**National Park Service**
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**Midwest Archeological Center**
Lincoln, Nebraska

# GEOPHYSICAL INVESTIGATIONS OF THREE SITES WITHIN THE KNIFE RIVER INDIAN VILLAGES NATIONAL HISTORIC SITE, MERCER COUNTY, NORTH DAKOTA

By
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Archeological Report 10

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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).

# ABSTRACT

The National Park Service's Midwest Archeological Center staff and instructors and participants of the 2010 NPS archeological prospection workshop, along with students from the University of North Dakota's 2010 fieldschool conducted geophysical investigations at three sites within Knife River Indian Villages National Historic Site in Mercer County, North Dakota. The geophysical investigations were conducted between May 10 and May 29, 2010. The investigations at the Elbee site, 32ME408, and Site 32ME2377 were requested by the KNRI superintendent as part of the compliance activities related to the erosion of the Knife River bank in the vicinity of the two sites. The geophysical investigations at the Taylor Bluff site, 32ME366, were conducted as part of the field exercises associated with the twentieth annual NPS archeological prospection workshop. The geophysical survey at the Elbee site included a resistance survey with a resistance meter and twin-probe array, a limited magnetic survey with a dual fluxgate gradiometer, and the re-analysis of the 2002 and 2006 magnetic data from the site. The geophysical survey at Site 32ME2377 included a resistance survey with a resistance meter and twin probe array and a magnetic survey with a single fluxgate gradiometer. Primary data collected at the Taylor Bluff site during the workshop included a ground-penetrating radar survey with a 400 mHz antenna and a magnetic survey with a dual fluxgate gradiometer. The geophysical surveys were conducted in order to identify buried archeological remains in the vicinity of the Knife River bank at the Elbee site and Site 32ME2377. The survey results provide a baseline of archeological geophysical data for a data recovery project by the University of North Dakota's archeological fieldschool. The survey data from Sites 32ME366, 32ME407, and 32ME2377 provide subsurface information for future park planning activities. The geophysical data also provide information on the potential damage to the archeological resources from the continued erosion of the Knife River bank. The geophysical surveys identified numerous buried archeological remains associated with the prehistoric human occupation of the Elbee site, the historic Native American occupation of the Taylor Bluff site, and more recent historic farming and modern NPS activities at all three sites. The combined total area investigated by the geophysical survey in the three KNRI geophysical project areas was 17,086 m2 or 4.22 acres. The Elbee site and the Taylor Bluff site were recommended as eligible for listing on the National Register of Historic Places while Site 32ME2377 was recommended as not eligible.

# ACKNOWLEDGEMENTS

This project was completed with support and assistance from the Knife River Indian Villages National Historic Site (KNRI) staff. Sincere appreciation is extended to former KNRI Superintendent Brian McCutchen, KNRI Resource Manager Maureen McGee-Bellineer, and the park's facility manager Chuck Folk who participated in the planning and implementation of the geophysical survey. I would also thank Ramon Jasso for mowing the tall grass at the Elbe site and at the Taylor Bluff site. All of the KNRI park staff went out of their way to make the MWAC crew feel welcome and provided assistance in getting the work done efficiently, safely, and as comfortably as possible during the archeological investigations. I would also like to thank Dr. Dennis Toom and his 2010 University of North Dakota archeological fieldschool students for their assistance during the geophysical survey of the Elbee site. I am sincerely grateful to the instructors and participants of the 2010 NPS archeological prospection workshop for all of their enthusiasm during the field exercises at the Taylor Bluff site.

At the Midwest Archeological Center, I would like to thank Dr. Mark Lynott (MWAC Manager) and Jeffery J. Richner (MWAC Park Archeology Program Manager), now both re tired, for their direction, leadership, and support during the project. I would also like to thank Jay Sturdevant, MWAC archeologist, for his additional insights concerning the park, its archeological resources, the effects of the flooding to the Elbee site, and the selection of the Taylor Bluff site for the archeological prospection workshop. I also appreciate the geophysical survey efforts of the MWAC field crew: Albert M. LeBeau III and Dustin Gonzales. I am also grateful for the support provided by Administrative Officer Jill Lewis, and the rest of the MWAC staff for all of their help without which this project would not have been completed as smoothly or efficiently as it was. Christina Swenson, Darin Schlake, Bryttie Duren, and Bailey Koziol provided logistical, computer, transportation, and personnel support during the project while Alan Weber and Jeff Larson provided editing and report preparation in the publishing of this document. I am sincerely grateful for their review comments of the draft manuscript.

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# INTRODUCTION

The geophysical surveys of the Elbee site, 32ME408, and Site 32ME2377, along the right bank of the Knife River within the Knife River Indian Villages National Historic Site (KNRI) in Mercer County, North Dakota (Figure 1), were conducted as part of an archeological investigation of the erosional effects of high water levels in the Knife River on the two sites by the National Park Service's (NPS) Midwest Archeological Center (MWAC) field crew in 2010 (De Vore 2010). The geophysical investigations were part of archeological data recovery within the two sites immediately adjacent to the river bank that sustained significant damage during the 2009 Spring ice flows and high water levels (Sturdevant 2009). The geophysical investigations at the Taylor Bluff site, 32ME366, on the left bank of the Knife River (Figure 1) were conducted as part of the NPS 2010 archeological prospection workshop (De Vore 2010).

The Knife River Indian Villages National Historic Site was established on October 26, 1974, by an Act of Congress and signed into law by President Gerald R. Ford (Public Law 93-486). The national historic site was established to preserve the archeological and historic value of the four major village sites (Big Hidatsa, Lower Hidatsa, Sakakawea, and Buchfink), to interpret the lifestyle of the Northern Plains indigenous villagers, and to conduct research related to the Northern Plains village tribes (Godfrey 2009:1; NPS 2008:11-14). By the end of 1978, the federal government managed to acquire approximately 1, 250 ac along the Knife River for the park through purchases, donations, or scenic easements (Godfrey 2009:112). Additional acquisitions of land, including the Kreiger Parcel in the early 1990s (Public Law 101-430), brought the total acreage of the park to 1,758 ac.

The geophysical investigations were conducted from May 10 to May 29, 2010, at the Elbee site, Site 32ME2377, and the Taylor Bluff site at the Knife River Indian Villages National Historic Site. The geophysical investigations at the Taylor Bluff site (Figure 2) were conducted as part of the NPS 2010 archeological prospection workshop while the investigations at the Elbee site (Figure 3) and Site 32ME2377 (Figure 4) were conducted as part of the archeological data recovery project with the University of North Dakota (UND) under the direction of Dennis Toom. The geophysical survey at the Elbee site consisted of a resistance survey with a resistance meter and twin-probe array and a limited magnetic survey with a dual fluxgate gradiometer. Previous geophysical investigations at the Elbee site consisted of magnetic surveys with single fluxgate gradiometers in 2002 and 2006 by Midwest Archeological Center archeologists and KNRI staff (De Vore 2008; Volf 2005). The geophysical investigations at Site 32ME2377 included a magnetic survey with a single fluxgate gradiometer and a resistance survey with a resistance meter and twin-probe array. Initially, Site 32ME2377 was identified as the Karishta site (32ME466) during the field investigations but subsequent re-evaluation of the site location indicated that the geophysical investigations were carried out to the east of the Karishta site on a different landform at the park. Therefore, Site 32ME2377 was recorded as a separate site during the project. The geophysical investigations at the Taylor Bluff site were part of the archeological prospection workshop during the week of May 24-28, 2010. The investigations included a ground-penetrating radar (GPR) survey of the project area with a GPR cart and 400 mHz antenna and a magnetic survey with a dual fluxgate gradiometer. Other geophysical survey instruments demonstrated during the workshop field exercises included a fluxgate gradiometer cart system, a single fluxgate gradiometer, a ground-penetrating radar system with a 500 mHz antenna, a ground-conductivity meter, a magnetic susceptibility field coil, and a magnetic susceptibility down-hole probe system. These techniques offered inexpensive, rapid, and relatively non-destructive and non-invasive methods of identifying and detecting buried archeological resources and site patterns, and also provided a means for sampling relatively large areas in an efficient manner (Roosevelt 2007:444-445; and Von Der Osten-Woldenburg 2005:621-626). The geophysical investigations were conducted in order to identify buried archeological remains in the vicinity of the bank erosion along the Knife River at the Elbee site and Site 32ME2377, as well as within the archeological prospection workshop project area at the Taylor Bluff site. This would provide a baseline of archeological geophysical data for the park's future planning activities and to provide information on the potential damage to the archeological resources at the Taylor Bluff site from historic farming and more recent park activities.

# ENVIRONMENTAL SETTING

The present KNRI geophysical project areas are located in the glaciated Missouri Plateau section of the Great Plains Province of the Interior Plains (Fenneman 1931:72-79; Hunt 1967:220-226). The project areas are also located within the Rolling Soft Shale Plain of the Northern Great Plains Spring Wheat Land Resource Region (USDA 2006:145-146). The moderately dissected, rolling plain consists of glaciated old plateaus, with some local badlands, buttes, hills, and occasional isolated mountains. Bedrock in the vicinity of KNRI includes the Paleocene age Sentinel Butte and Bullion Creek formations of "poorly lithified sand, silt, silty clay, and clay with shale and lignite" (Lovick and Ahler 1982:38) covered with Quaternary glacial, eolian, and alluvial deposits. The Elbee site is located on the mid-Holocene age "A" terrace above the right bank of the Knife River with small portions in the southwest corner of the site located on the Pleistocene Hensler and Stanton terraces (Lovick and Ahler 1982:39-42; NPS 1986:49; Reiten 1983:9-13). The terrace deposits are layers of silty sand grading upwards to clayey silt and capped by wind blown silt. For additional information on the environmental setting, the reader is referred to Lovick and Ahler (1982:34-47) and Toom et al. (2004:1.1-1.7).

Soils within the Rolling Soft Shale Plain are dominated by mollisols and entisols (Foth and Schafer 1980:116-125; USDA 2006:146). The soils are more or less freely drained with ustic soil moisture and frigid soil temperature regimes. Parent materials in Mercer County have several different origins including glacial till and other glacial materials, weathered material from water sorted till, wind- or water-deposited sandy and loamy materials, alluvium, residual bedrock, and porcelanite (Wilhelm 1978:107). The soils formed under mid and short prairie grass vegetation. Depth to bedrock ranges from shallow to very deep. All three project areas lay within the Havrelon-Lohler soil association of "level, deep, well-drained and moderately well-drained soils formed in material weathered from alluvium" (Wilhelm 1978:10). The soils within the Elbee site geophysical project area include the Straw loam (91B) located on three to six percent slopes, the Straw silty clay loam (7), and the Dimmick silty loam (5) on the Holocene "A", "B1", and "B2" terraces (Lovick and Ahler 1982:39-42; Wilhelm 1978:13-14,59-60,87-88,101). The Straw loam soil in the project area consists of a deep, well-drained, and gently sloping to undulating soil located on the low terrace on the right side of the Knife River (Wilhelm 1978:59,101). Formed in material weathered from loamy alluvium, the soil has a moderate permeability, medium surface runoff, moderate shrink-swell potential, moderate frost action, and a high available water capacity (Wilhelm 1978:59). The soil pH ranges from neutral to moderately alkaline (Wilhelm 1978:101). The soil-mapping unit composes the majority of the Elbee site project area. The Straw silty clay loam soil in the project area consists of a deep, well drained, and level soil located on the low terrace on the right side of the Knife River, which is occasionally flooded for brief periods (Wilhelm 1978:14,101). Formed in material weathered from loamy alluvium, the soil has a moderate permeability, slow surface runoff, moderate shrink-swell potential, moderate frost action, and a high available water capacity (Wilhelm 1978:14). The soil pH ranges from neutral to moderately alkaline (Wilhelm 1978:101). The Dimmick silty clay soil in the project area consists of a deep, very poorly drained, and level soil located in an old oxbow of the Knife River (Wilhelm 1978:13-14,87-88). Formed in material weathered from clayey sediments, the soil has a very slow permeability, shallow depth to the water table, high shrink-swell potential, moderate frost action, and a moderate to high available water capacity (Wilhelm 1978:14). The soil pH ranges from neutral to mildly alkaline (Wilhelm 1978:88). The soil within the boundary of the Site 32ME2377 geophysical project area consists of the Havrelon silty clay loam (14) on the Holocene "B2" terrace (Lovick and Ahler 1982:39-42; Wilhelm 1978:17-18,91). The Havrelon silty clay loam soil in the Site 32ME2377 project area consists of a deep, well drained, and level soil located on the bottom land on the right side of the Knife River (Wilhelm 1978:17-18,91). Formed from loamy alluvium, the soil has a moderate permeability, moderate surface runoff, low to moderate shrink-swell potential, moderate frost action, and a moderate available water capacity (Wilhelm 1978:18). The soil pH ranges from mildly to moderately alkaline (Wilhelm 1978:91). The soil-mapping unit comprises the entire area of the Site 32ME2377 project area. The soil within the boundary of the Taylor Bluff site geophysical project area consists of the Magnus silty clay loam (104) on the Holocene "A" terrace (Lovick and Ahler 1982:39-42; Wilhelm 1978:67,94). The Magnus silty clay loam soil in the Taylor Bluff project area consists of a deep, well-drained, and level soil located on the low terrace on the left side of the Knife River (Wilhelm 1978:67,94). Formed in materials weathered from clay alluvium, the soil has a slow to moderately slow permeability, slow surface runoff, high shrink-swell potential, moderate frost action, and a high available water capacity (Wilhelm 1978:67). The soil pH ranges from neutral to moderately alkaline (Wilhelm 1978:94). The soil mapping unit comprises the entire area of the Taylor Bluff project area. The soils provide adequate suitability for the geophysical survey techniques, although the ground-penetrating radar survey may be hampered by the high clay content.

The project areas also lie within the Saskatchewan biotic province (Dice 1943:24-26). The semiarid mixed grass plains are dominated by a mixture of short and mid-height grasses, including western wheatgrass, needle-and-thread grass, green needlegrass, and blue grama (Brown 1985:45-53; Jones and Cushman 2004:35-40; NPS 1986:49-52; Shelford 1963:334; USDA 2006:146). Little bluestem, prairie sandreed, and side oats grama occur on shallow soils in the region. Other prairie vegetation throughout the region includes prairie rose, leadplant, and western snowberry. Green ash, chokecherry, and buffaloberry may be found along draws and narrow valleys. Strips of deciduous trees are most commonly found along larger stream channels (Brown 1985:48-49,53; Dice 1943:25; NPS 1986:49-52; Shelford 1963:309-313).

In the region, bison, wapiti, and pronghorn antelope roamed the open plains until the mid to late 1800s (Brown 1985:49-51; Jones and Cushman 2004:42-50; Shelford 1963:335). During the prehistoric and historic periods, white-tailed deer were present in the timbered areas along streams and slopes. Wolves were also important predators until exterminated from the region in the late 1800s. Jackrabbits continue to be found throughout the region along with coyotes, prairie dogs, black-footed ferrets, badgers, mink, bobcats, and foxes (USDA 2006:146). Numerous other mammals and rodents also inhabit the region (Brown 1985:52; Jones and Cushman 2004:42-50; NPS 1986:49-52; Shelford 1963:334-336). Numerous species of birds inhabit the grasslands, the shrublands, and wooded areas of the region (Brown 1985:53; Jones and Cushman 2004:50-58; Shelford 1963:336). Gray partridge, sharp-tailed grouse, and prairie chicken represented some of the regional game birds, as well as migratory waterfowl, in both prehistoric and historic times. Numerous grassland and forest species of songbirds are present. Reptiles include several species of lizards, turtles, and snakes (Brown 1985:53;

Jones and Cushman 2004:58-63; Shelford 1963:336). Amphibians are found in the prairies, forests, and wetlands (Brown 1985:53; Jones and Cushman 2004:58-63; Shelford 1963:336). Fish, including rainbow trout, walleye, smallmouth bass, bluegill, yellow perch, and northern pike, and fresh water mussels are found in the streams throughout the region (Jones and Cushman 2004:58-63; NPS 1986:49-52; USDA 2006:146). Insects and other invertebrates abound throughout the region with grasshoppers being one of the most abundant insect groups (Brown 1985:53; Jones and Cushman 2004:64-66; Shelford 1963:336-339).

The region has a semiarid continental climate characterized by large daily and annual variations in temperature (Hunt 1967:226-227; NPS 1986:53-54; Wilhelm 1978:1-2,124-125). The project area lies within the transition zone between the middle-latitude dry climatic zone (Trewartha and Horn 1980:360-364) and the cool-summer subtype of the temperate continental climatic zone (Trewartha and Horn 1980:302-311). Winters are very cold and the summers are hot. The annual average temperature ranges between 3° and 8° C (USDA 2006:146). Annual January temperatures average -13.3° C (Bavendick 1941:1046; Wilhelm 1978:124). The lowest recorded winter temperature is –46° C (Bavendick 1941:1046). Annual July temperatures average 20.2° C (Bavendick 1941:1046). The highest recorded summer temperature is 42.2° C (Bavendick 1941:1046; Wilhelm 1978:124). Annual precipitation averages between 35.5 to 45.5 cm (Bavendick 1941:1046; USDA 2006:146; Wilhelm 1978:124) with the majority falling from April through September. The average seasonal snowfall is 68.58 cm per year (Wilhelm 1978:124). The growing season averages 109 days with killing frosts occurring as late as May 28th in the spring and as early as September 14th in the fall (Bavendick 1941:1046; Wilhelm 1978:125). Hail may occur with summer thunderstorms. Blizzards are common during the winter. Recent droughts have tended to be severe (Bavendick 1941:1054). The sun shines approximately 74% of the time in the summer and 53% of the time in the winter (Bavendick 1941:1054; Wilhelm 1978:2). The prevailing winds are from the west-northwest with more southerly winds occurring in the summer (Bavendick 1941:1054; Wilhelm 1978:2). The annual relative humidity averages 68 percent. These resources provide the basis of the aboriginal subsistence of prehistoric times and the historic and modern Euroamerican farming economy.

# CULTURAL RESOURCE INVESTIGATIONS

In 1974, the United States Congress authorized the establishment of the Knife River Indian Villages National Historic Site to commemorate the cultural history and lifeways of the Mandan and Hidatsa Indians and to preserve the archeological resources associated with the two native Northern Plains tribes. Since 1976, the National Park Service has conducted an extensive archeological and ethnohistorical research program to document the archeological and historical resources within the park. A four-volume summary of the program provides significant information on the archeological research program's objectives, research methods, cultural history and ethnohistory of the region, analysis of the material culture, and interpretive results (Thiessen 1993). The regional prehistory and history is divided into five major cultural periods: Paleo-Indian (10,000-6000 B.C.), Archaic (6000 B.C. to A.D. 1), Woodland (A.D. 1 to A.D. 1000), Plains Village (A.D. 1000-1861), and Euroamerican (A.D. 1861-present). Additional information on the cultural history of the Knife River Indian Villages National Historic Site and surrounding region, including the synopsis of archeological investigations in KNRI and the vicinity prior to 1974, may be found in park documents and archeological reports (Ahler 1978a:1-31; Godfrey 2009; Lehmer 1971:49-179; Lovick and Ahler 1982:47-84; NPS 1983:I/11-I/36, 1999:1/18-21,2/1-5; SHSND 1990:3.1-3.42, 5.1-5.51; Willey 1966; Zedeño et al. 2006:23-42).

### Elbee Site, 32ME408

The Elbee site (32ME408) was identified and recorded by a UND archeological crew in the Spring of 1978 (Ahler 1978b:14-16) during the investigations of a potential access road route and staging area for U.S. Army Corps of Engineers riverbank stabilization project at the Sakakawea Village site (32ME11). The site was located within the boundary of the William Russell farm complex in Tract 01-112 (Taylor 1978). At the time of the 1978 UND archeological investigations, the southern portion of the site contained the farmhouse, garage, chicken coop, grain storage bin, and livestock barn. The house was located on the side slope of the Pleistocene terrace on the southwest side of the site. The buildings and structures were demolished and the materials were removed. The basement of the house was filled and contoured to the surrounding landscape. The site consisted of a preceramic campsite overlain by two or more Plains Village occupations. The historic/modern Russell farmstead covers the entire site.

Lovick and Ahler (1982:236-237) described the Elbee site as follows:

> *The Elbee site is a complex, multicomponent site located on the northernmost extremity of the A terrace surface in the southern part of the KNRI. The site boundary is defined by the edge of the A terrace on the east and north and by the gravel road on the west; the boundary is ill-defined and arbitrary to the south. The site area as defined is about 3.1 hectares (7.75 acres). The site was defined and surveyed by conventional reconnaissance techniques. At the time of the survey the site surface was covered with dense grass and weedy plants, and visibility was limited to a few trails and some eroded areas on the terrace margin. The entire site surface appears to have been cultivated.*

> *The most recent component at the site is attributed to the William Russel [sic] farm complex, several buildings of which stood on the southern part of the site and farther to the southwest. The southern part of the site is heavily littered with farmyard debris and recent historic artifacts within and immediately beneath the sod cover.*
>
> *Several Plains Village period components exist at the site, as exposed and defined in salvage excavations conducted in 1978 in the path of a haul road to be constructed across the site ... The plowzone contains a very dispersed scatter of Knife River ware ceramics and Euro-American trade materials such as beads and metal items which indicate use of the site in the historic period by peoples who were probably interacting with the villagers at nearby Sakakawea Village. A few trade artifacts were also noted on the surface at various places beyond the excavations. This component has been classified as a debris scatter belonging to the general Plains Village tradition.*
>
> *The plowzone also contains the remnants of another, more prominent village period component assigned to the scattered village complex. Excavations revealed truncated storage pits, the remains of a circular house below the plowzone, and associated thin-walled, tool-decorated ceramics, all of which are part of the scattered village complex. These remains have been dated in the 15th and 17th century A.D... The 1938 aerial photographs of the area show several anomalies which could be additional circular houses at the site. One test unit at the site yielded yet another, earlier village age component in a buried humic horizon below the plowzone and about 30 cm below the present surface. The artifact content from this component is very meager, but it appears to represent a yet earlier scattered village complex component.*
>
> *The earliest component at the site was detected as a concentration of patinated KRF flaking debris and fire-cracked rock eroding from a localized area on the eastern edge of the A terrace. Excavation there yielded an intact aceramic component in a paleosol buried ca. 1 meter below the level of the A terrace surface. A C-14 date of 2974 ± 66 radiocarbon years B.P. on non-cultural charcoal is the nearby Elbee bluff cutbank at a depth of 2.6 m below the surface provides a maximum age for this component of at the site.*

As indicated in the previous discussion of the site, a pedestrian reconnaissance of the project area revealed an artifact scatter across the mid-Holocene “A”, “B1”, and “B2” terraces. Shovel tests along the potential route of the access road on the terrace indicated the presence of buried archeological materials. A radiocarbon date of 440 ± 40 BP places the Elbee site in the Extended Coalescent variant of the Plains Village Tradition (Ahler et al. 2007:86). Additional archeological investigations were conducted in the summer of 1978, including a magnetic survey of a 3,600 m2 block (Weymouth 1986a:18-28) encompassing both the proposed route of the service road and a major portion of the proposed construction staging area and subsequent excavations. The magnetic survey indicated the presence of numerous magnetic anomalies including a broad irregularly shaped series of anomalies of geologic origin and numerous small magnetic anomalies of varying amplitudes, which were caused by the presence of historic ferrous objects associated with the William Russell farm complex (Ahler 1978b:15; Lovick and Ahler 1984:236-237; Taylor 1978:KNRI-1548; Weymouth 1986a:18-28). There was, however, no correlation between the magnetic anomalies and the excavated archeological features, which consisted of cache pits, a circular row of post molds identified as a house structure, a hearth, an artifact concentration, and a pit (Ahler 1978b:15-16, Volf 2002:1-2; Weymouth 1986a:18-28). Weymouth (1986a:18-28) concluded that the discrepancy may have resulted from the large sensor-to-source distance used in the magnetic survey and the apparent non-magnetic contrast between the features and the surrounding soil matrix. Although the magnetic survey at the Elbee site did not provide additional insight into the buried archeological resources at the site, the use of magnetic survey techniques at other sites at KNRI, including the three major village sites of Lower Hidatsa (32ME10), Sakakawea (32ME11), and Big Hidatsa (32ME12) provided significant information on site structure and feature patterning (Weymouth and Nickel 1977; Weymouth 1979a, 1979b, 1986b:352-355, 1988). The 1978 archeological investigations were compiled in an edited volume by Stanley Ahler (1984) describing the site setting, the fieldwork, excavated features, and site chronology along with the analytical procedures and the analysis of the ceramics, stone tools, chipped stone debitage, faunal remains, and other artifacts.

In 2002, the Midwest Archeological Center staff conducted geophysical investigations at the Elbee site as part of a project to assess the impact of erosion along the vertical cutbank along the Knife River to the archeological record in the northern part of the Elbee site (Volf 2002:1). Twenty-five complete and two partial 20-m-by-20-m grid units were surveyed using a fluxgate gradiometer. Sixteen of the 27 grid units were also systematically swept with a metal detector in order to identify and remove the modern farm-related debris from the survey area. Three magnetic anomalies were identified for archeological excavations due to impending danger for bank erosion along the Knife River in the northern part of the geophysical project area (Volf 2002). Other identified magnetic anomalies were located in the southern part of the geophysical project area where the potential for active erosion was minimal.

Using the University of North Dakota's Archeological Field School participants, the Anthropology Research staff at UND conducted evaluative archeological excavations at the Elbee site in 2003 (Toom et al. 2004). Four small excavation blocks (i.e., 2-m-by-2-m units) were excavated during the field season. Three of the blocks were placed over the three magnetic anomalies identified as being potentially threatened by the continued erosion of the Knife River bank (Toom et al. 2004:3.1). The fourth block was placed near the cut bank at the far northern end of the site. The ground-truthing of the magnetic anomalies revealed two large undercut pits indicated by Anomaly A and Anomaly E in XU 1 and XU 2, respectively. Anomaly I, located in XU 3, was identified as an oval shaped hearth (Toom et al. 2004:3.1-3.18). A linear magnetic anomaly noted in the magnetic survey data may represent the Big Hidatsa to Sakakawea trail (Toom et al. 2004:6.3). The authors concluded the report by indicating the combination of magnetic survey work and ground-truthing excavations were so effective in the northern part of the site that they should be extended to the southern portion of the site.

