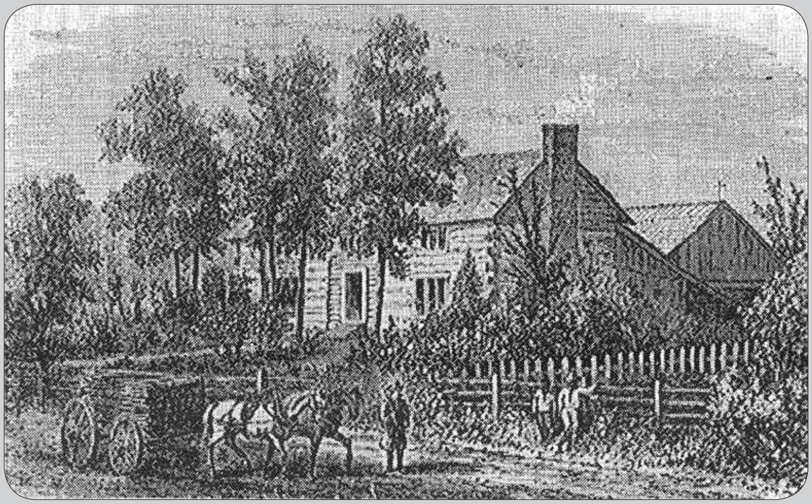
Geophysical Investigations at Two Residences Associated with Ulysses S. Grant in St. Louis County, Missouri

by
Steven L. De Vore

Midwest Archeological Center
Technical Report No. 100



HARDSCRABBLE

WISH-TON-WISH

NATIONAL PARK SERVICE
Midwest Archeological Center

Cover. (Top) Engraving of Hardscrabble in 1869 (Engraving opposite page 144 in *A Personal History of Ulysses S Grant*, by Albert D. Richardson, 1885)

Cover. (Bottom) Engraving of “Wishtonwish”–Dent Farm in 1856 (Engraving opposite page 139 in *A Personal History of Ulysses S Grant*, by Albert D. Richardson, 1885)

Geophysical Investigations at Two Residences Associated with Ulysses S. Grant in St. Louis County, Missouri

by

Steven L. De Vore

Midwest Archeological Center
Technical Report No. 100

United States Department of the Interior
National Park Service
Midwest Archeological Center
Lincoln, Nebraska

2007

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

ABSTRACT

The project consisted of geophysical investigations at the Hardscrabble residence (23SL1223) at the cemetery on St. Paul Churchyard and the Wish-ton-wish residence (23SL1222) on Anheuser-Busch's Grant's Farm. At Hardscrabble, the geophysical investigations included magnetic gradient, conductivity, and ground-penetrating radar surveys. A total area of 6,400 square meters was investigated including 4,800 square meters with fluxgate gradiometer, 2,000 square meters with a ground conductivity meter, and 400 square meters with a ground-penetrating radar cart system with a 400 mHz antenna. The results of the magnetic gradient survey indicated a roughly triangular area in the open grassy lawn adjacent to Rock Hill Road. Within the triangular area of magnetic anomalies, a rectangular depression was noted in one of the grid units, which may have been the location of the log cabin built by Ulysses S. Grant. Conductivity and radar data provided additional information on the nature of selected portions of the site.

Wish-ton-wish was located in the ostrich and aoudad pens on Grant's Farm. At Wish-ton-Wish, the geophysical investigations included resistance and ground-penetrating radar surveys. A total of 1,625 square meters was examined with the resistance system using a twin probe array and a ground-penetrating radar cart system with a 400 mHz antenna. The remains of the stone foundation of the residence were clearly visible in both data sets along with a well which may be associated with the residence. Although some foundation stones were visible on the surface, the geophysical data also suggested the location of the attached porches to the residence. In addition, both data sets indicated the presence of a lane around the residence foundation and a possible out building associated with the residence.

Based on the evaluation of the geophysical data collected at both sites, it is recommended that both sites be considered eligible for inclusion on the National Register of Historic Places.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

ACKNOWLEDGEMENTS

The author would like to thank the Site Manager Michael Ward and staff of Ulysses S. Grant National Historic Site (ULSG) for their support and knowledge of the Dent-Grant farmstead during the geophysical investigation phase of the project. During the survey, several park volunteers assisted in the project at Hardscrabble and Wish-ton-wish. I would like to thank all of them for their time and effort in helping setting up the geophysical survey grids and moving survey ropes during the project. These include Katherine Keetch, Dick Nixon, Tom Perry, Randy Harnish, Ida Boehlow, Dave Herries, and Julia Moeller. Katherine Keetch assisted at both project locations. Albert Banks from the maintenance staff at Ulysses S. Grant National Historic Site also assisted in the project at both Hardscrabble and Wish-ton-wish. Chris Eckard, Chief of Interpretation, transported the volunteers between the park and Grant's Farm during the investigations at the Wish-ton-wish project location. I would like to thank Andy Elmore, the manager at Grant's Farm, and his staff for their support and interest in the geophysical project. I would also like to thank Tim Hagar at St. Paul's Churchyard and his staff for their support and interest in the geophysical project. Both Andy Elmore and Tim Hagar provided permission to conduct the geophysical investigations on the respectively properties. I would also like to extend my appreciation to Alan O'Bright, Midwest Regional Architect and to Pam Sanfilippo, ULSG historian, for their comments on the draft report.

At the Midwest Archeological Center, a number of people deserve credit for helping complete this project. These include Dr. Mark Lynott, Dr. Ralph Hartley, and Thomas Thiessen. Dr. Douglas Scott, Dr. Virgil Nobel, and Karen Roberts provided information about the park including a historic overview and past archeological investigations. Production of this manuscript is attributed to Carrol Moxham for production oversight and to John Andresen for his diligent editorial skills. Bonnie Farkas, Jill Lewis, and Linda Zumpfe should also be commended for all of their hard work addressing the various fiscal and personnel issues related to the project.

