter to a minimum of –2, a maximum of 2, and units to absolute. Then one should identify weak and strong ferrous anomalies, which often represent modern intrusions into the site such as localized surface iron trash, wire fences, iron dumps, pipelines, and utility lines. Geological trends in the data set should also be identified. Since gradiometers provide inherent high pass filtering, broad scale geological trends are already removed from the data set. If such trends appear to exist, there may be changes in the topsoil thickness, natural depressions, igneous dikes or other geomorphological changes in the landscape. Final step prior to processing the data is to identify any defects in the data. These can range from periodic errors appearing as linear bands perpendicular to the traverse direction, slope errors appearing as shifts in the background between the first and last traverses, grid edge mismatches where discontinuities exist between grids, traverse striping consisting of alternating stripes in the traverse direction which most commonly occurs during zigzag or bi-directional surveys, and stager errors resulting in the displacement of a feature on alternate traverses (Geoscan Research 2001:Reference Card 3).

Initially, the spectrum function (Walker and Somers 1994:9/16,9/101-9/110) was applied to the data. The spectrum function provided analysis of the frequency spectrum of the data, splitting it into amplitude, phase, real, or imaginary components. The amplitude component was selected for the analysis to identify any periodic defects. These defects may have been the effects of cultivation (e.g., plow marks, ridge and furrow) or operator induced defects during data acquisition). It operated over the entire site data set. The spike tolerance was left in the default on position. This had the effect of reducing any broad spectral energy from noise spikes in the data set. No periodic defects were noted in the data set.

The magnetic data were “cleaned up” using the zero mean traverse algorithm (Walker and Somers 1994:9/17,9/125-9/129). This algorithm was used to set the background mean of each traverse within a grid to zero, which removed any stripping effects resulting from “scan to scan instrument and operator bias defects” (Jones and Maki 2002:16). It also was useful in removing grid edge discontinuities between multiple grids. The algorithm utilized the least mean square straight line fit and removal default setting on over the entire composite data set.

The statistics function (Walker and Somers 1994:9/17,9/115-9/116) was then applied to the entire magnetic data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The magnetic data ranged from –190.18 to 238.65 nT with a mean of 1.229 and a standard deviation of 20.142. The relatively high mean represents the affect of the large amount of historic iron material present at the project location. Generally, the mean should approximate zero, which represents the background magnetic.

The data set is interpolated to produce a uniform and evenly spaced data matrix (Walker and Somers 1994:9/16,9/67-9/69). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is an 8 x 2 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinx/x or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements is expanded using the sinx/x method. This yields a 8 x 4 data matrix. In the X direction, the number of data measurements are shrunk using the sinx/x method. This yields a 4 x 4 matrix.

The low pass filter was then used to remove high-frequency, small scale spatial details over the entire data set (Walker and Somers 1994:9/16,9/71-9/74). It was also used to smooth the data and to enhance larger weak anomalies. The function scanned the data set with a gaussian weighted, rectangular window set to the default values for the X radius of 1 unit and the Y radius of 1 unit.

The composite data files were then exported to separate xyz files for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2001:5/4-5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file names remained the same for all the files. The files were the exported to "expdata" folder in GEOPLOT. The files are then transferred to an appropriately named site folder in the SURFER 8 contouring and 3d surface mapping program's project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The open file command is selected to open the zero mean traverse, interpolate, and low pass filter processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/4** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/4** to provide the correct traverse interval position for the data. The value 500 was added to both the North and East coordinate values in order to express the results into the total station mapped coordinate system. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. Due to the large ranges of values, the data are also clipped to 20 for data values greater than 20 nT and to –20 for data values less than –20 nT. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 1999). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of lines field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For the present project, the data columns consist of 500 to 540 in the North or Y direction, 500 to 540 in the East or X direction with the X-spacing of 0.25 and the Y-spacing of 0.25. The Kriging gridding method was selected for processing the data. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name. Due to the presence of a small unsurveyed area in the northwest corner of the grid (10 x 9 m), a blanking file was constructed and applied to the grid file. The blanking file contains the X and Y coordinates used to outline the blanked portion of the grid, as well as, the number of parameter points and whether the blanking operation is located on the interior of the parameter points or on the exterior of these points. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 1999). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated (Figure 17). The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. The image map is created by selecting the image map operation from the map menu and opening the grid file. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a gradulated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another way to represent geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. Contour maps are useful in determining the strength of the magnetic anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the magnetic data.

Processing Ground-penetrating Radar Data

Initially, the GPR data is transferred from the DVL to a laptop computer through the parallel XFER cable using the Sensors and Software's WinPXFER program (Sensors and Software 2001:87-90). The WinPXFER software is started. On the DVL, the data in the Grid Project's current projects screen are selected from the DVL main menu. The data are transferred and stored in a sub-folder from the current data directory on the laptop computer. The data transfer progress is displayed on both the DVL and computer screens. After the GPR data files have been reviewed and verified in the laptop computer, the Grid Project's current projects in the DVL may be cleared from memory.

The GPR data from the project are processed by Sensors and Software's EKKO_ Mapper software (Sensors and Software 2002) which provides both profile or cross-sections (Figure 18) and time/depth slices or plan-view presentations (Figure 19) of the amplitude data. Since the traces within the forward and reverse lines are automatically positioned in the Noggin Smart System (Sensors and Software 2002:6), it is not necessary to manually reverse every second line. A new mapping project is opened under the new routine in the file menu or an existing project may be opened under the open or recent projects routines in the file menu. GPR lines to be included in the plan-view map are listed using the input lines menu (Sensors and Software 2002:10). The GPR data files (*.dt1) must be listed in the same folder. The direction of travel (y direction) is selected. The starting position and the traverse separation distance (0.5 m) are specified for the grid GPR data. The input lines menu also contains the routine for reversing GPR data is needed. The next step is to process the data. The process data menu contains several routines used to specify the details of the finished plain-view display (Sensors and Software 2002:10-12). These operations include a high pass filter to remove low frequency "wow" transmitter noise in the data, a down-the–trace filter to reduce the high frequency noise, a trace-to-trace averaging filter to emphasize horizontal reflectors, a background subtraction operation to remove horizontal reflectors, and a migration operation to collapse hyperbolas to point targets. Since all GPR maps are displays of the signal amplitude plotted is its X and Y positions, the software has four amplitude types (Sensors and Software 2002:21-24) available for mapping (i.e., raw, RMS, rectified, and enveloped). The raw amplitude when averaged over a time or depth range contains negative and positive values. The other three types convert the converts the trace data to positive values. Rectified, RMS, and enveloped amplitude values are recommended for the production of the display plots. The slices option provides the means to specify the number and type of plot either in time slices or depth slices. Times slices are generally used since GPR systems record the time for the radar or radio waves to travel to a target and return to the GPR unit. Depth has to be calculated before it can be used. Depth depends on the velocity of the wave to the target and back. Depth is determined by the following equation: **D = V x T/2** where **D** is depth (meters), **V** is velocity (meters/nanosecond), and **T** is the two-way travel time (nanoseconds). Velocity of the radar wave is determined by the dielectric permittivity of the material (Conyers and Goodman 1997:31-35; Sheriff 1973:51). Other physical parameters that affect the transmission of the radar wave include the magnetic permeability and electrical conductivity of the material. Increases or decreases in these parameters may increase the velocity, slow it down, or attenuate it so there is no reflected signal. In most heterogeneous soils, the various soil layers have differing affects on the velocity of the radar wave. The velocity may be estimated using velocity charts of common materials or (Sensors and Software 2002:29) or by identifying reflections in GPR profiles caused by buried objects, artifacts, or stratigraphic soil/sediment layers (Conyers and Goodman 1997:107-135).

The estimated velocity is used to determine depth parameters if depth slice windows are used to display the GPR data. The plots used in this report were calculated using a value of ca. 0.1 m/ns. The plot maps menu provides three map or visual display outputs: 1) processed map, 2) penetration map, and 3) noise map (Sensors and Software 2002:32-35). The GPR plain-view plots are created under the processed map operation as time slice maps. Individual GPR line profiles are displayed under the plot section menu (Sensors and Software 2002:36-43).

Processing Ground Conductivity Data

The ground conductivity data were downloaded into a laptop computer after the completion of survey at each site. The Polycorder 720 was connected to the laptop computer via the serial port by means of a 25 pin to 9 pin converter cable (Geonics 1997:19). On the laptop computer, the DAT38RT software was initialized and the copy files from Polycorder 720 routine was selected from the menu (Geonics 1997:19-25). The default fast mode was selected for copying or downloading the data from the Polycorder to the laptop computer. The fast mode permits the rapid transfer of all data files in the Polycorder's dirfile directory. The header and data files for each site are also sequentially copied and then simultaneously converted to the DAT38 file format. The dump program is selected on the Polycorder. The Ploycorder parameters for communications with the laptop are set to a baud rate of 9600 with 8 data bits, No parity and the Mating call equal to <CR>. At the ready prompt on the Polycorder, the Polycorder is driven by the laptop computer. Selecting the entry key on the laptop computer, the fast file copy from Polycorder 720 screen is displayed. The first prompt on the laptop computer asks for the Polycorder's file names. All is entered or the enter key is selected. The second prompt asks for the disk files in the Polycorder format. Two files are created for each site data file (i.e., the header file with H prefix plus file name and the data file with the D prefix plus file name). The third prompt identified the created file in DAT38 format. The Polycorder header and data files (i.e., the DL files) are converted into the DAT38 format with the file name and "G38" extension identifier). The serial port is set to com1. The copy files routine is selected from the menu on the laptop computer. The header file is transferred first followed by the data from each site file from the Polycorder to the laptop computer. Once the files have been transferred to the laptop computer, the next step is to create the data files. The enter data files routine is opened in the DAT38 program (Geonics 1997:35-37). A list of entered survey files is displayed in the window. The DAT38 (*.G38) file is selected. The screen then displays the profile lines within the file (with Component/Mode/ Orientation). Information including the measured component (i.e., conductivity phase), mode (i.e., vertical), and orientation (i.e., 1) are listed next to the line numbers. All of the lines in the file are selected by pressing <ENTER>. The final stage in the preparation of the data files for processing is the creation of the surfer XYZ (*.dat) files in ASCII format. The write file for contour package subroutine is selected from the main DAT38 menu (Geonics 1997:62-65). The surfer format is selected for the format of the created file. A file name is given to the finished file. The dipoles mode, instrument orientation, component, and survey geometry fields are left in the default values of vertical, 1, conductivity, and arbitrary respectively. The create file command is selected from the submenu. Messages and prompts are provided to enter the beginning and ending X and Y coordinates for each line in the survey grid file. All of the X and Y coordinates with the corresponding conductivity measurements are written to the *.dat file, a window displays the created data file. It can be examined without leaving the program. The file is saved in the DAT38 folder in the laptop computer. The *.dat files from the survey are then transferred to SURFER 8.

In SURFER 8 (Golden Software 2002), the data file created in DAT38 is opened through the open routine in the file menu. The data are presented in the worksheet display. The worksheet contains the East (X) coordinate in the A column, the North (Y) coordinate in the B column, and the data value (Z) in C column. In order to process the data in GEOPLOT (Geoscan Research 2001), the data values must be arranged in ascending order by sorting the X and Y values. All three columns are selected. The sort routine in the data menu is selected and the sort parameters are set with the Column B set for sorting first in ascending order and Column A set for sorting second in ascending order. The data are checked for the correct number of entries based on the number of traverses covered in the survey and by the number of sample intervals per traverses. The conductivity data collected from project contain 12,360 measurements taken over the 40 m by 40 m survey area (sample interval of 0.25 meters or 80 readings along the North axis and traverse interval of 0.5 meter or 21 lines along the East axis of the grid). In order to import the data into GEOPLOT, one must make certain that the total number of data values equals the number of measurements taken in the grid unit. For the present survey, a total of 12,800 readings are needed. The dummy value of 2047.5 is added at the correct spacing interval to complete the data matrix. The file is sorted in ascending order in with the X values sorted first and then the Y values sorted next to arrange the data in its correct orientation within the columns of the file's worksheet. The X and Y values are deleted from the file leaving the Z or data values. The data file is saved in SURFER 8 and then copied to GEOPLOT's impdata folder.

To process the data in GEOPLOT, the data is imported into GEOPLOT using the import data routine under the file menu. The default grid template is selected in the import data screen. The electromagnetic survey type is selected and the user defined category is selected as the instrument. The grid input template screen is displayed on the laptop computer. The ground conductivity survey information is entered under the general category, which contains the settings for the acquisition of the data and the instrumentation used to acquire the data (Table 4). The next step required entering the grid names for importing. The import data screen is displayed after the grid input template parameters are entered. In the import data screen, the import file format is set to Z. The import file parameters are set to top-left reference corner for the start of the grid data acquisition point and the import dummy value equals 2047.5. Unlike the X or East and Y or North directions in the original conductivity data, the X and Y directions in GEOPLOT are reversed with X representing the North direction and Y representing the East direction. Under the import file names, the drive is set to the d drive, the extension is set to the "dat" file extension type, and directory path is set to d:\geoplot\impdata. The correct data file is selected from the list of import file names. The imported grid files are saved to the correct sitename directory. The data file names for the grid unit included the grid unit number, followed by the letter "q" for the quadrature phase survey. A notification window indicates the successful completion of the import routine. Each grid data set actually consist of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the conductivity data, the grid files from the site must be combined into composite files. To construct a composite file, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2001:5/2). The master grid file names screen is displayed and the grid file names are entered into the mesh template in the correct location and orientation. The grid files are converted into a single composite file. The composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modification if necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file names included the site location acronym (i.e., sfc for Sac and Fox cemetery) and the letter "q" for the quadrature phase conductivity survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite files for the ground conductivity data collected at the site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2001:5/2-5/3). In order to continue to analyze the data, the grid or composite files must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window to clip with minimum value of –3, maximum value or 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data is displayed in a shade plot or trace plot. The clip parameters are set to a minimum of –3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing conductivity data begins with the inspection of the data changes on the background signal. These data changes are superimposed on the local geology. There should be a broad range in the archeological anomalies with weak anomalies or archeological features having less than 5 % change, typical anomalies with 5% to 20% change, and strong anomalies with greater than 20% change in conductivity values. The data are checked for noise spikes including low level spikes which create a noisy appearance in the data displays, and extremely high anomalous readings which may be as large as ±1000% about the mean. The large background, which underlies the archeology, may have a regional gradient that is dependent on the local geology, drainage, or topography. The regional gradient may change from virtually none to over 300% across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2001:Reference Card 2).

The statistics function (Walker and Somers 1994:9/17,9/115-9/116) was then applied to the entire magnetic data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The original data ranged from –4.576 to 32.288 mS/m with a mean of 16.280 mS/m and a standard deviation of 2.710 mS/m.

The conductivity data were “cleaned up” using the zero mean traverse algorithm (Walker and Somers 1994:9/17,9/125-9/129). This algorithm was used to set the background mean of each traverse within a grid to zero, which removed any stripping effects resulting from “scan to scan instrument and operator bias defects” (Jones and Maki 2002:16). It also was useful in removing grid edge discontinuities between multiple grids and instrument drift. The algorithm utilized the least mean square straight line fit and removal default setting on over the entire composite data set.

The next step is to run the edge match routine over the entire conductivity composite file (Walker and Somers 1994:9/16,9/59-9/61). The edge match function is used to remove any grid edge discontinuities. It compares the mean edge differences between two adjacent grids. The difference is subtracted from one of the grids to achieve a better edge match. One grid is selected along with the edge that is to be matched to the adjacent grid (i.e., top, bottom, left, or right side).

The data set is interpolated to produce a uniform and evenly spaced data matrix (Walker and Somers 1994:9/16,9/67-9/69). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is a 4 x 2 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinX/X or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements are expanded using the sinX/X method. This yields a 4 x 4 data matrix.

A high pass filter (Walker and Somers 1994:9/63-9/66) was used to remove the low frequency, large scale spatial detail (i.e., the slowly changing geological "background" response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the X radius and Y radius. The weighting uses the default gaussian setting. The resulting data is bipolar with the mean centered on zero. The original mean may be restored by using the add function (Walker and Somers 1994:9/25-28).

The composite data files were then exported to separate disk files in a data file format for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2001:5/4-5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file names remained the same for all the files. The files were the exported to "expdata" folder in GEOPLOT. The files are then transferred to an appropriately named site folder (i.e., sac&fox) in the SURFER 8 contouring and 3d surface mapping program's project folder (Golden Software 1999).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The Open File command is selected to open the zero mean traverse, edge match, interpolate, high pass filter processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/4** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/4 t**o provide the correct traverse interval position for the high pass filtered data. A value of 500 was added to both the North and East coordinate values. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 1999). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of line field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. The data columns consist of 500 to 540 in the North or Y direction, 500 to 540 in the East or X direction with the X-spacing of 0.25 and the Y-spacing of 0.25. The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The spline smoothing operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name. Due to the presence of a small unsurveyed area in the northwest corner of the grid (10 x 9 m), a blanking file was constructed and applied to the grid file. The blanking file contains the X and Y coordinates used to outline the blanked portion of the grid, as well as, the number of parameter points and whether the blanking operation is located on the interior of the parameter points or on the exterior of these points. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated (Figure 20). The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. Selecting the image map operation from the map menu and opening the grid file creates the image map. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. Contour maps are useful in determining the equal strength of the resistance anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the magnetic data.