In 2006, the Midwest Archeological Center staff conducted additional geophysical investigations at the Elbee site as part of a multiple-phased archeological project to assess the impact of erosion along the vertical cutbank along the Knife River to the archeological record in the northern part of the Elbee site (De Vore 2008:24). The geophysical survey techniques used during the investigations of the southern portion of the Elbee site included a magnetic survey and a test of the potential of ground-penetrating radar (GPR) techniques at the site (De Vore 2008). The magnetic survey was conducted with a fluxgate gradiometer. The ground-penetrating radar survey was conducted with a GPR cart system with a 400 mHz antenna. Twenty-nine complete 20-m-by-20-m and six partial 20-m-by-20-m grid units were established on the southern portion of the site. The magnetic data from the entire project area and the ground-penetrating radar profile data from grid unit 23 from the southern portion of the site provided information of the physical properties of the subsurface materials. Several magnetic and ground-penetrating radar anomalies were identified. There are 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. Weak magnetic dipole and monopole anomalies may be associated with the prehistoric/early historic occupation at the site. The GPR data also provided useful information concerning the buried archeological resources at the site.

### Site 32ME2377

Initially, the 2010 archeological investigations at Site 32ME2377 were originally thought to be located at the Karishta site, 32ME466. The Karishta site was identified during the 1976-1980 archeological reconnaissance survey of KNRI (Lovick and Ahler 1982:246). It was identified as a small lithic scatter found on both sides of a small erosional drainage cut into the "B1" terrace on the right side of the Knife River immediately north of the Elbee site. After completion of the geophysical investigations within the project area and consultation with the UND archeological staff, the project area was identified as a separate site. Documentation for Site 32ME2377 was completed for the new site in 2011 by MWAC archeologists. The site lies on the "B2" terrace on the right side of Knife River to the northeast of the Elbee site and east of the Karishta site.

### Taylor Bluff Site, 32ME366

The Taylor Bluff site (32ME366) was first identified as a fortified village site with a low, elongated U-shaped mound enclosure on the left bank of the Knife River by the Orin G. Libby and A. B. Stout archeological mapping expedition in 1909 (Trimble 1988:20-23; Wood 1986:52-53). Although the site had been cultivated, the expedition members noted earthlodge rings or depressions within the enclosure. In 1978, Jon Reiten noted the exposure of cultural materials on the cut bank along the Knife River in the vicinity of the Byron Grannis farm during his geological fieldwork at the park and named the site the Taylor Bluff site for KNRI archeologist John Taylor (Reiten 1983:59-65,100-102). The site was formally documented as Site 32ME366 during the 1976-1980 archeological pedestrian reconnaissance survey at KNRI by the University of North Dakota (Lovick and Ahler 1982:232-234). The site was located within the boundary of the Byron Grannis farm. The site extended beneath the county road to the cut bank of the Knife River, approximately 5.6 km above the confluence of the Knife River with the Missouri River.

At the time of the 1978 UND archeological investigations, the low mound enclosure was identified as a fortification ditch that extended from the river bank into the front yard of the Grannis farmstead, which then served as the KNRI headquarters, about midway between the house and the county road.

Lovick and Ahler (1982:232-234) described the Taylor Bluff site as follows:

*…an off-village activity area and a preceramic debris scatter site adjacent to and southwest of Big Hidatsa Village on the A and B1 terrace surfaces on the north side of the Knife River. The total site area is ca. 4.0 hectares (10 acres). There are three well-defined components at the site.*

*The main component consists of the remains of a semicircular fortification ditch on the A terrace and possibly related archeological materials in the adjacent, lower B1 terrace surface. The fortification ditch was mapped by the Libby-Stout expedition in 1909 which documented a D-shaped enclosure opening on the Knife River and measuring about 460 ft by 500 ft in size. Several lodge depressions were noted in cultivated and uncultivated portions of the interior. Today, ca. 60% of the enclosed area has been eroded away by the Knife River and much of the remainder has been heavily modified by cultivation and successive gravel road construction across the site. At least two trash filled storage pits are currently eroding from the cutbank, and the organic-rich deposits in the pits indicate a late post-contact village period age. The site continues to erode into the Knife River. The remnant of the fortification ditch now lies in the front yard of the KNRI headquarters and beneath the road and driveway at the Byron Grannis farm house.*

*The fortified part of the late village component at the site lies on the A terrace surface. Immediately to the southeast off the terrace scarp and on the B1 terrace (flood plain) lies the second major area of the late village component, a broad area of fairly dense subsurface artifact content discovered in the auger survey in this area…The auger samples are dominated by the presence of animal bone… with few other artifact classed encountered. This part of the site may have been used by the occupants of the fortified zone to the northwest, by the Big Hidatsa Villagers, or by both groups.*

*A second major component at Taylor Bluff consists of a fairly dense scatter of bone debris and charcoal in a paleosol exposed in the A terrace at the Knife River cutbank at a depth of ca. 1.8 m below surface. Charcoal from this stratum has been dated at 3431 ± 74 radiocarbon years B. P. (SMU-710). No diagnostic artifacts have been recovered from this zone. John Taylor conducted a small mitigation excavation near the KNRI headquarters in 1978 in an area of well-pump construction, and discovered a single patinated KRF core and a bone fragment in an apparent cultural horizon ca. 70-92 cm below surface. It is not known if this horizon relates to the cultural stratum exposed in the A terrace cutbank.*

*A third component at the site consists of the former Byron Grannis residence and garage (the former Grannis school house) which still stand on the site surface and which today form the components of the KNRI headquarters complex.*

*In sum, the Taylor Bluff site contains a very interesting and potentially informative archeological record of considerable significance to the interpretation of the KNRI. The late fortified village complex there is important to understanding the activities and history of the nearby Big Hidatsa Village. It may represent a refuge area established by a remnant of the one of the other Mandan or Hidatsa villages after their destruction by the Sioux in 1834 or by small-pox in 1837. If so, this site would provide a scientifically interesting capsule of data linkable to a single village subgroup and a very short period of occupation (1834-1845). All of the significant resources in the Taylor Bluff site continue to be threatened by future disturbance related to cutbank erosion along the Knife River, modification of the existing road which is now dangerously close to the Knife River cutbank, and by construction and development at the KNRI headquarters located on this site.*

In 1981, the Rocky Mountain Regional Office (RMRO) began planning activities for the construction of a new well and water system at the KNRI headquarters complex (Ahler et al. 1983:1-2). The well location was selected near the southwestern corner of the headquarters building. In order to mitigate the adverse effects of the undertaking, a data recovery project was developed for the compliance activities under the auspices of Section 106 of the National Historic Preservation Act of 1966 (NPS 2006). Fieldwork was conducted by University of North Dakota archeologists in June of 1982 (Ahler et al. 1983). Additional NPS construction projects, including the construction of a coal chute on the west side of the headquarters building and the park sign construction in the front yard of the headquarters complex and within the site boundary, were added to the UND field investigations during the following summer months. Five test units totaling ca. 8.4 m2 were excavated at the Taylor Bluff site. Stratified cultural components were identified in all five units. Identified cultural components included materials from the historic period, the Knife River phase, the prehistoric Plains Village period (possibly belonging to the Scattered Village complex), and a pre-village or preceramic period (Ahler et al. 1983:3,76-80).

During the fall of 1983, UND archeologists and archeological technicians conducted archeological investigations at the Taylor Bluff site prior to the construction of a stabilization structure along the left bank of the Knife River (Ahler 1988; Toom and Ahler 1984). Active erosion along the cutbank portion of the site was destroying a major portion of the site, as well as threatening the county road. The construction of the stabilization structure would destroy the remaining remnant of the site between the Knife River and the county road. The excavations were conducted to mitigate the adverse effect of the undertaking on the site. During the course of the archeological investigations, eight test units were excavated along the cutbank, as well as exposed features along the cutbank above the Knife River. The earliest recognized cultural component identified during the excavations was a preceramic period horizon dated to 3430 ± 70 radiocarbon years B.P. (Ahler 1988:301) at a depth of 1.8 to 2.0 m below surface. The second cultural component was part of the prehistoric Plains Village period between A.D. 1300 and 1600 (Ahler 1988:301-302). The third cultural component was tentatively identified as part of the early postcontact period and the Willows phase dating to A.D. 1600-1700 (Ahler 1988:302). The major cultural component identified during the excavations was the assigned to the late postcontact period after A.D. 1780 (Ahler 1988:302-305).

# 2010 GEOPHYSICAL INVESTIGATIONS

The three geophysical project areas are located in the central and northern parts of Knife River Indian Villages National Historic Site in Mercer County, North Dakota (De Vore 2010). The Elbee site lies on both sides of a park access road to the Knife River and the Sakakawea site parking lot (Figure 5). The site extends approximately 400 m along the terrace on the right bank of the Knife River and is approximately 120 m across from the river bank to the park boundary fence along County Road 37 at its widest point at the south end. The site contains domestic grasses with a few cottonwood trees near the Sakakawea site parking lot and fishing access to the Knife River.

The 2010 geophysical investigations at the Elbee site extended from the farmstead at the south end of the site to the north end of the site at the bend in the Knife River. A resistance survey with the twin-probe array was conducted across the project area. A limited dual fluxgate gradiometer survey was also conducted at the north end of the site during the 2010 investigations. Site 32ME2377 lies on the low terrace above the Knife River to the northeast of the Elbee site (Figure 6). The site measures approximately 40 m by 25 m along the right bank of the Knife River between the lower flood plain to the east and the higher Holocene "A" terrace to the west of the site. The vegetation on the site consists of mixed grasses and trees. A two-track fire access road runs along the north side of the site providing access from the locked entrance gate north of the site. A magnetic survey with the single fluxgate gradiometer and a resistance survey with the resistance meter and twin-probe array were conducted at the geophysical project area within the site. The Taylor Bluff site lies on the terrace above the left bank of the Knife River (Figure 7). It extends from the river bank across the county road into the maintenance facility yard (the old KNRI headquarters and Grannis farmstead). The site measures approximately 160 m by 190 m. The geophysical project area is located along the north side of the park boundary fence north of the gravel county road and on the west side of the park access road to the maintenance facility. The yard is covered with domestic grasses, the occasional cottonwood tree, and a few chokeberry bushes. A portion of the village fortification ditch is still visible in the yard south of the maintenance office building (former Grannis farmhouse). A magnetic survey with a dual fluxgate gradiometer and a ground-penetrating radar survey with a 400 mHz antenna were conducted across the geophysical project area during the 2010 archeological prospection workshop.

### Geophysical Grid Layout

The three geophysical grids for the three sites and associated geophysical project areas were established with an Ushikata S-25 TRACON surveying compass (Ushikata 2005) and a 100-meter tape measure (Figure 8). Wooden hub stakes for the grid unit corners were placed at 20-m intervals across the geophysical grids.

The geophysical grid at the Elbee site was established by Volf during his 2002 magnetic survey of the northern portion of the site (Volf 2002). The 2002 site datum was relocated in the southwest corner of the 2002 project area at N500/E500 and used for the 2006 (De Vore 2008) and the 2010 resistance and gradiometer surveys of the site (De Vore

2010). The geophysical grid was oriented 7° 45' west of magnetic north. The surveying compass was used to sight in the two perpendicular baselines and grid corners. Several of the original 2002 wooden stakes, which had been placed at 20-m intervals, were intact and used during the 2010 geophysical survey. The broken stakes were replaced with new wooden hub stakes. The north-south baseline paralleled the boundary fence line and measured 300 m along the boundary fence while the east-west baseline measured 60 m across the south end of the project area. Twenty-seven complete 20-m–by-20-m and six partial 20-m–by-20-m grid units were established within the geophysical project area a total project area of 12,286 m2 or 3.04 ac.

The initial mapping station at Site 32ME2377 was placed at the southwest corner of the geophysical project area approximately 5 m north and 5 m east of the gulley along the southwest side of the site (De Vore 2010). The geophysical grid was oriented on magnetic north. The surveying compass was used to sight in the two perpendicular baselines and grid corners. Wooden hub stakes were placed at the 20-m grid corners. The north-south baseline measured 40 m in length while the east-west baseline measured 20 m in length. Two complete 20-m–by-20-m grid units were established within the geophysical project area for a total project area of 800 m2 or 0.2 ac.

The initial mapping station at the Taylor Bluff site was placed 2 m north of the park boundary fence and 2 m west of the gravel entrance road to the maintenance facility (De Vore 2010). The geophysical grid was oriented 31 degrees east of magnetic north. The surveying compass was used to sight in the two perpendicular base lines and grid corners. Wooden hub stakes were placed at the 20-m grid corners. The north-south baseline measured 40 m in length while the east-west baseline measured 100 m in length. Ten complete 20-m–by-20-m grid units were established within the geophysical project area for a total project area of 4,000 m2 or 0.99 ac.

Twenty-meter survey ropes were placed along the north and south ends of the grid units connecting the grid unit corners at the Elbee site and at Site 32ME2377. These ropes formed the boundaries of each grid unit during the data collection phase of the survey in the two geophysical project areas (Figure 9). Additional ropes were placed at 2-m intervals across the grid units in a north-south orientation at the Elbee site for the resistance and magnetic surveys and at 1-m intervals across the grid units in a north-south orientation at Site 32ME2377 for the magnetic and resistance surveys (Figure 9). The guide ropes at the Taylor Bluff site were placed at the east and west ends of the grid units with the traverse ropes placed at 2-m intervals in the east-west directions for the magnetic survey. The guide ropes were placed at the east and west ends of the geophysical project area for the ground-penetrating radar survey at the Taylor Bluff site and traffic cones were used to mark the route of each profile line. The survey ropes were marked with different color tape at half-meter and meter increments, which was designed to help guide the survey effort. Once the geophysical survey of each grid unit was completed, the survey ropes were flipped to the next adjacent grid unit. As the survey activities progressed across the geophysical project area, a sketch map was completed identifying both cultural and natural surface features in the three project areas (Figures 10 through 12). The geophysical data were acquired across the grid units beginning in the lower left hand corner of each grid unit facing the direction of travel for the first traverse line (Geoscan Research 1987:43-54,2003:5/2-5/11) except for the ground-penetrating radar survey at the Taylor Bluff, which began in the lower right hand corner of the geophysical grid.

The geophysical survey grid corner stakes within the KNRI geophysical project areas were mapped with a Trimble GeoXH global positioning system (GPS) handheld receiver (Figure 13) and external antenna (Trimble 2007a) along with surface features including access roads, fence lines, and bench marks. The GPS readings at stationary points (i.e., grid unit corners and individual surface features) were collected with 30 readings from five or more satellites while line segment data were collected at one second intervals along the path of the line. The field GPS data were collected in the universal transverse mercator (UTM) projection for the Zone 14 North coordinates of the North American Datum of 1983 (NAD83) horizontal datum. The data were transferred to a laptop computer via the Trimble TerraSync software (Trimble 2007b,2007c). The data was then differentially corrected using the Trimble Pathfinder Office software (Trimble 2007d) using the continuously operating reference station (CORS Bismarck ND) site located 74 km away at Bismarck, North Dakota (Table 1). Seven files were processed with 7,197 (100%) of 7,197 selected positions code corrected by post-processing. Seven thousand one hundred ninety-seven (100%) of 7,197 selected positions were carrier corrected by post-processing with 124 (1.7%) of the code positions chosen over carrier since they were higher quality. The estimated range for the 7,197 corrected positions yielded 39.8% within an accuracy range of 0-15 cm, 30.2% within an accuracy range of 15-30 cm, 20.9% within an accuracy range of 30-50 cm, 8.5% within an accuracy range of 0.5-1.0 m, 0.6% within an accuracy range of 1.0-2.0 m, 0% within an accuracy range of 2.0-5.0 m, and 0% at an accuracy range greater than 5.0 m. The high dilution of precision (DOP) values resulted from a variety of sources including multi-pathing of the satellite signal through the overhead tree canopy, poor satellite geometry, and insufficient number of satellites present during the collection phase. After the raw survey data in the standard storage format (SSF) was post processed, the corrected data were exported as Excel data files and imported into Surfer 9 (Golden Software 2009) for final display (Figure 14).

## Geophysical Prospection Techniques

Geophysical prospection techniques available for archeological investigations consist of a number of techniques that record the various physical properties of 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 primarily ones that measure inherently or naturally occurring local or planetary fields created by earth-related processes under study (Heimmer and DeVore 1995:7,2000:55; Kvamme 2001:356,2005:424). 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 DeVore 1995:9, 2000:58-59; Kvamme 2001:355-356). The interaction of these signals and buried materials produces altered 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 resistance/resistivity, electromagnetic conductivity (including ground conductivity and metal detectors), magnetic susceptibility, and ground-penetrating radar. Acoustic active techniques, including seismic, sonar, and acoustic sounding, have very limited or specific archeological applications. Additional information on the basic geophysical techniques used during the present survey may be found in publications by Arnold Aspinall, Chris Gaffney, and Armin Schmidt (2008), Bruce Bevan (1991, 1998), Anthony Clark (2000), Lawrence B. Conyers (2004), Lawrence B. Conyers and Dean Goodman (1997), Andrew David (1995, 2001), Andrew David, Neil Linford, and Paul Linford (2008), Chris Gaffney and John Gater (2003), Chris Gaffney, John Gater, and Sue Ovenden (1991, 2002), Don H. Heimmer and Steven L. De Vore (1995, 2000), Kenneth Kvamme (2001, 2003, 2005), I. Scollar, A. Tabbagh, A. Hesse, and I. Herzog (1990), and John Weymouth (1986b).

### Magnetic Survey

A magnetic survey is a passive geophysical survey (see Aspinall et al. 2008; Bevan 1991, 1998:29-43; Breiner 1973; 1992:313-381; Burger 1992:389-452; Clark 2000:92-98, 174-175; Davenport 2001:50-71; David 1995:17-20; David et al. 2008:20-24; Dobrin and Savit 1988:633-749; Gaffney and Gater 2003:36-42, 61-72; Gaffney et al. 1991:6, 2002:7-9; Hanson et al. 2005:151-175; Heimmer and DeVore 1995:13, 2000:55-56; Kvamme 2001:357-358, 2003:441, 2005:434-436, 2006a:205-233, 2006b:235-250; Lowrie 1997:229-306; Milsom 2003:51-70; Mussett and Khan 2000:139-180; Nishimura 2001:546-547; Oswin 2009:43-54, 126-135; Robinson and Çoruh 1988:333-444; Scollar et al. 1990:375-519; Telford et al. 1990:62-135; Weymouth 1986b:343; and Witten 2006:73-116 for more details on magnetic surveying). A single fluxgate gradiometer was used at Site 32ME2377, while a dual fluxgate gradiometer system was used at the Taylor Bluff site and at the Elbee site.

A magnetic survey is a passive geophysical prospection technique used to measure the earth's total magnetic field at a point location. 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 artifacts have very strong effects on the local earth's magnetic field. Other cultural features that affect the local earth's 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 an inclination of approximately 60° to 70° (Milsom 2003:43; Weymouth 1986b:341). The project area has a magnetic field strength of approximately 58,800 nT (Peddie 1992; Sharma 1997:72-73) with an inclination of approximately 73° 54' (Peddie and Zunde 1988; Sharma 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 1-2 m below the ground surface with 3 m representing the maximum limit (Clark 2000:78-80; Kvamme 2001:358). Magnetic surveying applications to archeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects/artifacts

(Bevan 1991; Clark 2000;92-98; Gaffney et al. 1991:6; Heimmer and DeVore 1995,2000; Weymouth 1986b: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). The total field survey uses a single magnetic sensor. 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 Clark 2000:66-71; Milsom 2003:45-47; Scollar et al. 1990:450-469; Weymouth 1986b: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 and take a reading 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 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 magnetic gradient 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 a resolution of 0.1 nT (Kvamme 2001:358). Cesium gradiometers record the absolute total field values like the single-sensor total-field magnetometers. It also records the gradient change between the bottom and top sensors. 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 2003:46-47). 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 2003:46-47).

The single fluxgate gradiometer, the Geoscan Research FM256 fluxgate gradiometer (Figure 15), is a vector magnetometer, which measures the strength of the magnetic field in a particular direction (Geoscan Research 2006). The FM256 fluxgate gradiometer is an upgraded FM36 fluxgate gradiometer (Geoscan Research 1987) with increased memory capacity and greater download speed. The sensors of the fluxgate gradiometer must be accurately balanced and aligned along the direction of the field component to be measured. A reference point was selected at the Site 32ME2377 geophysical project area for balancing and aligning the gradiometers and for zeroing the conductivity meter. The gradiometer was balanced and the sensors aligned on magnetic north. Grid point N20/E0 was selected for balancing the gradiometer at Site 32ME2377. The two magnetic sensors in the single fluxgate gradiometer are spaced 0.5 m apart. The instrument is carried so the two sensors are vertical to one another with the bottom sensor approximately 30 cm above the ground. 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 provides a continuous record of the magnetic field strength. The original magnetic surveys at the Elbee site used the Geoscan Research FM-36 fluxgate gradiometer (De Vore 2008; Geoscan Research 1987; Volf 2002).

The magnetic survey for the single fluxgate gradiometer was designed to collect 8 samples per meter along 0.5-m traverses or 16 data values per square meter at the Site 32ME2377 geophysical project area (Table 2). The data were collected in a zigzag fashion with the surveyor alternating the direction of travel along each traverse across the grid. The magnetic surveys at the Elbee site in 2002 and 2006 (Table 2) used the same sampling strategy (De Vore 2008; Volf 2002). Sixty-four hundred data values were collected for each complete 20-m-by-20-m grid unit surveyed during the project. The magnetic data were recorded in the memory of the gradiometer and downloaded to a field laptop computer at the completion of the survey each day and at the end of the survey in each geophysical project area. The magnetic data from the single fluxgate gradiometer were imported into Geoscan Research's GEOPLOT software (Geoscan Research 2005) for processing. Both shade-relief and trace-line plots were generated in the field before the instrument's memory was cleared.

The dual fluxgate gradiometer system, the Bartington Grad 601-2 single axis magnetic gradiometer (Figure 16), is a vector magnetometer, which measures the strength of the magnetic field in a particular direction (Bartington Instruments 2007). The dual fluxgate gradiometer sensor configuration of the instrument uses two fluxgate gradiometer sensor tubes separated by a distance of1 m. The dual gradiometer records two lines of data during each traverse reducing the distance walked and the survey time by half compared to the time and distance covered with a single gradiometer system. The sensors must be accurately balanced and aligned along the direction of the field component to be measured. The reference point for balancing and aligning the dual gradiometer at the Elbee site is located at N760/E30 and at the Taylor Bluff site is located at 20 m east of the east side of the geophysical project area. The instrument is aligned on magnetic north. The fluxgate gradiometer sensor tubes in the dual gradiometer are spaced 1 m apart with the two tubes also spaced at 1 m apart. The instrument is carried so the two sensors in each tube are vertical to one another with the bottom sensors approximately 30 cm above the ground. 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 vertical sensors is recorded in the instrument's memory for both sensor tubes. These gradients are not in absolute field values but rather voltage changes, which are calibrated in terms of the magnetic field strength. The dual fluxgate gradiometer also provides a continuous record of the magnetic field strength across each line for each traverse across the grid unit.

The magnetic survey for the dual fluxgate gradiometer was designed to collect eight samples per meter along 1.0-m traverses or eight data values per square meter at the Elbee site geophysical project area (Table 3) and eight samples or 16 data values per square meter along 0.5-m traverses at the Taylor Bluff site geophysical project area (Table 3). The data were collected in a zigzag fashion with the surveyor alternating the direction of travel along each traverse across the grid. Thirty-two hundred data values were collected for each complete 20-m-by-20-m grid unit surveyed at the Elbee site and a total of 6,400 data values for each complete grid unit at the Taylor Bluff site. The magnetic data were recorded in the memory of the dual fluxgate gradiometer and downloaded to a field laptop computer when the instrument's memory became full, at the end of the day, and at the completion of the survey at the Taylor Bluff site geophysical project area; and at the end of the magnetic survey of the selected grid units at the Elbee site. The magnetic data from the dual fluxgate gradiometer were downloaded into the Bartington GRAD 601 software (Bartington Instruments 2007). The data were then imported into ARCHAEOSURVEYOR for processing (DW Consulting 2010). Shade-relief and trace-line plots were generated in the field before the instrument's memory cleared.

Resistance Survey

The resistance survey is an active geophysical technique, which injects a current into the ground (see Bevan 1991,1998:7-18; Burger 1992:241-318; Carr 1982; Clark 2000:27-63, 171-174; Davenport 2001:29-30; David 1995:27-28; David et al. 2008:24-28; Dobrin and Savit 1988:750-773; Gaffney and Gater 2003:26-36, 56-61; Gaffney et al. 1991:2; 2002:7; Hallof 1992:39-176; Heimmer and DeVore 1995:29-35, 2000:59-60; Kvamme 2001:358-362, 2003:441-442, 2005:434-436; Lowrie 1997:206-219; Milsom 2003:83-116; Mussett and Khan 2000:181-201; Nishimura 2001:544-546; Oswin 2009: 32-43, 118-126; Robinson and Çoruh 1988:445-478; Scollar et al. 1990:307-374; Sharma 1997:207-264; Somers 2006:109-129; Telford et al. 1990:522-577; Van Nostrand and Cook 1966; Weymouth 1986b:318-341; Witten 2006:299-317; and Zonge et al. 2005:265-300 for more details on resistivity surveys). The voltage is measured and by Ohm's Law, one may compute the resistance at any given point (R=V/I where R is resistance, V is voltage, and I is current). Due to the problem of contact resistance between two electrodes in the ground, a typical resistance survey makes use of four electrodes or probes. The current passes through two electrodes and the voltage is measured between the other two probes. The configuration of the electrodes also varies (see Milsom 2003:99 and Weymouth 1986b:324 for common configurations).

Resistance or resistivity changes result from electrical properties of the soil matrix. Changes are caused by materials buried in the soil, differences in soil formation processes, or disturbances from natural or cultural modifications to the soil. In archeology, the instrument is used to identify areas of compaction and excavation, as well as buried objects such as brick or stone foundations. It has the potential to identify cultural features that are affected by the water saturation in the soil, which is directly related to soil porosity, permeability, and chemical nature of entrapped moisture (Clark 2000; Heimmer and De Vore 1995:30). 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 objects, excavation, habitation sites, and other features affecting water saturation (Heimmer and De Vore 1995:37). The resistivity survey may sometimes detect the disturbed soil matrix within the grave shaft.