TABLE OF CONTENTS

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

During the week of April 12-16, 2004, the Midwest Archeological Center (MWAC) staff conducted geophysical investigations of two residences occupied by the Ulysses S. and Julia Dent Grant family during the 1850s in St. Louis County, Missouri. The two areas were originally located within the farmstead owned by Grant's father-in-law, Frederick Dent. The Ulysses S. Grant National Historic Site (ULSG) staff requested that the Midwest Archeological Center personnel provide geophysical investigations of the two areas to locate and define the limits of the archeological resources associated with the residences (Douglas D. Scott, personal communications, 2004). Data from the investigations were used in the development of the archeological overview and assessment of the park resources (Scott et al. 2004), although the two residential sites were located outside the existing park boundary at Dent and Grant's White Haven residence.

The project area containing the Hardscrabble residence (23SL1223) is located in the open area of the St. Paul Churchyard in the S ½ of the NE ¼ of the SW ¼ and the N ½ of the SE ¼ of the SW ¼ of Section 9, Township 44 North, Range 6 East of St. Louis County, Missouri (Figure 1). The site consists of a historic artifact scatter with surface and subsurface features related to the log cabin built by Ulysses S. Grant in 1856. The project area of the Wish-ton-wish residence (23SL1222) is located in the ostrich and the aoudad (Barbary sheep) pens in Deer Park on the back side of the 281 acre Anheuser-Busch's Grant Farm wildlife preserve in the NW ¼ of the NE ¼ of the NE ¼ of Section 20, Township 44 North, Range 6 East of St. Louis County, Missouri.

The goal of this project was to delimitate the extent of the Dent/Grant family residences. At the Hardscrabble project location, magnetic, ground conductivity, resistivity vertical electrical sounding, and ground-penetrating radar techniques were used to examine the site. Six thousand four hundred square meters were examined in the undeveloped lawn area at cemetery at the St. Paul Churchyard. At the Wish-ton-wish project location, resistance, resistivity vertical electrical sounding, and ground-penetrating radar techniques were used to delimit the foundation of the Wish-ton-wish residence. The total area investigated at Wish-ton-wish consisted of 1,625 square meters in the two adjacent ostrich and aoudad pens. Magnetic gradient survey techniques were not used at the Wish-ton-wish project area due to the close proximity of the eight foot high chain link fences and livestock feed troughs and large hay rack. The gradiometer used at the Hardscrabble site malfunctioned and was not useable for the project at Wish-ton-wish. Several individuals in the ULSG park's Volunteers in the Park (VIP) program assisted in setting up and mapping the geophysical grids, laying out and moving the survey ropes, and conducting some of the geophysical data acquisition. ULSG staff also provided assistance during the geophysical investigations at both locations.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

2. ENVIRONMENTAL SETTING

The present project is located in the dissected till plains section of the Central Lowlands Province of the Interior Plains (Fenneman 1938:588-605). Carl Chapman (1975:1-19) further divides the physical environment of Missouri based on his archaeological work in the state. The State of Missouri is divided into six general physiographic regions. The project area lies in the Greater St. Louis locality of the Northeastern Prairie Region in the dissected till plains section of the state. The eastern section of the region coincides with the Mississippi River hills.

The project area consists of undulating or rolling topography formed by the erosion of the uplands by numerous drainages feeding into Gravois Creek, a tributary of the River Des Peres which flows into the Mississippi River approximately ten kilometers east of the project area. The ridgetops are narrow with moderate sloping to steep ridge slopes and narrow valley floors. Bedrock is comprised of Mississippian aged limestones and shales (Unklesbay and Vineyard 1992). Although separated by the Gravios Creek valley, the Hardscrabble project area at the St. Paul Churchyard cemetery and the Wish-ton-wish project area at Grant's Farm both lie at an elevation of approximately 185 meters above mean sea level.

The project areas lie within the Central Mississippi Valley Wooded Slopes land resource area of Missouri, Illinois, and Indiana of the Central Feed Grains and Livestock Region (USDA 1981:121-122). The soils in eastern Missouri are dominated by Typic Udalfs of the Alfisol order (Foth and Schafer 1980:149-160), although the young alluvial soils of the floodplains are primarily Entisols and Inceptisols (Forth and Schafer 1980:37,63). Alfisols are formed under forest vegetation (Forth and Schafer 1980:143). The soils are deep with medium to moderately fine textures with mixed mineralogy. The soils are well to moderately well drained with udic soil moisture and mesic soil temperature regimes. Parent materials consist of loess, alluvium, aeolian, and residual material or some combination of these materials (Benham 1982:72; Missouri Cooperative Soil Survey 2003). The Central Mississippi Valley Wooded Slopes land resource area contains soils that formed under oak-hickory forest vegetation. Depth to bedrock ranges from shallow to very deep. The project areas lie within the Menfro-Winfield-Urban soil association of "gently sloping to very steep, well drained and moderately well drained, deep soils formed in loess, and Urban land; on uplands" (Benham 1982:7).

The soil within the Hardscrabble project area is identified as the Winfield-Urban land complex with 2 to 5 percent slopes (Benham 1982:29-30). Urban lands consist of areas covered by buildings and other structures, streets, parking lots, land leveling or excavation, and other man made features that obscure or alter the native soils to the point where identification is not possible (Benham 1982:29). Urban lands tend to be impervious to water where the ground is covered. This soil complex consists of the deep, moderately well drained Winfield silt loams (Benham 1982:71-72) intermixed with Urban land. Developed in loess, these soils are found on gently sloping wide ridgetops and upper side slopes. Urban development has not appreciably alternated the native Winfield soil. The Winfield soils have a moderate permeability which may be moderately slow in modified or reworked areas. Surface runoff is medium. Natural fertility of the soil is medium with low organic matter content. The soil pH ranges from neutral to very strongly acidic. The soil complex is commonly found in yards, parks, gardens, and open areas between buildings.