Interpretation – Magnetic Data

Interpretation of the magnetic data (Bevan 1998:24) from the project requires a description of the buried archeological feature of object (e.g., its material, shape, depth, size, and orientation). The magnetic anomaly represents a local disturbance in the earth's magnetic field caused by a local change in the magnetic contract between buried archeological features, objects, and the surrounding soil matrix. Local increases or decreases over a very broad uniform magnetic surface would exhibit locally positive or negative anomalies (Breiner 1973:17). Magnetic anomalies tend to be highly variable in shape and amplitude. They are generally asymmetrical in nature due to the combined affects from several sources. To complicate matters further, a given anomaly may be produced from an infinite number of possible sources. Depth between the magnetometer and the magnetic source material also affect the shape of the apparent anomaly (Breiner 1973:18). As the distance between the magnetic sensor on the magnetometer and the source material increases, the expression of the anomaly becomes broader. Anomaly shape and amplitude are also affected by the relative amounts of permanent and induced magnetization, the direction of the magnetic field, and the amount of magnetic minerals (e.g., magnetite) present in the source compared to the adjacent soil matrix. The shape (e.g., narrow or broad) and orientation of the source material also affects the anomaly signature. Anomalies are often identified in terms of various arrays of dipoles or monopoles (Breiner 1973:18-19). A magnetic object in made of magnetic poles (North or positive and South or negative). A simple dipole anomaly contains the pair of opposite poles that relatively close together. A monopole anomaly is simply one end of a dipole anomaly and may be either positive or negative depending on the orientation of the object. The other end is too far away to have an affect on the magnetic field.

Magnetic anomalies of archeological objects tend to be approximately circular in contour outline. The circular contours are caused by small size of the objects. The shape of the object is seldom revealed in the contoured data. The depth of the archaeological object can be estimated by half-width rule procedure (Bevan 1998:23-24; Breiner 1973:31; Hinze 1990; Milsom 1996:53-54; Telford et al. 1990:87). The approximations are based on a model of a steel sphere with a mass of 1 kg buried at a depth of 1.0 m below the surface with the magnetic measurements made at an elevation of 0.3 m above the ground. The depth of a magnetic object is determined by the location of the contour value at half the distance between the peak positive value of the anomaly and the background value. With the fluxgate gradiometer, the contour value is half the peak value since the background value is approximately zero. The diameter of this contour (Bevan 1998:Fig. B26) is measured and used in the depth formula where **depth = diameter – 0.3 m** (Note: The constant of 0.3 m is the height of the bottom fluxgate sensor above the ground in the Geoscan Research FM36 were I carry the instrument during data acquisition. This value needs to be adjusted for each individual that carries the instrument.). The mass in kilograms of the object (Bevan 1998:24, Fig. B26) is estimated by the following formula**: mass = (peak value - background value) * (diameter)^3/60**. It is likely that the depth and mass estimates are too large rather than too small, since they are based on a compact spherical object made of iron. Archeological features are seldom compact but spread out in a line or lens. Both mass and depth estimates will be too large. The archaeological material may be composed of something other than iron such as fired earth or volcanic rock. Such materials are not usually distinguishable from the magnetic data collected during the survey (Bevan 1998:24). The depth and mass of features comprised of fired earth, like that found in kilns, fireplaces, or furnaces could be off by 100 times the mass of iron. If the archeological feature were comprised of bricks (e.g., brick wall, foundation, or chimney), estimates could be off by more than a 1000 times that of iron. The location of the center of the object can also be determined by drawing a line connecting the peak positive and peak negative values. The rule of thumb is that the center of the object is located approximately one third to one half of the way along the line from the peak positive value for the anomaly. One should also be cautious of geophysical anomalies that extend in the direction of the traverses since these may represent operator-induced errors.

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The magnetic anomalies may be classified as three different types (Figure 21). The most noticeable in the data set are the three linear anomalies. The other two types of anomalies are the dipole anomalies with strong north poles and weak south poles. The third type is the monopoles. Several of the dipole and monopole anomalies are extremely strong. Forty-eight anomalies were identified and evaluated (Table 5). It is highly probable that these anomalies represent modern iron items. The majority of these anomalies occur east of the linear anomaly that runs north south through the geophysical gird. There is also a triangular area in the southwestern part of the grid that has several strong anomalies. These are located along the base of the entrance ramp from the gravel state line road. In the center of the western third of the geophysical grid are several weaker dipole anomalies. These are arranged in two nearly parallel rows oriented east west. Based on the location and strength of these anomalies, it is highly probable that they represent materials associated with the graves in the cemetery.

Interpretation – Ground-penetrating Radar Data

The first six radar images (Figures 22-27) illustrate plan views of 20 cm (8 in) thick depth-slices of the 40-m by 40-m grid block. The black box in the upper left corner represents "missing data" in a corner of the grid that could not be fully surveyed because of a line formed by several large round hay bales. Apparent in Figure 22 is a pattern of curved lines that swirl around the center of the image. These can be attributed to the patterns of movement of agricultural equipment most recently used to cultivate and harvest the hay crop. Some of the radar reflections may also have been produced by a tractor when a brush pile centered around 20 m north and 22 m east was removed to facilitate the geophysical survey. Figure 22 presents the average strength of the reflected radar signal from the top 20 cm (8 in) of the soil. The next two plan maps show the next lower 20-cm (8 in) slices (Figures 23 and 24). The circular pattern around the brush pile changes only slightly in these images. A broad region of moderately strong (dark) reflections is present in the upper right corner of the grid (Figure 23) and a smaller similar region of dark moderately strong reflections is present in the lower right corner of the same image. The lower right corner of the grid was located in a depressed area of the site where the soil was much wetter. The high amplitude radar reflections in this area can be attributed to the increased soil moisture in the lower right corner of the geophysical grid. Although not as prominent a depression, the upper right portion of the grid was a relatively low area and had supported a distinctly different ground cover that indicated that this area also had moister soil conditions than elsewhere in the grid.

The next three plan maps (Figures 25-27) show changes in the radar reflections from strata below most of the recent agricultural impacts. Apparent in all three images, spanning 24-48 inches below the surface, is a strong narrow band of reflections that extends from 15 m east at the south side of the grid to a point 12 m east and 29 m north. From this latter point, the linear anomaly extends northeast toward the 34 m north point along the east side of the grid. This feature appears as a right angle slightly offset from the orientation of the grid. The magnetic gradiometer map (Figure 20) closely matches the GPR rendering of this right angle feature while the conductivity data (Figure 34) matches the GPR map mostly along the north-south leg of the anomaly. Other less dramatic linear anomalies also appear in some of these images. Figure 25 shows a weak but distinct linear anomaly that extends southwest from the corner (12 m east and 29 m north) of the main anomaly to the point at about 16 m north on the west side of the grid. This linear anomaly is not visible in the lowest level (Figure 27) and is barely represented in the image shown in Figure 26.

Also visible in Figures 26 and 27 is a shorter east-west oriented linear anomaly that extends from 15 m east and 9 m north to a point near 32 m east and 11 m north. The signature of this anomaly closely matches that of the major right angle feature. It can also be seen in the magnetic data (Figures 20 and 21) but is absent or weakly represented in the conductivity data (Figure 34) as was the east-west oriented segment of the main linear anomaly. Beginning with Figure 25 one can identify a small number of localized (ca. 1 m diameter) high amplitude anomalies in the center of the grid. Several of these appear to be closely associated with the linear anomalies (e.g. N509/E515, N511/E533, N526/E514, and N529/E512). Some of these, such as the one at N511/E533, are also recognizable in the magnetic data (Figure 20).

Figures 28-33 illustrate a series of radar profiles starting with lines near the west edge of the geophysical grid. Figures 28 and 29 show four profiles from the portion of the grid that was only 30 m long from south to north. The top image in Figure 28 presents the radar reflections from the western most limit of the grid (LINE 0). The radar signature associated with the weak linear feature can be seen at 15-16 m north on this first traverse. On the traverse located 2 m to the east (LINE 4), seen in the bottom image of Figure 28, the weak linear anomaly is located at 19 m north. Figure 29 illustrates traverses located at 8 m and 10 m east into the grid. The weak linear anomaly is located at about 24.5 m north in the top image and at about 26.5 m north in the lower image. While identifiable in these four profiles, there is little indication of the nature of the source for the weak linear feature. There is nothing about the feature that would suggest it was associated with the use of the area as a cemetery. One would expect that typical historic graves would produce an anomaly more like the distinct parabolic reflections seen at about 21 m north on the two images seen in Figure 29 at approximately 0.8 m in depth. Although these anomalies near N521/E508 and N521/E510 compare favorably with some grave anomalies, they appear more typical of circular pits than the long rectangular excavation that is typical of historic Euro-American grave shafts.

Figures 30 and 31 illustrate some of the traverses from near the center of the grid, including ones that cross the north-south segment of the strong linear anomaly. The top image in Figure 30 illustrates the traverse located at 14 m east. This profile crosses the north-south portion of the linear anomaly between 12 m and 17 m north. Because of the shallow angle between the course of the feature and the radar traverse, the antenna was over or very close to the target for a substantial distance, producing multiple reflections in close proximity to each other. This profile also crosses the east-west segment of the linear feature at 29 m north where a pronounced parabolic reflection can be seen. The bottom image in Figure 30 illustrates the traverse one meter to the east. This traverse crosses the north-south segment near the 4 m north point, the short east-west anomaly at 9m north and the long east-west anomaly at about 29 m north. The source for these anomalous reflections appears to be about 50-80 cm (19-31 in) below the present surface. Figure 32 illustrates traverses at 28 m and 32 m east. The short east-west linear anomaly is located at about 11 m north in both the top and bottom images but is much stronger in the profile at 32 m east. The long east-west linear feature is seen at 31 m north in the top image and 32 m north in the bottom image. Near its east end, the short east-west linear anomaly is marked by an unusually strong reflection. This can be seen in the plan maps in Figures 25-27 and at 11 m north in the bottom profile in Figure 32. Vertical segments of rods, pipes, and metal posts often produce similar patterns. The magnetic data (Figures 20 and 21) also indicate a very strong response at this location that probably results from a good-sized piece of iron or steel. The short east-west feature is seen in the top image of Figure 33 at 12 m north, while 6 m farther east (bottom image Figure 33) this short feature was not detected. The long east-west anomaly continues to trend slightly north and can be seen at about 32.5 m north in the top image and 33.5 m north in the bottom image (Figure 33).

Interpretation – Ground Conductivity Data

Ground conductivity surveys are much faster to complete than the resistivity surveys but are also more complicated (Bevan 1998:29). Like the resistivity surveys, ground conductivity surveys detect changes in soil contracts (Figure 34). These soil contracts can result from natural conditions or from cultural activities (Bevan 1988:31-33). The conductivity anomalies represent the location and approximate shape of the features; however, different kinds of features can produce similar conductivity anomalies. They also detect metal objects. The resulting conductivity anomalies from buried metal (e.g., utility lines, pipes, and objects) may hide other features in immediate vicinity.

The conductivity data revealed portions of the fence lines noted in the magnetic and GPR data. The disturbed area in the center of the grid units contained a brush pile when the site was first visited in 2002. The brush was removed before the survey began but a large circular area hade been disturbed from the clean-up endeavors. There are also a series of negative value readings that represent historic iron/steel artifacts or materials.

Interpretation – Combined Geophysical Data Sets

Another approach to the interpretation of the geophysical data from the Sac and Fox Nation of Missouri multiple family cemetery project is to combine the data sets. The conductivity data was prepared in an image plot. The contoured magnetic data was superimposed on top of the conductivity data (Figure 35). By reversing the image and contour data plots, one can view the magnetic data as an image plot with the contoured conductivity data superimposed on top of the magnetic data (Figure 36). Comparing the metal anomalies in the conductivity data to the magnetic anomalies can provide information on the nature of the metal anomaly (Figure 37). If the two types of geophysical data are represented by an anomaly inn the same location, it is highly certain that the metal object is iron or steel. The lack of a correlation between the two data sets suggests that the conductivity anomaly by itself may represent a conductive metal other than iron of steel (e.g., brass, copper, lead, zinc, etc.) or the magnetic anomaly may represent a fired clay feature or object (e.g., fire hearth, pottery, bricks, etc.)

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9. CONCLUSIONS AND RECOMMENDATIONS

During the November 2003, the Midwest Archeological Center staff conducted geophysical investigations at the location of a historic Sac and Fox multiple family cemetery (Site 25RH122) in Richardson County, Nebraska. The project was conducted for the Sac and Fox Nation of Missouri. During the investigations, approximately 1,500 square meters were surveyed with a Geoscan Research FM36 fluxgate gradiometer, with a Sensors and Software Noggins 250 smart cart ground-penetrating radar system (Nickel 2001), and the Geonics EM38 ground conductivity meter.

The magnetic and ground conductivity data collected at the cemetery sites provided information of the physical properties (magnetic and conductance) of the subsurface materials. Numerous magnetic anomalies were identified. A series of linear magnetic and conductivity anomalies appear to represent the remnants of old fence lines. There area several high magnetic dipoles as well as a number of weak magnetic dipoles. The strong magnetic dipoles represent large concentrations of magnetic iron, probably of recent or modern agricultural origin. Weaker magnetic dipole anomalies, especially those located in the western central part of the investigation area may be associated with the unmarked graves. Negative conductivity anomalies correspond to several strong and weak magnetic anomalies indicating that they are composed of iron or steel. Other magnetic anomalies, not identified in the conductivity data, suggest the presence of fired material, such as, burned earth, bricks, or hearths.

The GPR data reveal a linear metallic reflector that enters the grid from the south at about 15 m east, extends northwest to N529/E512, and then turns east-northeast and exits the grid near N533/E540. This feature represents the remnants of a fence or corral. Although distinct, the radar reflections suggest a narrow and somewhat intermittent source. The possibility that the reflections stem from an agricultural source is further suggested by the strong but short east-west segment that appears to conform to the same orientation as the east-west axis of the main feature. The main linear anomaly and the short east-west extension both appear to originate within the top meter of the site and may be as shallow as 50 cm (19 in). It is possible that these strong linear features were on or just above the surface during a flood in the 1990s when as much as a foot and a half (47 cm) of soil may have been deposited over the earlier landform. If the flood deposited as much sediment as the local informants believe, then a large portion of the geophysical data are dominated by soils that postdate the use of the area for mortuary purposes. The few anomalies that originate at or below the pre-flood surface and which generally conform to expectations for pit features are located in the west-central part of the grid (Figures 27 and 29).

Several geophysical anomalies identified during the investigations suggest the presence of a number of grave locations in the west central part of the surveyed area. While these techniques represent extremely valuable methodologies for the initial investigation of cemeteries and grave locations, it may necessary to verify the identified anomalies as graves through some means of excavation. The question could be raised that the use of traditional excavation methods would have been more productive. It is true that the excavations would have allowed a better view of the subsurface materials; however, the amount of time and costs in labor and analysis to conduct such excavations would have been substantially higher to cover the same area investigated with the geophysical techniques. With an estimated cost of $3,000.00 per cubic meter of excavation, approximately two excavation units could have been placed on the site. The chances of placing one excavation over the top of unmarked graves in the cemetery would be astronomical. It would still not provide information on the location of multiple graves in the cemetery. Nor would it be feasible or even ethical to conduct such excavations in a known cemetery location without an impending treat of destruction to the cemetery. Preliminary shovel testing of the cemetery would also not provide substantial information on the location of the graves due to the lack of depth necessary to verify the presence of the graves. The use of an auger or posthole digger does not open up enough area to visually inspect the soil matrix for the boundaries of the grave. There is also high probability of damaging any skeletal remains during the auguring operations. Overall, geophysical techniques provide the best initial evaluative phase of cemetery investigations where eminent destruction of the cemetery is not at issue. There may be a need for follow up archeological excavations to verify the geophysical anomalies identified during the survey efforts. These excavations can be more efficiently planned with the geophysical background data than through the use of traditional archeological excavation strategies in extremely cultural sensitive areas such as cemeteries.

This report has provided an analysis of the geophysical data collected during four days at the cemetery site (25RH122). Based on the evaluation of the geophysical anomalies, placement of a protective fence should be along the route of the pre-1937 fence line in the middle of the field. The remnants of the fence line are clearly visible in the geophysical data sets and extend from N500/E515 to N540/E512. In order to clarify the nature of the anomalies interpreted as possible graves, it would be useful to conduct a downhole magnetic susceptibility survey of the identified anomalies. In addition, the geophysical grid should be expanded to the west to follow the rows of anomalies suspected of being graves. Although the location is associated with known cemetery with unmarked graves, it is not recommended that any additional archeological investigations in the form of excavations be conducted at this site at the present time. Should there be any development on or near this site, then a research design needs to be developed for the implementation of archeological excavations to determine the nature and extent of the Sac and Fox multiple family cemetery.

Finally, refinement of the archeological and geophysical interpretation of the survey data is dependent on the feedback of the archeological investigations following geophysical survey (David 1995:30). Should additional archeological investigations occur at the site investigated during this project, the project archeologist is encouraged to share additional survey and excavation data with the geophysical investigators for incorporation into the investigators' accumulated experiences with archeological problems. Throughout the entire geophysical and archeological investigations, communication between the geophysicist and the archeologist is essential for successful completion of the archeological investigations. It is also important for the investigators to disseminate the results of the geophysical survey and archeological investigations to the general public, which in this case are the Sac and Fox tribal descendants. It is through their support in funds and labor that we continue to make contributions to the application of geophysical techniques to the field of archeology.

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TABLES

Table 1. Individuals buried in the Sac and Fox Nation of Missouri multiple family cemetery.

Name	Name	Name	Name
Charles Connell	Esther Green	Old Man Warp	Edmore Robidoux
Curtis Connell	Eliza Green		Annie Robidoux
Vera Connell			Louis Robidoux
Verda Connell			Joe Robidoux
Festus Connell			Katie English Robidoux
John Connell (?)			

Table 2. Aerial photographs of the Sac and Fox Nation of Missouri cemetery project area.