The Geoscan Research RM15-D resistance meter uses the PA20 multiple-probe array (Geoscan Research 2007). Arranged as a twin-probe array, a current and voltage probes are located on a mobile frame, which is moved around the site (Figure 17). Two additional probes are located away from the survey area, which also consists of a current probe and voltage probe. The mobile probes are set 0.5 m apart on the multiprobe array frame. The remote probes are set a distance 30 times the mobile probe separation at the Elbee site and Site 32ME2377 from the nearest point on the grid units or 15 m for the 0.5-m mobile probe separation. The remote probes are moved after reaching the maximum length of the electrical cable. The ohm value on the resistance meter is recalibrated with each move to retain consistency of the resistance readings across the grid units. Calibration involves taking a reading before moving the remote probes and then re-establishing the same ohm value by moving the remote probes closer together or farther apart until the same value is reached. The probes on the frame are located at a fixed distance apart. A general rule of thumb for the depth investigation of resistance survey is that the depth is equal to the distance of probe separation. This value is not a unique number but an average for the volume of soil 0.5 m depth and a surface diameter of 0.5 m under the center point of the instrument frame. The probes are connected to the resistance meter, which is also on the frame. Different lengths of the removable probe array beams may be added to the frame to expand the separation distance of the probes; however, this requires the resurvey of the grid for each change in the probe separation distance. The addition of a multiplexer unit allows for the collection of multiple parallel probe measurements or multiple depth measurements. The measurement is taken when the mobile probes make contact with the ground and completes the electrical circuit. The resulting resistance value is the average of 16 readings. The average value is stored in the resistance meter's memory until downloaded to a field laptop computer.

The resistance survey was designed to collect two samples per meter along 1.0-m traverses or two data values per square meter at the Elbee site (Table 4) and two samples per meter along 0.5-m traverses at Site 32ME2377 (Table 4). The data were collected in a zigzag fashion with the surveyor maintaining the alternating the direction of travel for each traverse across the grid. Sixteen hundred data values were collected for a complete 20-m-by-20-m grid unit at Site 32ME2377, and 800 data values were collected for each completer grid unit at the Elbee site. The resistance data were recorded in the memory of the resistance meter and downloaded to a laptop computer at the completion of each day's survey effort or at the end of the survey. The resistance data were imported into GEOPLOT software (Geoscan Research 2005) for processing. Both shade-relief and trace-line plots were generated before the instrument's memory was cleared.

## Ground-Penetrating Radar Survey

The ground-penetrating radar (GPR) survey is an active geophysical technique that uses pulses of radar energy (i.e., short electromagnetic waves) that are transmitted into the ground through the surface-transmitting antenna (see Annan 2005:357-438; Bevan 1991, 1998:43-57; Clark 2000:118-120, 183-186; Conyers 2004, 2006:131-159,2007:329-344; Conyers and Goodman 1997; Davenport 2001:89-103; David 1995:23-27; Gaffney and Gater 2003:47-51, 74-76; Gaffney et al. 1991:5-6, 2002:9-10; Goodman et al. 2007:375-394; Heimmer and DeVore 1995:42-47, 2000:63-64; Kvamme 2001:363-365, 2003:442-443, 2005:436-438; Lowrie 1997:221-222; Milson 2003:167-178; Mussett and Khan 2000:227-231; Nishimura 2001:547-551; Scollar et al. 1990:575-584; Weymouth 1986b:370-383; and Witten 2006:214-258 for more details on GPR surveys). This 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 penetration depth 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. 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).

The success of the survey is dependent on soil and sediment mineralogy, clay content, ground moisture, depth of the archeological resource, 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 content. Dry soils and sediments, especially those with low clay content, represent the best conditions for energy propagation. 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 for grave shafts and trenches. At times, radar cannot profile deep enough or the strata may be so complex as to render the trenches, graves, and other types of excavations indistinguishable from the surrounding soil profile.

The TerraSIRch SIR System-3000 survey cart system (GSSI 2003) operated an antenna at a nominal frequency of 400 megahertz (mHz). The antenna was mounted in a cart that recorded the location of the radar unit along the grid line (Figure 18). The GPR profiles were collected along 0.5 m traverses beginning in the southwest corner of the grid unit with the initial profile collected from west to east (Table 5). The data were collected in a zigzag or bidirectional fashion with the surveyor alternating the direction of travel for each traverse across the grid. An 80 nanosecond time window was open for data collection. Five hundred twelve samples were collected for each scan, and 50 scans were collected per meter. One hundred ten radar profiles were collected across the northern half of the Taylor Bluff geophysical project area for a linear distance of 8,040 m. Ground penetrating radar surveys generally represent a trade-off between depth of detection and detail. Lower-frequency antennas permit detection of features at greater depths but they cannot resolve objects or strata that are as small as those detectable by higher-frequency antennas. 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 excavation wall 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. Reasonable estimates of the velocity of the radar signal in the site's soil can be achieved by this method (Conyers and Lucius 1996). Using one of the hyperbolas on a radargram profile from the geophysical project area (Goodman 2005:76), the velocity was calculated to be approximately 7.3 cm per nanosecond (ns). For a time slice between 5 and 15 ns with the center at 10 ns (two-way travel time), the approximate depth to the center of the GPR slice would be 36.5 cm. With a time window of 80 nanoseconds, the GPR profile extended to a depth of 2.82 meters. A value of 17.1 was calculated for the dielectric constant. The GPR data were recorded on a 512 mb compact flash card and transferred to a field laptop computer at the end of the survey.

## Geophysical Data Processing

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme 2001:365; Music 1995; Neubauer et al. 1996). . Roger Walker and Lewis Somers (Geoscan Research 2004,2005) provide strategies, alternatives, and case studies on the use of several processing routines commonly used to process magnetic, resistance, and conductivity data in the GEOPLOT software. David et al. (2008:42-45) presents a basic description of steps involved in the processing of magnetic, resistance, and ground penetrating radar data. Kenneth Kvamme (2001:365) also 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 (David et al. 2008:45-49; 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 Single Fluxgate Gradiometer Magnetic Data

Upon completion of the magnetic survey with the single fluxgate gradiometer system, the data were processed in GEOPLOT (Table 2). The grid data file was transformed into a composite file (Geoscan Research 2005:3/15-3/20) and a zero mean traverse was applied to remove any traverse discontinuities that may have occurred from operator handling or heading errors (Geoscan Research 2004:6/107-6/115). A threshold between -5 and 5 was applied to the data in order to aid in the correct preservation of extended high-magnitude magnetic responses from ferrous materials. It also preserves linear features oriented in the traverse direction. The magnetic data from the 2002 and 2006 magnetic surveys at the Elbee site geophysical project area, after the application of the zero mean traverse operation, ranged from -204.8 nT to 193.0 nT with a mean of 0.01 nT and a standard deviation of 3.687 nT. The magnetic data from the magnetic survey at the Site 32ME2377 geophysical project area, after the application of the zero mean traverse operation, ranged from -40.2 nT to 128.1 nT with a mean of 0.05 nT and a standard deviation of 2.756 nT. Upon completion of the zero mean traverse function, the data were interpolated by expanding the number of data points in the traverse direction and by reducing the number of data points in the sampling direction to provide a smoother appearance in the data set and to enhance the operation of the low-pass filter (Geoscan Research 2004:6/53-6/56). This changed the original 8-x-2 data point matrix into a 4-x-4 data point matrix. The low-pass filter was then applied over the entire data set to remove any high frequency, small scale spatial detail. This transformation results in the improved visibility of larger, weak archeological features (Geoscan Research 2004:6/57-6/60). The data were then exported as an ASCII dat file and placed in the SURFER 9 mapping program (Golden Software 2009; Oswin 2009:86-95). Image and contour maps of the single fluxgate gradiometer data were generated for the 2002/2006 magnetic within the present Elbee site survey area (Figure 19) and the Site 32ME2377 survey area (Figure 20).

Processing Dual Fluxgate Gradiometer Data

Upon completion of the magnetic surveys at the Elbee and the Taylor Bluff sites, the data were processed in ArchaeoSurveyor (Table 3). The grid data files were assembled into a composite file (DW Consulting 2010:32-33). The destripe processing routine was applied to remove any traverse discontinuities or striping effects that may have occurred from operator handling, heading errors, instrument setup, or instrument drift during the survey, as well as to equalize differences between grids (DW Consulting 2010:68-69). The magnetic data from the magnetic survey at the Elbee site geophysical project area, after the application of the destriping operation, ranged from -15.0 nT to 22.7 nT with a mean of -0.01 nT and a standard deviation of 1.069 nT. The magnetic data from the magnetic survey at the Taylor Bluff site geophysical project area, after the application of the destriping operation, ranged from -100.0 nT to 99.6 nT with a mean of -0.27 nT and a standard deviation of 6.654 nT. Upon completion of the destripe function, the data were interpolated by expanding the number of data points in the traverse direction and by reducing the number of data points in the sampling direction to provide a smoother appearance in the data set and to enhance the operation of the low-pass filter (DW Consulting 2010:70). This changed the original 8-x-1 data matrix at the Elbee site and the original 8-x-2 data point matrix at the Taylor Bluff Site into 4-x-4 data point matrices for the two geophysical project areas. The low-pass filter was then applied over the entire data set to remove any high-frequency, small-scale spatial detail (DW Consulting 2010:80). This transformation resulted in the improved visibility of larger, weak archeological features. The data were then exported as an ASCII dat file and placed in the SURFER 9 contouring and 3d surface mapping program (Golden Software 2009) for final the display (Oswin 2009:86-95). Image and contour plots of the magnetic data were also generated the project areas at the Elbee site (Figure 21) and the Taylor Bluff site (Figure 22).

Processing Resistance Data

Upon completion of the resistance survey, the data were processed in GEOPLOT. The grid files were combined to form a composite file and further processed in GEOPLOT (Table 4). Erroneous data resulting in the faulty insertion of the value 204.7 as the dummy value were removed with the search and replace routine, which looks for a specified number or range of values and replaces them with a different specified value (Geoscan Research 2004:6/85-6/85). Due to numerous contrast discontinuities between the grid units, the add function was applied to several data blocks to correct the discontinuities by adding a constant value to the data in the inclusive data blocks (Geoscan Research 2004:6/11-6/13) for the Elbee resistance data. The edge-matching routine was then applied to the Elbee resistance data to further remove edge discontinuities between the grids (Geoscan Research 2004:6/45-6/47). Grid edge discontinuities in twin-probe resistance surveys have resulted from improper placement of the remote electrodes during a station move when one has reached the length limit of the remote electric cable. It may also be caused by changing environmental conditions during the resistance survey. The resistance data composite files from the Elbee site and Site 32ME2377 geophysical project areas were then despiked to remove any erroneous measurements (Geoscan Research 2004:6/35-6/39). Despiking may be accomplished with the processing routine in GEOPLOT or manually by editing each individual grid file. The resistance data from the resistance survey at the Elbee site survey area after the application of the add, edge-matching, and despiking routines ranged from 83.7 ohms to 158.1 ohms with a mean of 91.32 ohms and a standard deviation of 3.199 ohms. The resistance data from the resistance survey at the Site 32ME2377 survey area, after the application of the despiking routine, ranged from 6.2 ohms to 9.3 ohms with a mean of 7.24 ohms and a standard deviation of 0.528 ohms. The interpolation routine was applied to the data set to arrange the data in an equally spaced 4-x-4 square matrix from the original 2-x-1 matrix at the Elbee site and the 2-x-2 matrix at Site 32ME2377 (Geoscan Research 2004:6/53-6/56). A high-pass filter was then applied over the composite data set. The high-pass filter was used to remove low-frequency, large-scale spatial detail such as a slowing changing geological 'background' trend (Geoscan Research 2004:6/49-6/52). The data were then exported as an ASCII dat file and placed in the SURFER 9 mapping program (Golden Software 2009; Oswin 2009:86-95). Image and contour maps of the resistance data were generated for the Elbee Site survey grid area (Figure 23) and the survey grid area at Site 32ME2377 (Figure 24).

Processing Ground-Penetrating Radar Data

The GPR radargram profile line data are imported into GPR-SLICE (Goodman 2005) for processing. The first step in GPR-SLICE is to create a new survey project under the file menu. This step identifies the file name and folder locations. The next step is to transfer the GPR profile data to the project folder, then create the information file. The file contains the basic information on profile names and data format, the number of profiles, lengths of the profiles with the starting and ending locations along the x and y axes along with the number of samples per scan, scans per marker, markers per unit of measurement, the data format size, and the extent of the open time window in nanoseconds (ns). The information file can be edited if necessary to correct profile lengths. The 16-bit GSSI radargrams are imported into the GPR-SLICE project folder for further processing. The 16-bit data are then converted to remove extraneous header information and to regain the data. During the conversion process, the signal is enhanced by applying gain to the radargrams. Once the conversion process is completed, the next step is to reverse the profile data. Since the radargrams were collected in the zigzag mode, every even line needs to be reversed. The next step is to insert navigation markers into the resample radargrams, which are based on the total number of scans in the radargram. The next step is to create the time slices of the profile data (Conyers and Goodman 1997; Goodman et al. 1995). The program resamples the radargrams to a constant number of scans between the markers and collects the time slice information from the individual radargrams. The number of slices is identified along with the slice thickness, which allows for adequate overlap between the slices. The offset value on the radargram where the first ground reflection occurs is identified and is used to identify the first radargram sample at the ground surface. The cut parameter is set to resample the GPR data. The final step in the slice menu is to create the XYZ data files for each slice. The slices are gridded using the Kriging algorithm to estimate the interpolated data. A low-pass filter is then applied to the dataset to smooth noisy data in the time slices. At this point, one may view the time-sliced radar data in the pixel map menu for the GPR survey at the Taylor Bluff site (Figure 25). In addition, the original processed grid slices and the low-pass filtered grid slices can be exported in the Surfer grid format. The surfer grid file is transformed into an image plot in Surfer 9. Generally, one or more time slices are selected for further display and analysis for each GPR project area. Time slice 3 from 8 to 13 ns has been selected as the representative sample slice from the Taylor Bluff site geophysical project area (Figure 26). The ground-penetrating radar data from time slice 3 before the low-pass filter was applied to the data ranged from 4,828,128 SI units of amplitude strength to 115,610,453 SI units of amplitude strength with a mean of 32,026,414 SI units of amplitude strength, and a standard deviation of 12,252,297 SI units of amplitude strength. The slice data from the project area are interpolated to create the 3D dataset in the grid menu. The number of grids is now equal to 96 (((20-1)*5)+1). The 3D data may be displayed as a series of z slices in the creation of a 3D cube with a jpeg output for animating the 3D cube.

## Geophysical Data Interpretations

Andrew David (1995:30) defines interpretation as a "holistic process and its outcome should represent the combined influence of several factors, being arrived at through consultation with others where necessary." Interpretation may be divided into two different types consisting of the geophysical interpretation of the data and the archaeological interpretation of the data. At a simplistic level, geophysical interpretation involves the identification of the factors causing changes in the geophysical data. Archeological interpretation takes the geophysical results and tries to apply cultural attributes or causes. In both cases, interpretation requires both experience with the operation of geophysical equipment, data processing, and archeological methods; and knowledge of the geophysical techniques and properties, as well as known and expected archeology. Although there is variation between sites, several factors should be considered in the interpretation of the geophysical data. These may be divided between natural factors, such as geology, soil type, geomorphology, climate, surface conditions, topography, soil magnetic susceptibility, seasonality, and cultural factors, including known and inferred archeology, landscape history, survey methodology, data treatment, modern interference, etc. (David 1995:30; David et al. 2008:49). The grouping of anomalies or pattern recognition is also an important aspect of interpretation. It should also be pointed out that refinements in the geophysical interpretations are dependent on the feedback from subsequent archeological investigations. The use of multiple instrument surveys provides the archeologist with very different sources of data that may provide complementary information for comparison of the nature and cause (i.e., natural or cultural) of a geophysical anomaly (Clay 2001). Each instrument responds primarily to a single physical property: magnetometry to soil magnetism, electromagnetic induction to soil conductivity, resistivity to soil resistance, and ground-penetrating radar to dielectric properties of the soil (Weymouth 1986b:371).

## Interpreting the Magnetic Data

Interpretation of the magnetic data (Bevan 1998:24) from the project requires a description of the buried archeological feature or 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 effects 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 is 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 effect 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 the half-width rule procedure (Bevan 1998:23-24; Breiner 1973:31; Milsom 2003:67-70). 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 where 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 composed 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 composed of bricks (e.g., brick wall, foundation, or chimney), estimates could be off by more than a 1,000 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. The magnetic gradient anomalies may be classified as three different types: linear, dipole, and monopole.

Analysis of the magnetic data while in the field indicated the presence of numerous magnetic anomalies within the three geophysical project areas. These anomalies appear to be associated with metal artifacts and buried archeological features, as well as modern intrusions.

The magnetic surveys at the Elbee site were conducted in 2002 (Volf 2002) and 2006 (De Vore 2008) with a single fluxgate gradiometer (Figure 27). The 2010 magnetic survey was limited to the northern portion of the site (an 80-m-by-40-m block) and used a dual fluxgate gradiometer (Figure 28). Numerous dipole and monopole anomalies are present across the site with increasing concentrations of anomalies in the southern portion of the site in the vicinity of the Russell farm building complex. Rectangular clusters of magnetic anomalies appear to represent the locations of former farm buildings. Farm-related lanes and two-track roads, as well as the park access road, are identified as linear magnetic anomalies. A segment of a possible trail between the Sakakawea site and the Big Hidatsa site is present in the southern part of the 2010 geophysical project area. Several concentrations or clusters of magnetic anomalies containing monopole and dipole anomalies occur across the site. The clusters appear to represent possible prehistoric house floors and associated pit features. A large natural depression at the northern end of the site is also evident in the magnetic data. The guide wires and associated anchors to a power pole near N565/E500 are represented as large magnetic dipoles. A Department of the Interior/National Park Service marker is also indicated near N635/E530. Three clusters of magnetic anomalies are identified in the dual fluxgate gradiometer data from 2010. Two of these locations coincide with clusters of magnetic anomalies from the 2002 magnetic survey. Magnetic anomalies present in the 2010 magnetic data are also noted in the 2002 magnetic data.

Analysis of the magnetic data from Site 32ME2377 indicates the possible presence of a historic or recent structure in the southern part of the project area (Figure 29). Several dipole anomalies provide a rough rectangular pattern. Other single dipole anomalies occur within the geophysical project area at the site. The magnetic anomalies consist of simple and complex dipoles with relatively strong magnetic strengths associated with the high and low values of the dipoles. Their orientations and shapes also suggest that the dipoles are associated with metal objects.

The magnetic data from the geophysical project area at the Taylor Bluff site consists of numerous positive monopole anomalies, simple and complex dipole anomalies, as well as clusters of monopole and dipole magnetic anomalies and linear groupings of magnetic anomalies (Figure 30). In the west side of the geophysical project area, a series of four linear anomalies represent modern NPS leach field lines. A buried utility line is also present in the southwestern part of the project area and is identified by a series of alternating negative and positive anomalies resembling a string of alternating black and white beads. A gravel access lane from the farm period runs through the middle of the project area and is approximately 12 m wide. A large magnetic anomaly at the northeast corner of the project area may represent a buried utility vault of reinforced concrete. The linear magnetic anomaly with a relatively low positive contrast suggests the location of the site's fortification ditch. Other positive monopole anomalies appear to represent village pit features which range from 2 to 10 nT in strength. Stronger monopole anomalies, as well as simple dipole and complex dipole anomalies may represent fire-related features and metal objects associated with the village site, as well as more recent metal artifacts from the farm period and modern NPS activities. Small clusters of magnetic anomalies suggest location of buried archeological features while larger clusters suggest the locations of the village lodge floors.

## Interpreting the Resistance Data

Interpretation of the resistivity data results in the identification of lateral changes in the soil. Since the array parameters are kept constant throughout the survey, the resulting resistance values vary with changes in the subsurface sediments/soil matrix and buried archeological resources. For each probe separation, the depth penetration is approximately the same as the distance between the current and potential probe on the mobile array frame, which was 0.5 m. The resistance measurement for each point represents the average value for the hemispheric volume of soil with the same radius. If the soil below the survey area were uniform, the resistivity would be constant throughout the area. Changes in soil characteristics (e.g., texture, structure, moisture, compactness, etc.) and the composition of archeological features result in differences in the resistances across the surveyed grid. Large general trends reflect changes in the site's geology whereas small changes may reflect archeological features. An advantage to the resistance survey and its interpretation is its usefulness in areas that have high concentrations of metal objects such as the Elbee site (De Vore 2008; Volf 2002).

The resistance survey of the Elbee site covered approximately two-thirds of the combined 2002 and 2006 magnetic project area (Figure 31). Seven circular resistance anomalies may represent possible lodge floors. These anomalies consist of the low-resistance halo surrounding a higher resistive core. The linear anomaly identified as a possible trail connecting the two major village sites is also indicated by a weak linear resistive anomaly. Historic two-tracks, farm building foundations, UND excavation units, and the modern NPS gravel service road are also indicated in the resistance data. The resistance data from Site 32ME2377 is more difficult to interpret due to the relatively narrow range of resistance values (Figure 32). A weak linear anomaly appears to represent a two-track lane to a possible square or rectangular building location. The park's recent fire lane is also identified by a linear low-value anomaly near the northeast corner of the geophysical project area.

## Interpreting the Ground-Penetrating Radar Data

Analysis and interpretation of the GPR data may be conducted in several different ways. The individual radargrams for each profile line may be analyzed for hyperbolic reflections. The radargrams may be combined and processed to provide planar time slices of the data. The time slices may also be combined to form 3D cubes of the GPR data. The majority of the GPR radargrams show numerous small reflections along any given profile. Most of the analysis of the GPR data is done with the 3D display while moving through the numerous time slices, but in order to provide a graphic representation of the anomalous areas an individual time slice was selected.

A ground-penetrating radar survey was conducted at the Taylor Bluff site as part of the 2010 NPS archeological prospection workshop (De Vore comp. 2010). Time slice 3 from 8 to 13 nanoseconds was selected for further interpretation (Figure 33). The gravel road bed, leach field line, and the buried utility line locations are suggested by low-amplitude strength GPR linear anomalies. The fortification ditch is also indicated by a low-amplitude GPR reflection. The lodge floors and at least one cluster of potential pit features appear as circular moderately high amplitude reflections. However, the most noticeable linear GPR anomalies across the project area represent windrowed grass from the mowing of the project area immediately prior to the GPR survey. During the week of the workshop, GPR data collected in some of the grid units suggested that the curing of the grass over the week prior to the workshop resulted in less effect on the resulting profile data than immediately after mowing the project area.

## Combined Geophysical Data Set Interpretations

A different way of looking at the geophysical data collected during the investigations of the three geophysical project areas at KNRI is to combine the complementary data sets into one display. Several of the different geophysical anomalies overlap suggesting a strong correlation between the geophysical data and the buried archeological features (Ambrose 2005; Kvamme 2007:345-374; Kvamme et al. 2006). These areas of overlap would be considered areas of high probability for ground-truthing and the investigations of buried archeological resources. While these correlations are important, individual isolated occurrences also need ground-truthing in order to determine their unique nature as well. Complementary data (Clay 2001) from the geophysical survey efforts at the Elbee site geophysical project area indicate the locations of potential lodge floors and the trail between villages, as well as locations of farm building foundations, two-track roads, archeological excavation units, NPS markers and other modern National Park Service modifications to the site and landscape (Figure 34). Complementary data (Clay 2001) from the geophysical survey efforts at the Site 32ME2377 geophysical project area indicate the locations of farm-related ferrous objects, a two-track road, and a possible building foundation, as well as modern National Park Service modifications to the site and landscape (Figure 35). Complementary data (Clay 2001) from the geophysical survey efforts at the Taylor Bluff site geophysical project area indicate the locations of possible lodge floors, storage pits, hearths, and fortification ditch, as well as a farm-related access road and ferrous objects, and modern National Park Service modifications to the site and landscape, including leach field lines, buried utility lines, and a buried re-enforced concrete vault (Figure 36).

# CONCLUSIONS AND RECOMMENDATIONS

The geophysical investigations were conducted from May 10 to May 29, 2010, at three sites in Knife River Indian Villages National Historic Site in Mercer County, North Dakota. The geophysical survey included magnetic surveys with the single fluxgate gradiometer at Site 32ME2377 and with the dual fluxgate gradiometer at the Elbee site and the Taylor Bluff site; a resistance survey with a resistance meter and twin-probe array at the Elbee site and Site 32ME2377; and a ground-penetrating radar (GPR) survey with a GPR cart system and 400 mHz antenna at the Taylor Bluff site. The single fluxgate gradiometer data from the 2002 and 2006 magnetic surveys at the Elbee site were also incorporated into the 2010 findings. The geophysical survey was conducted in order to identify buried archeological remains in the vicinity of the bank erosion along the Knife River at the Elbee site and Site 32ME2377, as well as within the archeological prospection workshop project area at the Taylor Bluff site in order to provide a baseline of archeological geophysical data for the park's future planning activities. The geophysical surveys at the Elbee site and Site 32ME2377 provided information of the erosional damage to the sites from flooding of the Knife River and to provide information on the potential damage to the archeological resources at the Taylor Bluff site from historic farming and more recent park activities. A total area of 17,086 m2 or 4.22 ac was investigated during the geophysical survey of the three geophysical project areas during 2010.

The surveys resulted in the identification of numerous subsurface anomalies. The magnetic and resistance data collected at the Elbee site and Site 32ME2377 provided information of the physical properties (magnetic and soil resistance properties) of the subsurface materials. Standard methods for conducting geophysical investigations were used with standard 20-m–by-20-m grid sizes where feasible. The results of the geophysical survey provided data on the location of potential lodge floors, fortification ditches, hearths and other fire-related features, storage pits, connecting village trails, and historic agricultural and modern National Park Service modifications to the landscape at the three geophysical project areas at Knife River Indian Villages National Historic Site in Mercer County, North Dakota.

Finally, refinement of the 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 two geophysical project areas investigated during this project, the project archeologist is encouraged to share additional survey and excavation data with the geophysical investigator for incorporation into the investigator's 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. 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.