The soils within the Wish-ton-wish project area consist of the karst Urban land-Harvester complex with 2 to 9 percent slopes (Benham 1982:23) and the karst Menfro silt loam with 2 to 14 percent slopes (Benham 1982:22). The karst Urban land-Harvester soil complex consists of the deep, moderately well drained Harvester silt loams (Benham 1982:65-66) intermixed with Urban land. Developed in reworked loess fill over buried or truncated loess soils, these soils are found on gently undulating and gently rolling uplands. Modern development has covered or altered many natural limestone sinks in the area. Urban development has not appreciably alter the native Harvester soil. The Harvester soils have a moderately slow permeability with rapid surface runoff. Natural fertility of the soil is medium with very low organic matter content. The soil pH ranges from neutral to slightly acidic. The soil complex is commonly found in yards, parks, gardens, undeveloped tracks around limestone sinks, and open areas between buildings. The karst Menfro silt loam is a deep, well drained soil formed in thick loess (Benham 1982:22,67). The soils are found on gently undulating and gently rolling uplands. Like the Harvester soil mapping unit, the area within the Menfro soil mapping unit also contains circular or elongated limestone sinks. The Menfro soils have a moderately permeability with medium surface runoff. Natural fertility of the soil is medium with moderately low organic matter content and very high available water capacity. The soil pH ranges from neutral to strongly acidic.

The project area also lies within the Carolinian biotic province (Dice 1943:16-18). The oak-hickory forest is the historic climax vegetation of this portion of the larger Northeastern Deciduous Forest biotic community extending across the central Midwest and Eastern Atlantic coastal states (Braun 1938:517; Brown et al. 1998:29,37; Reichenbacher et al. 1998; Shelford 1963:57-63; Sutton and Sutton 1985:58-70). The oak-hickory climax forest contains trees that require lower moisture levels and is typically found in the western and southern areas of the lowest effective rainfall within the Northeastern Deciduous Forest province (Braun 1938:517). This hardwood association contains a rich diversity of tree species. The mixed deciduous forest community contains many of the plant species common to the northeastern oak-hickory deciduous forest (Brown et al, 1998:29; Shelford 1963:57-63; Steyermark 1963; Sutton and Sutton 1985:58-70). These forests consist of medium tall, multilayered, broadleaf deciduous species. Dominate species include the bitternut hickory, shagbark hickory, white oak, pin oak, black oak, and black walnut. Along the floodplains, the deciduous forests are dominated by hackberry, cottonwood, black willow, and American elm (Shelford 1963:57; Sutton and Sutton 1985:68). Other minor forest species include dogwood, sycamore, linden, boxelder, mulberry, cedar, and prickly ash (Sutton and Sutton 1985:68). Persimmon, chokeberry, wild plum, wild grapes, and mushrooms are some of the resources used by prehistoric inhabitants of the region, as well as, the historic Euroamerican settlers. These forests have well developed undergrowth vegetation communities of small trees, shrubs, and fords, including redbuds, hornbeam, pawpaw, hawthorn, gooseberry, sumac, sweet haw, blackberry, raspberry, jack-in-the-pulpit, bloodroot, mayapple, wild asters, goldenrods, chenopods, ragweeds, and smartweed (Phillips 1979; Shelford 1963:57-59,94-99,118-119; Steyermark 1963). They are often interrupted by freshwater marshes and prairie communities.

In the deciduous forests during the prehistoric and historic periods, deer were present in the timbered areas along streams and slopes, along with bear, squirrel, and cottontail rabbits (Shelford 1963:59-60; Sutton and Sutton 1985:66-70). Turkeys, ruffed grouse, raccoons, opossums, squirrels, and skunks were common along with foxes and woodchucks. Numerous other mammals and rodents also inhabited the region including bison, elk, and wolves (Schwartz and Schwartz 1959; Shelford 1963:57-63; Sutton and Sutton 1985:66-70). Numerous species of birds inhabited the grasslands, the shrublands, and wooded areas of the region (Sutton and Sutton 1985:68-69). Reptiles included several species of lizards, turtles, and snakes (Shelford 1963:60; Sutton and Sutton 1985:70). Amphibians were found in the prairies, forests, and wetlands (Sutton and Sutton 1985:70). Fish, including catfish, carp, and bass, and fresh water mussels were found in the streams throughout the region (Buchanan 1980; Pfleiger 1971). Insects and other invertebrates abound throughout the region (Shelford 1963:60-62; Sutton and Sutton 1985:69).

The region has a typical continental climate characterized by large daily and annual variations in temperature (Moxom 1941:945-954). The project area lies within the subhumid continental climatic zone (Thornthwaite 1948). Winters are fairly brisk and the summers are warm (Moxom 1941:953-954). Annual January temperatures average -1.11° C (Benham 1982:2,88). The average daily minimum winter temperature is -6.11° C. The lowest recorded winter temperature is -30° C (Moxom 1941:947). Annual July temperatures average 25.94° C (Moxom 1941:88). The average daily maximum temperature in the summer is 31.56° C. The highest recorded summer temperature is 43.33° C (Moxom 1941:947). Annual precipitation averages 85.88 centimeters (Benham 1982:2,88) with the majority falling from April through September. The average seasonal snowfall is 45.21 centimeters per year (Benham 1982:2,88). The growing season averages 210 days with killing frosts occurring as late as April 3rd in the spring and as early as October 29th in the fall. Severe thunderstorms occur occasionally with hail and high winds. Although these are generally local in extend and of short duration, the resulting damage can be severe. Droughts may occur anytime throughout the year, but are most damaging during the crop growing season (Moxom 1941:954). Flooding may occur along smaller streams on the average of one to two times in the spring and early summer months during most years. Occasional severe flooding of the Missouri and Mississippi Rivers can produce heavy losses. The sun shines approximately 70% of the time in summer and 50% of the time in winter (Benham 9182:2). The prevailing winds are from the south with the highest average windspeed of 19.31 kilometers per hour occurring in March (Benham 1982:2).