Date		Can	Frames	Scale	Film
National Archives and Records Administration					
8-27-1937	RG 145	Can 876	UG-6-403 & 404	1:20,000	240mm black and white panchromatic
9-25-1940	RG 145	ON 28386	UG-6A-56 & 57	1:20,000	240mm black and white panchromatic
10-21-1947	RG 145	ON 29040	UG-4D-9 & 10	1:20,000	240mm black and white panchromatic
Aerial Photography Field Office					
7-27-1955			UG-2P-125 & 126	1:20,000	240mm black and white panchromatic
8-12-1959			UG-3W-183 & 184	1:20,000	240mm black and white panchromatic
8-27-1965			UG-2FF-2 & 3	1:20,000	240mm black and white panchromatic
6-24-1971			UG-1MM-70 & 71	1:20,000	240mm black and white panchromatic
9-7-1979	USDA 40		31147-179-173 & 174	1:40,000	240mm black and white panchromatic
4-23-1982	HAP 82F	409405	15-48 &49	1:60,000	240mm color infrared
6-19-1988	NAPP	0953	264-27 & 28	1:40,000	240mm color infrared
3-26-1993	NAPP		639-27 & 28	1:40,000	240mm black and white panchromatic
03-30-1999	NAPP		11331-47 & 48	1:40,000	240mm black and white panchromatic

Table 3. Acquisition and instrumentation information for the gradiometer survey used in the grid input template.

Acquisition	value	Instrumentation	value
Sitename	sac&fox	Survey Type	Gradiometer
Map Reference		Instrument	FM36
Dir. 1st Traverse	N	Units	nT
Grid Length (x)	20 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	20 m	Baud Rate	2400
Traverse Interval (y)	0.5 m	Averaging	Off
Traverse Mode	Zig-Zag	Averaging Period	16

Table 4. Acquisition and instrumentation information for the ground conductivity survey used in the grid input template.

Acquisition	value	Instrumentation	value
Sitename	sac&fox	Survey Type	EM
Map Reference		Instrument	EM38
Dir. 1st Traverse	N	Units	mS/m
Grid Length (x)	20 m		
Sample Interval (x)	0.25 m		
Grid Width (y)	20 m		
Traverse Interval (y)	0.5 m		
Traverse Mode	Parallel		

Table 5. Magnetic gradient anomaly interpretations at Site 25RH122.

Magnetic Gradient Anomaly Number	Anomaly Center Point Location	Peak Value (nT)	Background Value (nT)	Contour Interval (nT) at halfway point between peak and background	Diameter of Contour Interval (m)	Depth of Anomaly (m)	Mass of Anomalous Object (kg)
1	N500.72/ E502.76	52.46	0.00	26.23	0.32	0.02	0.029
2	N503.00/ E505.09	45.62	0.00	22.81	0.49	0.19	0.089
3	N503.97/ E507.18	55.97	0.00	27.99	0.25	surface	0.015
4	N503.10/ E508.43	21.90	0.00	10.95	0.43	0.13	0.040
5	N500.67/ E509.91	116.05	0.00	58.03	0.33	0.03	0.067
6	N514.01/ E501.31	7.00	0.00	3.50	0.43	0.13	0.009
7	N515.13/ E503.23	11.96	0.00	5.98	0.35	0.05	0.070
8	N513.70/ E505.23	10.50	0.00	5.25	0.41	0.11	0.012
9	N512.99/ E506.93	7.10	0.00	3.55	0.57	0.27	0.022
10	N512.40/ E509.28	10.31	0.00	5.15	0.33	0.03	0.006
11	N510.94/ E511.25	13.60	0.00	6.80	0.43	0.13	0.018
12	N516.82/ E502.71	5.84	0.00	2.92	0.37	0.07	0.005
13	N517.63/ E506.31	8.29	0.00	4.15	0.41	0.11	0.009
14	N513.22/ E512.12	56.98	0.00	28.49	0.48	0.18	0.105
15	N517.65/ E509.48	15.88	0.00	7.94	0.47	0.17	0.027
16	N514.85/ E510.56	188.74	0.00	94.37	1.16	0.86	4.910
17	N520.27/ E503.60	12.05	0.00	6.03	0.60	0.30	0.043
18	N522.94/ E502.21	13.92	0.00	6.96	0.47	0.17	0.024
19	N527.23/ E504.71	8.45	0.00	4.23	0.52	0.22	0.020
20	N527.32/ E517.65	6.74	0.00	3.37	0.48	0.18	0.012
21	N514.89/ E519.24	129.90	0.00	64.95	0.37	0.07	0.113
22	N512.71/ E517.60	201.64	0.00	100.82	0.72	0.32	1.254
23	N510.74/ E518.75	13.00	0.00	6.50	0.38	0.08	0.012
24	N515.63/ E515.20	83.65	0.00	42.83	0.47	0.17	0.147
25	N513.90/ E520.65	176.26	0.00	88.13	0.83	0.53	1.680

Table 5. Concluded.

Magnetic Gradient Anomaly Number	Anomaly Center Point Location	Peak Value (nT)	Background Value (nT)	Contour Interval (nT) at halfway point between peak and background	Diameter of Contour Interval (m)	Depth of Anomaly (m)	Mass of Anomalous Object (kg)
26	N512.32/ E520.25	95.85	0.00	47.93	0.29	surface	0.040
27	N515.03/ E524.23	27.97	0.00	13.99	0.32	0.02	0.015
28	N517.63/ E528.24	7.63	0.00	3.82	0.16	surface	0.0005
29	N503.85/ E520.24	24.70	0.00	12.35	0.43	0.13	0.032
30	N504.27/ E527.85	200.16	0.00	100.08	0.53	0.23	0.506
31	N506.95/ E532.52	57.84	0.00	28.92	0.59	0.29	0.195
32	N508.85/ E527.05	198.93	0.00	99.47	0.53	0.23	0.503
33	N515.25/ E538.08	201.43	0.00	100.72	0.56	0.26	0.590
34	N508.92/ E536.89	10.85	0.00	5.43	0.72	0.42	0.047
35	N505.41/ E536.11	6.16	0.00	3.08	0.43	0.13	0.008
36	N502.88/ E534.76	9.05	0.00	4.53	0.48	0.18	0.017
37	N522.81/ E521.11	11.72	0.00	5.86	0.45	0.15	0.018
38	N522.58/ E522.63	31.20	0.00	15.60	0.34	0.04	0.020
39	N524.10/ E526.58	7.36	0.00	3.68	0.48	0.18	0.014
40	N524.90/ E523.20	9.83	0.00	4.92	0.43	0.13	0.013
41	N523.28/ E524.14	11.90	0.00	5.95	0.45	0.15	0.016
42	N524.10/ E534.70	15.61	0.00	7.81	0.37	0.07	0.014
43	N525.92/ E536.09	8.19	0.00	4.10	0.51	0.21	0.018
44	N528.94/ E536.78	5.00	0.00	2.50	0.45	0.15	0.008
45	N528.83/ E524.29	57.10	0.00	28.55	1.69	1.39	2.560
46	N534.57/ E536.76	55.40	0.00	27.71	0.58	0.28	0.090
47	N536.07/ E523.54	21.09	0.00	10.55	0.70	0.40	0.011
48	N539.05/ E532.40	11.30	0.00	5.65	0.33	0.03	0.007

FIGURES

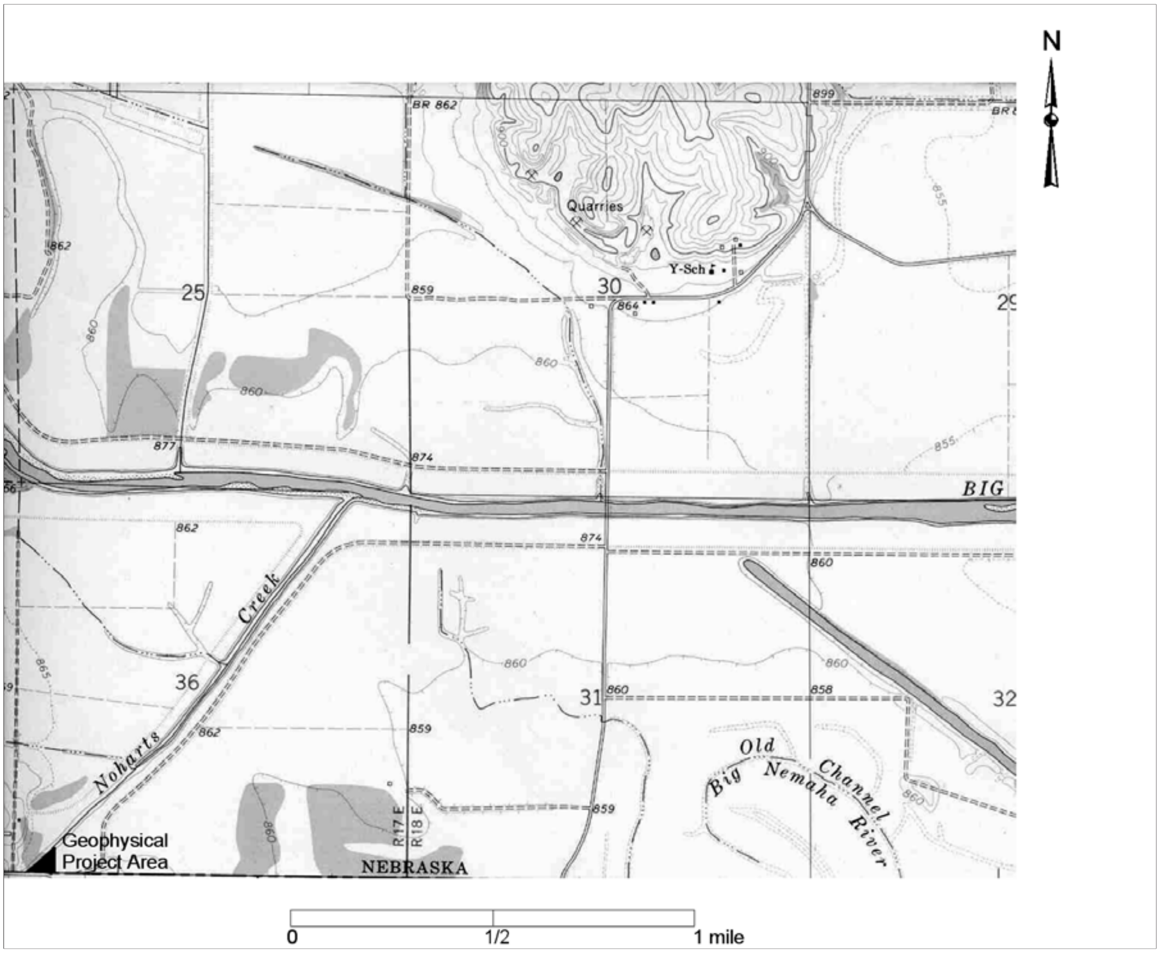

Figure 1. Location of the geophysical project area within Section 36 (adapted from the 1965 United State Geological Survey 7.5 minute topographic quadrangle for Rulo, Nebraska).

Figure 2. Location of the Iowa and Sac and Fox reservation lands in Kansas and Nebraska in 1854 (adapted from the Colton 1854 map of Kansas and Nebraska).

Figure 3. Location of the Iowa and the Sac and Fox reservations in Kansas and Nebraska and the present geophysical project area (adapted from the 1866 U.S. General Land Office map).

SAC AND FOX MULTIPLE FAMILY CEMETERY

Figure 4. Extent of Sac and Fox reservation lands in Kansas and Nebraska with present holdings identified and the location of the geophysical project area (courtesy of the Sac and Fox Nation of Missouri).

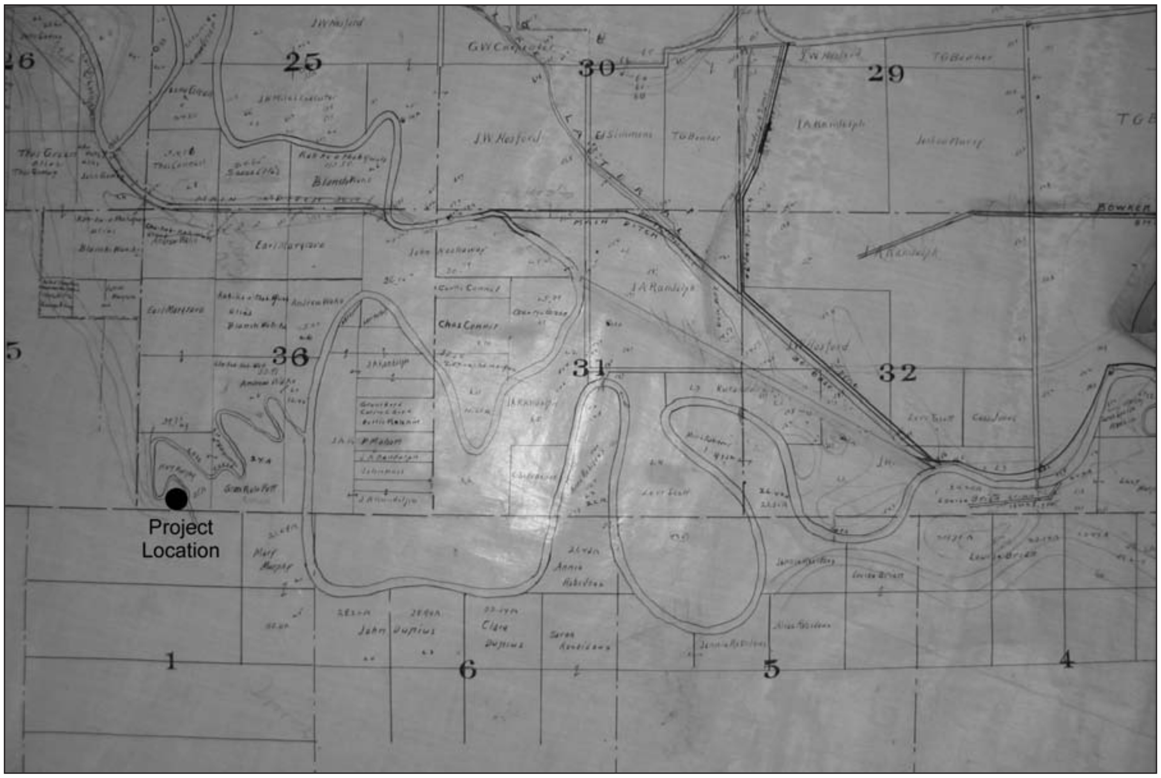

Figure 5. 1906 rectification plans for the channelization of the Big Nemaha River (courtesy of the Richardson County Surveyor).

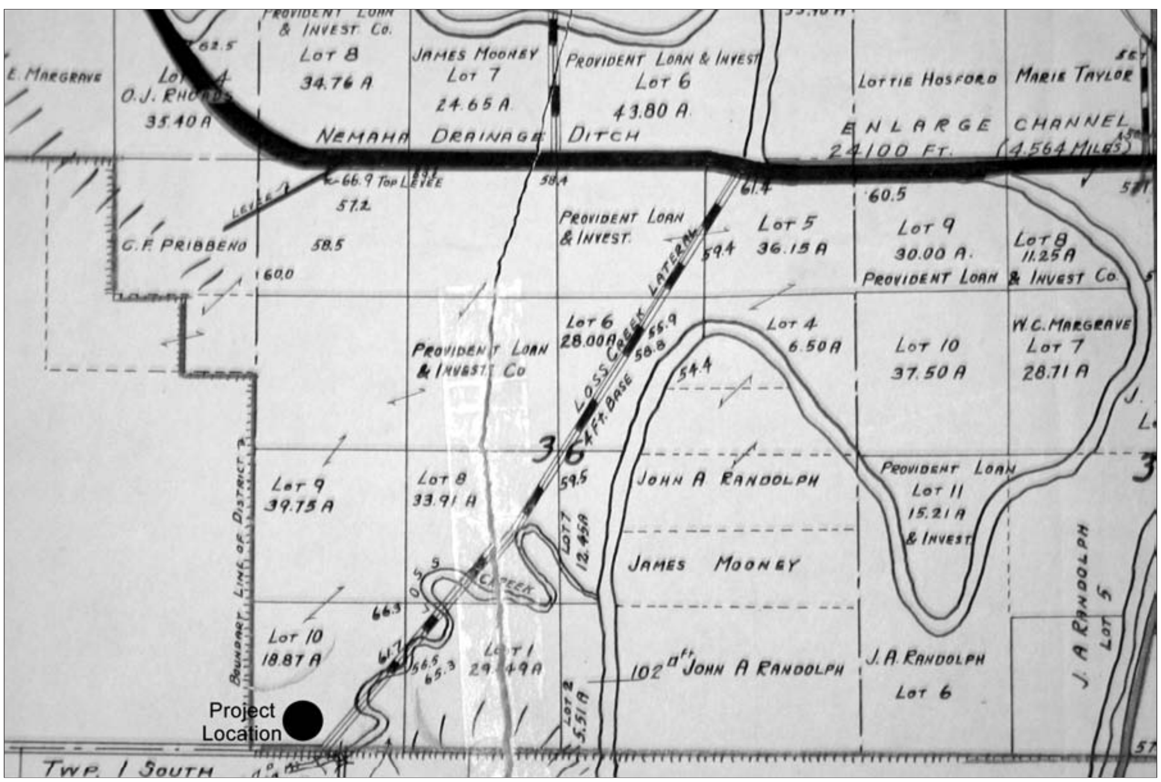

Figure 6. Portion of Drainage District No. 1 1927 plat showing channelized Big Nemaha River and Loss (Noharts) Creek lateral (courtesy of the Richardson County Surveyor).