The Taylor Bluff site and the Elbee site are included in the Knife River Villages National Historic Site Archeological District, which was listed in 1974 on the National Register of Historic Places that was established by the National Historic Preservation Act of 1966 (NPS 1993:7-9). The National Register of Historic Places documents the importance of buildings, structures, archeological sites, districts, and objects that are important to our national, regional, and local prehistory and history (Andrus 1990:i). Generally archeological sites are evaluated for their potential to yield information to our understanding of human history and prehistory under Criterion D (Andrus 1990:21-24). The Elbee site has a high degree of subsurface integrity with several subsurface features identified in the geophysical data from the site. Based on the geophysical investigations and past archeological investigations (Ahler 1984; Toom et al. 2004), the site has the potential to answer research questions concerning site chronology, regional settlement patterns, and Native American subsistence patterns. A similar statement can be made for the Taylor Bluff site, although the site has been more affected by erosion and road construction activities than the Elbee site (Ahler 1988; Ahler (ed.) 1988; Ahler et al. 1983; Toom and Ahler 1984). The archeo-geophysical data suggests that there is a high degree of site integrity remaining on the north side of the county road in the yard to the side of the maintenance facility even though several impacts from farming and modern NPS activities have reduced the site integrity. The potential storage features, lodge floors, and fortification ditch can provide significant information on historic Native Americans related to chronology, subsistence, settlement patterns, and effects of European diseases on the Native American villagers along the upper Missouri River. Although Site 32ME2377 retains a high degree of subsurface integrity, the mid-20th-century site contains little scientific information that would aid in our understanding of the mid-20th-century farming activities; therefore, Site 32ME2377 is recommended as not eligible for listing on the NRHP.

This report has provided a review and analysis of the geophysical data collected during the geophysical investigations at three sites within Knife River Indian Villages National Historic Site. The geophysical techniques applied to the investigations at KNRI have proven successful in the identification of buried archeological resources in the present geophysical project areas. This information will be used by the Midwest Archeological Center and the Knife River Indian Villages National Historic Site staffs to guide further archeological inquiry into the nature of the archeological resources of the Native American villages and help direct future National Park Service geophysical surveys and archeological excavations at other locations within the boundary of Knife River Indian Villages National Historic Site.

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# TABLES

Table 1. Global positioning system post processed and corrected grid coordinates for the KNRI geophysical project areas.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -101.386406 | 47.3440763 | 494.19 | 319744.32 | 5246162.725 | 514.069 | Geophys Feature Pt | stake | 32ME408 |
| 2 | -101.38667 | 47.3440747 | 494.61 | 319724.371 | 5246163.162 | 514.492 | Geophys Feature Pt | stake | 32me408 |
| 3 | -101.3869352 | 47.344073 | 494.63 | 319704.337 | 5246163.584 | 514.513 | Geophys Feature Pt | stake | 32me408 |
| 4 | -101.3872 | 47.3440752 | 494.59 | 319684.344 | 5246164.44 | 514.467 | Site Datum | 2002 datum | 32me408 |
| 5 | -101.3872012 | 47.3442511 | 493.8 | 319684.853 | 5246183.986 | 513.676 | Geophys Feature Pt | stake | 32me408 |
| 6 | -101.3869367 | 47.3442509 | 494.49 | 319704.831 | 5246183.351 | 514.366 | Geophys Feature Pt | stake | 32me408 |
| 7 | -101.3866712 | 47.344256 | 494.91 | 319724.9 | 5246183.312 | 514.791 | Geophys Feature Pt | stake | 32me408 |
| 8 | -101.3864058 | 47.3442443 | 494.25 | 319744.902 | 5246181.397 | 514.131 | Geophys Feature Pt | stake | 32me408 |
| 9 | -101.3864063 | 47.3444136 | 494.12 | 319745.443 | 5246200.211 | 513.999 | Geophys Feature Pt | stake | 32me408 |
| 10 | -101.3866702 | 47.3444241 | 494.69 | 319725.549 | 5246201.989 | 514.567 | Geophys Feature Pt | stake | 32me408 |
| 11 | -101.3869358 | 47.3444352 | 494.52 | 319705.523 | 5246203.836 | 514.397 | Geophys Feature Pt | stake | 32me408 |
| 12 | -101.3872011 | 47.3444334 | 493.38 | 319685.478 | 5246204.246 | 513.263 | Geophys Feature Pt | stake | 32me408 |
| 13 | -101.3872023 | 47.3446131 | 493.22 | 319686.005 | 5246224.223 | 513.098 | Geophys Feature Pt | stake | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 14 | -101.3869378 | 47.3446126 | 494.6 | 319705.98 | 5246223.553 | 514.483 | Geophys Feature Pt | stake | 32me408 |
| 15 | -101.3866725 | 47.3446154 | 494.88 | 319726.027 | 5246223.255 | 514.761 | Geophys Feature Pt | stake | 32me408 |
| 16 | -101.3864076 | 47.3446194 | 494.12 | 319746.045 | 5246223.083 | 514.004 | Geophys Feature Pt | stake | 32me408 |
| 17 | -101.386409 | 47.3447959 | 494.7 | 319746.541 | 5246242.7 | 514.576 | Geophys Feature Pt | stake | 32me408 |
| 18 | -101.3866728 | 47.3447945 | 494.8 | 319726.616 | 5246243.158 | 514.675 | Geophys Feature Pt | stake | 32me408 |
| 19 | -101.386937 | 47.3447942 | 494.18 | 319706.659 | 5246243.732 | 514.056 | Geophys Feature Pt | stake | 32me408 |
| 20 | -101.3872037 | 47.3447925 | 493.03 | 319686.506 | 5246244.16 | 512.906 | Geophys Feature Pt | stake | 32me408 |
| 21 | -101.3872045 | 47.3449732 | 493.01 | 319687.064 | 5246264.238 | 512.887 | Geophys Feature Pt | stake | 32me408 |
| 22 | -101.3869393 | 47.3449754 | 493.92 | 319707.102 | 5246263.875 | 513.795 | Geophys Feature Pt | stake | 32me408 |
| 23 | -101.386674 | 47.3449773 | 494.77 | 319727.147 | 5246263.468 | 514.653 | Geophys Feature Pt | stake | 32me408 |
| 24 | -101.386942 | 47.3451534 | 493.73 | 319707.5 | 5246283.658 | 513.605 | Geophys Feature Pt | stake | 32me408 |
| 25 | -101.3872059 | 47.3451529 | 492.9 | 319687.567 | 5246284.218 | 512.781 | Geophys Feature Pt | stake | 32me408 |
| 26 | -101.3872072 | 47.3453328 | 492.66 | 319688.08 | 5246304.206 | 512.542 | Geophys Feature Pt | stake | 32me408 |
| 27 | -101.3869425 | 47.3453332 | 493.46 | 319708.078 | 5246303.636 | 513.339 | Geophys Feature Pt | stake | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 28 | -101.3867957 | 47.3452769 | 494.43 | 319718.97 | 5246297.044 | 514.312 | Geophys Feature Pt | doi bench | 32me408 |
| 29 | -101.3869439 | 47.3455134 | 493.6 | 319708.582 | 5246323.666 | 513.48 | Geophys Feature Pt | stake | 32me408 |
| 30 | -101.3872079 | 47.3455129 | 492.85 | 319688.644 | 5246324.221 | 512.726 | Geophys Feature Pt | stake | 32me408 |
| 31 | -101.3872103 | 47.345693 | 492.56 | 319689.076 | 5246344.243 | 512.439 | Geophys Feature Pt | stake | 32me408 |
| 32 | -101.3872111 | 47.3458719 | 492.46 | 319689.629 | 5246364.129 | 512.341 | Geophys Feature Pt | stake | 32me408 |
| 33 | -101.3869462 | 47.345873 | 493.08 | 319709.636 | 5246363.635 | 512.955 | Geophys Feature Pt | stake | 32me408 |
| 34 | -101.3869533 | 47.3458455 | 492.98 | 319709.005 | 5246360.593 | 512.86 | Geophys Feature Pt | bank m stake | 32me408 |
| 35 | -101.3869533 | 47.3458176 | 493.24 | 319708.912 | 5246357.493 | 513.122 | Geophys Feature Pt | bank m stake | 32me408 |
| 36 | -101.38695 | 47.3456133 | 493.92 | 319708.467 | 5246334.788 | 513.799 | Geophys Feature Pt | bank m stake | 32me408 |
| 37 | -101.3869469 | 47.34605 | 492.52 | 319710.19 | 5246383.311 | 512.393 | Geophys Feature Pt | stake | 32me408 |
| 38 | -101.3872109 | 47.3460508 | 492.36 | 319690.254 | 5246384.011 | 512.237 | Geophys Feature Pt | stake | 32me408 |
| 39 | -101.3872127 | 47.3462309 | 492.41 | 319690.725 | 5246404.025 | 512.291 | Geophys Feature Pt | stake | 32me408 |
| 40 | -101.3869489 | 47.3462332 | 492.99 | 319710.662 | 5246403.663 | 512.867 | Geophys Feature Pt | stake | 32me408 |
| 41 | -101.3868806 | 47.3462333 | 493.13 | 319715.821 | 5246403.52 | 513.011 | Geophys Feature Pt | stake | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 42 | -101.3868158 | 47.3464145 | 492.99 | 319721.327 | 5246423.511 | 512.869 | Geophys Feature Pt | stake | 32me408 |
| 43 | -101.3869499 | 47.3464139 | 492.33 | 319711.203 | 5246423.749 | 512.208 | Geophys Feature Pt | stake | 32me408 |
| 44 | -101.3872139 | 47.3464122 | 492.6 | 319691.257 | 5246424.177 | 512.478 | Geophys Feature Pt | stake | 32me408 |
| 45 | -101.3872678 | 47.3464611 | 493.22 | 319687.354 | 5246429.734 | 513.094 | Other Point | boundary fence | 32me408 |
| 46 | -101.3872685 | 47.3458886 | 492.75 | 319685.347 | 5246366.11 | 512.629 | Other Point | 2nd power pole | 32me408 |
| 47 | -101.3869918 | 47.3457223 | 492.79 | 319705.68 | 5246346.999 | 512.667 | Excavation Unit | geophysical | 32me408 |
| 48 | -101.386991 | 47.3457428 | 492.88 | 319705.807 | 5246349.272 | 512.761 | Excavation Unit | geophysical | 32me408 |
| 49 | -101.386675 | 47.3450813 | 494.48 | 319727.426 | 5246275.028 | 514.354 | Excavation Unit | geophysical | 32me408 |
| 50 | -101.3866507 | 47.3450801 | 494.7 | 319729.255 | 5246274.837 | 514.581 | Excavation Unit | geophysical | 32me408 |
| 51 | -101.3866777 | 47.3450648 | 494.71 | 319727.164 | 5246273.203 | 514.586 | Excavation Unit | geophysical | 32me408 |
| 52 | -101.386649 | 47.3450675 | 494.73 | 319729.338 | 5246273.433 | 514.613 | Excavation Unit | geophysical | 32me408 |
| 53 | -101.3864772 | 47.3447219 | 494.55 | 319741.141 | 5246234.629 | 514.431 | Excavation Unit | geophysical | 32me408 |
| 54 | -101.3864525 | 47.3447235 | 494.53 | 319743.009 | 5246234.753 | 514.408 | Excavation Unit | geophsical | 32me408 |
| 55 | -101.3864508 | 47.3447072 | 494.43 | 319743.079 | 5246232.934 | 514.31 | Excavation Unit | geophysical | 32me408 |
| 56 | -101.386475 | 47.3447076 | 494.56 | 319741.26 | 5246233.042 | 514.441 | Excavation Unit | geophysical | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 57 | -101.3864864 | 47.3444255 | 494.13 | 319739.434 | 5246201.714 | 514.007 | Excavation Unit | geophysical | 32me408 |
| 58 | -101.3864869 | 47.3444106 | 494.28 | 319739.342 | 5246200.064 | 514.161 | Excavation Unit | geophsical | 32me408 |
| 59 | -101.3865093 | 47.3444083 | 494.46 | 319737.647 | 5246199.857 | 514.343 | Excavation Unit | geophysical | 32me408 |
| 60 | -101.3865102 | 47.3444249 | 494.38 | 319737.635 | 5246201.709 | 514.258 | Excavation Unit | geophysical | 32me408 |
| 61 | -101.3863554 | 47.343982 | 493.93 | 319747.817 | 5246152.132 | 513.811 | Excavation Unit | geophysical | 32me408 |
| 62 | -101.3863237 | 47.3439839 | 493.92 | 319750.219 | 5246152.268 | 513.799 | Excavation Unit | geophysical | 32me408 |
| 63 | -101.3863216 | 47.3439698 | 493.89 | 319750.33 | 5246150.697 | 513.767 | Excavation Unit | geophysical | 32me408 |
| 64 | -101.3863527 | 47.3439665 | 494.12 | 319747.97 | 5246150.4 | 514 | Excavation Unit | geophysical | 32me408 |
| 65 | -101.3872514 | 47.3439465 | 494.79 | 319680.023 | 5246150.254 | 514.667 | Other Point | boundary fence/gate | 32me408 |
| 66 | -101.387195 | 47.3437134 | 494.42 | 319683.489 | 5246124.23 | 514.304 | Geophys Feature Pt | stake | 32me408 |
| 67 | -101.3869292 | 47.343717 | 493.53 | 319703.579 | 5246124.005 | 513.413 | Geophys Feature Pt | stake | 32me408 |
| 68 | -101.3866639 | 47.3437139 | 492.25 | 319723.607 | 5246123.05 | 512.132 | Geophys Feature Pt | stake | 32me408 |
| 69 | -101.3864033 | 47.3437119 | 494.01 | 319743.277 | 5246122.223 | 513.896 | Geophys Feature Pt | stake | 32me408 |
| 70 | -101.3861323 | 47.3437225 | 493.55 | 319763.784 | 5246122.771 | 513.43 | Geophys Feature Pt | stake | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 71 | -101.3861261 | 47.3435438 | 493.83 | 319763.642 | 5246102.9 | 513.713 | Geophys Feature Pt | stake | 32me408 |
| 72 | -101.3863912 | 47.3435421 | 494.67 | 319743.619 | 5246103.327 | 514.548 | Geophys Feature Pt | stake | 32me408 |
| 73 | -101.3866587 | 47.34354 | 494.59 | 319723.404 | 5246103.713 | 514.467 | Geophys Feature Pt | stake | 32me408 |
| 74 | -101.3869222 | 47.3435392 | 494.42 | 319703.498 | 5246104.232 | 514.299 | Geophys Feature Pt | stake | 32me408 |
| 75 | -101.3871837 | 47.3435391 | 494.32 | 319683.746 | 5246104.828 | 514.201 | Geophys Feature Pt | stake | 32me408 |
| 76 | -101.3871869 | 47.3433528 | 493.47 | 319682.869 | 5246084.139 | 513.35 | Geophys Feature Pt | stake | 32me408 |
| 77 | -101.3869243 | 47.3433571 | 494.17 | 319702.719 | 5246084.005 | 514.05 | Geophys Feature Pt | stake | 32me408 |
| 78 | -101.3866634 | 47.3433566 | 494.14 | 319722.421 | 5246083.35 | 514.026 | Geophys Feature Pt | stake | 32me408 |
| 79 | -101.3863956 | 47.343356 | 494.04 | 319742.65 | 5246082.658 | 513.92 | Geophys Feature Pt | stake | 32me408 |
| 80 | -101.3861331 | 47.3433561 | 494.31 | 319762.476 | 5246082.058 | 514.195 | Geophys Feature Pt | stake | 32me408 |
| 81 | -101.3858696 | 47.34336 | 494.26 | 319782.393 | 5246081.88 | 514.142 | Geophys Feature Pt | stake | 32me408 |
| 82 | -101.3858539 | 47.3431869 | 494.03 | 319782.99 | 5246062.614 | 513.912 | Geophys Feature Pt | stake | 32me408 |
| 83 | -101.3861295 | 47.3431805 | 494.3 | 319762.153 | 5246062.543 | 514.187 | Geophys Feature Pt | stake | 32me408 |
| 84 | -101.3863969 | 47.3431769 | 494.72 | 319741.943 | 5246062.762 | 514.6 | Geophys Feature Pt | stake | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 85 | -101.3866584 | 47.3431774 | 495.04 | 319722.192 | 5246063.418 | 514.92 | Geophys Feature Pt | stake | 32me408 |
| 86 | -101.3869259 | 47.3431762 | 494.74 | 319701.982 | 5246063.902 | 514.616 | Geophys Feature Pt | stake | 32me408 |
| 87 | -101.3871849 | 47.343177 | 494.37 | 319682.42 | 5246064.589 | 514.251 | Geophys Feature Pt | stake | 32me408 |
| 88 | -101.3869191 | 47.3429981 | 494.04 | 319701.889 | 5246044.093 | 513.921 | Geophys Feature Pt | stake | 32me408 |
| 89 | -101.3866614 | 47.3429956 | 495.69 | 319721.348 | 5246043.228 | 515.567 | Geophys Feature Pt | stake | 32me408 |
| 90 | -101.386388 | 47.3430028 | 493.23 | 319742.025 | 5246043.396 | 513.113 | Geophys Feature Pt | stake | 32me408 |
| 91 | -101.3861218 | 47.3430029 | 493.63 | 319762.126 | 5246042.788 | 513.508 | Geophys Feature Pt | stake | 32me408 |
| 92 | -101.3858656 | 47.342998 | 493.1 | 319781.461 | 5246041.648 | 512.981 | Geophys Feature Pt | stake | 32me408 |
| 93 | -101.3855972 | 47.3430036 | 494.04 | 319801.757 | 5246041.647 | 513.92 | Geophys Feature Pt | stake | 32me408 |
| 94 | -101.3855978 | 47.3428209 | 494.67 | 319801.087 | 5246021.343 | 514.551 | Geophys Feature Pt | stake | 32me408 |
| 95 | -101.3858628 | 47.3428195 | 494.32 | 319781.066 | 5246021.804 | 514.203 | Geophys Feature Pt | stake | 32me408 |
| 96 | -101.3861283 | 47.3428183 | 494.41 | 319761.012 | 5246022.29 | 514.296 | Geophys Feature Pt | stake | 32me408 |
| 97 | -101.3863916 | 47.3428203 | 494.43 | 319741.131 | 5246023.122 | 514.315 | Geophys Feature Pt | stake | 32me408 |
| 98 | -101.3869222 | 47.3428169 | 495.37 | 319701.038 | 5246023.965 | 515.248 | Geophys Feature Pt | stake | 32me408 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 99 | -101.3872425 | 47.3427479 | 499.44 | 319676.61 | 5246017.045 | 519.321 | Other Point | boundary fence post | 32me408 |
| 100 | -101.3872434 | 47.3432979 | 493.86 | 319678.413 | 5246078.162 | 513.743 | Other Point | boundary fence post | 32me408 |
| 101 | -101.3872432 | 47.3439089 | 493.26 | 319680.513 | 5246146.065 | 513.136 | Other Point | boundary fence/gate | 32me408 |
| 102 | -101.3871842 | 47.343902 | 492.67 | 319684.945 | 5246145.154 | 512.545 | Geophys Feature Pt | stake | 32me408 |
| 103 | -101.3869378 | 47.3438914 | 495.25 | 319703.524 | 5246143.409 | 515.13 | Geophys Feature Pt | stake | 32me408 |
| 104 | -101.386659 | 47.3438925 | 493.23 | 319724.584 | 5246142.892 | 513.107 | Geophys Feature Pt | stake | 32me408 |
| 105 | -101.3872622 | 47.3456092 | 493.1 | 319684.871 | 5246335.057 | 512.981 | Photograph Location | stake | 32me408 |
| 106 | -101.3872627 | 47.3457186 | 493.12 | 319685.21 | 5246347.213 | 512.992 | Photograph Location | stake | 32me408 |
| 107 | -101.3872632 | 47.3458149 | 493.25 | 319685.496 | 5246357.91 | 513.124 | Photograph Location | stake | 32me408 |
| 108 | -101.3872519 | 47.3423766 | 503.45 | 319674.633 | 5245975.801 | 523.334 | Other Point | wood post | 32me408 |
| 109 | -101.3865345 | 47.3441012 | 495.12 | 319734.698 | 5246165.787 | 515.005 | Excavation Unit | geophysical | 32me408 |
| 110 | -101.3865337 | 47.3440818 | 495.27 | 319734.69 | 5246163.628 | 515.146 | Excavation Unit | geophysical | 32me408 |
| 111 | -101.3865107 | 47.3440839 | 495.1 | 319736.436 | 5246163.818 | 514.979 | Excavation Unit | geophysical | 32me408 |
| 112 | -101.386512 | 47.3441007 | 495.09 | 319736.395 | 5246165.68 | 514.971 | Excavation Unit | geophysical | 32me408 |
| 113 | -101.3906424 | 47.3596135 | 496.23 | 319477.357 | 5247899.122 | 516.086 | Geophys Feature Pt | ne ctr | 32me366 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 114 | -101.3908082 | 47.359473 | 496.48 | 319464.363 | 5247883.893 | 516.338 | Geophys Feature Pt | stake | 32me366 |
| 115 | -101.3909734 | 47.3593329 | 496.41 | 319451.407 | 5247868.705 | 516.263 | Geophys Feature Pt | se ctr | 32me366 |
| 116 | -101.3909671 | 47.3593104 | 495.63 | 319451.809 | 5247866.186 | 515.481 | Other Point | maintenance gate | 32me366 |
| 117 | -101.3909876 | 47.3593194 | 495.79 | 319450.29 | 5247867.233 | 515.643 | Other Point | boundary fence | 32me366 |
| 118 | -101.3911798 | 47.3594469 | 495.4 | 319436.213 | 5247881.847 | 515.257 | Geophys Feature Pt | stake | 32me366 |
| 119 | -101.3913866 | 47.3595592 | 495.22 | 319420.978 | 5247894.815 | 515.076 | Geophys Feature Pt | stake | 32me366 |
| 120 | -101.3915935 | 47.3596716 | 495.02 | 319405.741 | 5247907.784 | 514.875 | Geophys Feature Pt | stake | 32me366 |
| 121 | -101.3918009 | 47.3597834 | 495.16 | 319390.458 | 5247920.688 | 515.018 | Geophys Feature Pt | stake | 32me366 |
| 122 | -101.3918647 | 47.3597848 | 494.88 | 319385.649 | 5247920.991 | 514.737 | Other Point | boundary fence | 32me366 |
| 123 | -101.3920077 | 47.3598954 | 495.36 | 319375.228 | 5247933.612 | 515.217 | Geophys Feature Pt | sw ctr | 32me366 |
| 124 | -101.3921692 | 47.3599446 | 495.32 | 319363.202 | 5247939.452 | 515.176 | Other Point | boundary fence-wood post | 32me366 |
| 125 | -101.3918417 | 47.3600354 | 495.41 | 319388.238 | 5247948.784 | 515.264 | Geophys Feature Pt | stake | 32me366 |
| 126 | -101.3917247 | 47.3601331 | 495.32 | 319397.409 | 5247959.371 | 515.176 | Geophys Feature Pt | nw ctr | 32me366 |
| 127 | -101.3915083 | 47.3600301 | 495.31 | 319413.398 | 5247947.418 | 515.164 | Geophys Feature Pt | stake | 32me366 |
| 128 | -101.3916314 | 47.3599262 | 495.38 | 319403.747 | 5247936.161 | 515.234 | Geophys Feature Pt | stake | 32me366 |

Table 1. Continued.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 129 | -101.3914251 | 47.3598138 | 495.1 | 319418.944 | 5247923.198 | 514.958 | Geophys Feature Pt | stake | 32me366 |
| 130 | -101.3912912 | 47.3599264 | 495.11 | 319429.437 | 5247935.392 | 514.967 | Geophys Feature Pt | stake | 32me366 |
| 131 | -101.3910718 | 47.3598255 | 494.26 | 319445.661 | 5247923.671 | 514.112 | Geophys Feature Pt | stake | 32me366 |
| 132 | -101.3911879 | 47.3597097 | 495.48 | 319436.498 | 5247911.069 | 515.335 | Geophys Feature Pt | stake | 32me366 |
| 133 | -101.3910138 | 47.3595872 | 495.6 | 319449.223 | 5247897.054 | 515.457 | Geophys Feature Pt | stake | 32me366 |
| 134 | -101.39086 | 47.3597183 | 495.51 | 319461.284 | 5247911.267 | 515.37 | Geophys Feature Pt | stake | 32me366 |
| 135 | -101.3908354 | 47.3595214 | 495.89 | 319462.474 | 5247889.334 | 515.744 | Site Feature Point | palisade | 32me366 |
| 136 | -101.3909897 | 47.3596222 | 495.84 | 319451.16 | 5247900.886 | 515.7 | Site Feature Point | palisade | 32me366 |
| 137 | -101.3911923 | 47.359706 | 495.49 | 319436.148 | 5247910.672 | 515.35 | Site Feature Point | palisade | 32me366 |
| 138 | -101.3916395 | 47.3597072 | 495.2 | 319402.388 | 5247911.839 | 515.054 | Site Feature Point | palisade | 32me366 |
| 139 | -101.3914273 | 47.359747 | 495.2 | 319418.547 | 5247915.78 | 515.052 | Site Feature Point | palisade | 32me366 |
| 140 | -101.3908899 | 47.3592654 | 495.66 | 319457.48 | 5247861.005 | 515.513 | Other Point | maintenance gate | 32me366 |
| 141 | -101.3906558 | 47.3591338 | 493.98 | 319474.708 | 5247845.839 | 513.837 | Other Point | boundary fence | 32me366 |
| 142 | -101.3904038 | 47.3589958 | 493.43 | 319493.27 | 5247829.918 | 513.287 | Other Point | boundary fence | 32me366 |
| 143 | -101.3864256 | 47.3472142 | 492.27 | 319753.522 | 5246511.47 | 512.149 | Geophys Feature Pt | stake | 32me2377 |

Table 1. Completed.