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

3. PREHISTORIC BACKGROUND

Missouri archeology may be divided between the prehistoric and historic periods. The prehistoric periods defined for Missouri archeology include the Early Man (prior to 12000 B.C.), the Paleoindian (12000-8000 B.C.), the Dalton (8000-7000 B.C.), the Archaic (7000-1000 B.C.), the Woodland (1000 B.C.-A.D. 900), and the Mississippian (A.D. 900-A.D. 1700) periods (see Benchley 1976; Chapman 1975,1980; Fuller 2004; Harl 1995; O'Brien and Wood 1998; and Wright 1987 for a broad view of the prehistory of the St. Louis metro area and for the State of Missouri). The historic period in Missouri is divided into the Immigrant (A.D. 1700-1830), the New State (A.D. 1820-1860), the Civil War (A.D. 1860-1865), the Gilded Age (A.D. 1860-1900), and the Modern (A.D. 1900 to present) periods (Fuller 2004).

The Early Man Period (prior to 12000 B.C.) is recognized by some archeologists to represent the initial stage of colonization of the Americas by immigrants from Asia. The period is poorly understood. In Missouri, some have suggested that the Shriver site in Daviess County contains evidence for a pre-Clovis stone tool technology; however, the dates and interpretations of the site have been questioned by others (Fuller 2004).

The Paleoindian period is placed between 12,000 and 8,000 B.C. The period is typically divided into three complexes based on projectile point types: 1) the Clovis, 2) the Folsom, and 3) the Plano. Traditionally, the Clovis complex is characterized by the presence of fluted Clovis projectile points (see Chapman 1975:60-94 and O'Brien and Wood 1998:55-66 for more information on the Clovis complex in Missouri). Viewed as efficient large game hunters, the people of the Clovis complex hunted mammoth, mastodon, extinct forms of bison, and other Pleistocene animals. Clovis sites in Missouri include the Kimmswick site where Clovis points were found in direct association with mastodon (Fuller 2004). Most of the Clovis sites in St. Louis County are limited to isolated surface finds of Clovis projectile points (Chapman 1975:67-68; O'Brien and Wood 1998:57-58). The Folsom complex is also recognized by the presence of fluted projectile points (Folsom points) and the hunting of extinct forms of bison (see Chapman 1975:60-94 and O'Brien and Wood 1998:66-69 for more information on the Folsom complex in Missouri). The Late Paleoindian complex is actually a series of different complexes referred collectively as Plano. The Plano complexes represent the last cultural systems associated with the Pleistocene megafauna. These terminal complexes of the Paleo-Indian period are represented by a number of different projectile point types, including Agate Basin, Alberta, Eden, Hell Gap, Milnesand, Plainview, and Scottsbluff. Plano sites throughout the Plains consist of kill sites, butchering sites, long term camp sites, and short term camp sites (O'Brien and Wood 1998:69-73,84-89).

In Missouri, the transition between Paleoindian complexes and the Archaic period is represented by the Dalton period between 8000 and 7000 B.C. (Chapman 1975:95-126 and O'Brien and Wood 1998:73-100 for more information on the Dalton Period in Missouri). The period is characterized by changes in seasonal temperature and precipitation patterns (Fuller 2004). These climatic changes triggered evolutionary changes in the Pleistocene plant and animal communities which resulted in new substance and hunting strategies for the human populations. The diagnostic artifact is the serrated and beveled edged Dalton point. Deer appears to be the primary large mammal although smaller animals were also hunted. Plant food processing is represented by the occurrence of mortars, manos, and grinding slabs. The lowest occupational level in Graham Cave exhibits the best known Dalton assemblage in the Northeastern Prairie region of the state (Chapman 1975:105).

Beginning around 7,000 to 6,500 B.C., the climate started to become warmer and drier. The end of the Pleistocene saw the decline and extinction of the megafauna. Hunting in the Archaic period shifted from large megafauna to smaller game (see Chapman 1975:126224 and O'Brien and Wood 1998:101-167 for more information on the Archaic period in Missouri). People were becoming less nomadic. As the climate during the period continues to warm and become drier, prairies expand while forests decrease in area. Deer were replaced in the diet with greater proportions of rabbits, fish, and birds (Fuller 2004). By the end of the Archaic period, the climatic conditions became more mesic allowing the increase of the forest into the prairies of the Middle Archaic. There was also an increase in the local exploitation of plant foods. Grinding slabs for processing plant materials into food was a common feature in the Archaic toolkit. Stone tools increased in the diversity of shapes, sizes, and functions. The Archaic period has often been further split into three subdivisions: 1) Early Archaic, 7000-5000 B.C.; 2) Middle Archaic, 5000-3000 B.C.; and 3) Late Archaic, 3000-1000 B.C (Fuller 2004). The Early Archaic period was marked by the introduction of several new lithic tool types and forms, including the Graham Cave side notched, Hidden Valley stemmed, Rice lobed, Rice contracting stemmed, Rice lanceolates, and St. Charles notched projectile points (Fuller 2004). The Jakie stemmed and Big Sandy projectile points served as indicators of the Middle Archaic period (Fuller 2004). Full grooved ground stone axes were also added to the Archaic toolkit during the Middle Archaic. The Late Archaic period was a period of increased lithic tool diversification with Nebo Hill lanceolate, Sedalia lanceolates, Smtih basal notched, Table stemmed, Stone square stemmed, Big Sandy notched, Etley, and Afton projectile points added to the Late Archaic toolkit (Fuller 2004). Three-quarter grooved axes were also introduced into the Archaic toolkit. Pottery, domesticated plants, large village sites and elaborate burial mounds (e.g., the Hatten Mound) were introduced in the Late Archaic period.