SAC AND FOX MULTIPLE FAMILY CEMETERY

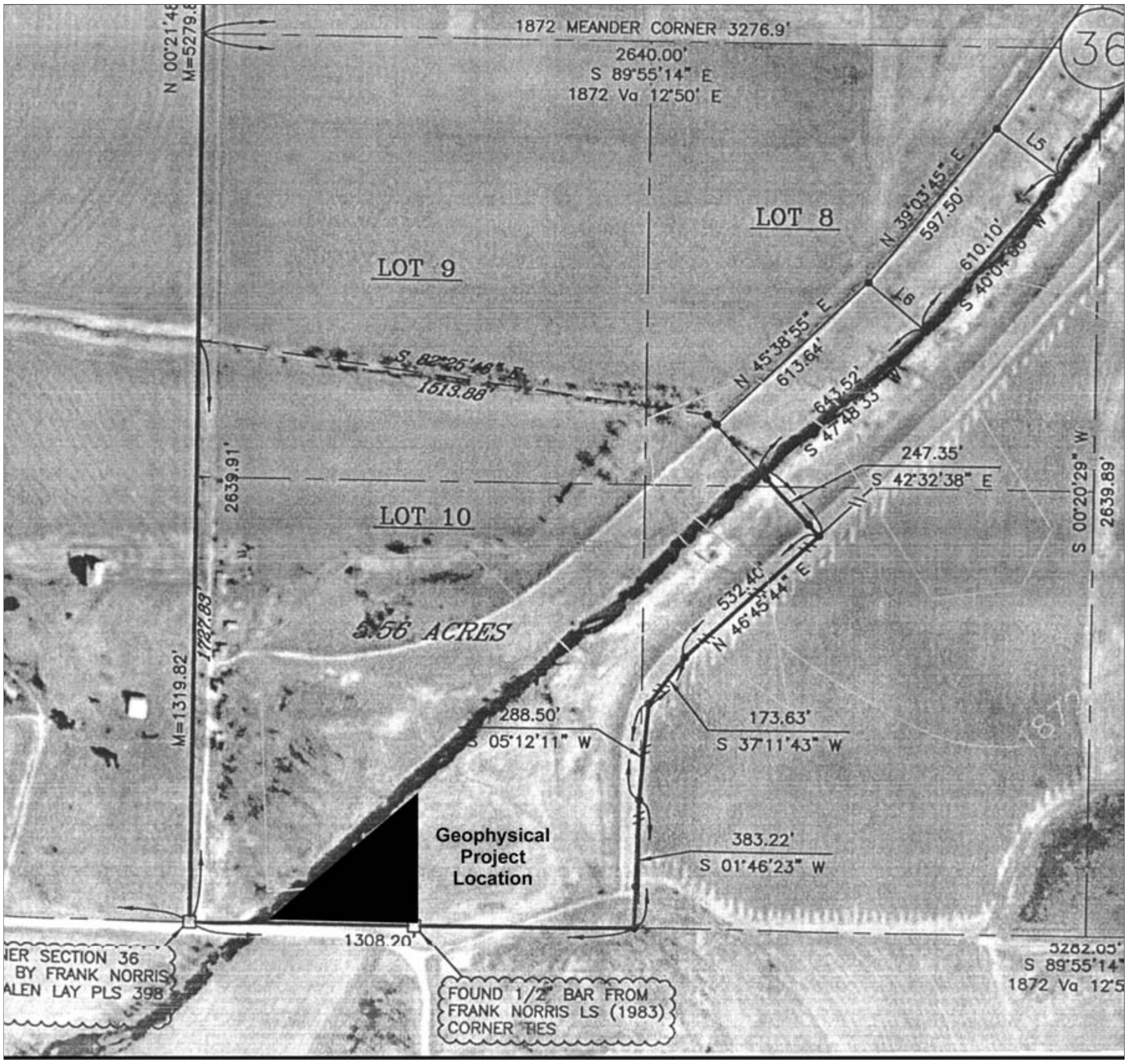

Figure 7. 2003 aerial plat of Section 36 showing location of the geophysical project area (courtesy of the Richardson County Surveyor).

Figure 8. 1907 photograph of the Sac and Fox cemetery (photographer unknown; courtesy of the Sac and Fox Nation of Missouri museum).

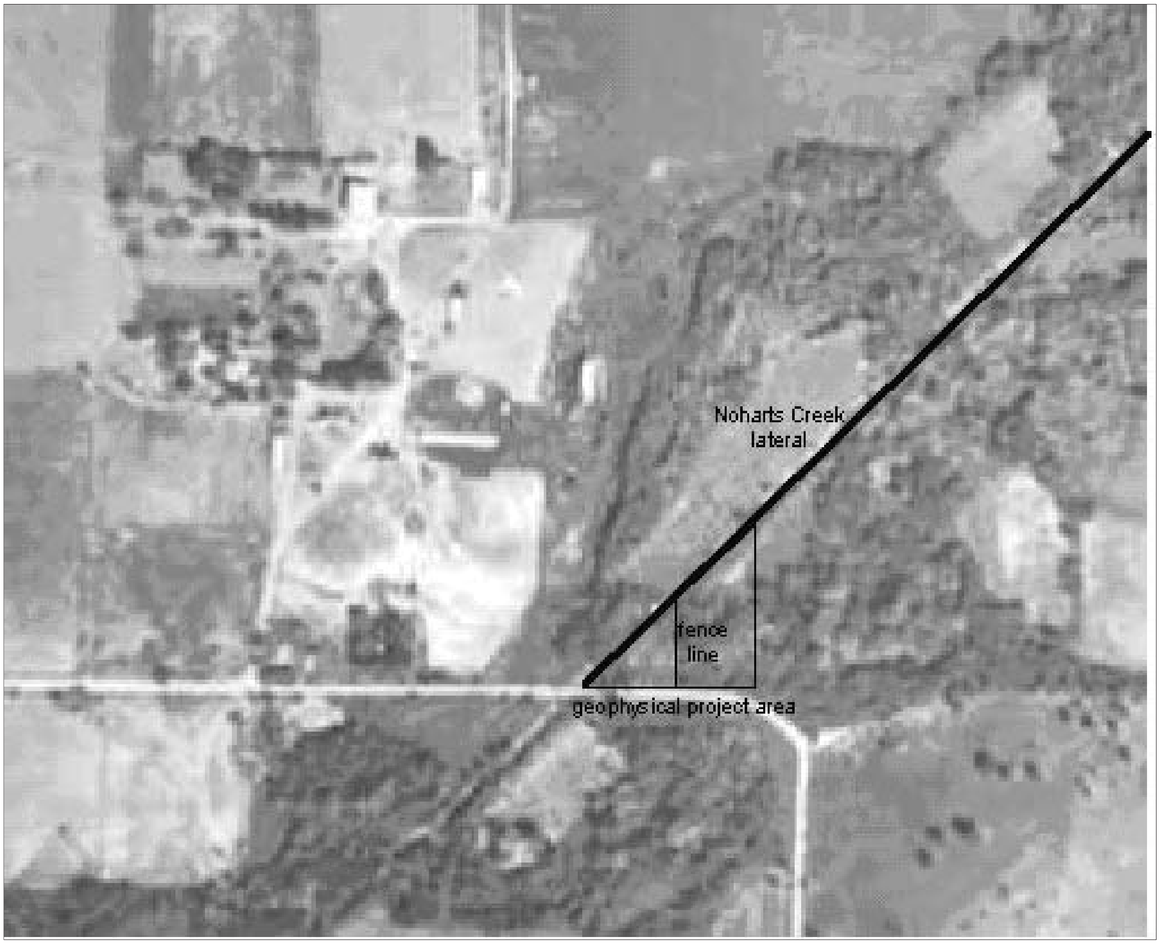

Figure 9. U.S. Department of Agriculture 1937 aerial photograph of project area.

Figure 10. U.S. Department of Agriculture 1965 aerial photograph of project area.

Figure 11. U.S. Department of Agriculture 1999 aerial photograph.

Figure 12. Project area (view to the east northeast).

SAC AND FOX MULTIPLE FAMILY CEMETERY

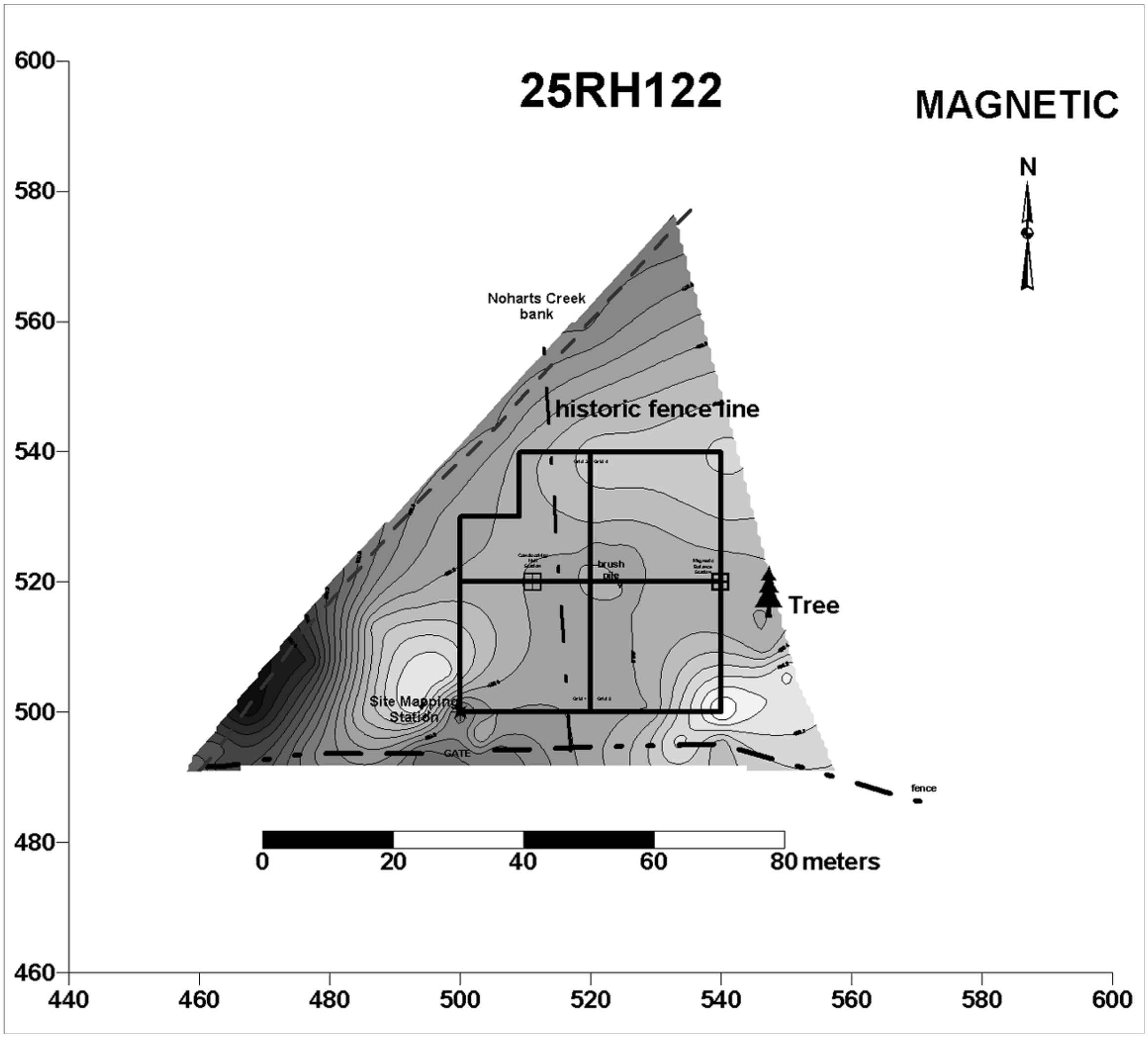

Figure 13. Topographic map of the geophysical project area.

Figure 14. Geoscan Research FM36 fluxgate gradiometer (Photograph actually from Oregon Trail investigations since not photographs were taken during the present project).

Figure 15. Sensors and Software's Noggin [Plus] ground penetrating radar cart system with a 250 mHz antenna (view to the east).

Figure 16. Geonics EM38 conductivity meter (Photograph actually from Mormon Pioneer Trail investigations since not photographs were taken during the present project).

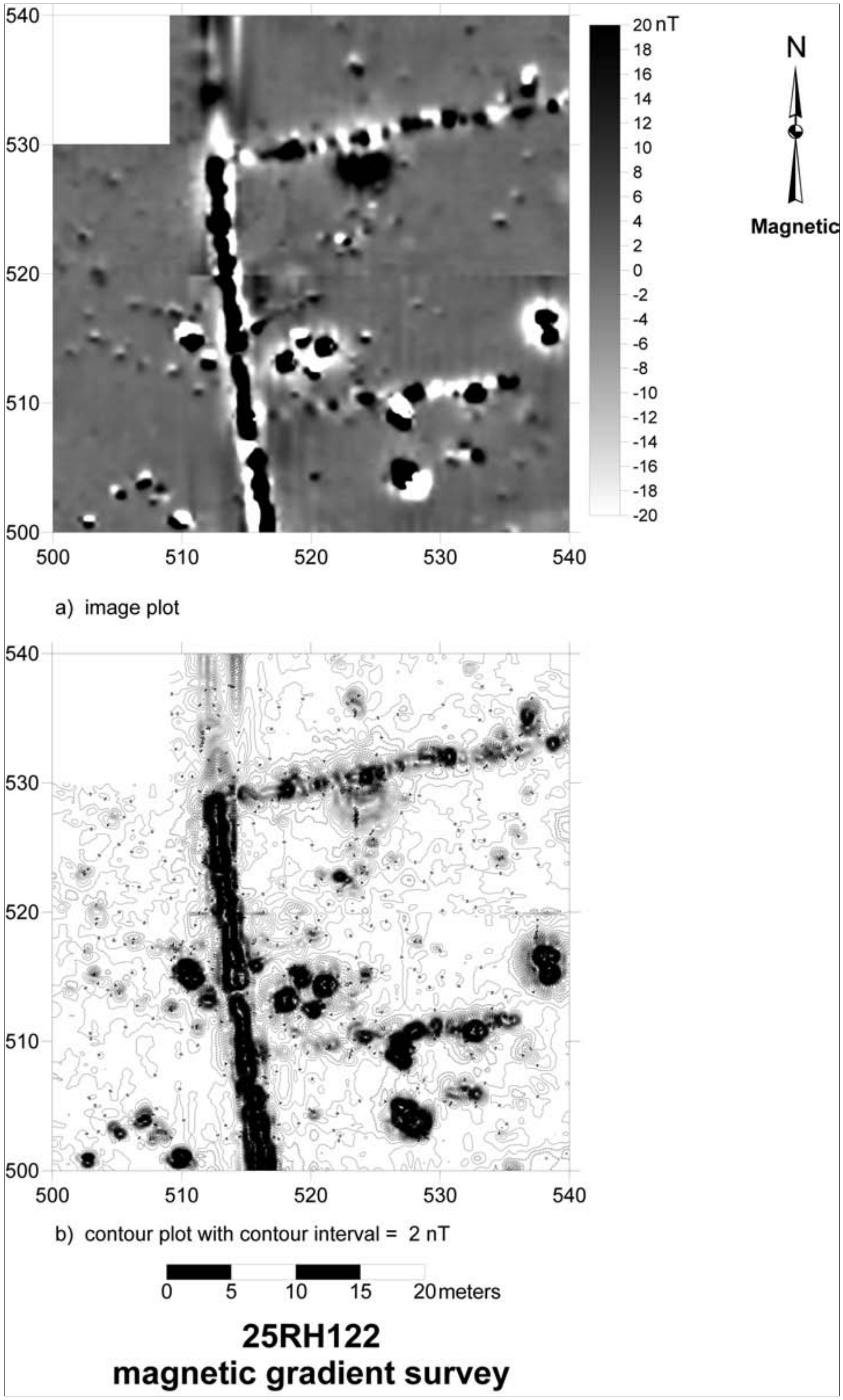

Figure 17. Magnetic gradient image and contour data plots.

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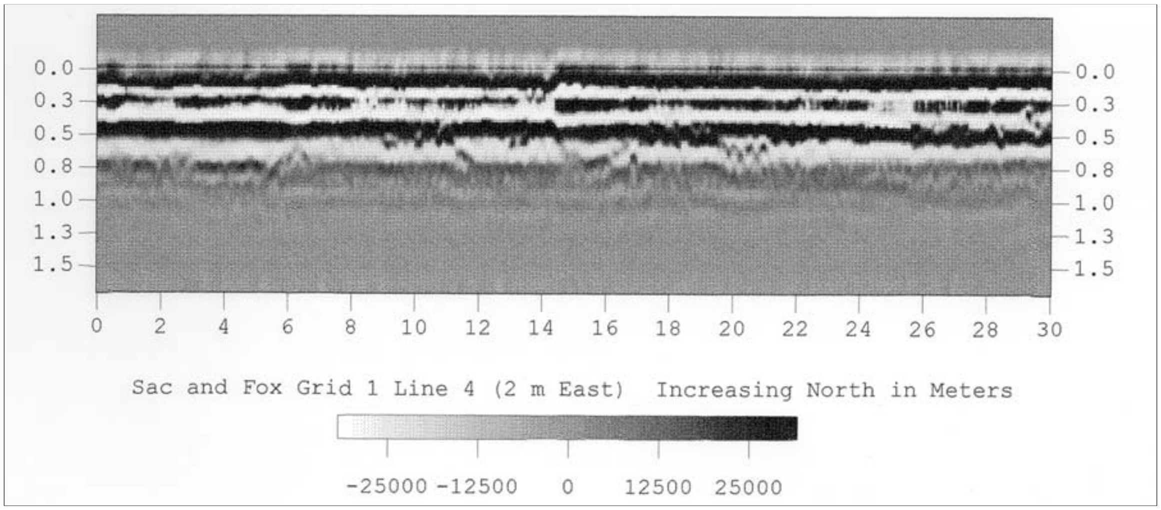

Figure 18. GPR profile along Line 4.