| Item No. | Longitude | Latitude | elevation | Easting | Northing | elevation | GPS POINT TYPE | Description | Site No.S |
|---|---|---|---|---|---|---|---|---|---|
| 144 | -101.3864572 | 47.3470398 | 492.31 | 319750.541 | 5246492.168 | 512.191 | Geophys Feature Pt | stake | 32me2377 |
| 145 | -101.3864852 | 47.3468618 | 492.24 | 319747.822 | 5246472.448 | 512.117 | Geophys Feature Pt | stake | 32me2377 |
| 146 | -101.3862247 | 47.3468399 | 491.6 | 319767.422 | 5246469.41 | 511.476 | Geophys Feature Pt | stake | 32me2377 |
| 147 | -101.3861987 | 47.3470165 | 491.98 | 319769.987 | 5246488.976 | 511.857 | Geophys Feature Pt | stake | 32me2377 |
| 148 | -101.3861675 | 47.3471983 | 492.02 | 319772.965 | 5246509.111 | 511.894 | Geophys Feature Pt | stake | 32me2377 |
| 149 | -101.3908445 | 47.359728 | 496.17 | 319462.488 | 5247912.313 | 516.025 | Geophys Feature Pt | stake | 32me366 |
| 150 | -101.3910595 | 47.359834 | 495.64 | 319446.619 | 5247924.589 | 515.495 | Geophys Feature Pt | stake | 32me366 |
| 151 | -101.3912602 | 47.3599541 | 495.31 | 319431.87 | 5247938.406 | 515.17 | Geophys Feature Pt | stake | 32me366 |
| 152 | -101.3914705 | 47.3600633 | 495.46 | 319416.368 | 5247951.027 | 515.316 | Geophys Feature Pt | stake | 32me366 |
| 153 | -101.3916777 | 47.3601748 | 495.04 | 319401.099 | 5247963.893 | 514.896 | Geophys Feature Pt | stake | 32me366 |
| 154 | -101.3918473 | 47.3600318 | 495.01 | 319387.809 | 5247948.397 | 514.86 | Geophys Feature Pt | stake | 32me366 |
| 155 | -101.3916362 | 47.359923 | 495.66 | 319403.372 | 5247935.812 | 515.518 | Geophys Feature Pt | stake | 32me366 |
| 156 | -101.3914331 | 47.3598077 | 495.1 | 319418.319 | 5247922.528 | 514.958 | Geophys Feature Pt | stake | 32me366 |
| 157 | -101.3912191 | 47.3596992 | 495.84 | 319434.101 | 5247909.976 | 515.7 | Geophys Feature Pt | stake | 32me366 |
| 158 | -101.3910115 | 47.3595878 | 495.77 | 319449.403 | 5247897.121 | 515.622 | Geophys Feature Pt | stake | 32me366 |

Table 2. Acquisition and instrumentation information for the single fluxgate gradiometer surveys used in the grid input template at the KNRI geophysical project areas.

| **GENERAL** | | | |
|---|---|---|---|
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | 32ME2377 (originally 32me466) | Survey Type | Single Single Fluxgate Gradiometer |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | Geoscan Research FM-256 |
| Dir. 1st Traverse | Magnetic North | 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 | 19200 |
| Traverse Interval (y) | 0.5 m | Number of Sensors (tubes) | 1 |
| Traverse Mode | Zigzag | Download Software | Geoscan Research GEOPLOT |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | GEOPLOT | | |
| Grid | 1G-2G | | |
| | | | |
| Mesh | GM | | |
| Composite | GC | GCZ, GCZI, GCZIL, GCZILR | |

Table 2. Completed.

| **GENERAL** | | | |
|---|---|---|---|
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | knrimag (2002 and 2006 magnetic surveys) | Survey Type | Single Fluxgate Gradiometer |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | Geoscan Research FM-36 |
| Dir. 1st Traverse | Grid 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 | Number of Sensors (tubes) | 1 |
| Traverse Mode | Zigzag | Download Software | Geoscan Research GEOPLOT |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | GEOPLOT | | |
| Grid | lbg1-lbg4, lbg29,lbg31, | | |
| 500n500e to 740n520e | | | |
| Mesh | mag | | |
| Composite | | mag, magz, magzi, magzil, magzilr | |

Table 3. Acquisition and instrumentation information for the dual fluxgate gradiometer surveys used in the grid input template at the KNRI geophysical project areas.

| **GENERAL** | | | |
|---|---|---|---|
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | 32me408 | Survey Type | Dual Fluxgate Gradiometer |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | Bartington Grad601-2 |
| Dir. 1st Traverse | Grid 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 | 19200 |
| Traverse Interval (y) | 1.0 m | Number of Sensors (tubes) | 2 |
| Traverse Mode | ZigZag | Download Software | Grad601 |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | ArcheoSurveyor 2 | | |
| Grid | dga01-dga04 | | |
| Mesh | | | |
| Composite | dgac | dgacz, dgaci, dgacil | |
| | | | |

Table 3. Continued.

| GENERAL | | | |
|---|---|---|---|
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | KNRI2010 (32me366) | Survey Type | Dual Fluxgate Gradiometer |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | Bartington Grad601-2 |
| Dir. 1st Traverse | Grid 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 | 19200/2400 |
| Traverse Interval (y) | 0.5 m | Number of Sensors (tubes) | 1 |
| Traverse Mode | Zigzag | Download Software | Grad601 |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | GEOPLOT | | |
| Grid | m01-m05, w01-w06 | | |
| Mesh | | | |
| Composite | m-tue, m-wed, m-total | m-tue2, m-tue2, m-wed 2, m-wed3, m-total270, m-totalz, m-totalzi, m-totalzil, m-totalr | |

Table 3. Completed.

| **GENERAL** | | | |
|---|---|---|---|
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | KNRI2010 (32me366) | Survey Type | Dual Fluxgate Gradiometer |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | Bartington Grad601-2 |
| Dir. 1st Traverse | Grid 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 | 19200/2400 |
| Traverse Interval (y) | 0.5 m | Number of Sensors (tubes) | 1 |
| Traverse Mode | Zigzag | Download Software | Grad601 |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | GEOPLOT | | |
| Grid | m01-m05, w01-w06 | | |
| Mesh | | | |
| Composite | m-tue, m-wed, m-total | m-tue2, m-tue2, m-wed 2, m-wed3, m-total270, m-totalz, m-totalzi, m-totalzil, m-totalr | |

Table 4. Acquisition and instrumentation information for the resistance survey used in the grid input template at the KNRI geophysical project areas.

| | | | |
|---|---|---|---|
| **GENERAL** | | | |
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | 32me408 | Survey Type | Resistance |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | RM15-D |
| Dir. 1st Traverse | Grid N | Units | Ohm |
| Grid Length (x) | 20 m | Current Range | AUTO |
| Sample Interval (x) | 0.5 m | Gain Range | AUTO |
| Grid Width (y) | 20 m | Baud Rate | 9600 |
| Traverse Interval (y) | 1.0 m | Frequency | 137 Hz |
| Traverse Mode | Zigzag | High Pass Filter | 13 Hz |
| **ACCESSORIES** | | | |
| | **Accessories** | **Value** | |
| | Array Hardware | PA5 | |
| | Interface | AD1 | |
| | Log Mode | Single | |
| | Configuration | Twin | |
| | Probe Spacing | 0.5 | |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | GEOPLOT | | |
| Grid | 1R-33R | | 9RA, 10RA, 11RW, 12RA, 13RW-15RW, 16RA, 17RW-18RW, 19RA-20RA, 21RT-22RT, 21RW-33RW, |
| Mesh | 10R8R, 10R8RM, RM, RMW | | |
| Composite | RC, RCA, RCW | RCD, RCDE, RCDEI, RCDEIH, RCDEIHR, RCDER | RCAD, RCWAE, RCWAED, RCWAEDI, RCWAEDIH, RCWD, RCWPR |

Table 4. Completed.

| **GENERAL** | | | |
|---|---|---|---|
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| Sitename | 32me2377 (originally 32me466) | Survey Type | Resistance |
| Map Reference | 1968 (photo revised 1981) Stanton, North Dakota 7.5 minute quadrangle | Instrument | RM15-D |
| Dir. 1st Traverse | Grid N | Units | Ohm |
| Grid Length (x) | 20 m | Current Range | AUTO |
| Sample Interval (x) | 0.5 m | Gain Range | AUTO |
| Grid Width (y) | 20 m | Baud Rate | 9600 |
| Traverse Interval (y) | 0.5 m | Frequency | 137 Hz |
| Traverse Mode | Zigzag | High Pass Filter | 13 Hz |
| **ACCESSORIES** | | | |
| | Accessories | Value | |
| | Array Hardware | PA5 | |
| | Interface | AD1 | |
| | Log Mode | Single | |
| | Configuration | Twin | |
| | Probe Spacing | 0.5 | |
| **FILE NOMENCLATURE** | **Raw Data** | **Processed Data** | **Corrected Data** |
| Processing Software | GEOPLOT | | |
| Grid | 1R-2R | | |
| Mesh | RM | | |
| Composite | RC | RCD, RCDI, RCDIH, RCDHIR | |

Table 5. Acquisition and instrumentation information for the ground penetrating radar survey at the Taylor Bluff Site at KNRI.

| | | | |
|---|---|---|---|
| **GENERAL** | | | |
| **Acquisition** | **Value** | **Instrumentation** | **Value** |
| File Nam | TAYLORA, | Survey Type | GPR |
| Number of Profile Lines | 41 in TAYLORA, 69 in TAYLORB, 110 total profile lines | Instrument | GSSI TerraSIRch SIR 3000 |
| Dir. 1st Traverse | Grid E | Samples/scan | 512 |
| Grid Length (x) | 100 m | Bits/sample | 16 |
| Scans/meter | 50 | Scans/second | 50 |
| Grid Width (y) | 40 m | Meters/mark | 1 |
| Traverse Interval (y) | 0.5 m | Diel Constant | 8 |
| Traverse Mode | Zigzag | Antenna | 400 mHz |
| **ACCESSORIES** | | | |
| | Channel(s) | 1 | |
| | Range Gain (dB) | -20.0 15.0 30.0 30.0 45.0 | |
| | Position Correction | 0 ns | |
| | Vertical IIR LP N = 1F | 800 mHz | |
| | Vertical IIR HP N = 1F | 100 mHz | |
| | Position (ns) | 0 | |
| | Range (ns) | 80 | |

# FIGURES

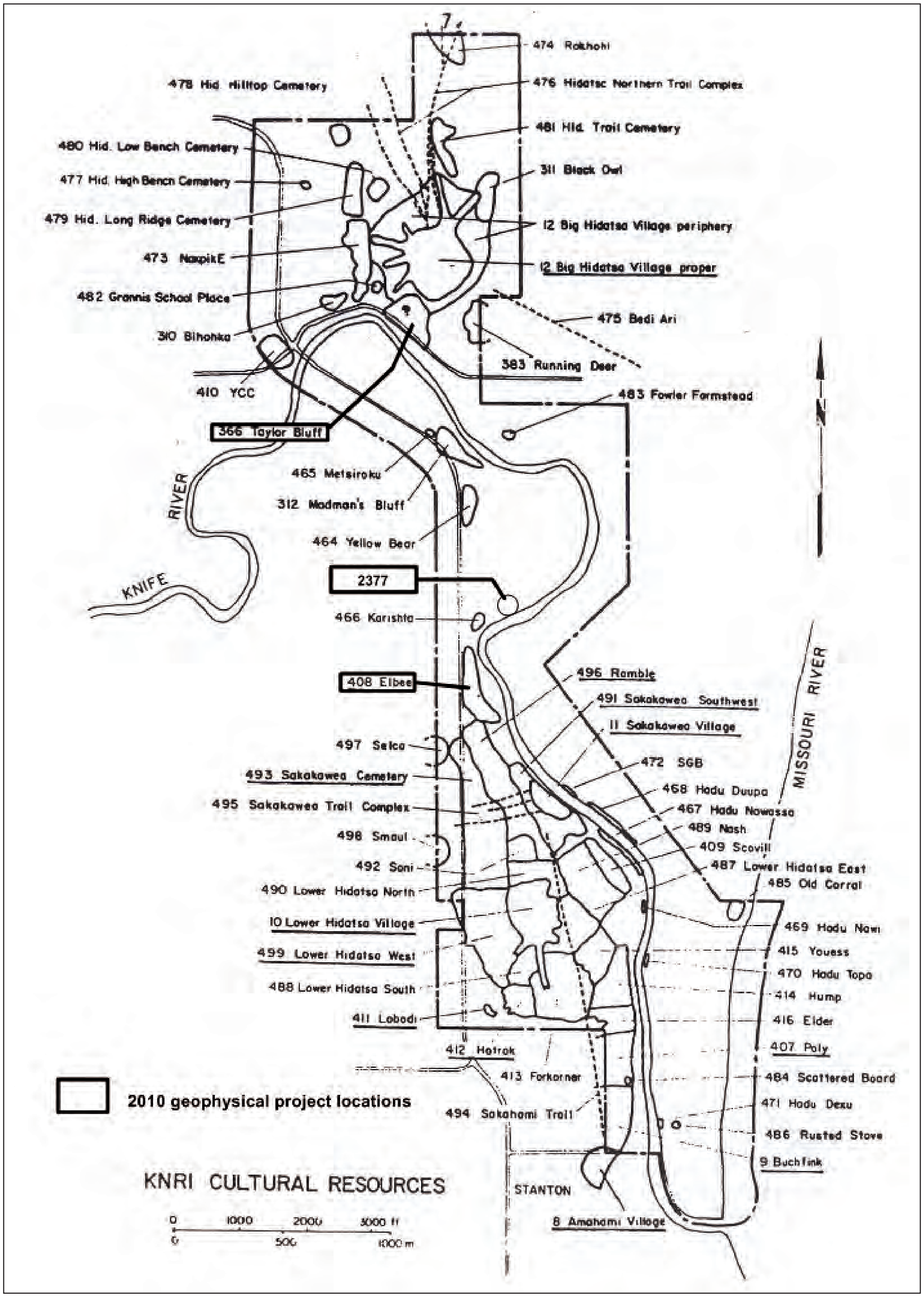
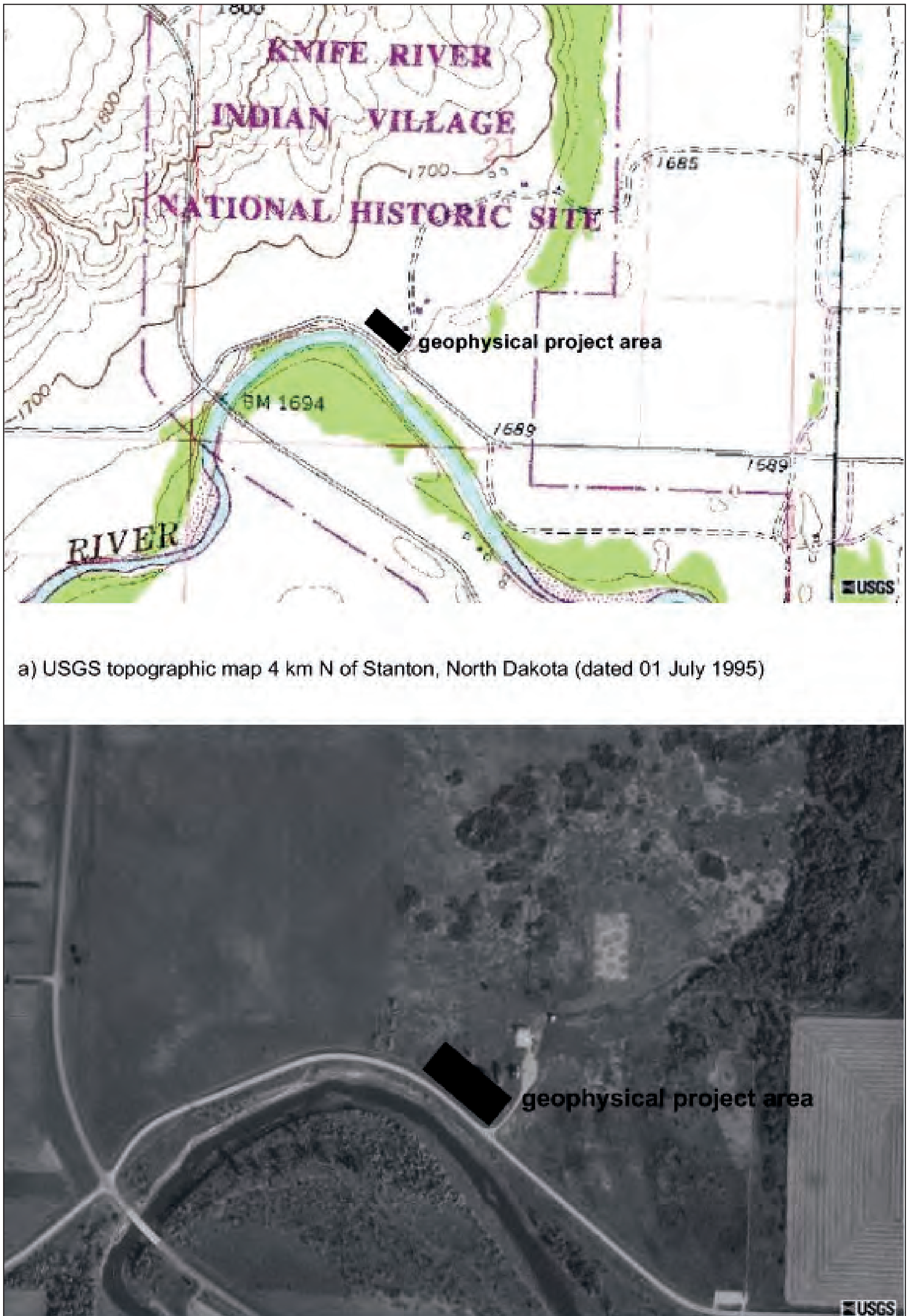


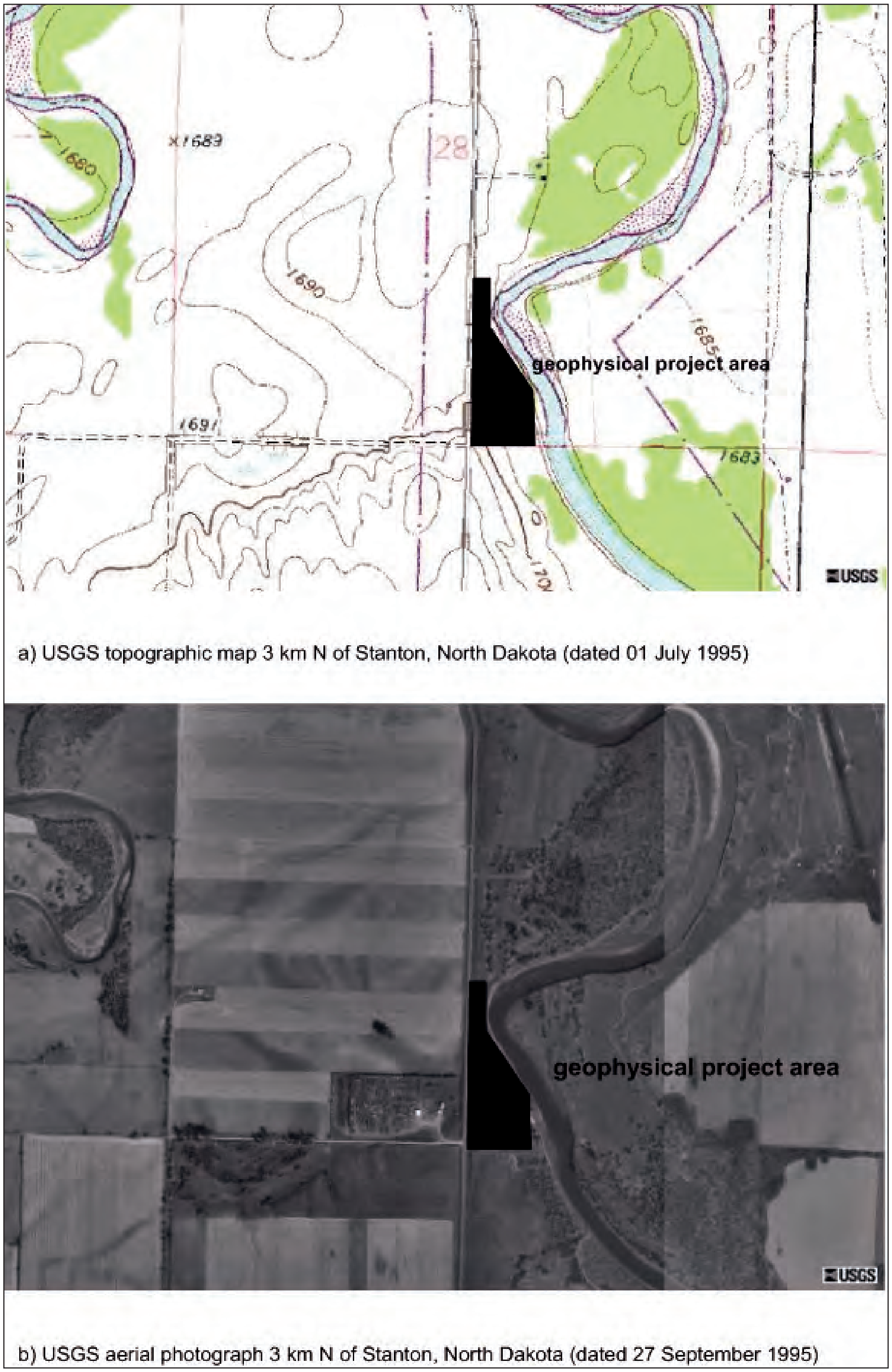

**Figure 1.** Location of the geophysical project areas at Knife River Indian Villages National Historic Site, Mercer County, North Dakota.




a) USGS topographic map 4 km N of Stanton, North Dakota (dated 01 July 1995)

b) USGS aerial photograph 4 km N of Stanton, North Dakota (dated 27 September 1995)

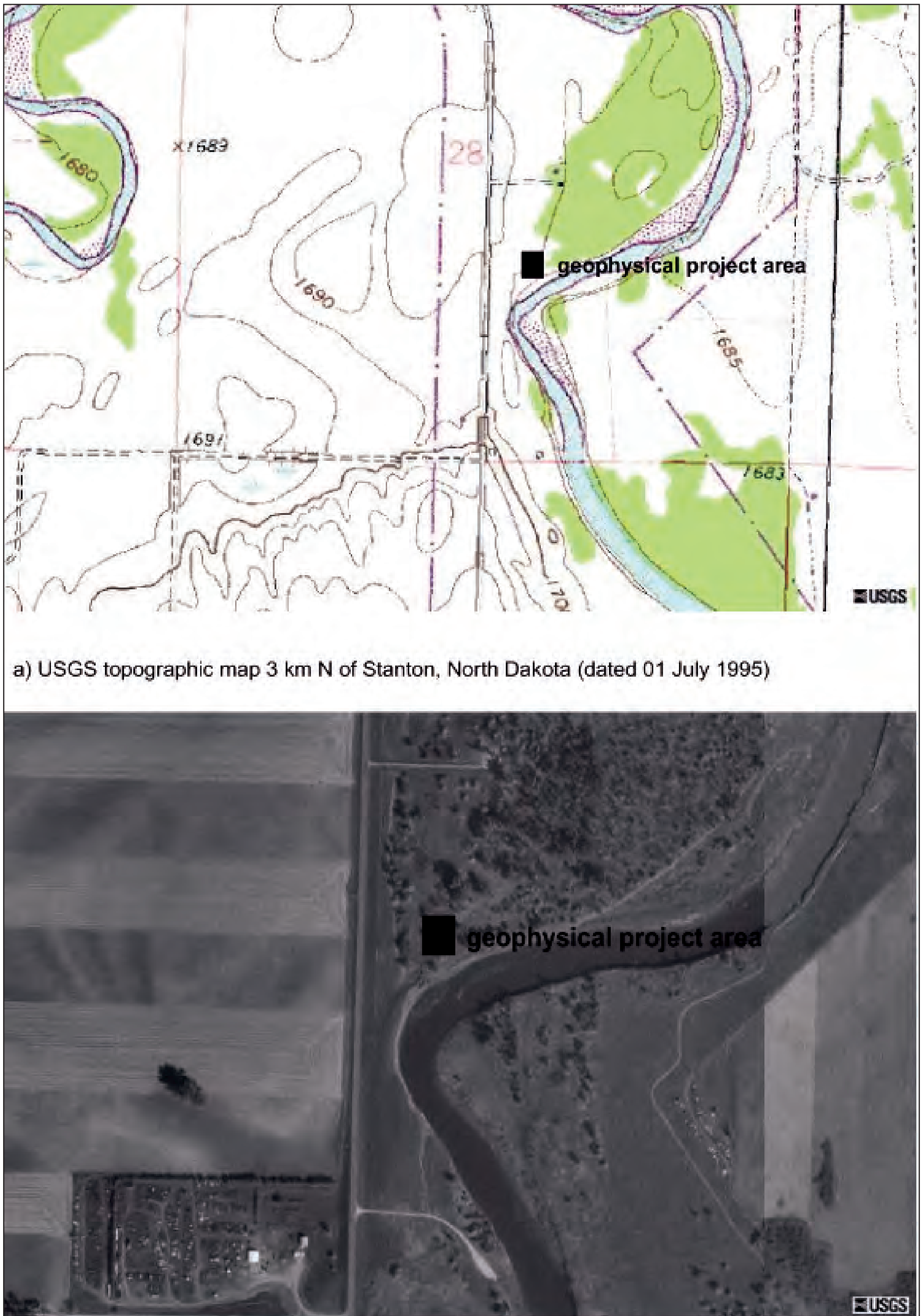
**Figure 2.** Location of the geophysical project area at the Taylor Bluff site.




a) USGS topographic map 3 km N of Stanton, North Dakota (dated 01 July 1995)

b) USGS aerial photograph 3 km N of Stanton, North Dakota (dated 27 September 1995)

**Figure 3.** Location of the geophysical project area at the Elbee site.




a) USGS topographic map 3 km N of Stanton, North Dakota (dated 01 July 1995)

b) USGS aerial photograph 3 km N of Stanton, North Dakota (dated 27 September 1995)

**Figure 4.** Location of the geophysical project area at Site 32ME2377.

**Figure 5.** General view of the Elbee site from the south end of the 2010 geophysical project area (view to the north).

**Figure 6.** General view of Site 32ME2377 from the northeast corner of the 2010 geophysical project area (view to the southwest).

**Figure 7.** General view of the Taylor Bluff site from the southeast corner of the 2010 geophysical project area (view to the northwest).

**Figure 8.** Using the surveying compass to set out the geophysical grid at the Taylor Bluff site (view to the northeast).