The Woodland period saw widespread social and technological changes. Pottery, burial mounds, and the domestication of plants continued to proliferate. Long-distance trade networks, increased complexity of the social systems, and the development of chiefdoms occurred (see Chapman 1980:9-137 and O'Brien and Wood 1998:168-294 for more information on the Woodland period in Missouri). Typically the period has been divided into three subdivisions: 1) Early Woodland, 1000-500 B.C.; 2) Middle Woodland, 500 B.C.-A. D. 400; and 3) Late Woodland, 400-900 A.D. (Fuller 2004). Subsistence continued to depend on hunting and gathering with the addition of domesticated plants like squash, marshelder, and maize. Black Sand incised ceramics were identified in the northern part of the state during the Early Woodland. Langtry and Kramer stemmed projectile points occurred in the Early Woodland period. The Middle Woodland was dominated by the influence of Hopewellian traits from further east in the Ohio region. New corner and side notched projectile point types included Snyders, Mankers, Ensor, Castroville, Frio, Gary, and Dickson varieties (Fuller 2004). Decorated grit and grog tempered pottery contained designs created by stamped designs, incised lines, bosses, hollow reed impressions, and cord-wrapped impressions (Fuller 2004). Animal and human clay figurines were also manufactured. The bow and arrow made their appearance in the Late Woodland period. Projectile points included the Ovate, Scallorn, and Rice side notched arrow points.

The Mississippian period between A.D. 900 and 1700 was marked by large permanent villages and maize agriculture (see Chapman 1980:138-261and O'Brien and Wood 1998:223-357 for more information on the Mississippian period in Missouri). The large fortified towns, such as Cahokia across the Mississippi River in Illinois, had large temple mounds with plaza and astronomical observatories (Fuller 2004). Shell-tempered pottery and small triangular projectile points represented the tool technology of the period. Major population declines occurred in the 13th and 14th centuries. The final phase of the Mississippian period represented the protohistoric period and the development of historically recognized tribes. The Oneota culture of the late Mississippian period developed into the historic Missouri and Osage (Fuller 2004). The end of the period saw the first contact between the Native American tribes and the European explorers from France and Spain. Louis Jolliet and Father Jacques Marquette explored the Mississippi River for the French in 1673. The French continued to dominate the Mississippi River through most of the 1700s.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

4. HISTORICAL OVERVIEW

The Immigrant period in Missouri history represents the arrival of the Euro-Americans (French, Spanish, and English) during the 18th century (Benham 1982:2-3; Fuller 2004; Primm 1981:1-7). The trading post settlement of St. Louis was created in 1764 by employees of the Maxent, Laclède and Company of New Orleans (Primm 1981:9). In 1767, Spain acquired the Louisiana Territory including Missouri (CIN 2004; Williams 2001). The territory is returned to France in 1800. In 1803, the newly formed United States purchased the territory from France. Near the end of the period, Eastern tribes were removed from the eastern United States to Missouri including the Kickapoo, Delaware, Shawnee, Miami, Peoria, and the Potawatomies. St. Louis County was organized in 1808 and the city of St. Louis was incorporated in 1809 (Benham 1982:2). It was during the Immigration period that Frederick Dent moved his family to St. Louis in 1817 with the intent of establishing a business (O'Bright and Marolf 1999:2.55). He built the White Haven residence on his farm on Gravois Creek (Richardson 1885:75). The family used the residence as a summer home during the first few years in St. Louis (Simon 1975:42).

In 1820, Missouri was admitted to the United States of America (Fuller 2004). The New State period beginning with statehood in 1820 and ending with the start of the Civil War period in 1860 saw the change from a fur trapping and trading economy with Native Americans to a Euro-American farming economy (Fuller 2004). In 1827, Dent moved his wife and five children, including Julia Boggs Dent (born in 1826), to the White Haven farm (Simon 1975:30,33). During the 1830s, Fredrick Dent continued to develop the farm over his St. Louis mercantile business (O'Bright and Marolf 1999:2.57). The 1850 Missouri agricultural census indicated that Dent accumulated approximately 900 acres of land and had 30 slaves laboring on the farm (Little 1993:41-43). During his first assignment at Jefferson Barracks in St. Louis following graduation from West Point in 1843, Second Lieutenant Ulysses S. Grant met his future wife, Julia Boggs Dent, on one of many visits in 1844 to the Dent White Haven estate, which was the home of West Point classmate, Frederick Dent, Jr. (Grant 1999:19-20; Richardson 1885:75-76). The prospective issue of Texas annexation resulted in the transfer of Lt. Ulysses S. Grant and the 4th U.S. Infantry regiment to western Louisiana in the Spring of 1844. The Congress of the United States passed the Texas annexation bill, which was signed by President John Tyler on the 1st of March, 1845. President James K. Polk sent orders to General Zachary Taylor of organize the army in Corpus Christi, Texas. The 4th U.S. Infantry with Lt. Grant arrived in Corpus Christi in September of 1845. The Mexican War began in 1846 and ended in 1848. Lt. Grant was in numerous battles from the first battle at Palto Alto to the capture of Mexico City (Grant 1999:19-87; Richardson 1885:76-111). Miss Dent and Lt. Grant continued to conduct a romantic relationship by letter during these years. In July 1848, the 4th infantry regiment along with Lt. Grant was transported from Mexico to Mississippi. Lt. Grant obtained a four month leave of absence. On August 22, 1848, Julia Boggs Dent and Ulysses S. Grant were married in St. Louis (Grant 1999:97; Richardson 1885:113). During the next few years, the Grant family moved from military post to military post along the Great Lakes (Grant 1999:96-105; Richardson 1885:113-136). Separation from his family during his assignment to the West Coast, which by 1852 included two sons, caused Grant to resign his commission in 1854 (Grant 1999:106; Post 1904:28-29; Richardson 1885:135). On his return to St. Louis, Grant helped his father-in-law operate the White Haven farm. Initially, the family stayed at the White Haven residence (O'Bright and Marolf 1999:2.58). In 1855, the Grant family moved to the Wish-ton-wish residence on the west side of the White Haven property. The stone residence was originally built by Julia's brother, Lewis, between 1848 and 1849 (Figure 2). Julia's father gave his daughter's family 100 acres in the vicinity of the present day St. Paul Churchyard cemetery (Figure 3). During the summer of 1856, Grant built the family a four-room, two-story dogtrot log cabin (Hardscrabble) on the land given to them by Fredrick Dent (Figure 4). The family moved into the Hardscrabble cabin that fall; however, their stay at Hardscrabble was short lived. The death of Julia's mother resulted in the Grant family's move back to White Haven in January 1857. Economic hardship, as well as illness, forced Grant to sell his farm in the fall of 1858. For a while, he tried his hand at the real estate with Harry Boggs in St. Louis. A deed of trust was filed against Frederick Dent placing 862 acres of the White Haven farm under trusteeship to Henry Boggs (O'Bright and Marolf 1999: 2.58).