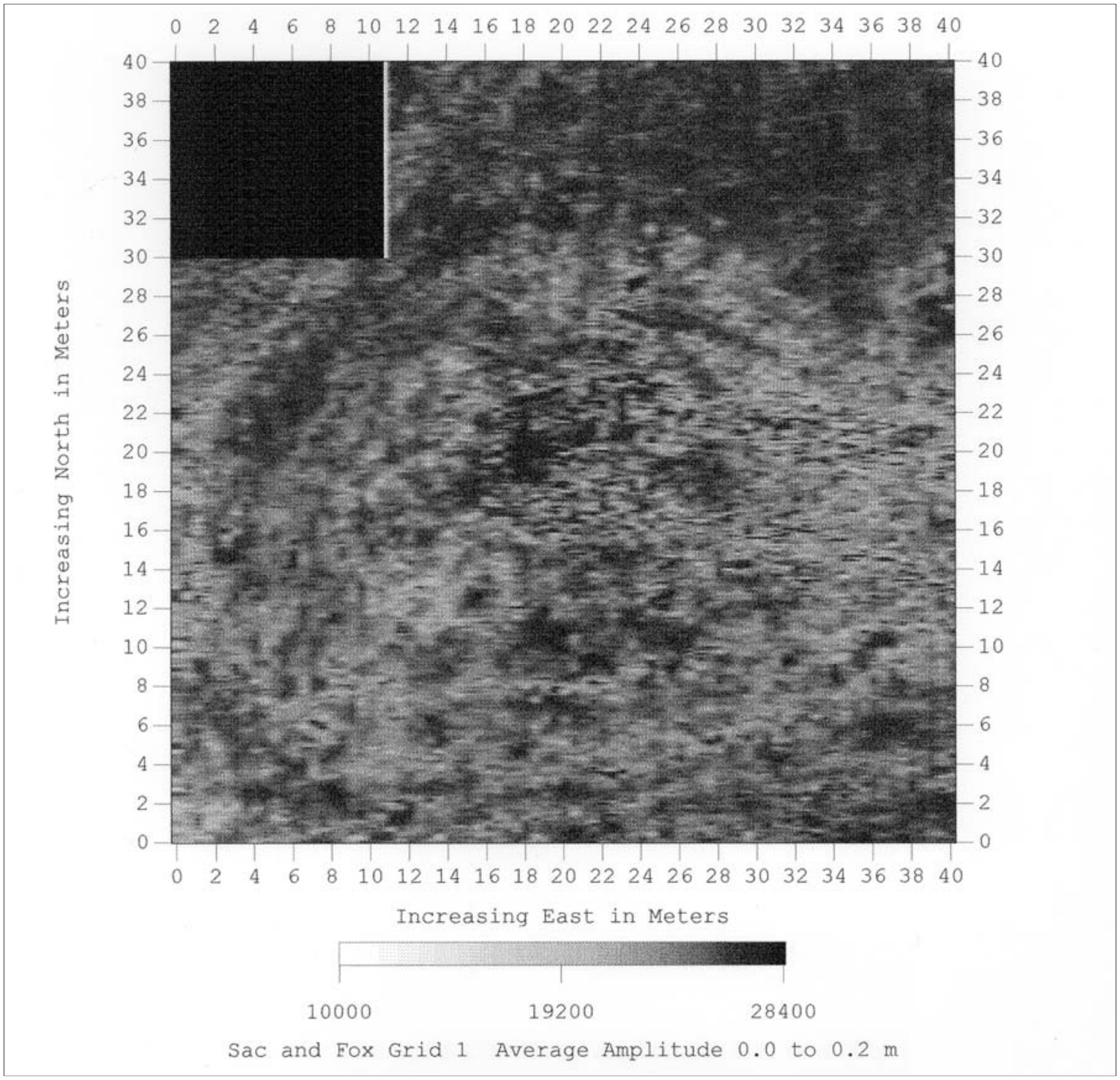

Figure 19. GPR time/depth slice.

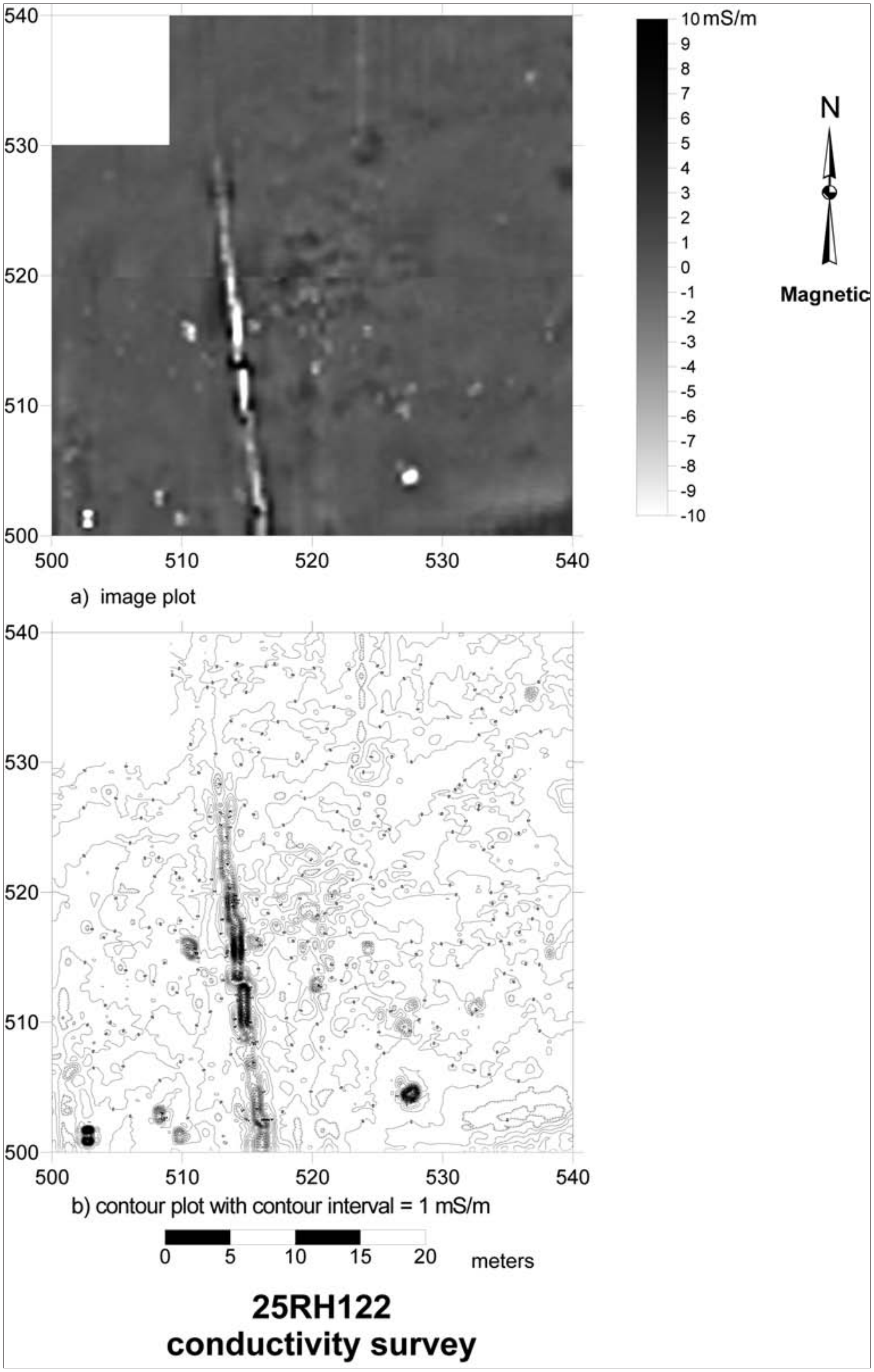

Figure 20. Conductivity image and contour data plots.

SAC AND FOX MULTIPLE FAMILY CEMETERY

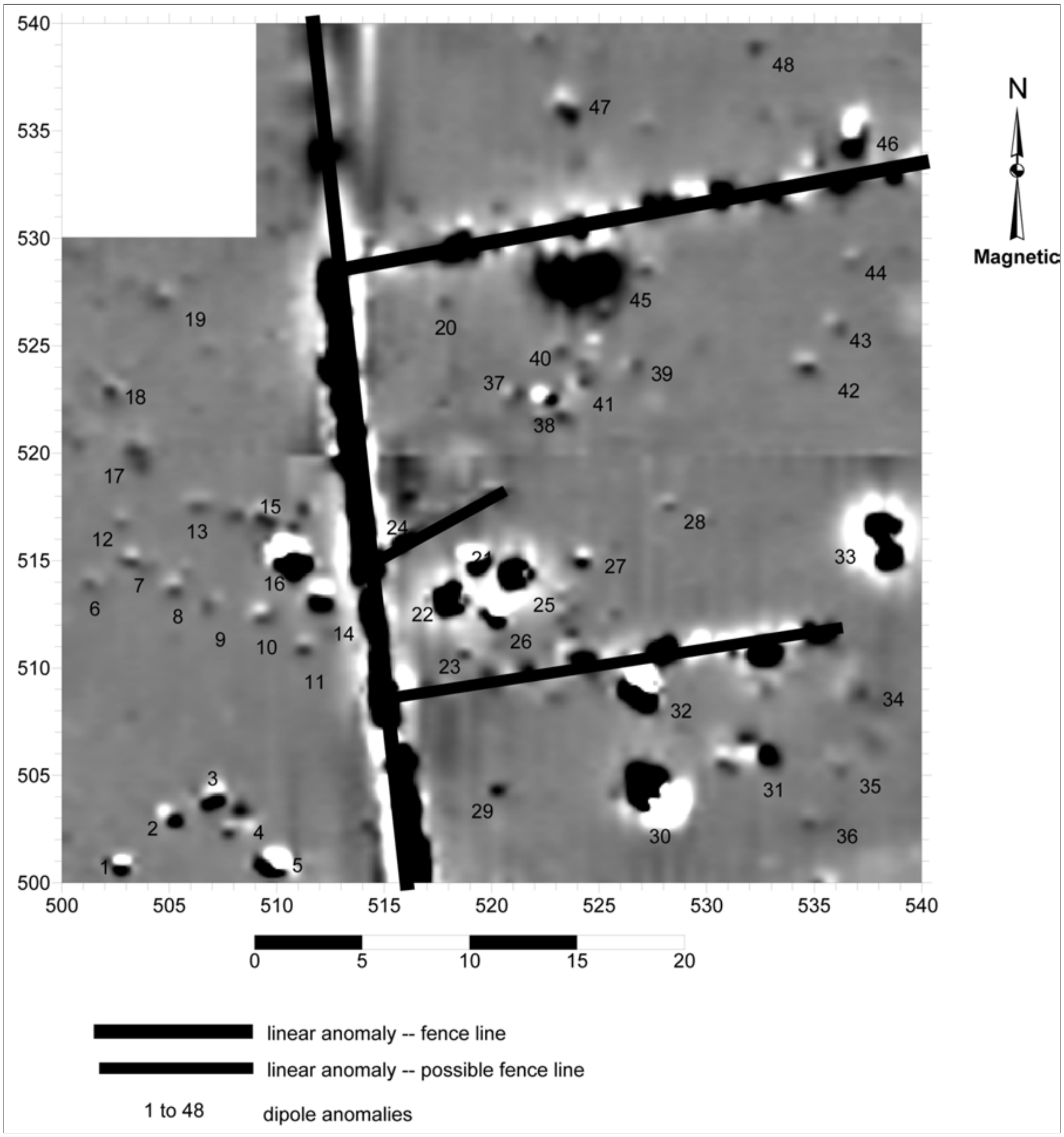

Figure 21. Magnetic gradient anomalies located within the geophysical project area. The linear anomalies probably represent the remnants of fence lines. Between N510 and N530 and E500 and E513 are several weak dipole anomalies that probably represent the locations of graves within the Sac and Fox tribal/family cemetery.

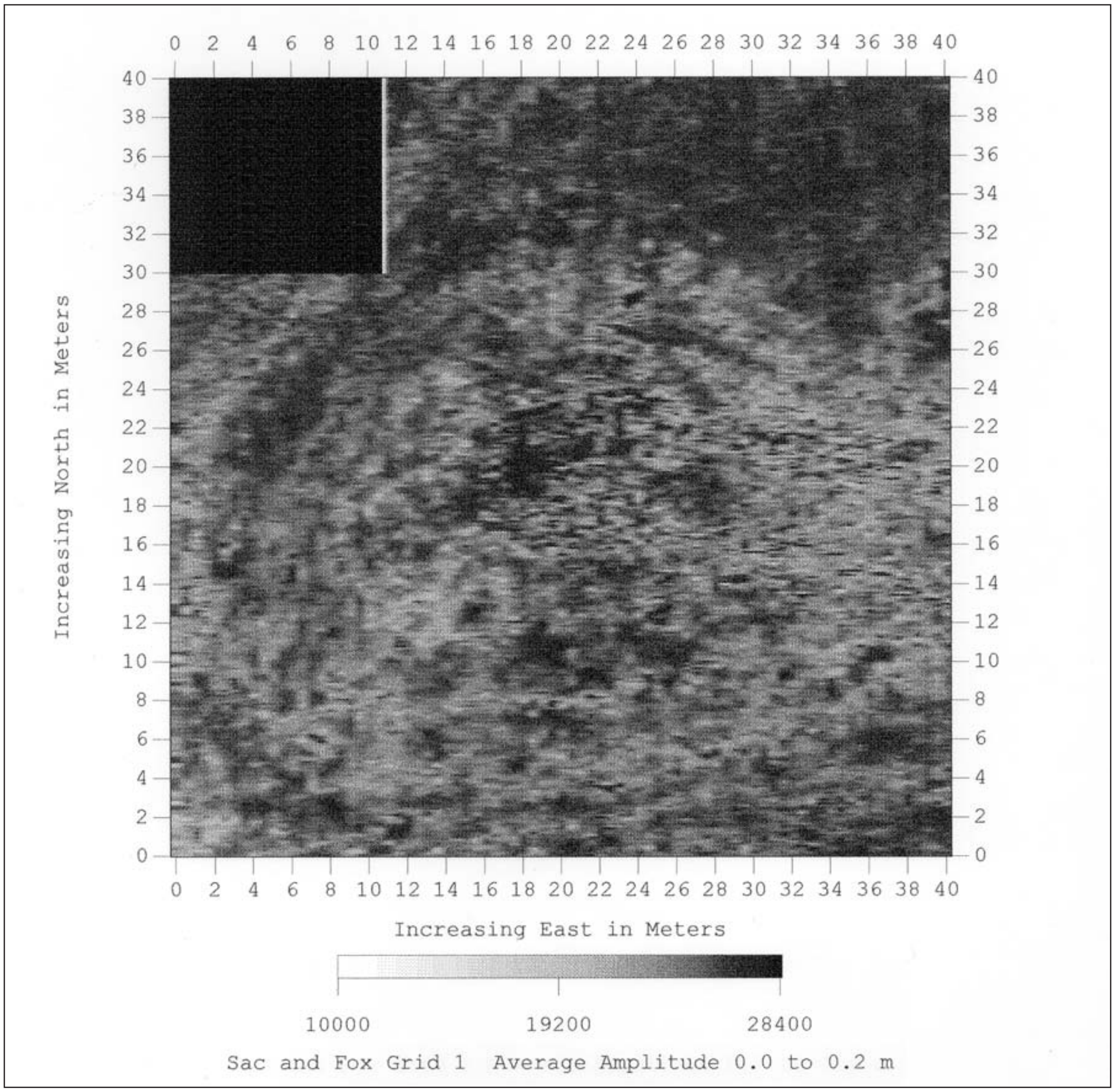

Figure 22. Plan view of average amplitude of radar reflections from 0.0 to 0.2 m below the ground surface. The black box in the northwest corner (upper left) indicates missing data from the region that was covered by large round hay bales. The circular pattern in the center of the grid was produced by agricultural equipment and cultivation activities (Note: In order to use the correct grid location values, add 500 to both the East and North coordinates in the radar plan views).