**Figure 9.** Laying out the geophysical survey ropes on the Site 32ME2377 geophysical project area (view to the west).

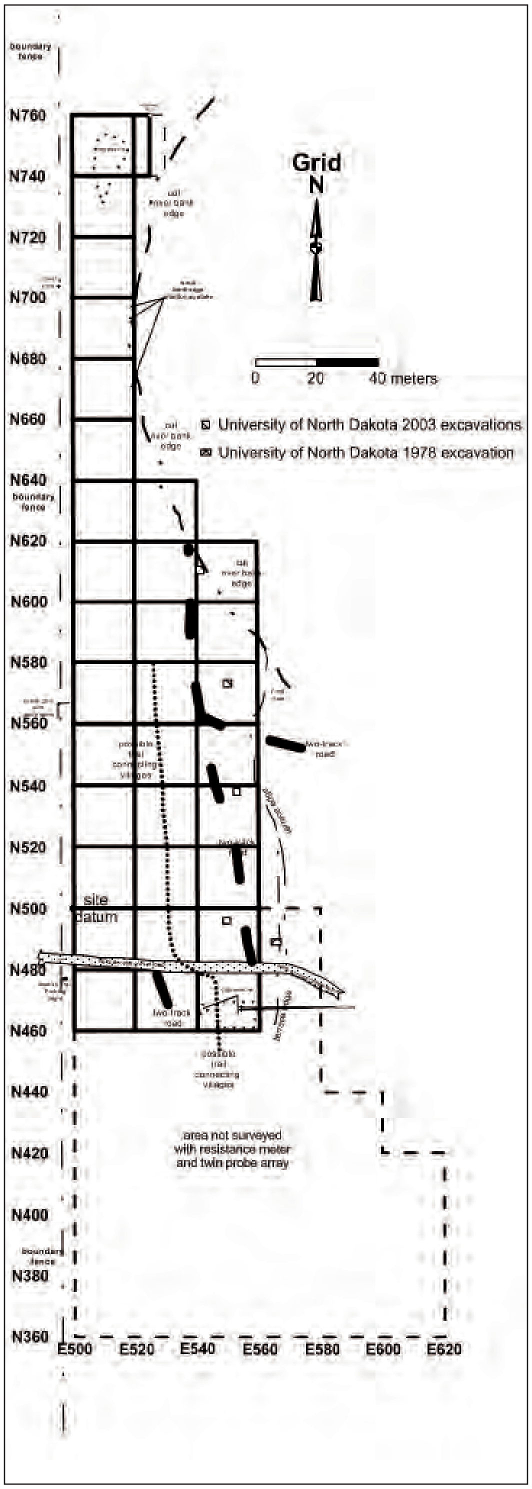



**Figure 10.** Sketch map of the Elbee site geophysical project area.

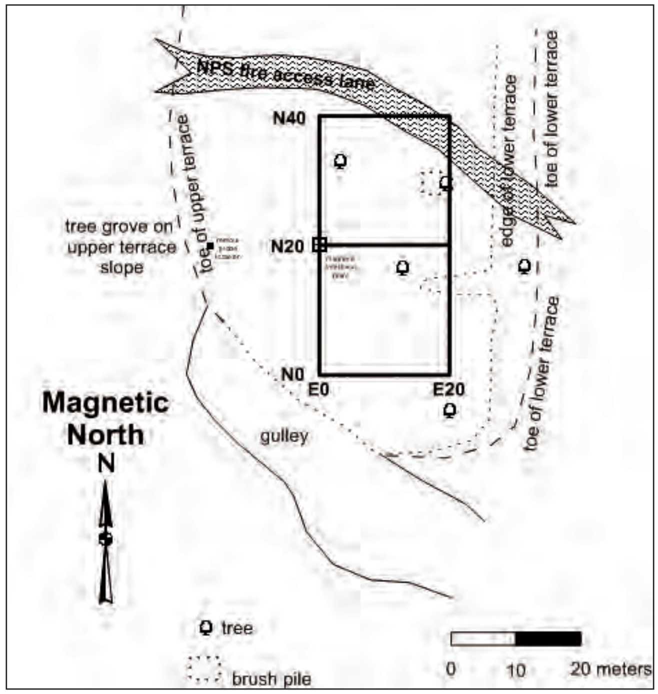



**Figure 11.** Sketch map of the Site 32ME2377 geophysical project area.

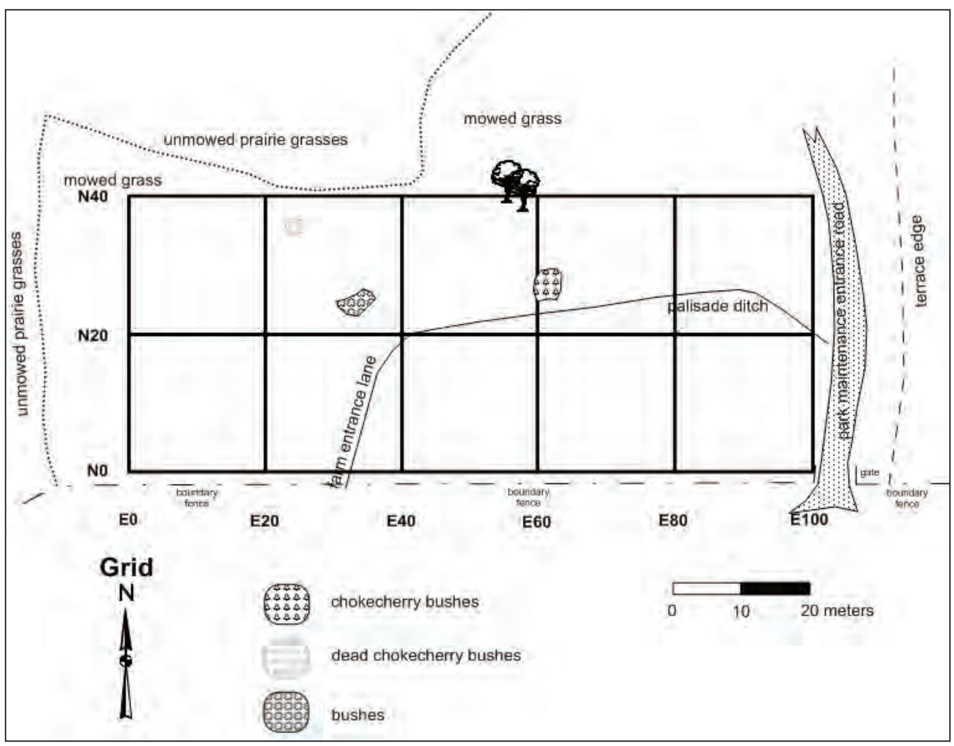



**Figure 12.** Sketch map of the Taylor Bluff geophysical project area.

**Figure 13.** Mapping the grid corner stakes with the GPS unit at the Elbee site geophysical project area (view to the northwest).

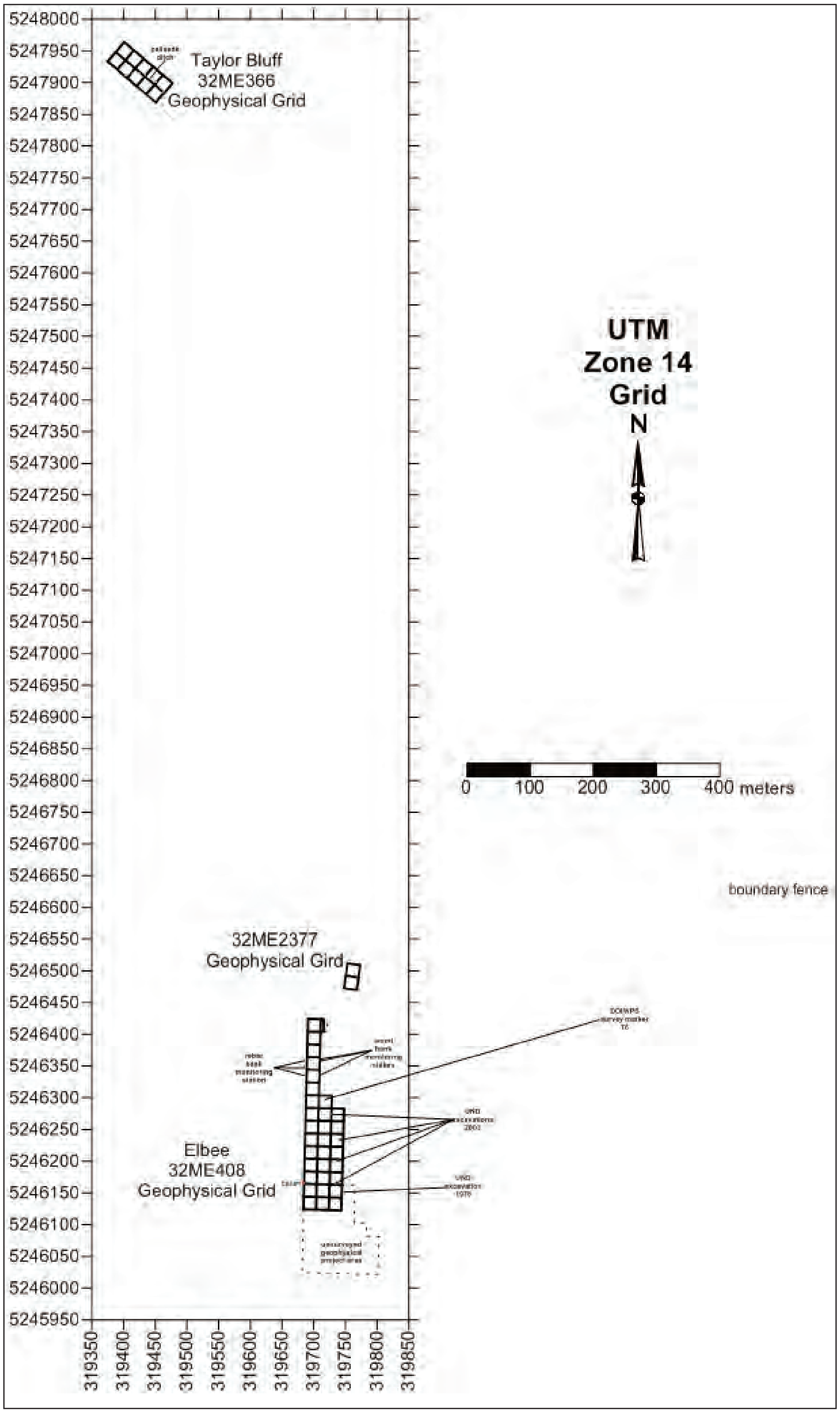



**Figure 14.** UTM grid of the geophysical project areas at Knife River Indian Villages National Historic Site.

**Figure 15.** Participants practicing with the single fluxgate gradiometer at the Taylor Bluff site during the archeological prospection workshop (view to the east).

**Figure 16.** Conducting the magnetic survey with the dual fluxgate gradiometer at the Elbee site (view to the north).

**Figure 17.** Conducting the resistance survey with the resistance meter and twin-probe array at Site 32ME2377 (view to the south).

**Figure 18.** Conducting the ground penetrating radar survey with a GPR cart and 400 mHz antenna at the Taylor Bluff site (view to the northeast).

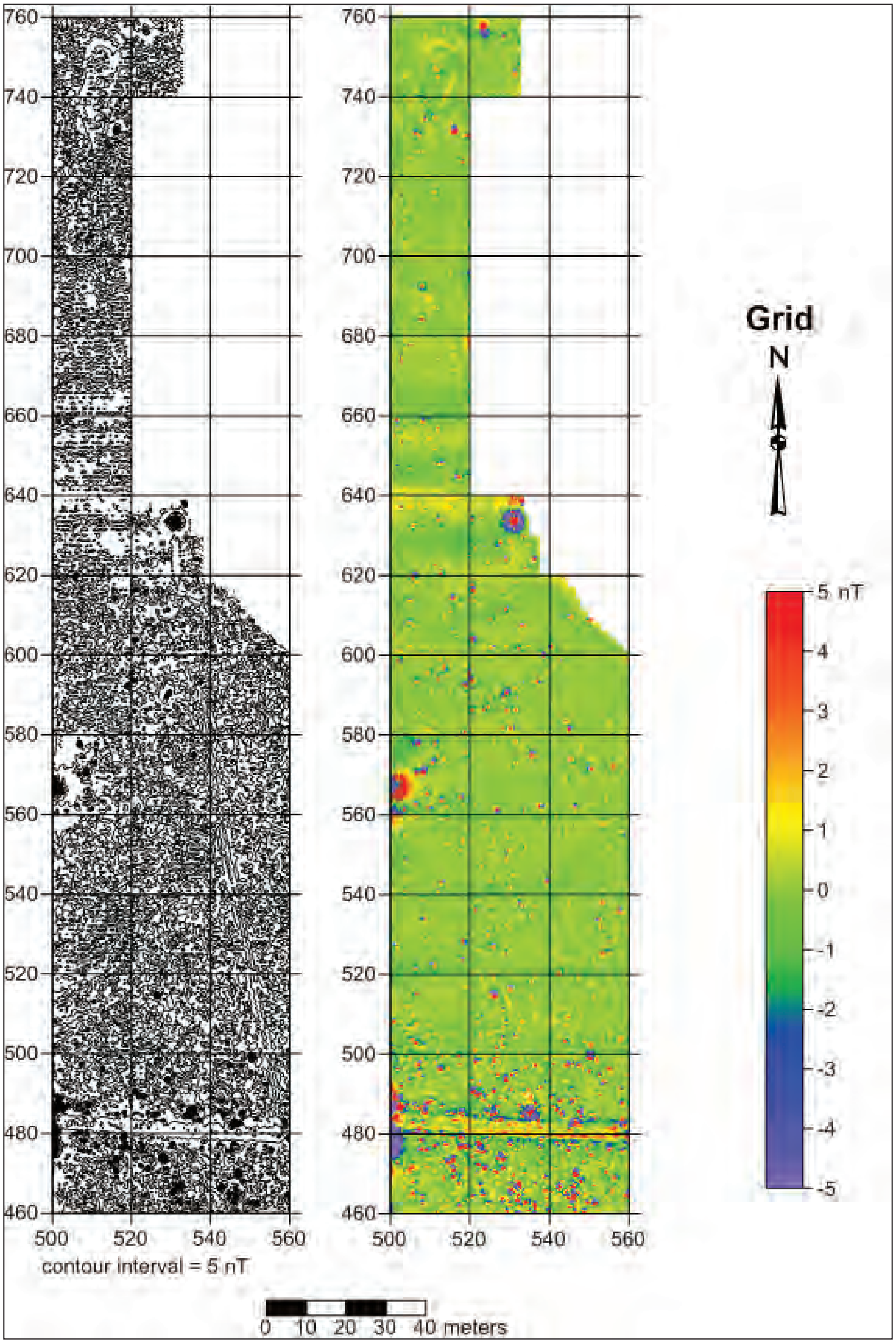



**Figure 19.** Image and contour plots of the single fluxgate gradiometer magnetic data from the 2002/2006 geophysical investigations of the Elbee site within the 2010 geophysical project area.

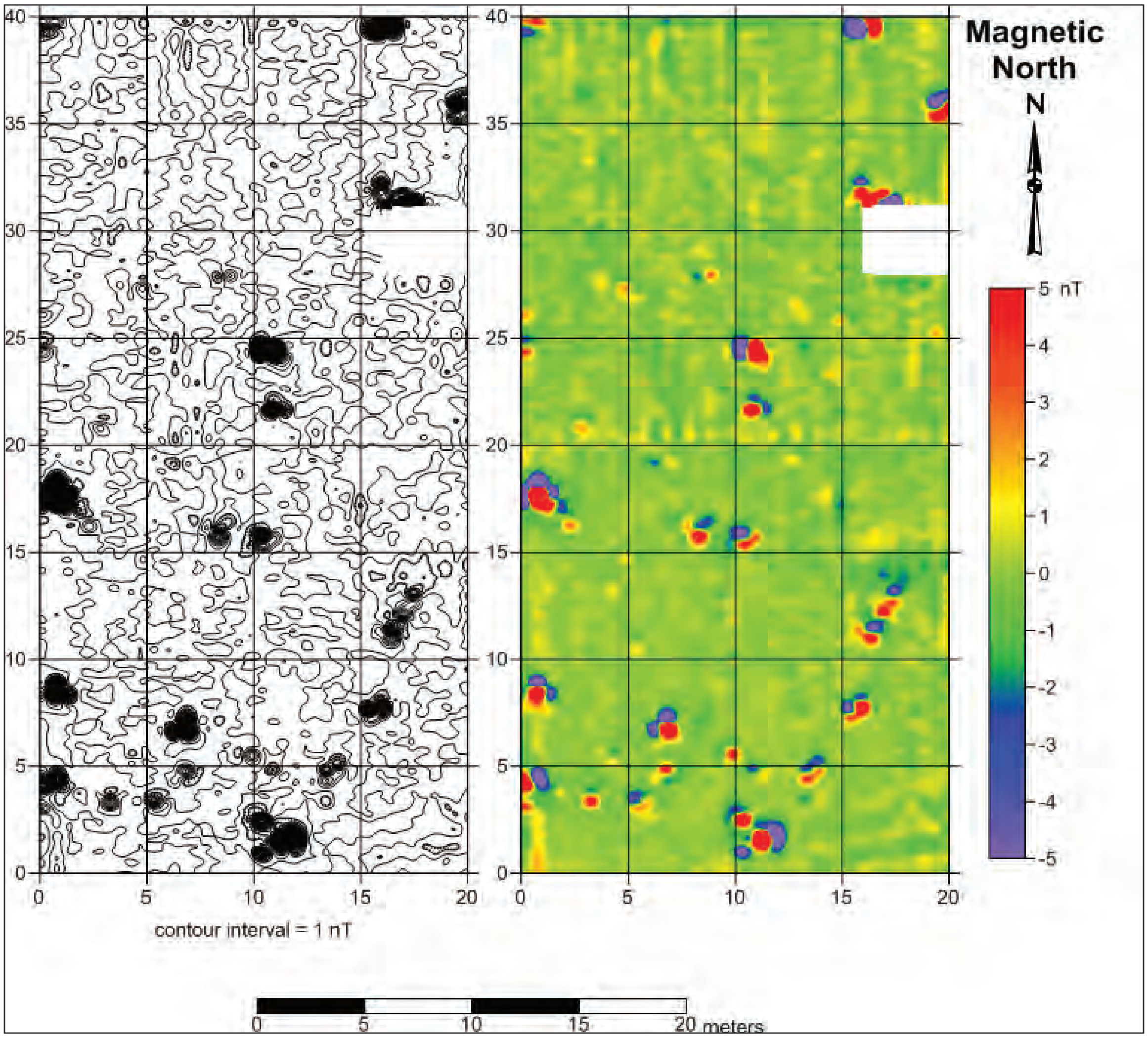



**Figure 20.** Image and contour plots of the single fluxgate gradiometer magnetic data from the Site 32ME2377 geophysical project area.

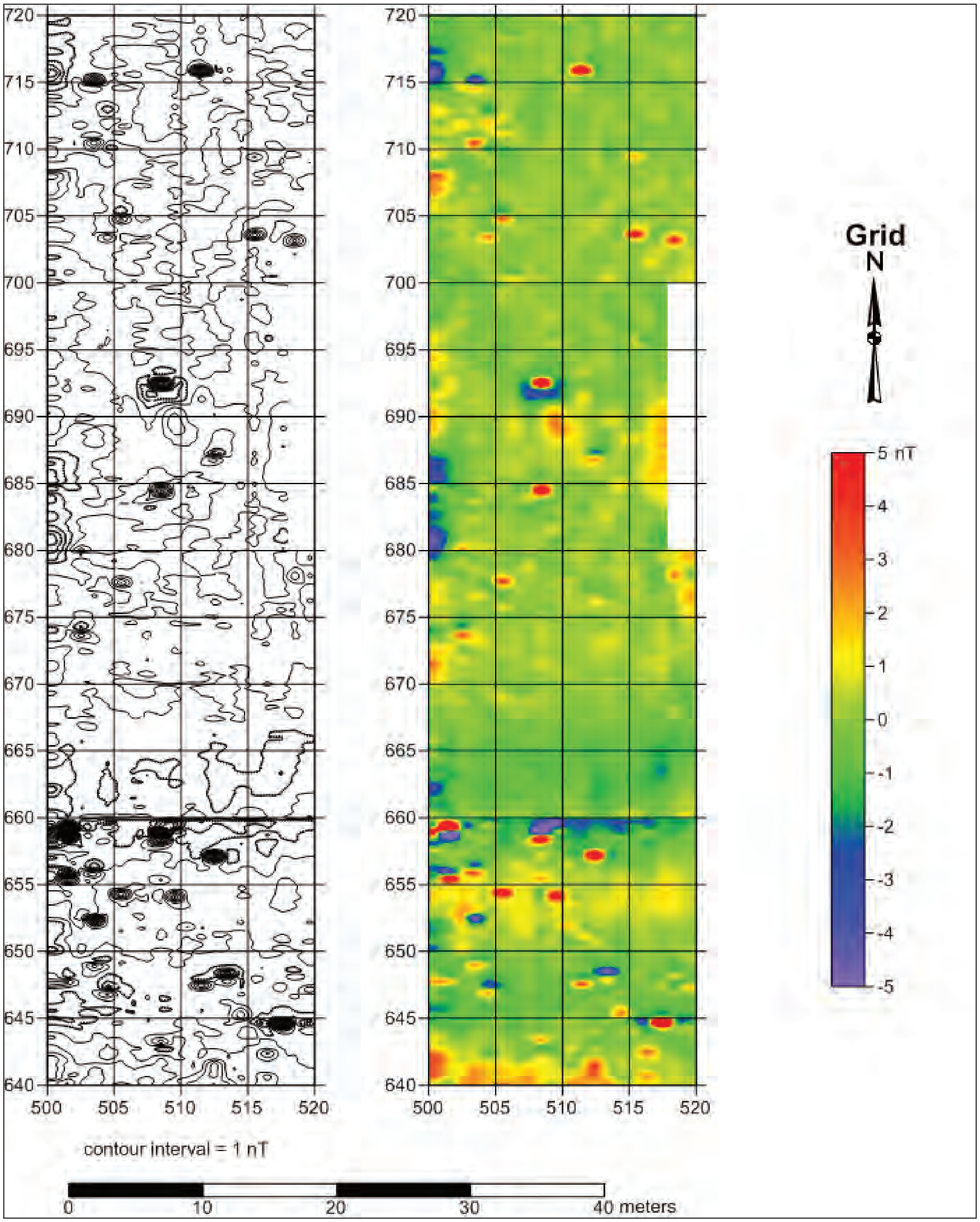



**Figure 21.** Image and contour plots of the dual fluxgate gradiometer magnetic data from the northern portion of the Elbee site geophysical project area.

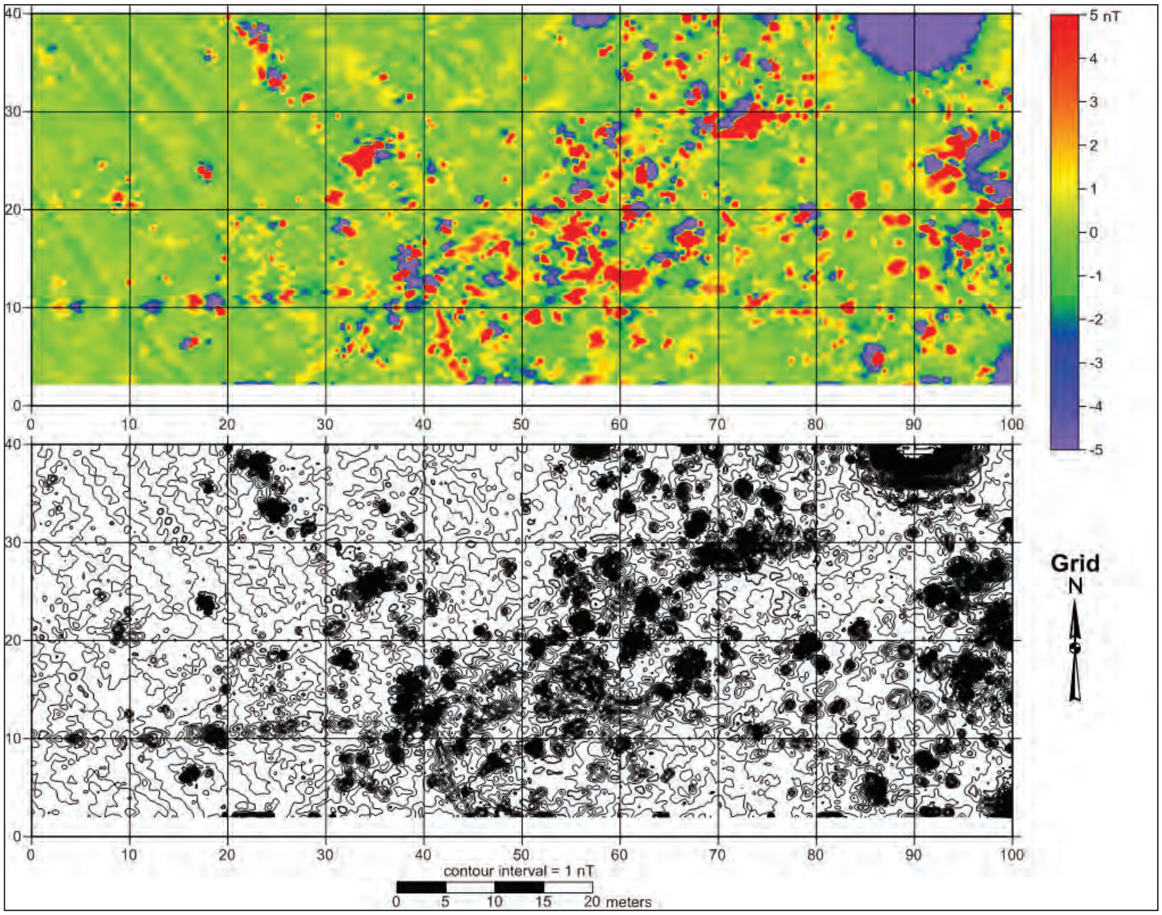



**Figure 22.** Image and contour plots of the dual fluxgate gradiometer magnetic data from the Taylor Bluff geophysical project area.