The Civil War period (1860-1865) in Missouri was a period of divided loyalties among the citizens with some siding on the Union site and others wanting to leave and join the Confederate States of America (Fuller 2004; Primm 1981:239-286). Throughout the war, Missouri remained a part of the Union. St. Louis became a major Federal center with military barracks, hospitals, arsenal, and shipyards for the construction of ironclad ships (Fuller 2004). The Grant family left St. Louis in the spring of 1860 for Galena, Illinois. He was to work with his brothers, Simpson and Orvil, in the family leather goods store until the start of the Civil War (Grant 1999:106-115:Richardson 1885:159-168). In Missouri, public auction to settle the debt of the White Haven farm in 1861 resulted in the sale of 271 acres at the north end of the farm to Fredrick Dent's eldest son John C. Dent. Fredrick Dent later deeded the White Haven property to Ulysses S. Grant. He suggested that Grant transfer some of the land to John Stewart but is unclear if the transfer was made (O'Bright and Marolf 1999:2.58-2.59; Sanfilippo, personal communications 2005). Back in Illinois at the start of the Civil War, Grant organized and mustered state volunteers. He was soon appointed Colonel of the 21st Illinois Infantry regiment and his second military began. By September 1861, he had risen to the rank of Brigadier General of the volunteers. With victories in the Mississippi Valley, Grant was appointed General-in-Chief by President Abraham Lincoln in March 1864. With the Army of the Potomac, Grant pinned down General Robert E. Lee's Army of Northern Virginia resulting in the final surrender of Lee at Appomattox Court House on April 9, 1865 (Grant 1999:116-575: Richardson 1885:169-498).

The Gilded Age (1860-1900) in Missouri overlapped with the Civil War period and extended to the beginning of the 20th Century. It was a period of reconstruction to the social and physical damage caused by the Civil War (Fuller 2004; Primm 1981:287-344). The construction of elaborate businesses, residences, churches, theaters, etc. during this period catapulted St. Louis into one of the leading cities in the Midwest. During 1865, Grant began acquiring his father-in-law's landholdings in St. Louis and Jefferson Counties.

Among these holdings was Grant's original Hardscrabble residence (O'Bright and Marolf 1999:2.59). Grant hired William Elrod to manage the farm in 1866. In 1868, Grant was nominated for the office of the President of the United States by the radical Republicans and was elected. He served two terms as President from March 4th, 1869 to March 3rd, 1877 (Richardson 1885:537-544). During his presidency, Grant continued an interest in the St. Louis property. He had his tenant manager move into the White Haven house in 1868. By 1873, Grant had acquired some 650 acres of the Colonel Dent estate including the White Haven location. In October 1873, Grant replaced William Elrod with a new tenant, Nat Carlin (O'Bright and Marolf 1999:2.64). Included in Grant's holdings were Dent's original White Haven residence, Grant's residence at Hardscrabble, and Lewis Dent's home at the Wish-ton-wish residence. During his presidency, Grant and his family escaped to St. Louis for short periods. While in St. Louis, Grant and his family generally stayed at the Wish-ton-wish residence until it was destroyed by fire in 1873 (O'Bright and Marolf 1999:2.61-2.65). During the troubled second term, Grant was unable to maintain communication with the Carlin, especially after the death of his friend Charles Ford in 1873 on whom he had relied for assistance. As a result, he had Carlin sell off the livestock and possessions, to lease the land, and collect his final pay. The land was leased to Conrad B. R. Leis and his family between 1877 and 1894 (O'Bright and Marolf 1999:2.65). Following his presidency, Ulysses and Julia Grant moved to New York City. The collapse of a banking business with Ferdinand Ward in 1884 caused Grant to use the White Haven farm as collateral for a loan from Grant's friend William Vanderbilt (O'Bright and Marolf 1999:2.66). When Ward left the country with the money, Grant transferred the White Haven farm in 1885 to Vanderbilt's agent, William J. Van Arsdale. Grant died on July 23rd, 1885, in Mount McGregor, New York, soon after the transaction. Although Grant had lost his fortune and property, he managed to finish his personal memoirs before his death in order to provide for his wife, Julia. Vanderbilt maintained ownership of the land for three years until 1888 when he sold it to Luther Conn. Conn raised horses and cattle on the farm until he sold it ca. 1905 (O'Bright and Marolf 1999:2.64). In 1889, Conn sold 132 acres surrounding the Hardscrabble residence to Henry J. Weber but retained ownership to the cabin. Two years later, Conn sold the cabin to two real estate developers, Edward and Justin Joy. The Joys disassembled the cabin and moved it to a lot in Old Orchard in nearby Webster Groves.