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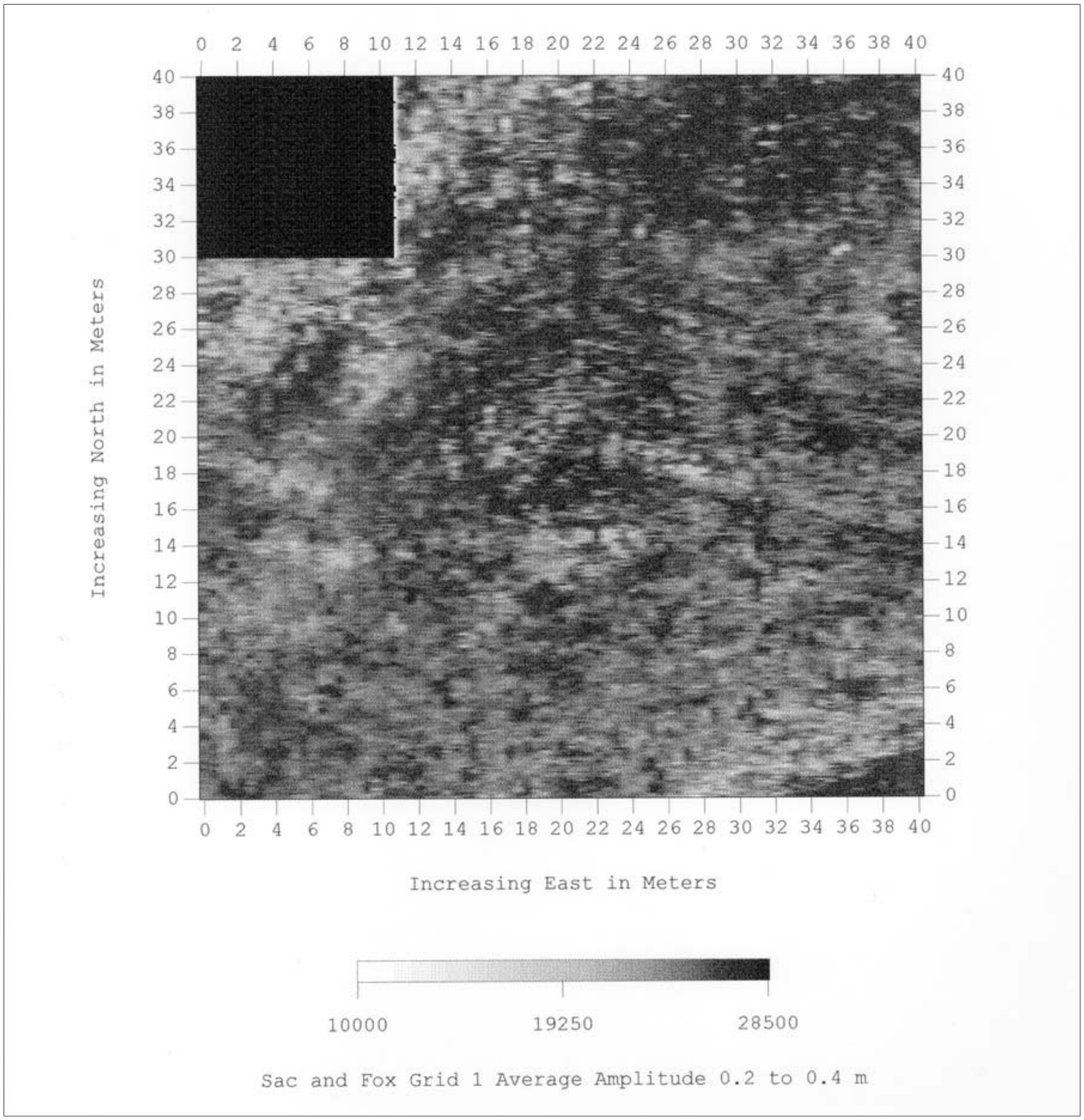

Figure 23. Plan-view of average amplitude of radar reflection from 0.2 to 0.4 m below the ground surface. A large pile of wood and brush had been removed from the center of the circular pattern in the middle of the grid. Dark regions (strong radar reflections) in the top right and bottom right corners of the grid were caused by moist soil.

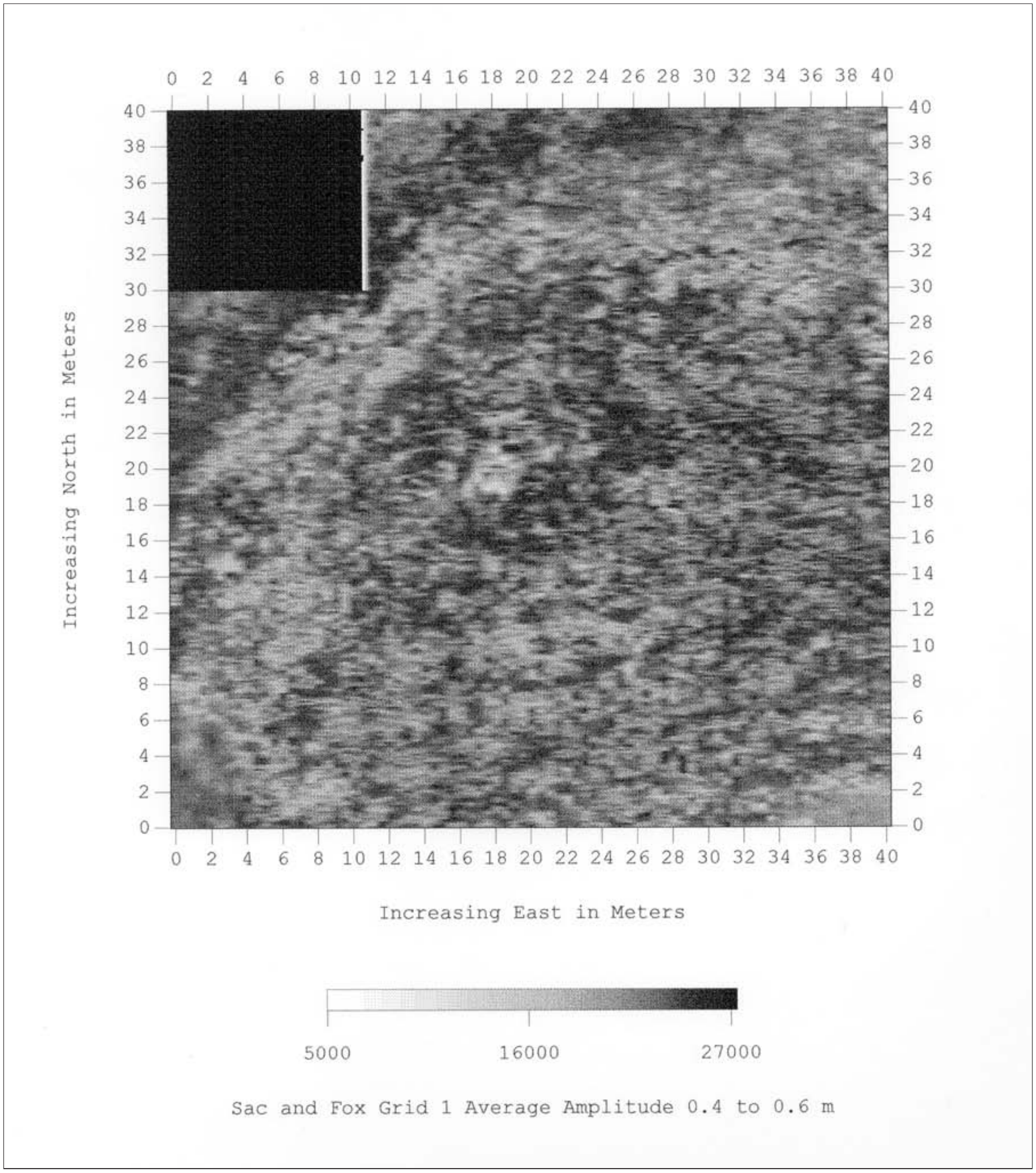

Figure 24. Plan view of average amplitude of radar reflection from 0.4 to 0.6 m below the ground surface. The effects of soil cultivation and soil moisture are largely absent at this depth. The linear pattern across the northwest corner may be related to earthmoving associated with straightening the channel of Noharts Creek.

SAC AND FOX MULTIPLE FAMILY CEMETERY

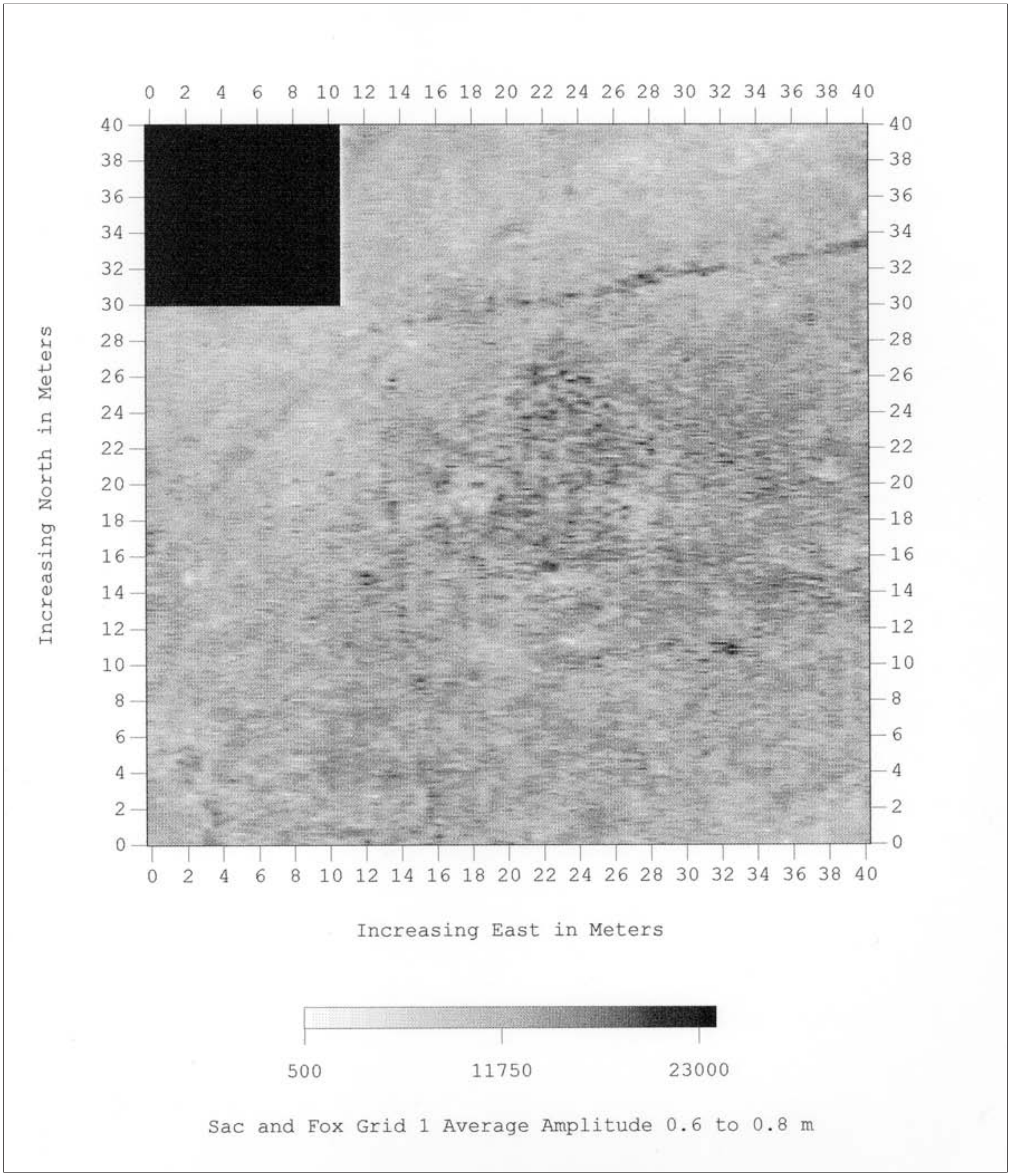

Figure 25. Plan view of average amplitude of radar reflections from 0.6 to 0.8 m below the ground surface. The effects of soil cultivation are absent at this depth. Linear anomalies extend north from N500/E515 (N0/E15), west from N534/E540 (N34/E40), and northeast from N516/E500 (N16/E0).

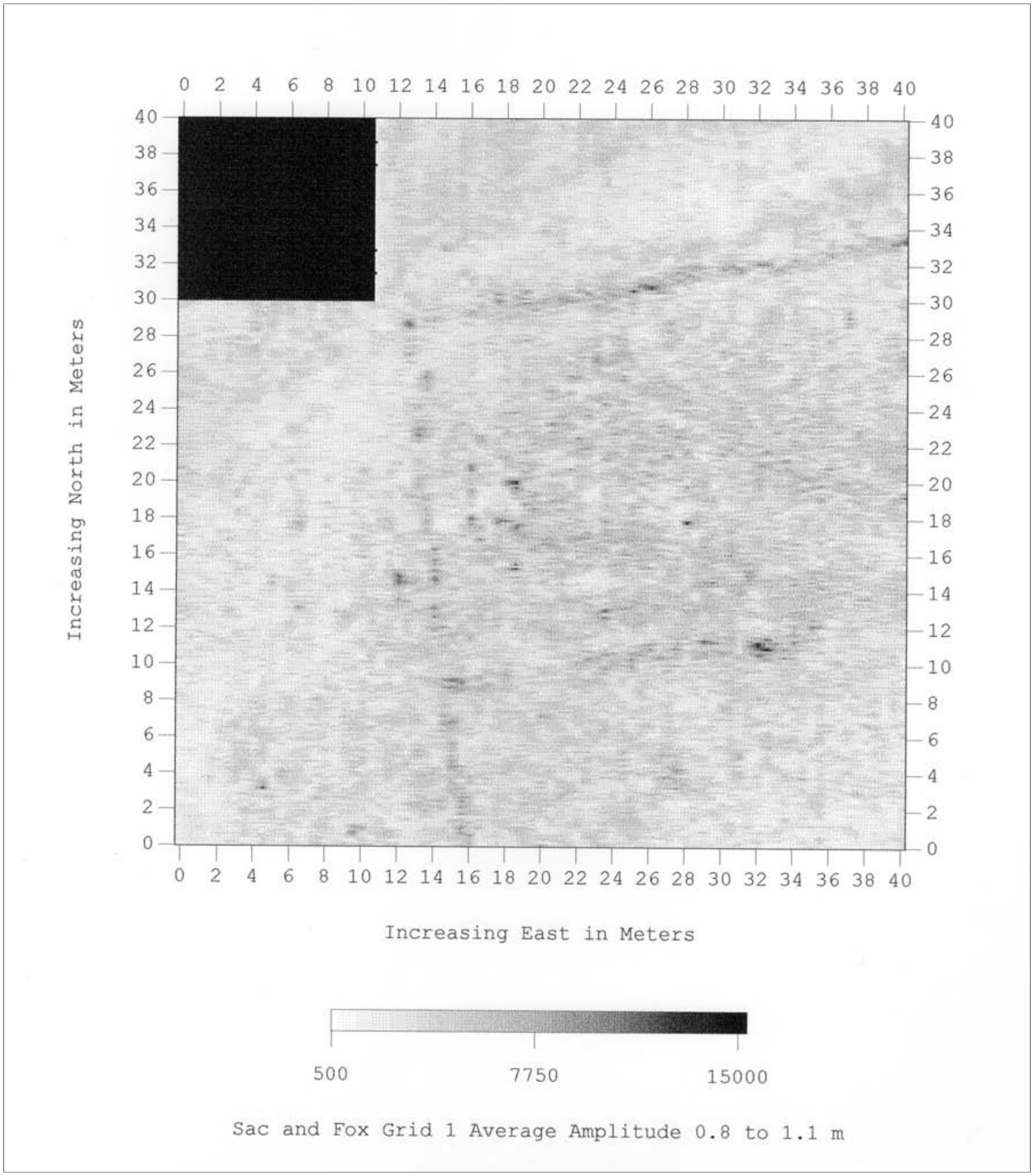

Figure 26. Plan view of average amplitude of radar reflections from 0.8 to 1.1 m below the ground surface. Linear anomalies extending north from N500/E515 (N0/E15) and west from N534/E540 (N34/E40) are more prominent and another segment extending from N509/E515 (N9/E15) toward N511/E532 (N11/E32) has become visible. The weak anomaly extending northeast from N516/E500 (N16/E0) is not well represented.

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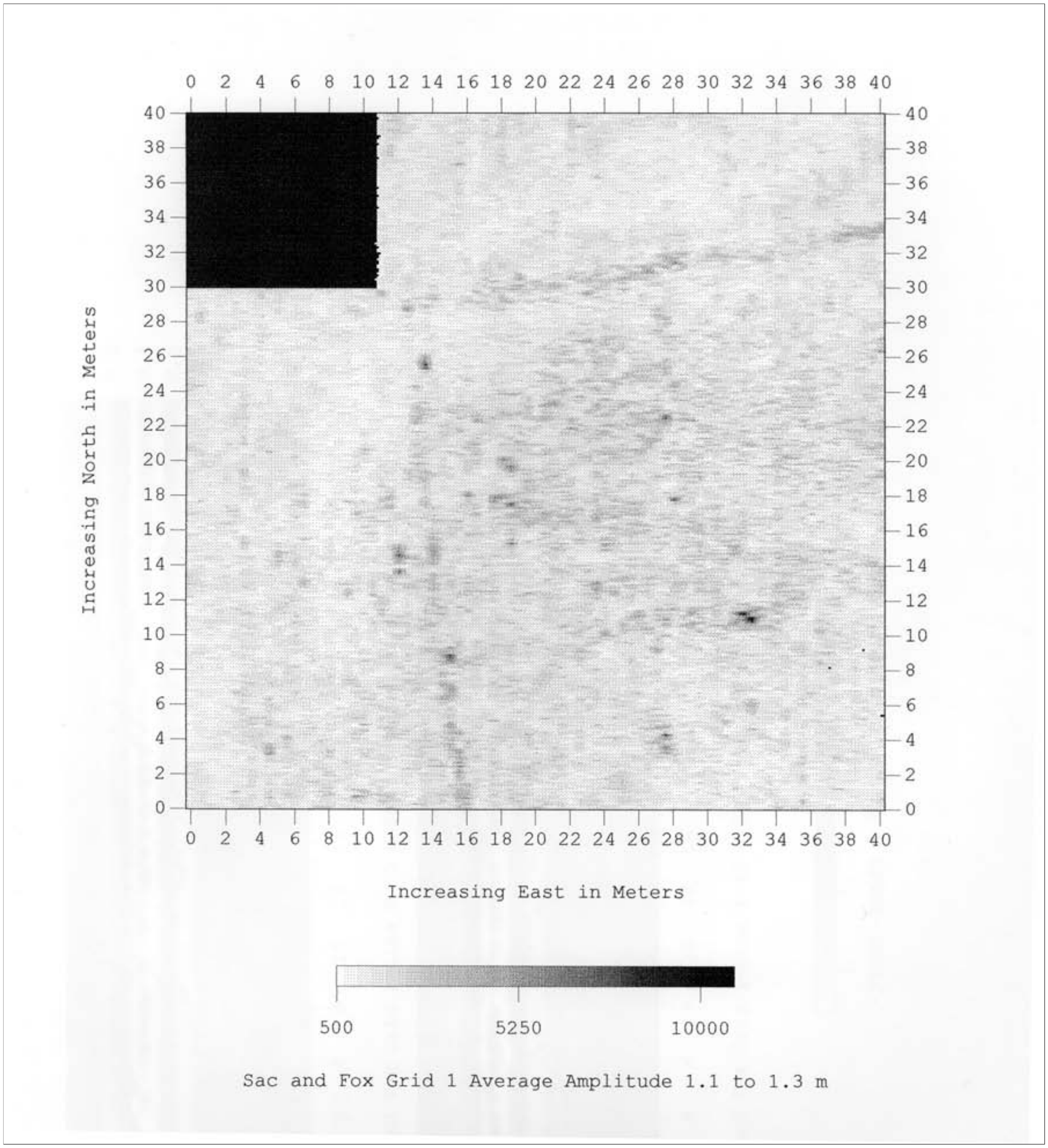

Figure 27. Plan view of average amplitude of radar reflections from 1.1 to 1.3 m below the ground surface. Linear anomalies extending north from N500/E515 (N0/E15), west from N534/E540 (N34/E40), and between N509/E515 (N9/E15) toward N511/E532 (N11/E32) remain visible. Several of the localized anomalies at this level are associated with linear features. Those anomalies that might represent burial pits or graves are concentrated in the west central portion of the grid between N512/E500 (N12/E0), N512/E512 (N12/E12), N522/E512 (N22/E12), and N522/E500 (N22/E0).