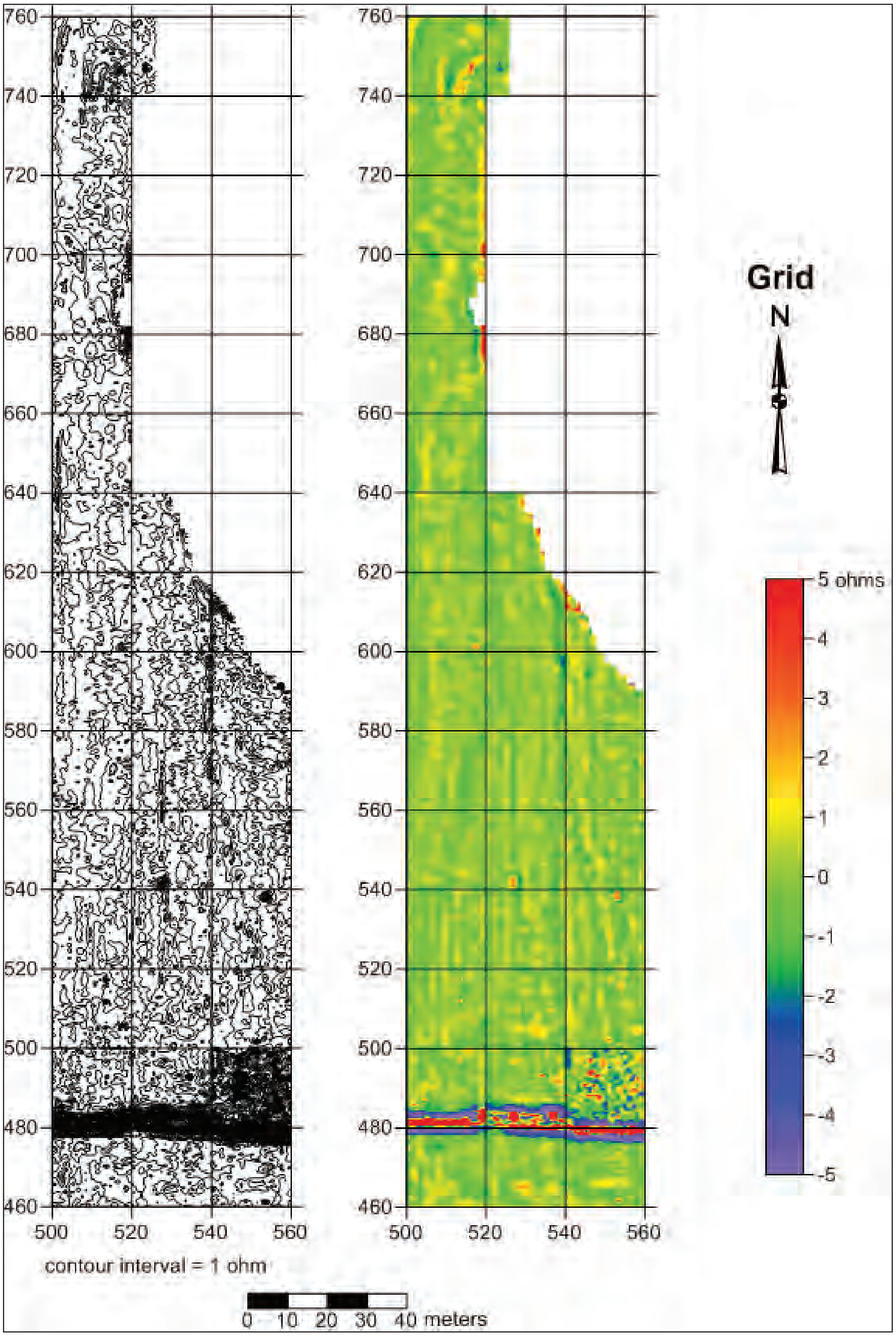



**Figure 23.** Image and contour plots of the resistance data from the Elbee site geophysical project area.

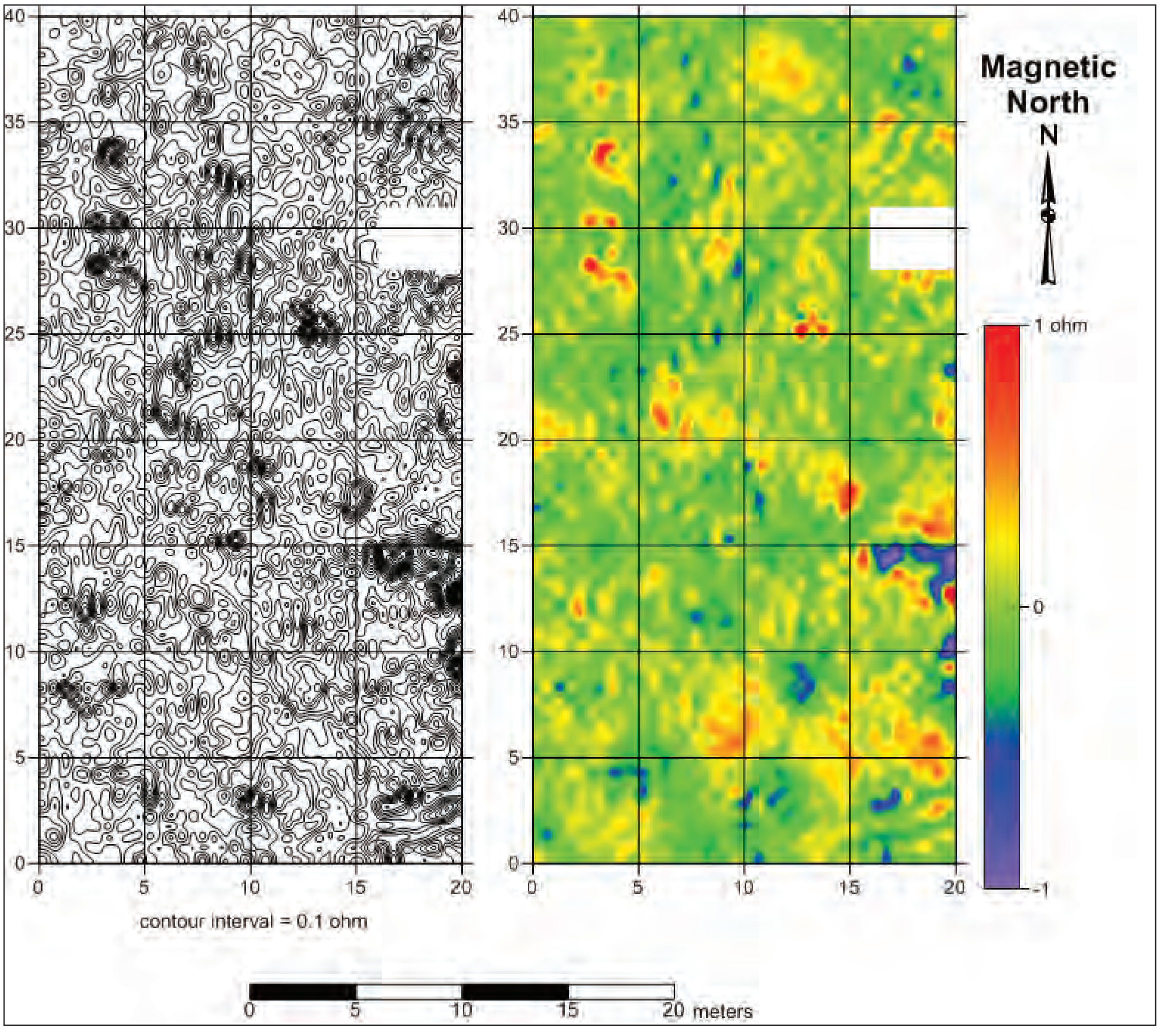



**Figure 24.** Image and contour plots of the resistance data from the Site 32ME2377 geophysical project area.

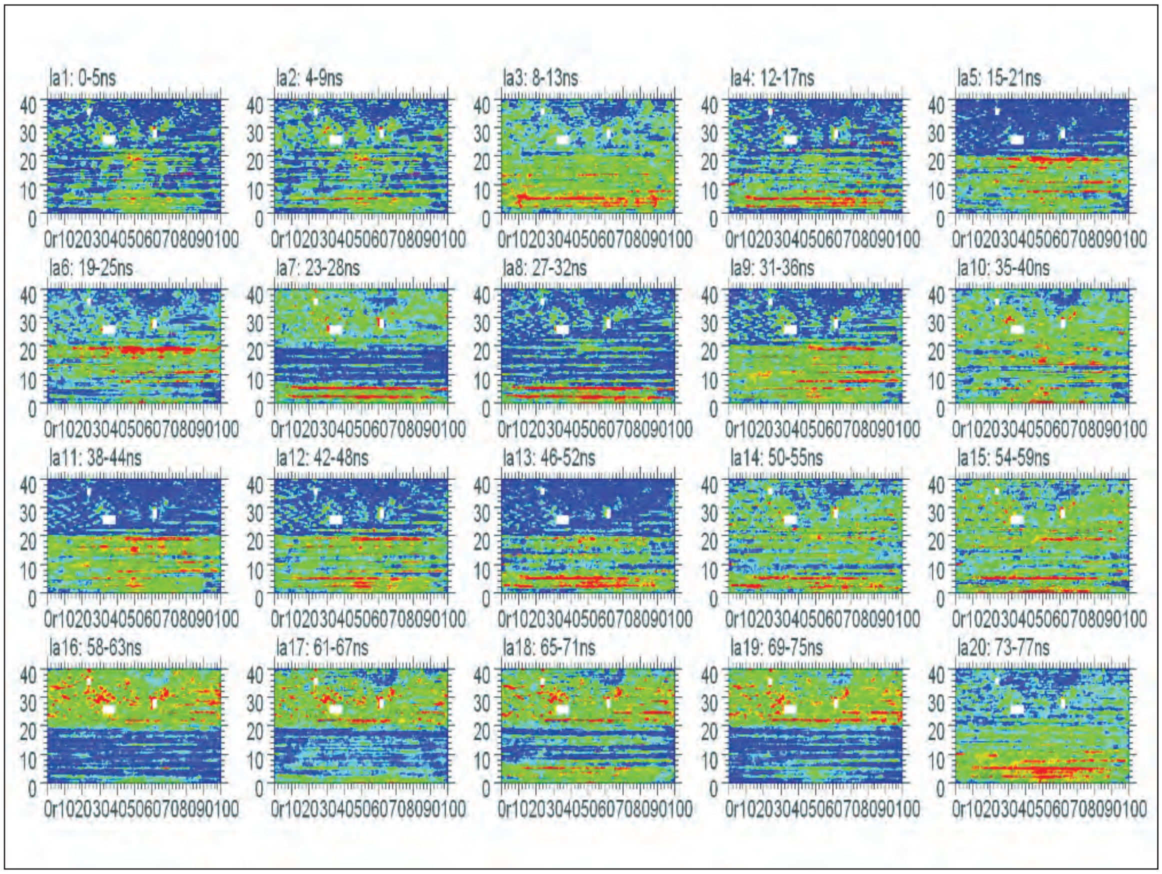



**Figure 25.** Time-slice data from the GPR survey of the Taylor Bluff site geophysical project area.

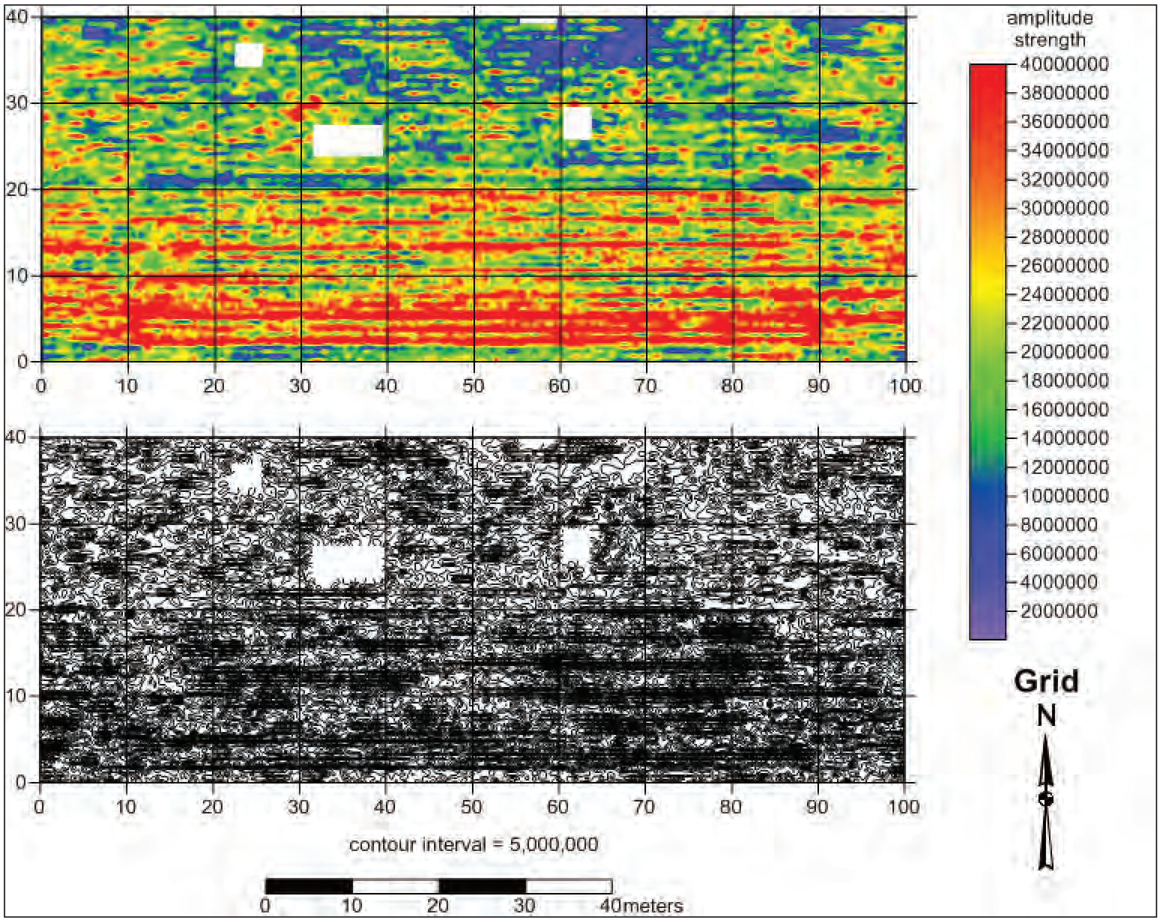



**Figure 26.** Image and contour plot of the ground penetrating radar time slice 3 (8-13 ns) data from the Taylor Bluff site geophysical project area.

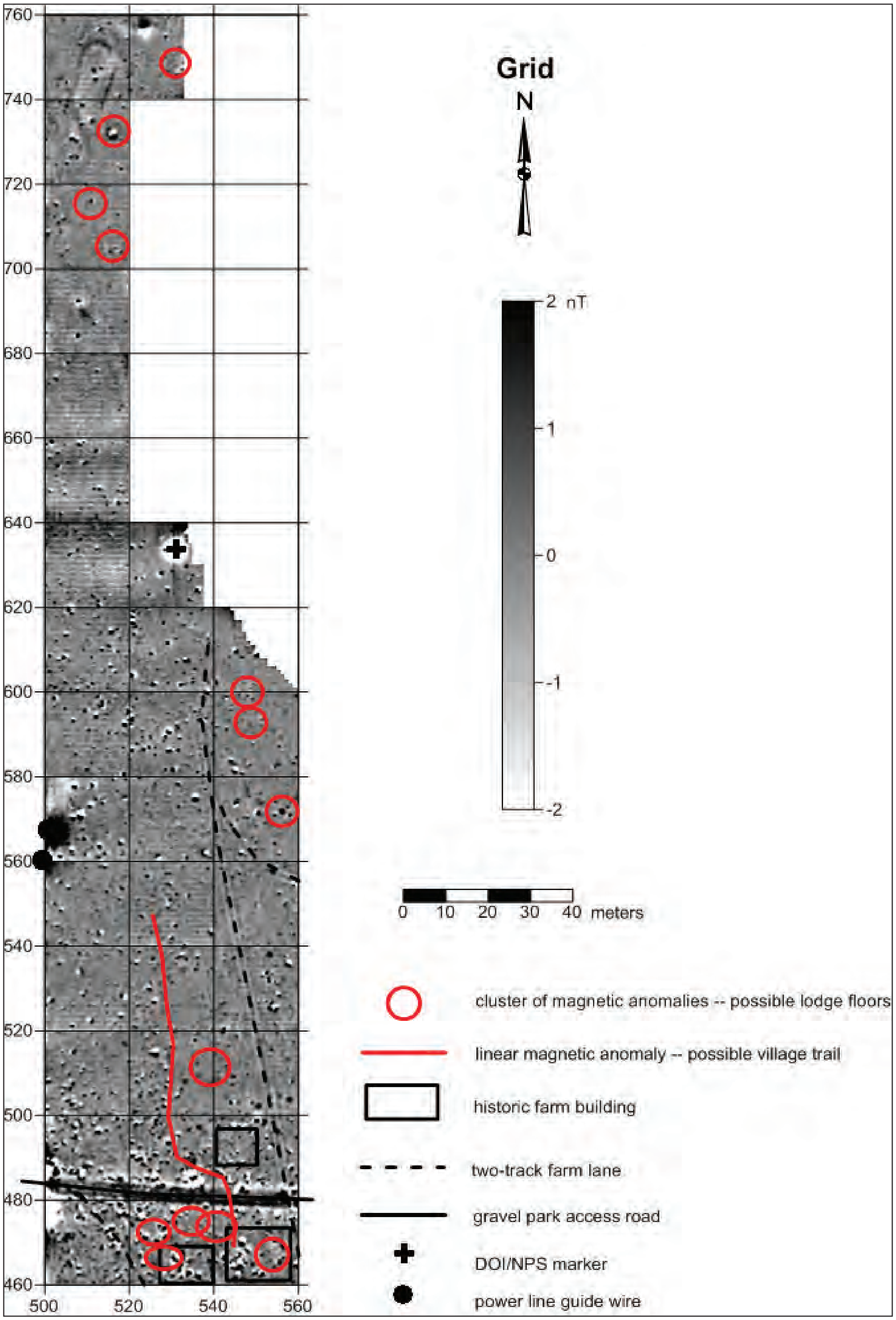



**Figure 27.** Interpretation of the magnetic data from the 2002/2006 single fluxgate gradiometer survey for the 2010 Elbee site geophysical project area.

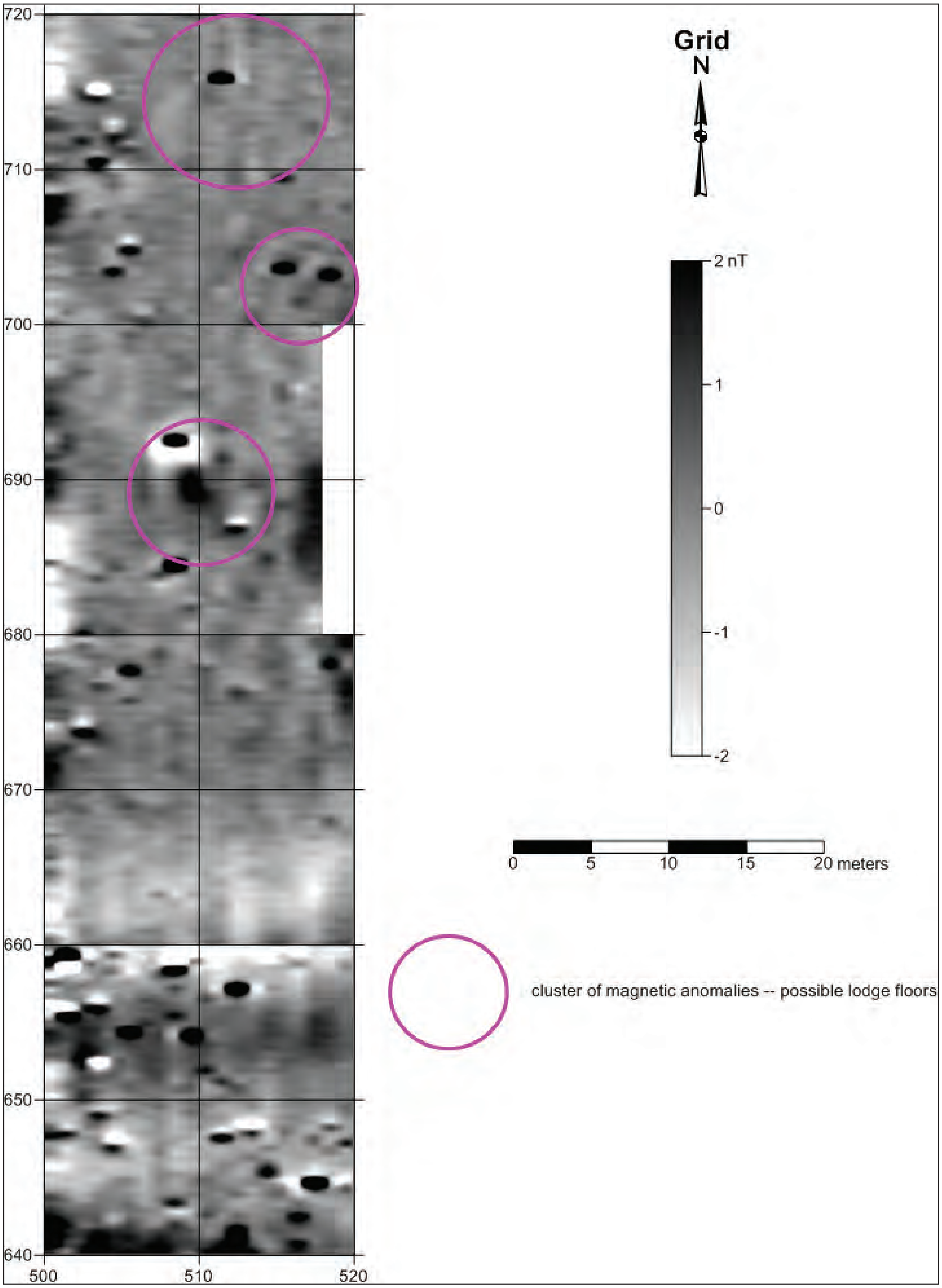



**Figure 28.** Interpretation of the magnetic data from the dual fluxgate gradiometer survey at the northern end of the Elbee site geophysical project area.

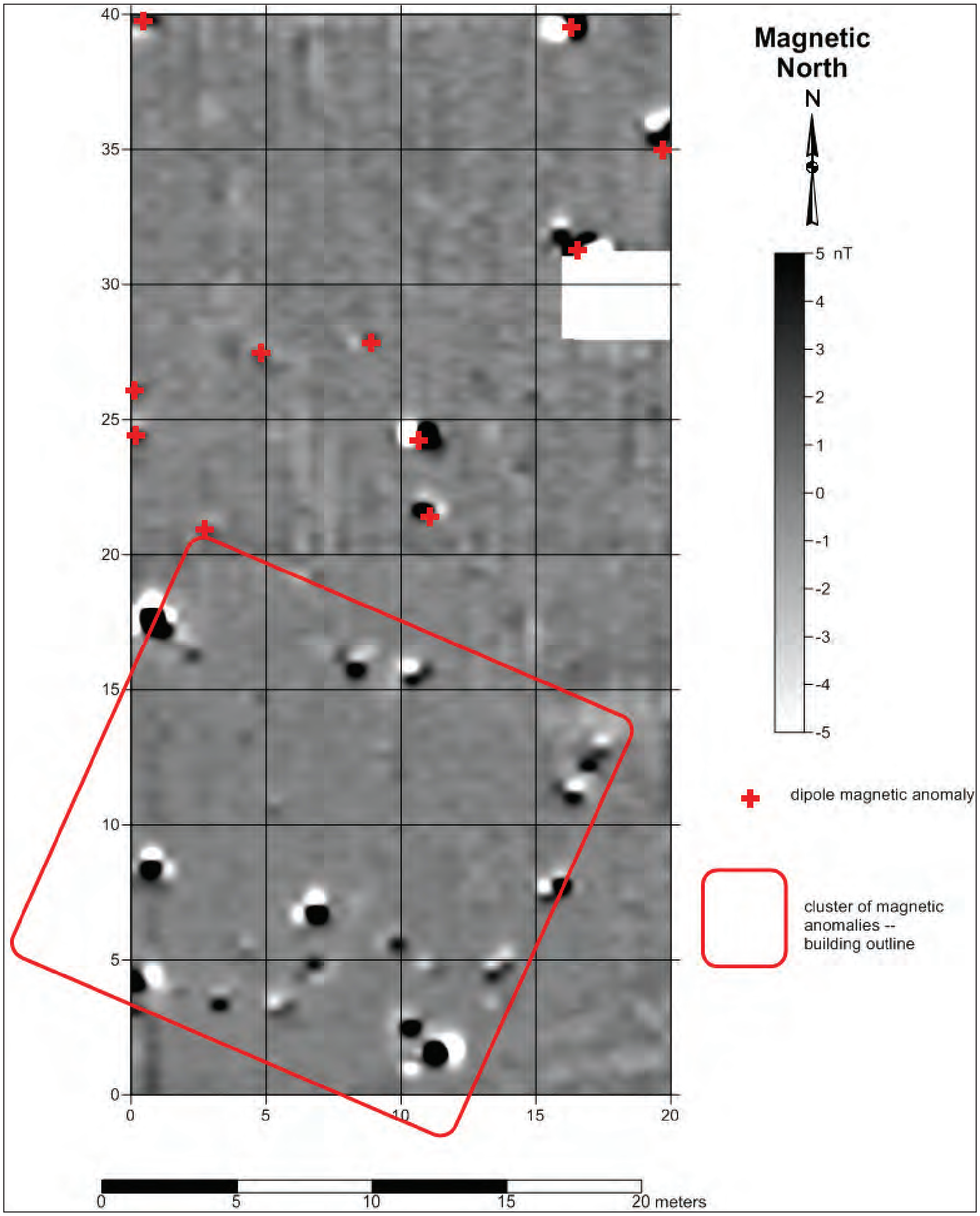



**Figure 29.** Interpretation of the magnetic data from the single fluxgate gradiometer survey at Site 32ME2377 geophysical project area.