As Missouri and St. Louis entered the Modern Period beginning in 1900 (Fuller 2004), Julia Dent Grant passed away in 1902. She was buried with her husband at Grant's tomb in New York. Conn subdivided the White Haven property and sold the southern portion to Adolphus Busch in 1903 (O'Bright and Marlof 1999:2.67). Today, this portion of the original Dent property is occupied by Grant's Farm, a 281 acre wildlife preserve operated by Anheuser-Busch, Inc. The stone foundations of the Wish-ton-Wish property are still visible on Grant's Farm. The White Haven residence and surrounding acres were sold by Conn to the St. Louis Development Company in 1907 (O'Bright and Marolf 1999:2.67). The property was in the hands of the Wenzlick family for three generations (Sanfilippo, personal communications, 2005). Finally in 1989, the Congress of the United States authorized the creation of the Ulysses S. Grant National Historic Site with the White Haven residence as the main attraction. The property was purchased through non-federal funds from St. Louis

County and the State of Missouri and donated to the National Park Service (Moore 1994). In 1990, the 9.65 acre park commemorating the life, military career and Presidency of Ulysses S. Grant was open to the public. In 1903, the Joys sold the Hardscrabble cabin to C. F. Blanke who used it to attract the 1904 St. Louis World's Fair crowds at his company's coffee display (NPS n.d.; Post 1904:14-16). August A. Busch bought the cabin from Blanke in 1907. He had the cabin moved to the family estate which was once the property of Dent and Grant families. In 1977, the Anheuser-Busch, Inc., restored the cabin and it is now open to public visitation on Grant's Farm. The original site of Hardscrabble is located in Section 1 of St. Paul Churchyard. The cemetery was established in 1925 for the relocation of graves from the earlier St. Paul cemetery which was threatened by suburban development. In 1946, the Webster Groves Chapter of the Daughters of the American Revolution (DAR) placed a bronze marker near the location of the Hardscrabble cabin built by Ulysses S. Grant (NPS n.d.).

5. FILE SEARCH AND ARCHEOLOGICAL DOCUMENTATION

A file search of archeological resources at the Missouri State Historic Preservation Office (Missouri Department of Natural Resources, Jefferson City) was conducted for the archeological overview and assessment of the Ulysses S. Grant National Historic Site on August 7, 2002 (Douglas D. Scott, personal communications 2004). A file search of the Archaeological Survey of Missouri (University of Missouri-Columbia) records was also conducted (ASM Identification Number 04-10-142). The immediate project area lies within the Middle Mississippi archeological study unit (Wright 1987:B14/1-B14/13). The unit consists of four watersheds along the Mississippi River valley. Numerous archeological investigations have occurred in the St. Louis metro area. Over 1,200 archeological sites have been recorded by the Missouri State Historic Preservation Office and the Missouri Archaeological Society (Scott et al. 2004:7). A few cultural resource management investigations have been conducted in the vicinity of ULSG (Benchley 1976; Browman 1980; Browman et al. 1977; Nixon et al. 1982, Nixon et al. 1982; Nobel 1997; Ott 2003; Price 1996,1997). Ten prehistoric and historic period archeological sites have been recorded along Gravois Creek near the Ulysses S. Grant National Historic Site (Scott et al. 2004:7). The file search of the Archaeological Survey of Missouri records indicated the presence of 14 documented sites within the six sections (i.e., St. Louis County: Township 44 North, Range 6 East; Sections 8, 9, 16, 17, 20, and 21) surrounding the project locations. Eleven sites contain prehistoric material. Three sites are historic residences or farmsteads including two sites associated with the White Haven residence located on the Ulysses S. Grant National Historic Site.

Several archeological investigations have been conducted at ULSG since its opening in 1990 (MWAC 1998; Nobel 1997; NPS 1993:5; Price 1996,1997; Price and Hastings 1998; Scott 2001a,2001b,2002a,2002b,2003). These investigations have been in support of site restoration and management-driven activities (Scott et al. 2004:8-24). Geophysical investigations of archeological resources at the Park have also been conducted since its establishment (Nickel 2001; Weymouth 1993). The historic structures report of the Park was completed in 1999 (O'Bright and Marolf 1999). The resource management plan was initially drafted in 1993 (NPS 1993). The Midwest Archeological Center staff recently completed the Park's archeological overview and assessment (Scott et al. 2004).

The Wish-ton-wish residence site (23SL1222) is a historic artifact scatter with surface and subsurface features related to the stone house built by Lewis Dent between 1848 and 1849. Ulysses S. Grant and his family stayed in the house after he resigned his commission in the regular army in 1854. Initially, the family stayed at the White Haven residence. In 1855, the Grant family moved to the Wish-ton-wish residence on the west side of the White Haven property. They remained at the residence until Grant finished the house at Hardscrabble in 1856. The Grant family also stayed at the residence during his presidency on their visits to St. Louis between 1869 and 1877. The house burned down in 1873. It was located in the ostrich and aoudad (Barbary sheep) pens in Deer Park on the south side of Grant's Farm wildlife preserve in the NW ¼ of the NE ¼ of the NE ¼ of

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

Section 20, Township 44 North, Range 6 East of St. Louis County, Missouri (Figure 5). Located in UTM zone 15, the Northing coordinate is 4269225 m and the Easting coordinate is 729815 m. The site measures approximately 100 m east-west by 50 m north-south with an area of 5,000 m^2. The owner of the property is Grant's Farm at 1-5-1 Gravois Road in St. Louis. The site is located on the ridgetop overlooking an unnamed upland drainage that flows into Gravois Creek. Gravois Creek is located approximately 1.275 km to the east. The site lies at an elevation of 189 meters (620 feet) above mean sea level. The rectangular stone foundation consisting of limestone slabs is partially evident on a small mound between the two animal pens. The foundation measures approximately 20 m (northeast to southwest) by 7 m (northwest to southeast). The shelter for the animal pens is located to the east of the foundation and the chain link fence separating the two pens runs across the northern end of the foundation. In the aoudad pen, there is also a covered well which may be associated with the original residence. The well measures approximately 1.25 m in diameter and is covered with cement posts to keep the animals out. It is located approximately 10 m southwest of the stone foundation. Obstacles in the aoudad pen include the metal feeding troughs and the large steel hay rack. There are also several trees in the pen. Some of these are within the project survey area. The lower section of the trees has been covered with chain link barriers to keep the aoudads from damaging the trees. The grass within the pen has been well cropped by the aoudads. Surface visibility is greater than 75%. The pens are also surrounded by chain link fence to separate the animals from the bison, Texas long-horn cattle, and Ankole (Watusi) cattle in the main part of Deer Park. During the development of ULSG's archeological overview and assessment (Scott et al. 2004:31-32), recommendations for multi-instrument geophysical survey were presented to the ULSG park staff for investigations of the Wish-ton-wish site (23SL1222) in cooperation with the Grant's Farm staff.