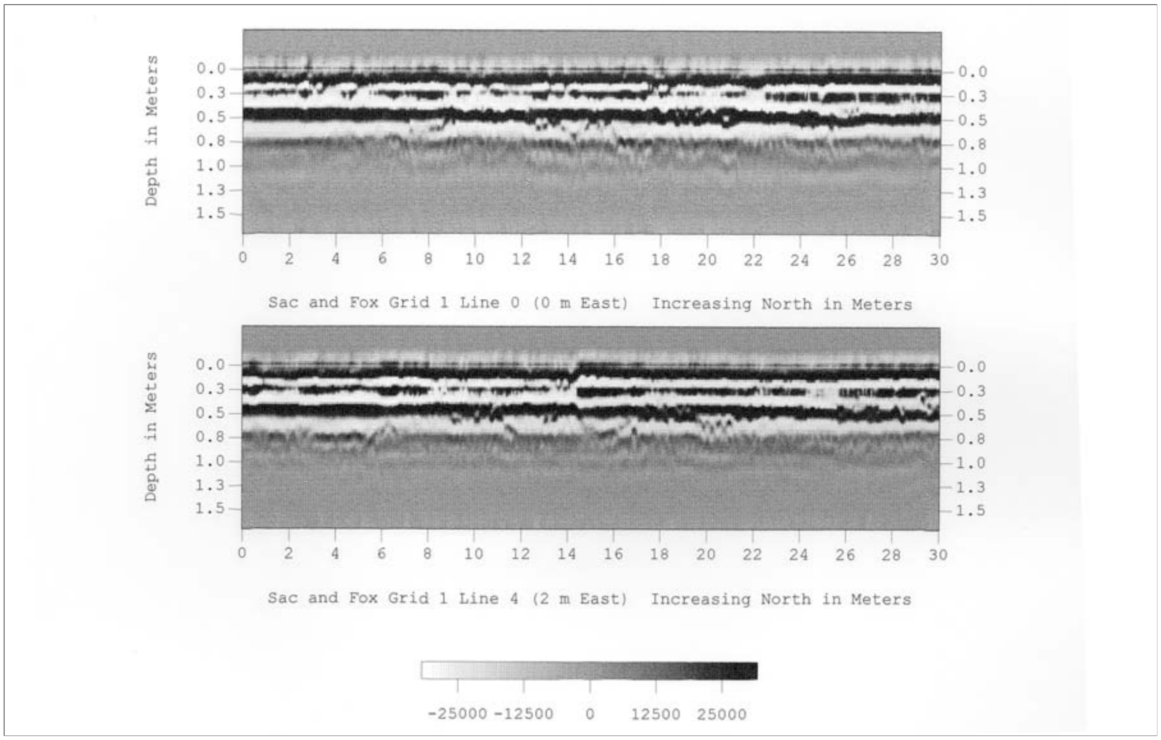

Figure 28. Radar profiles at the west edge of the grid (top image and 2 m east into the grid (bottom image). The source of the weak linear anomaly in the west portion of the grid can bee seen at about 16 m north in the top image and at 19 m north in the bottom image.

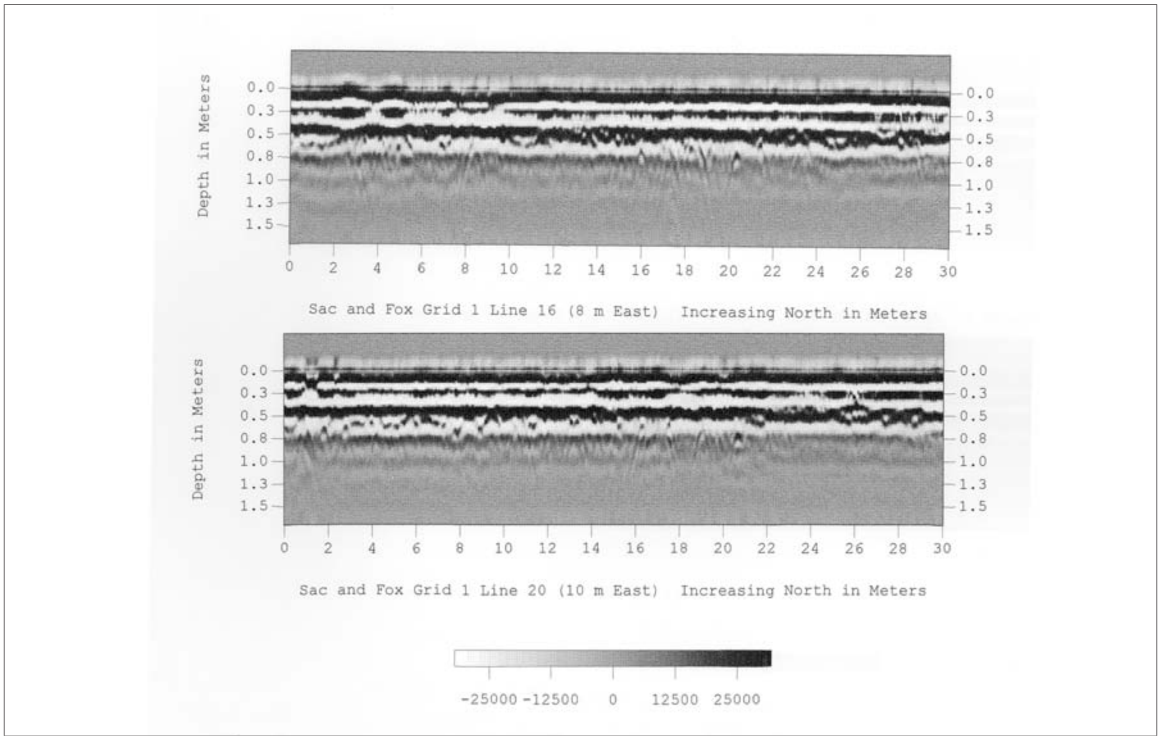

Figure 29. Radar profiles from the traverses 8 m east (top image) and 10 m east (bottom image). The source of the weak linear anomaly in the west portion of the grid can bee seen at about 24.5 m north in the top image and at 26.5 m north in the bottom image. Possible burial pit or grave features are seen between 20 m and 21 m north in both profiles.

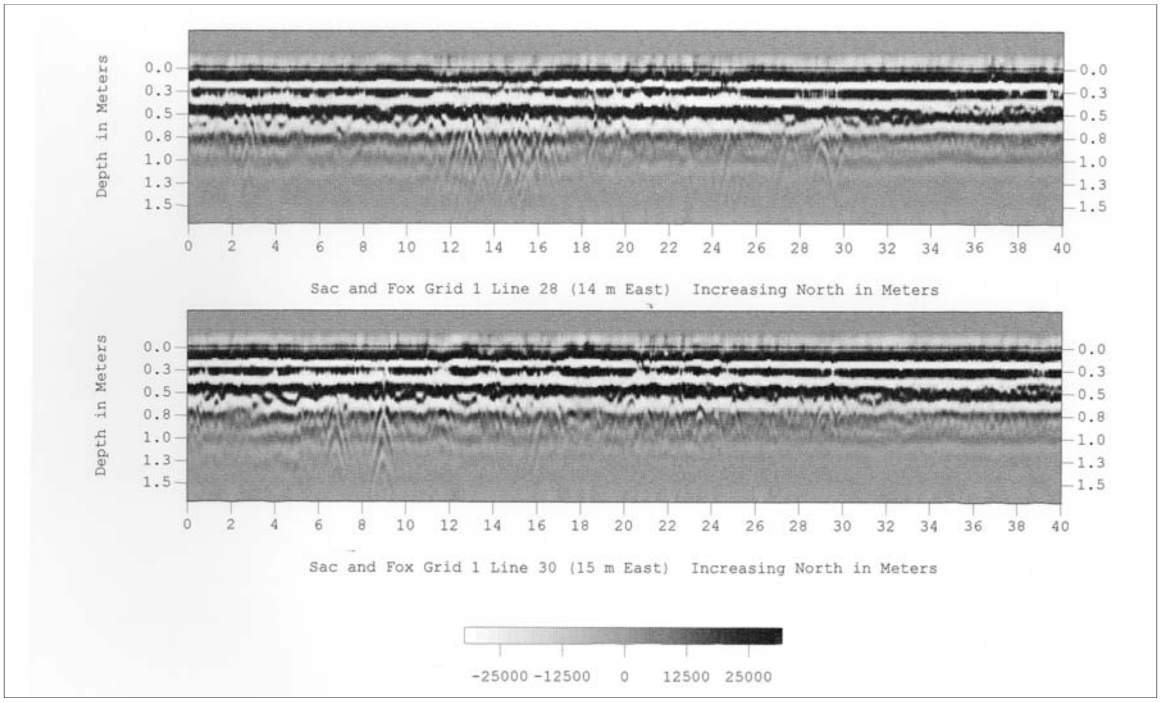

Figure 30. Radar profiles from the traverses 14 m east (top image) and 15 m east (bottom image). The north-south segment of the strong linear anomaly is seen between 12 m and 17 m north in the top image and at 4 m north in the bottom image. The long east-west segment of the strong anomaly is seen at about 28.5 m north in the top image and at 29 m north in the bottom image.

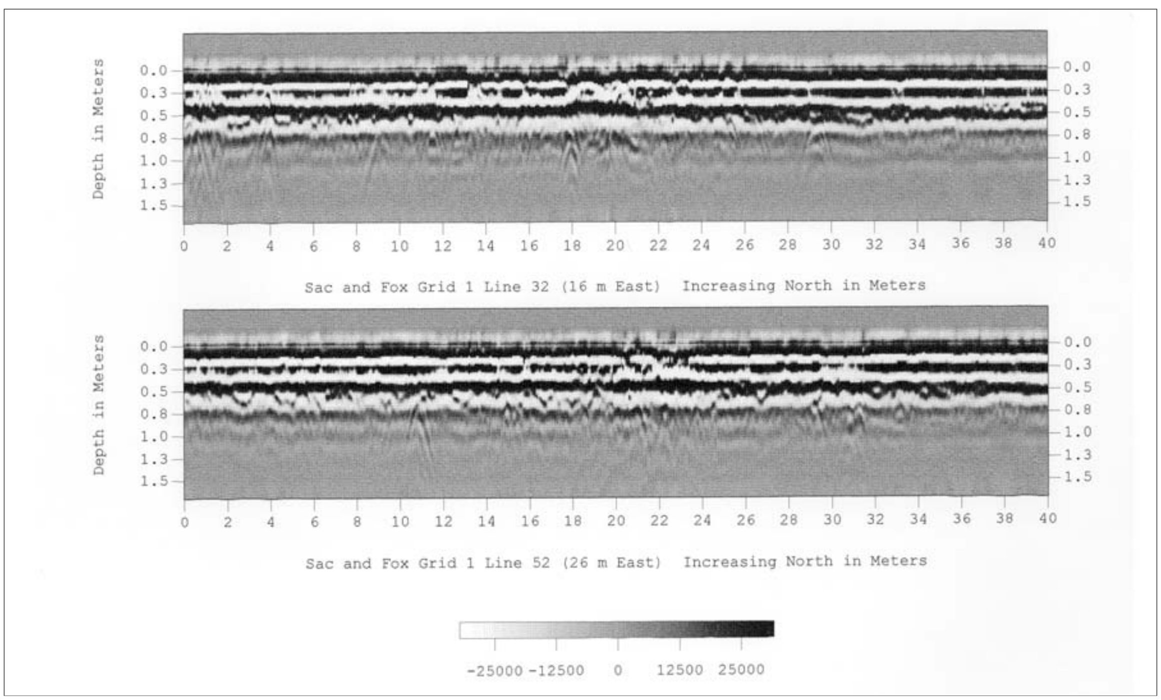

Figure 31. Radar profiles from the traverses 16 m east (top image) and 26 m east (bottom image). The north-south segment of the strong linear anomaly is seen at 1 m north in the top image. The long east-west segment of the strong anomaly is seen at about 29 m north in the top image and at 31 m north in the bottom image. The short east-west linear anomaly is visible at 9 m north in the top image and at 11 m north in the bottom image.

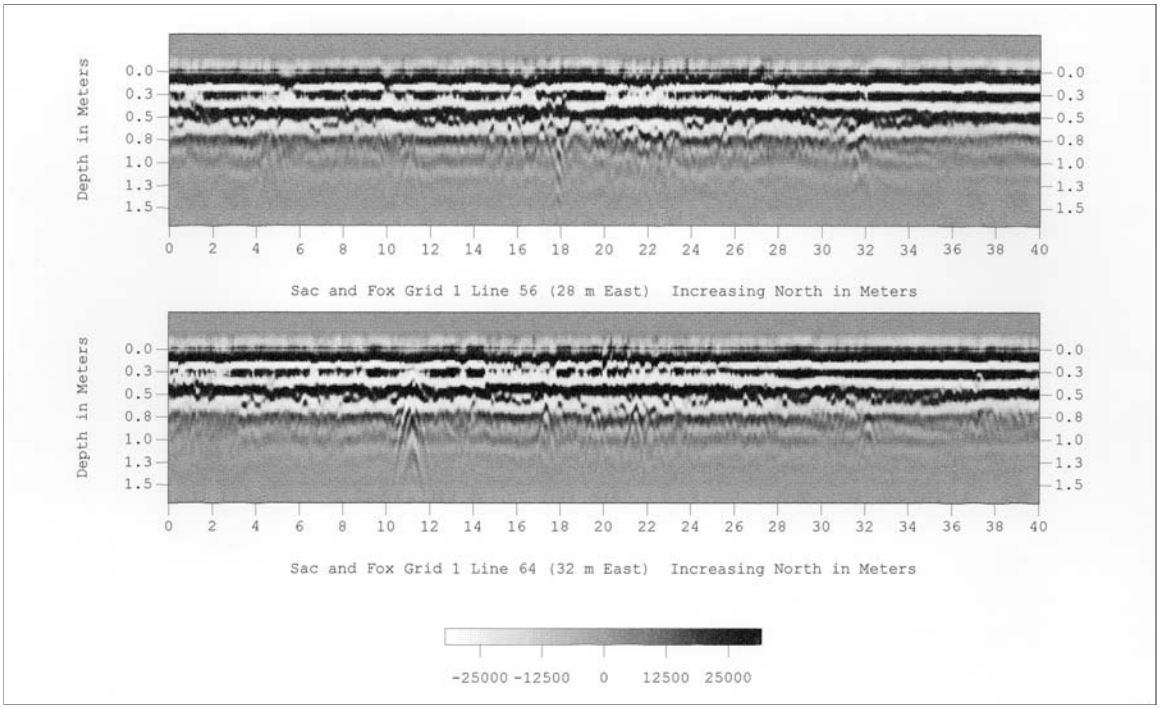

Figure 32. Radar profiles from the traverses 28 m east (top image) and 32 m east (bottom image). The long east-west segment of the strong linear anomaly is seen at about 31.5 m north in the top image and at 32 m north in the bottom image. The short east-west linear anomaly is visible at 10.5 m north in the top image and at 11.5 m north in the bottom image. Reflections typical of metal objects occur at 18 m and 32 m north in the top image.