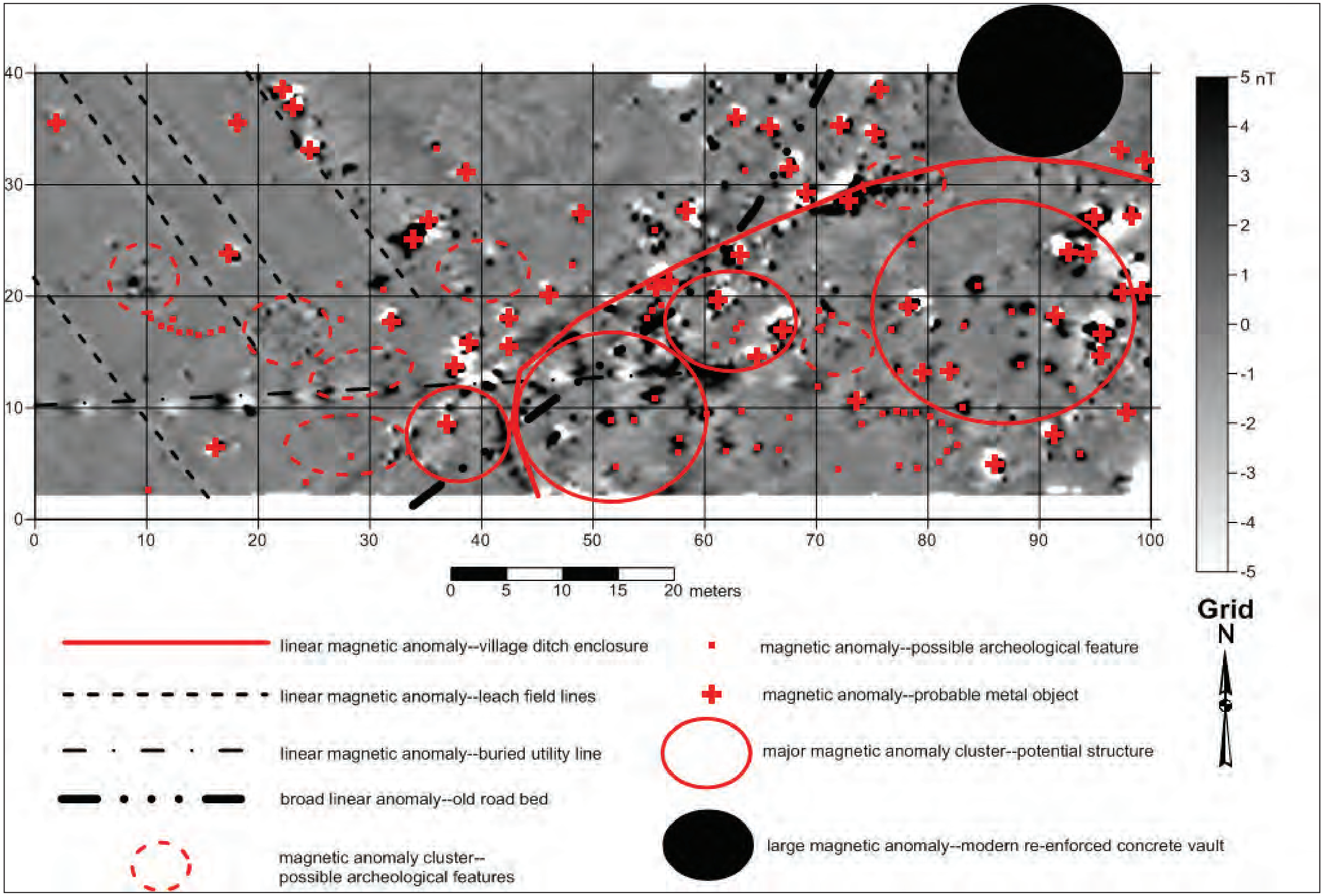



**Figure 30.** Interpretation of the magnetic data from the dual fluxgate gradiometer survey at the Taylor Bluff site geophysical project area.

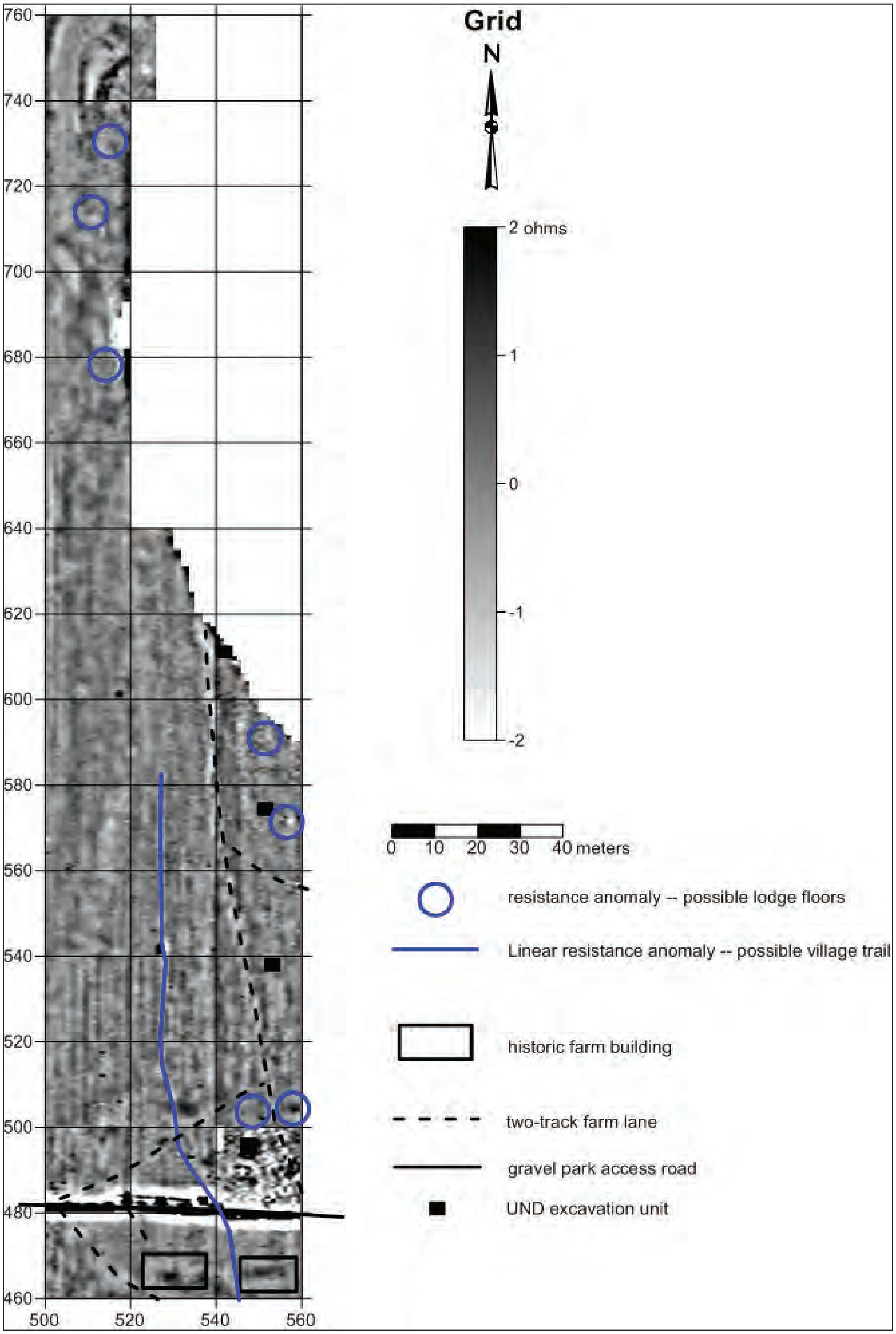



**Figure 31.** Interpretation of the resistance data from the Elbee site geophysical project area.

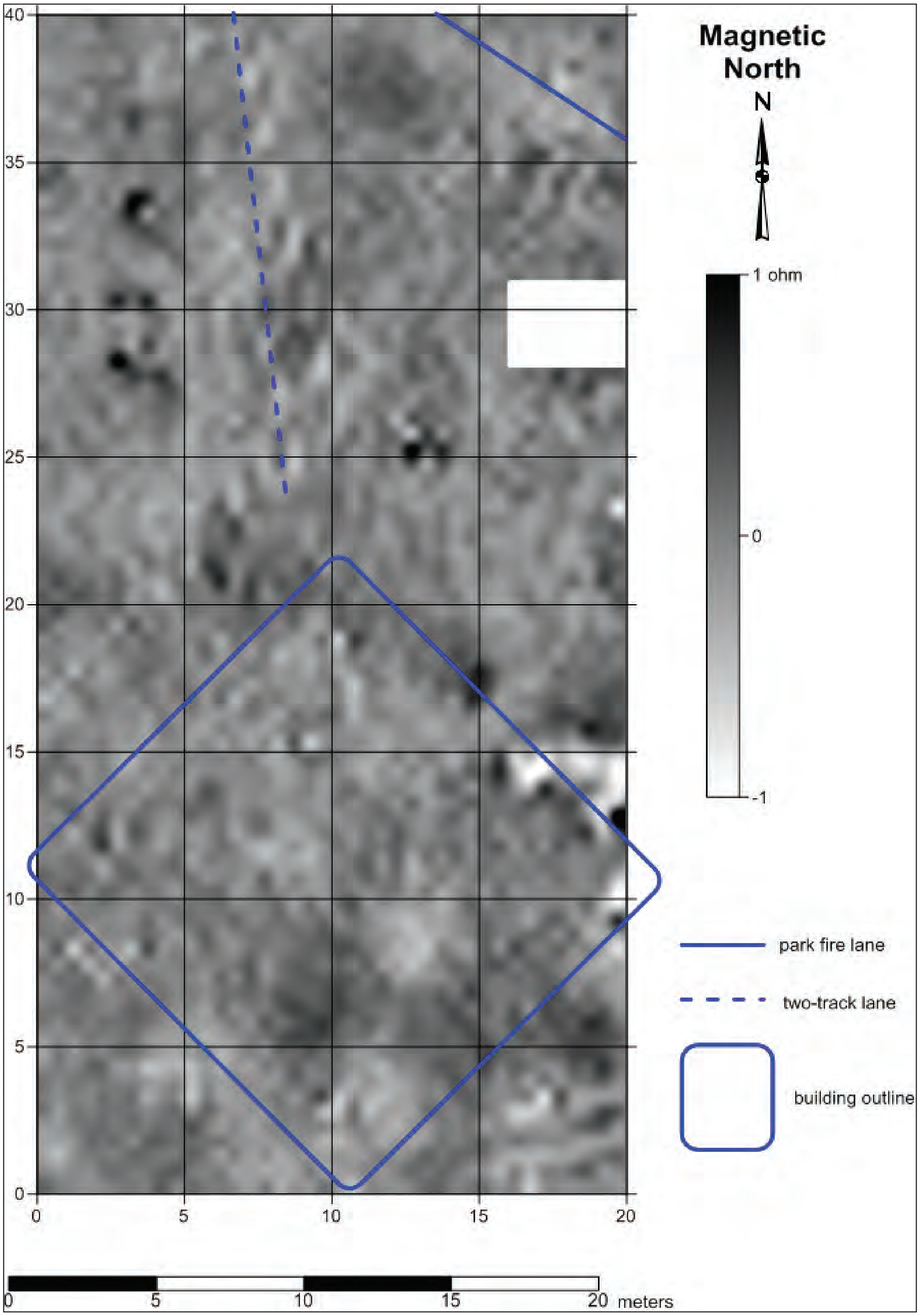



**Figure 32.** Interpretation of the resistance data from the Site 32ME2377 geophysical project area.

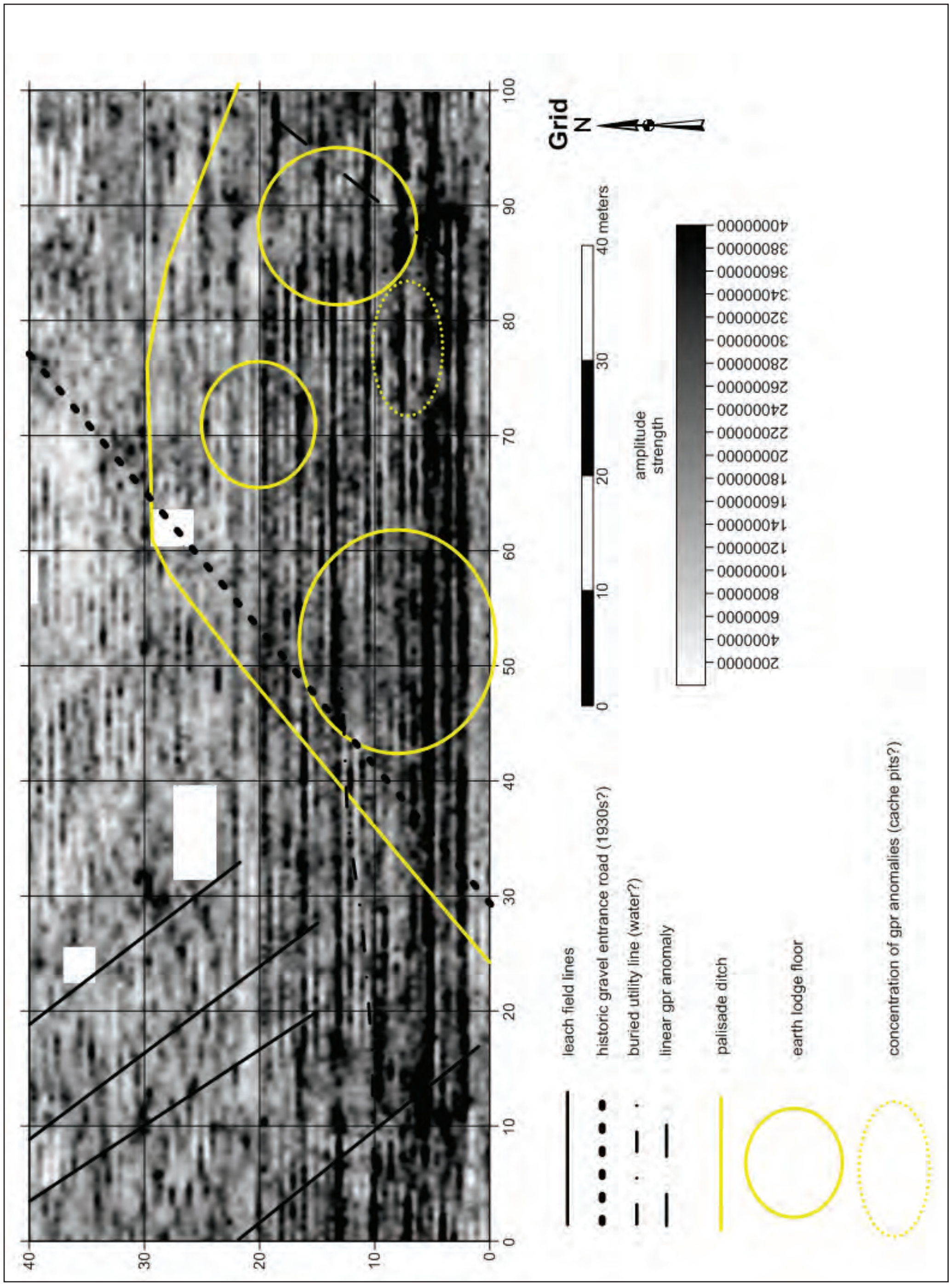



**Figure 33.** Interpretation of the ground-penetrating radar time-slice 3 data from the Taylor Bluff geophysical project area.

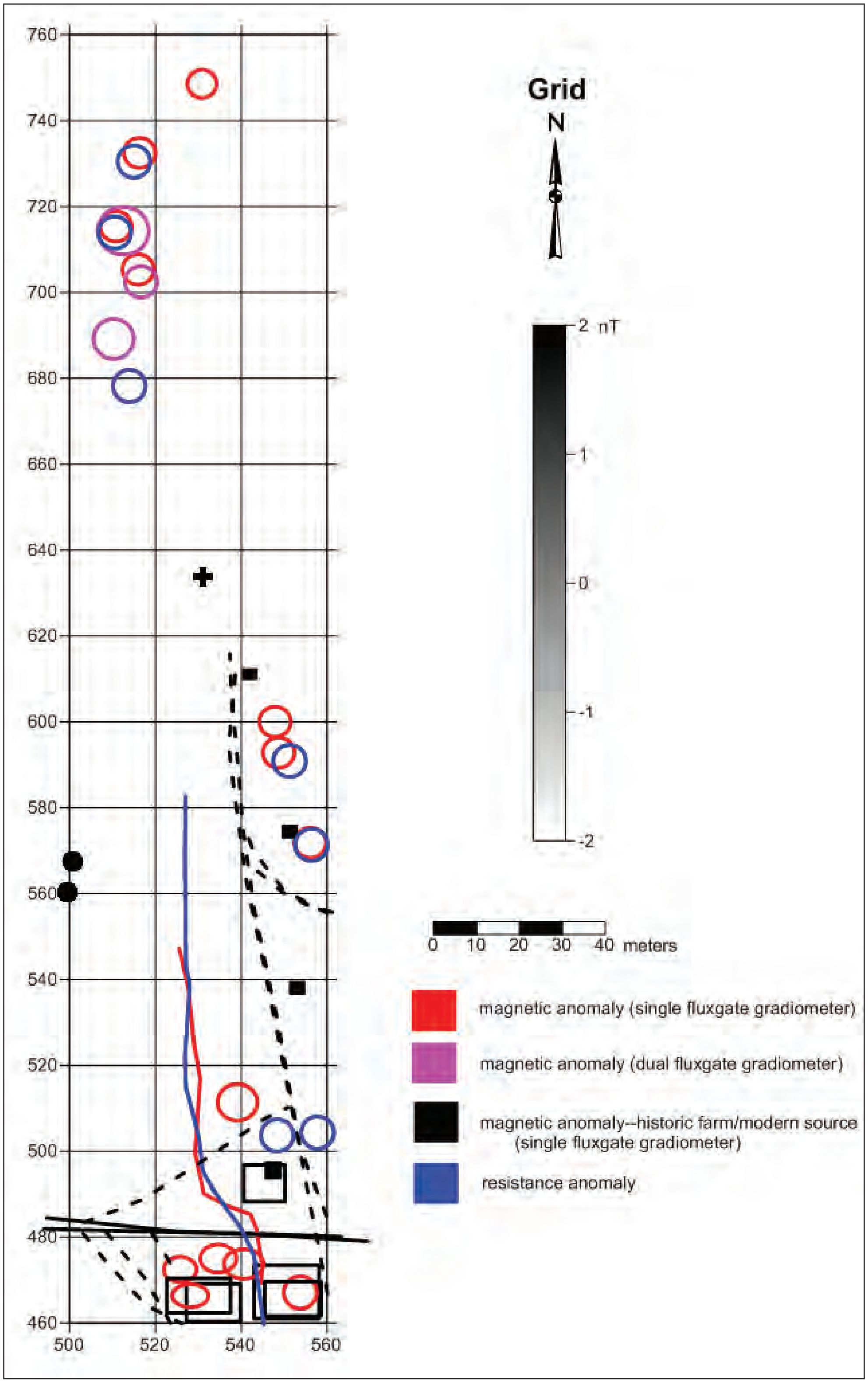



**Figure 34.** Combined magnetic and resistance anomalies from the Elbee site geophysical project area.

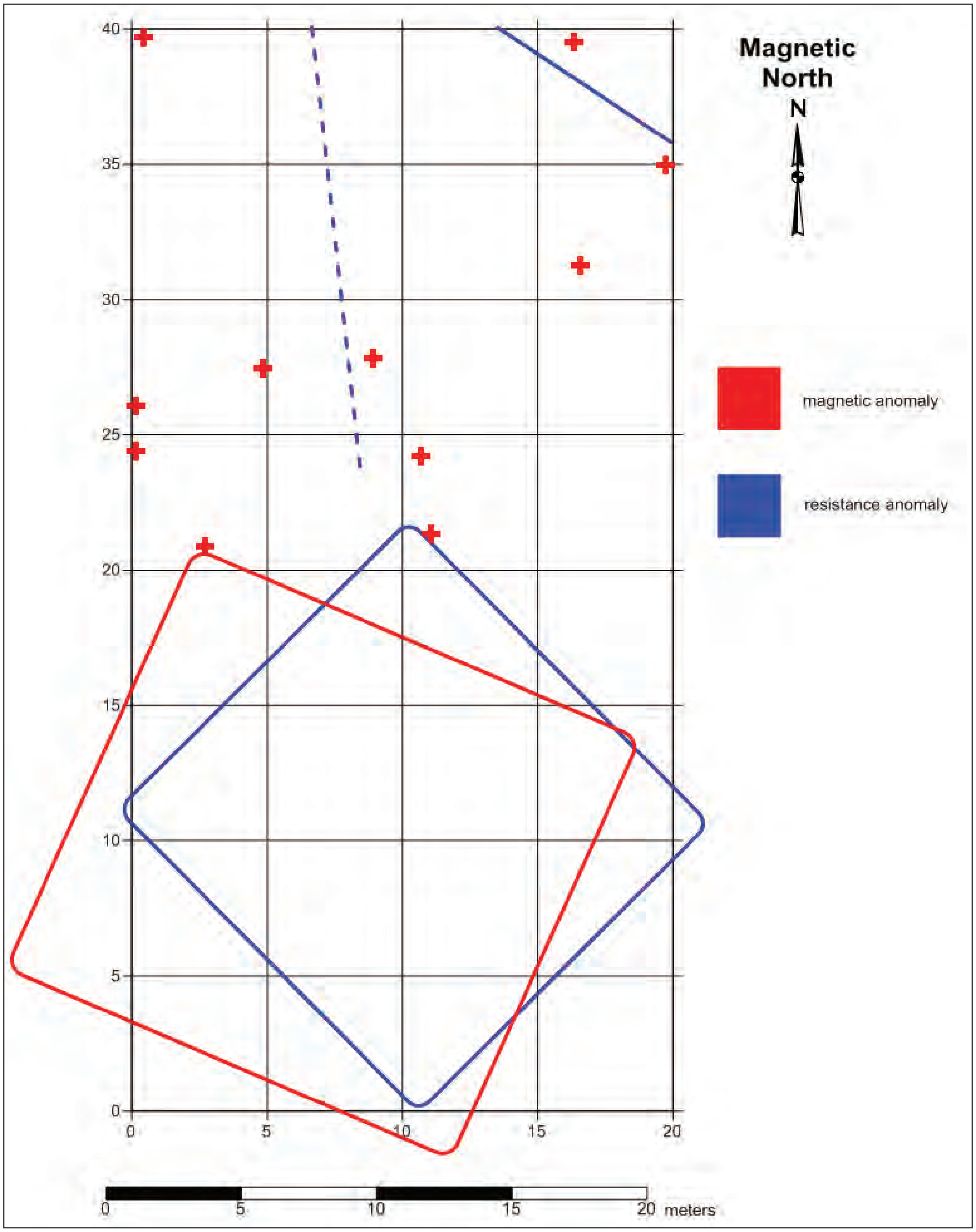



**Figure 35.** Combined magnetic and resistance anomalies from the Site 32ME2377 geophysical project area.

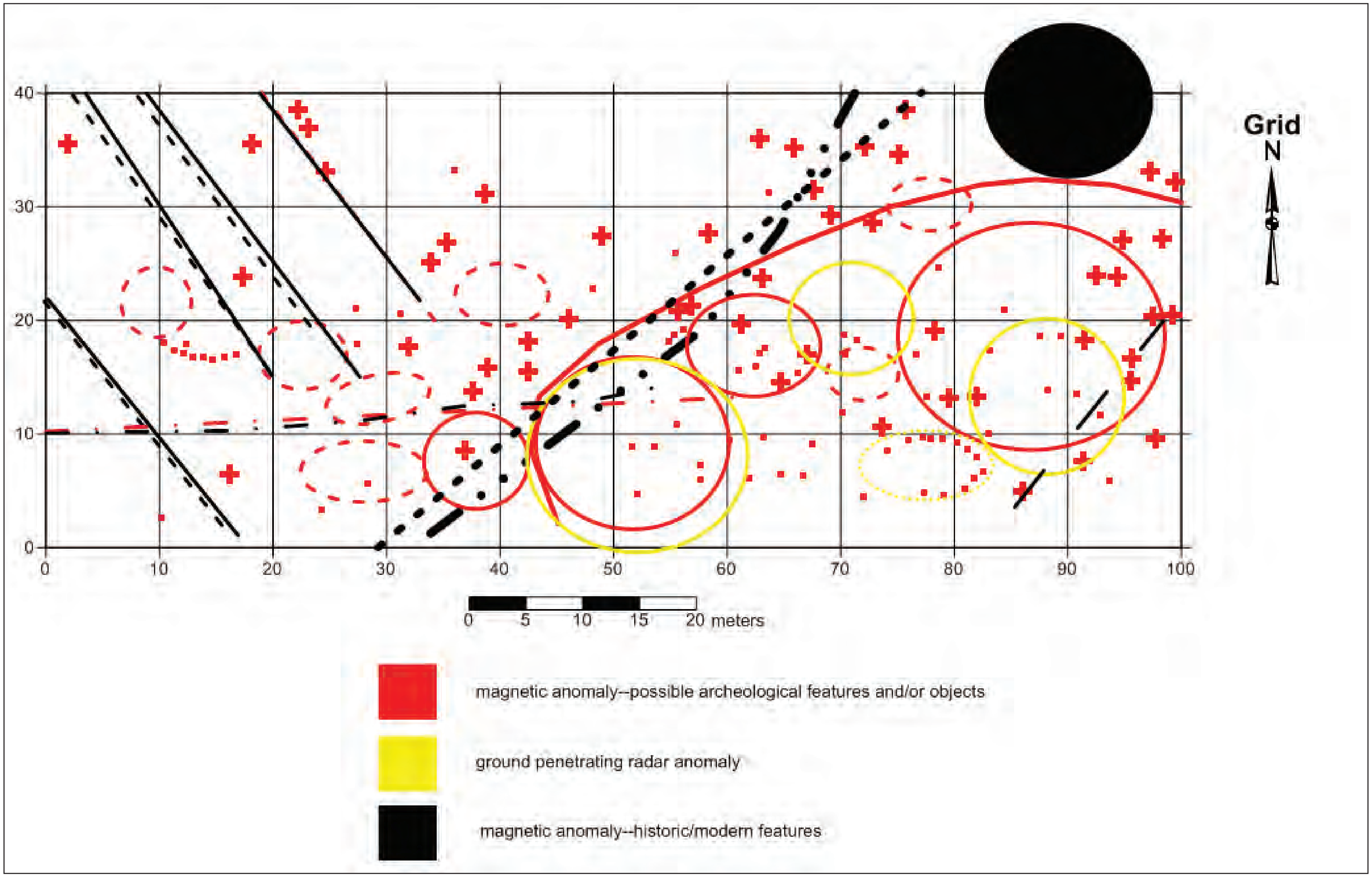



**Figure 36.** Combined magnetic and ground-penetrating radar anomalies from the Taylor Bluff site geophysical project area.