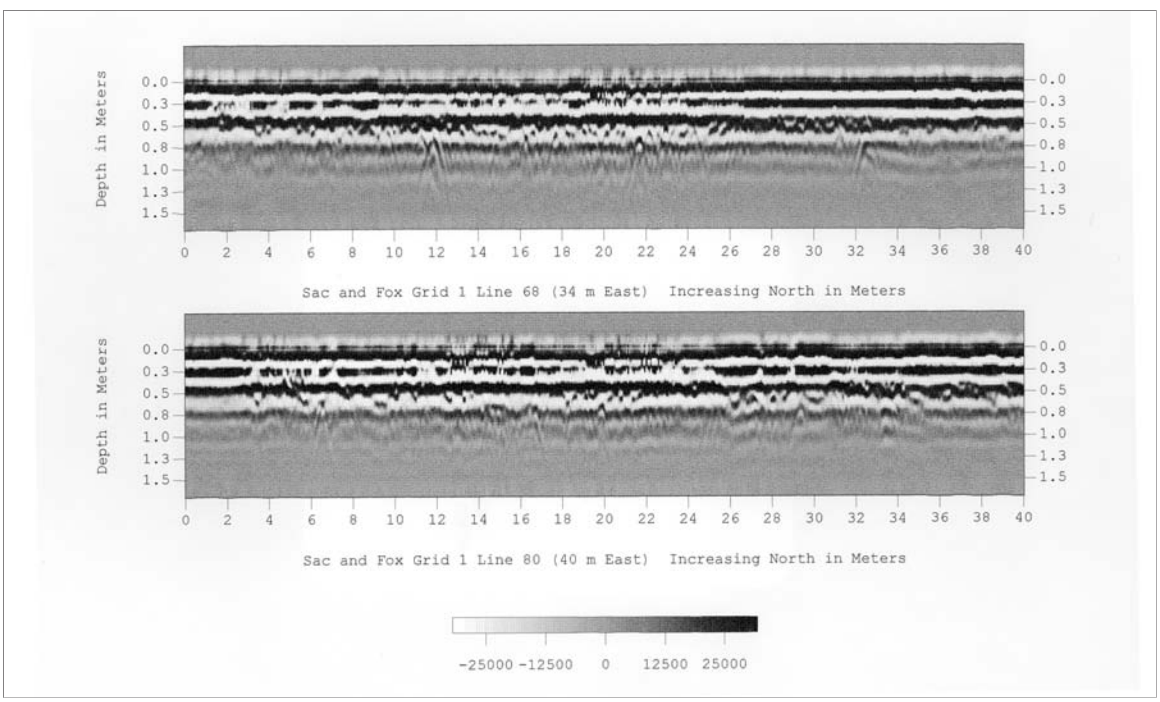

Figure 33. Radar profiles from the traverses 14 m east (top image) and 40 m east (bottom image). The long east-west segment of the strong linear anomaly is seen at about 32.5 m north in the top image and at 33.5 m north in the bottom image. The short east-west linear anomaly is visible at 11.5 m north in the top image and is absent in the bottom image.

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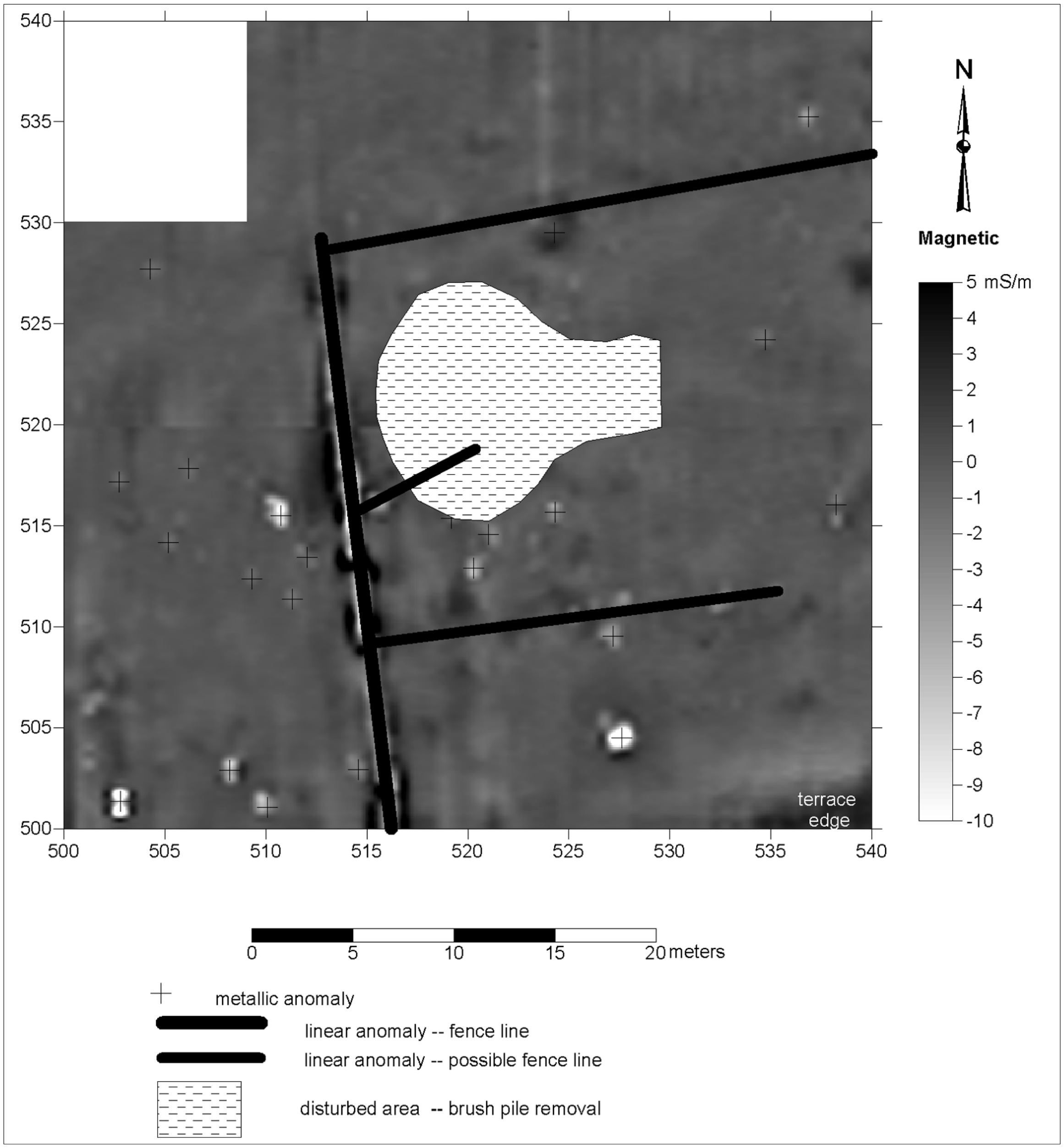

Figure 34. Conductivity anomalies located within the geophysical project area. The linear anomalies probably represent the remnants of fence lines and represent complementary data to the magnetic gradient and ground penetrating radar data. Between N510 and N520 and E500 and E513 are several negative anomalies that correspond to magnetic gradient and ground penetrating radar anomalies believed to be associated with the locations of graves within the Sac and Fox tribal/family cemetery.

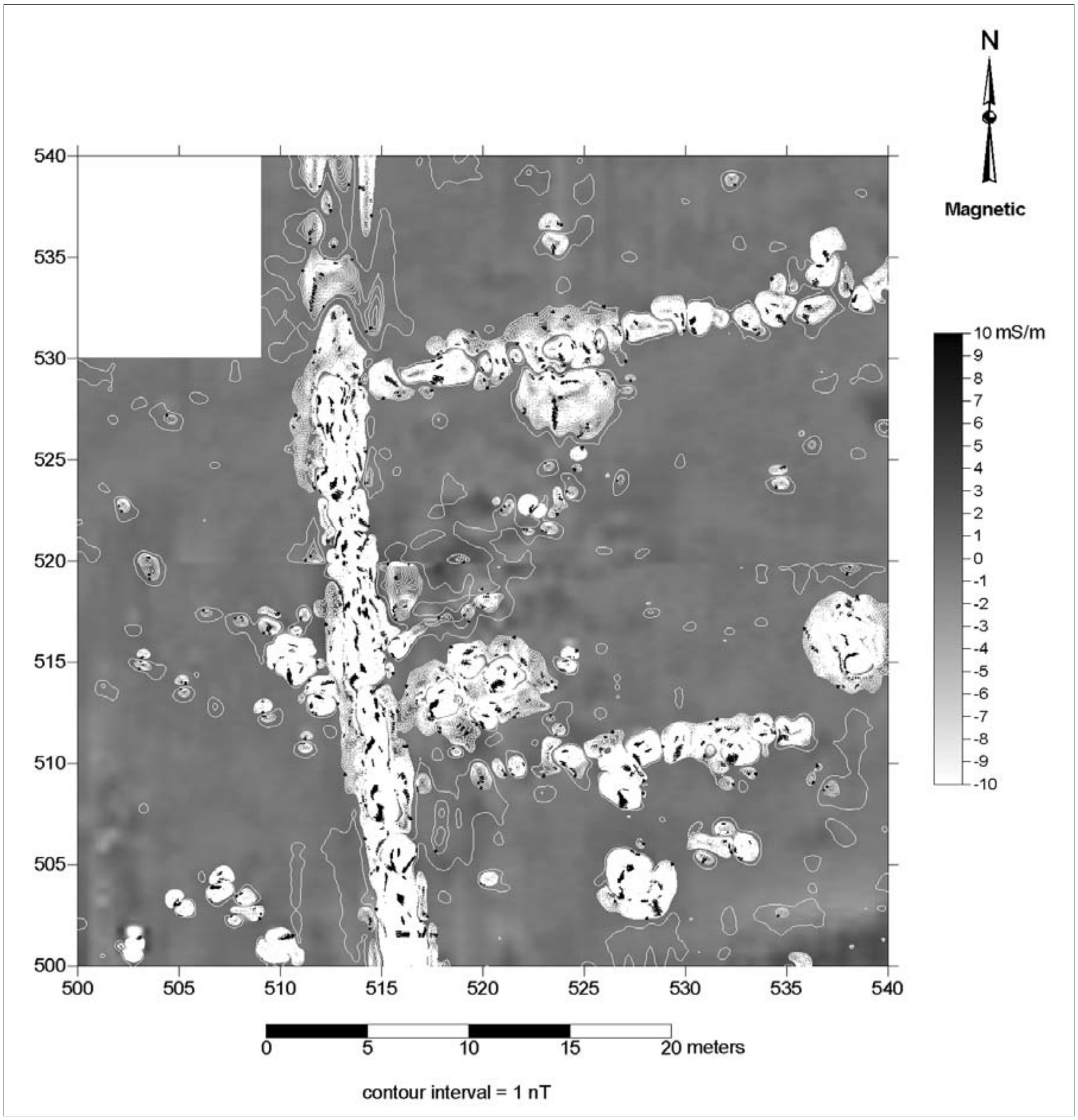

Figure 35. Conductivity data overlain with magnetic gradient contours.

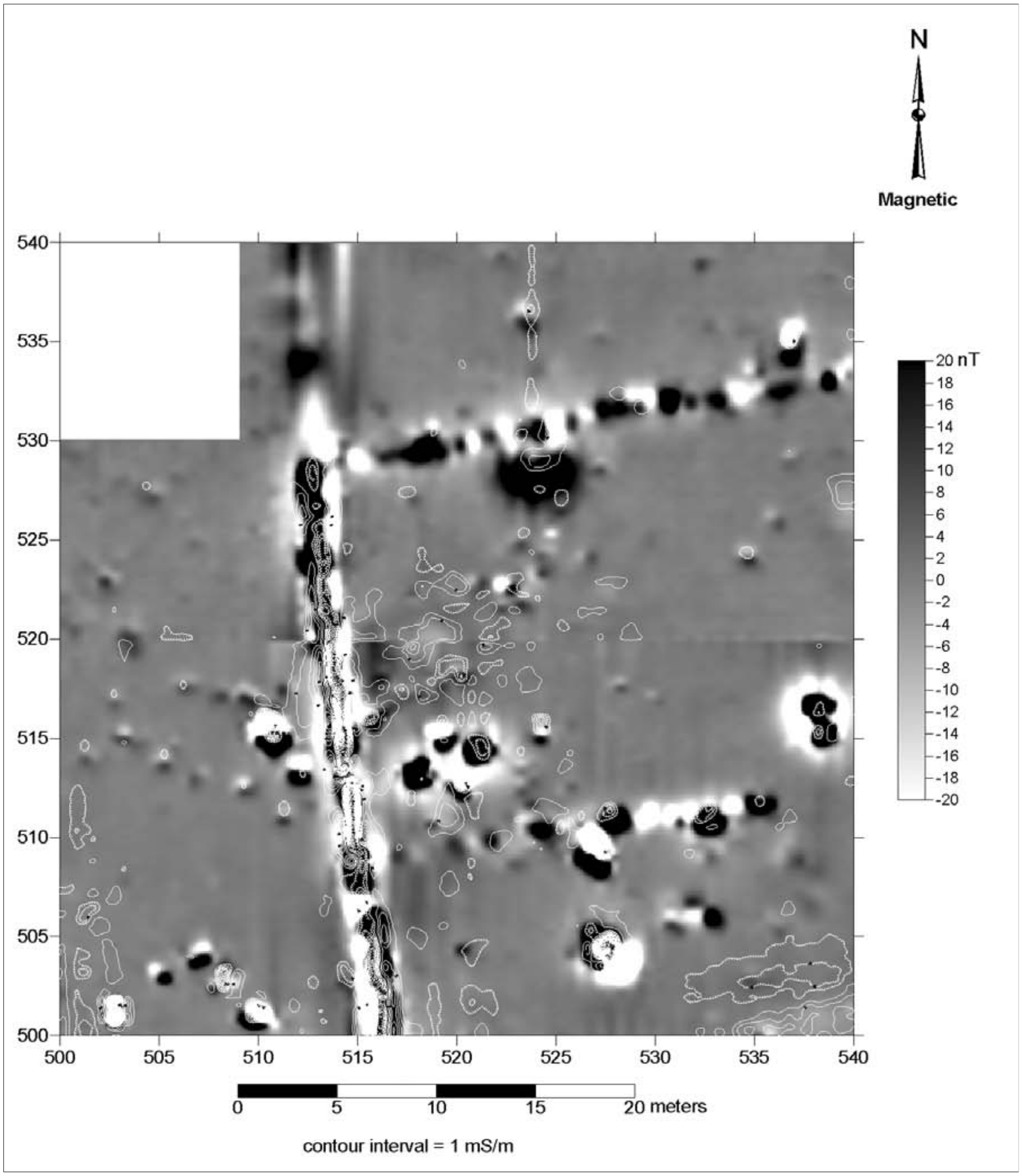

Figure 36. Magnetic gradient data overlain with conductivity contours.

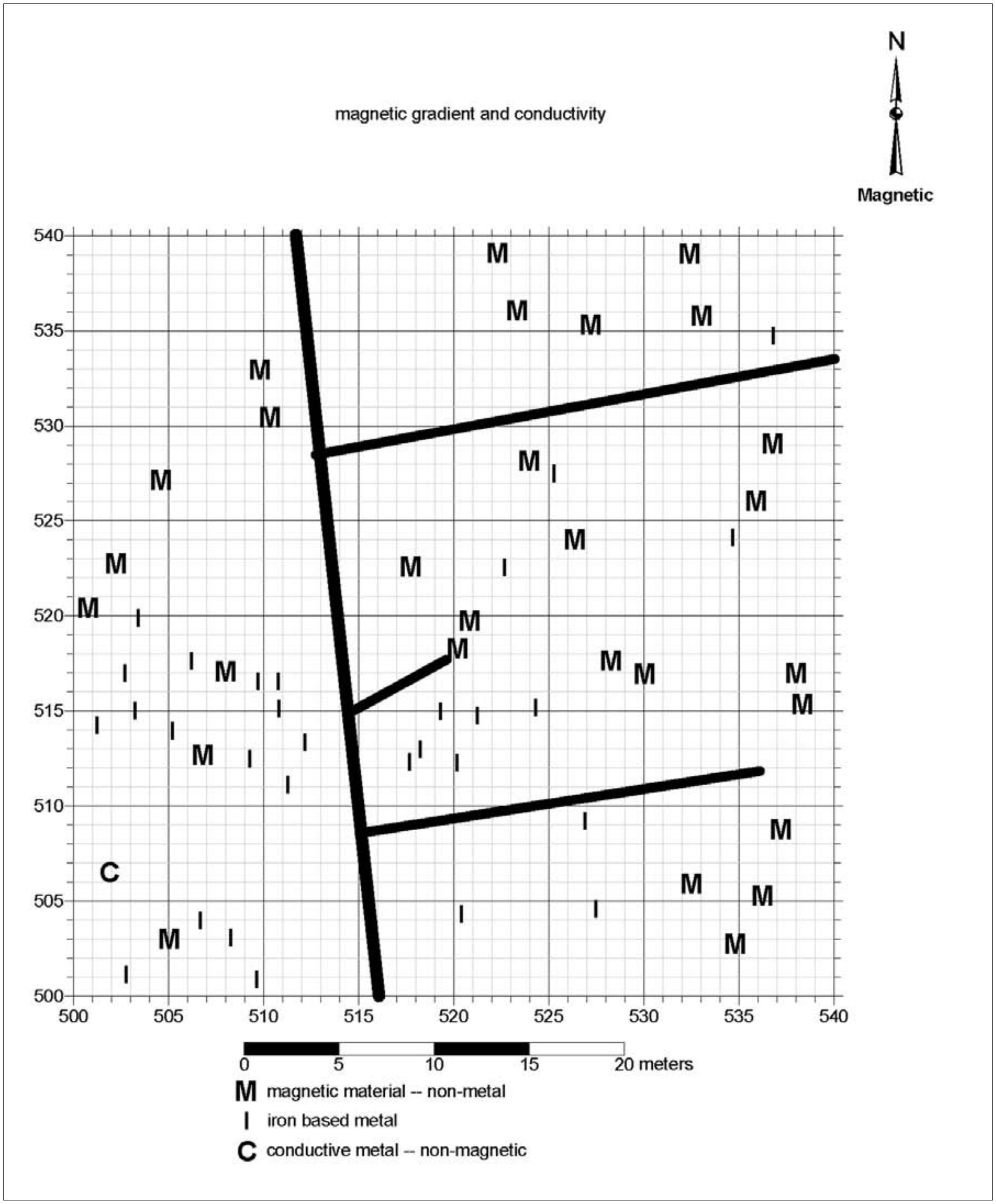

Figure 37. Comparison of the nature of magnetic gradient and conductivity anomalies.

SAC AND FOX MULTIPLE FAMILY CEMETERY