The project area containing the Hardscrabble residence (23SL1223) is located an open area of the St. Paul Churchyard in the S ½ of the NE ¼ of the SW ¼ and the N ½ of the SE ¼ of the SW ¼ of Section 9, Township 44 North, Range 6 East of St. Louis County, Missouri (Figure 6). The UTM coordinates for the site are Northing 4271340 m and Easting 730680 m. The site measures 200 m east-west by 80 m north-south for a site area of 16000 m^2. The site consists of a historic artifact scatter with surface and subsurface features related to the log cabin built by Ulysses S. Grant in 1856. The Grant family occupied the four-room, two-story, dogtrot style, log cabin until January 1857. Over the intervening years the house has been sold and moved three times. The house now resides on Grant's Farm and is open to the public. The site is located on the grassy lawn section of the cemetery at St, Paul Churchyard at 7600 Rock Hill Road in St. Louis. Although the site is regularly mown, the dense stand of grasses provided for a surface visibility of less than 5%. A small grove of trees is located near the middle of the site above Rock Hill Road. The site sits on the ridgetop and side slope the lies above Gravois Creek at an elevation of 189 m (620 feet) above mean sea level. Gravois Creek lies approximately 1.35 km to the south. A rectangular depression measuring approximately 8 m east-west by 5 m north-south is located approximately 20 m northeast of the DAR marker. The main concentration of materials and features is located within a 200 m east-west by 80 m north-south area between the entrance to the cemetery off of Rock Hill Road, the asphalt service road, and the western boundary of the cemetery. During the development of ULSG's archeological overview and assessment (Scott et al. 2004:31), recommendations for multi-instrument geophysical survey were presented to the Park staff for investigations of the Hardscrabble site (23SL1223) in cooperation with the St. Paul Churchyard staff.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

6. GEOPHYSICAL PROSPECTION TECHNIQUES

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

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

Passive Geophysical Prospection Techniques

The passive geophysical prospection technique used during the project is the magnetic survey. As indicated above, passive techniques measure existing physical properties of the earth. Other passive geophysical techniques include the measurement of earth's natural electrical fields, gravitational fields, radiometric measurement of radioactive elements, and thermal measurements of soil temperature changes. These passive methods with limited archeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis.

Magnetic Surveys

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

Magnetic field strength is measured in nanoteslas (nT; Sheriff 1973:148). In North America, the earth's magnetic field strength ranges from 40,000 to 60,000 nT with an inclination of approximately 60° to 70° (Burger 1992:400; Milsom 2003:55; Weymouth 1986:341). The project area has a magnetic field strength of approximately 55,160 nT with an inclination of approximately 68.35° (Peddie 1992; Peddie and Zunde 1988; Sharama 1997:72-73). Magnetic anomalies of archeological interest are often in the ±5 nT range, especially on prehistoric sites. Target depth in magnetic surveys depends on the magnetic susceptibility of the soil and the magnetic mass associated with buried features and objects. For most archeological surveys, target depth is generally confined to the upper one to two meters below the ground surface with three meters representing the maximum limit (Clark 2000:78-80; Kvamme 2001:358). Magnetic surveying applications for archeological investigations have included the detection of architectural features, soil disturbances, and magnetic objects (see Bevan 1991,1998:29-43; Breiner 1973; Burger 1992:389-452; Clark 2000:92-98,174-175; David 1995:17-20; Gaffney and Gater 2003:36-42,61-72; Gaffney et al. 1991:6,2002:7-9; Heimmer and DeVore 1995:13,2000:55-56; Kvamme 2001:357-358; Lowrie 1997:229-306; Milson 2003:51-70; Mussett and Khan 2000:139-180; Nishimura 2001:546-547; Scollar et al. 1990:375-519; and Weymouth 1986:343 for more details on magnetic surveying).

Two modes of operation for magnetic surveys exist: 1) the total field survey and 2) the magnetic gradient survey. The instrument used to measure the magnetic field strength is the magnetometer (Bevan 1998:20). Three different types of magnetic sensors have been used in the magnetometer: 1) proton free precession sensors, 2) alkali vapor (cesium or rubidium) sensors, and 3) fluxgate sensors (for a detailed description of the types of magnetometers constructed from these sensors see Aitken 1974; Clark 2000:66-71; Milsom 2003:58-62; Scollar et al. 1990:450-469; Weymouth 1986:343-344).

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

The magnetic gradient survey is conducted with a gradiometer or a magnetometer with two magnetic sensors separated by a fixed vertical distance. The instrument measures the magnetic field at two separate heights. The top sensor reading is subtracted from the bottom sensor reading. The resulting difference is recorded. This provides the vertical gradient or change in the magnetic field. Diurnal variations are automatically canceled. This setup also minimizes long range trends. The gradiometer provides greater feature resolution and potentially provides better classification of the magnetic anomalies. Two commonly used gradiometers in archeological investigations are the cesium gradiometer and the fluxgate gradiometer. They are capable of yielding 5 to 10 measurements per second at an accuracy resolution of 0.1 nT (Kvamme 2001:358). Cesium gradiometers record the absolute total field values like the single sensor magnetometers. The fluxgate sensors are highly directional, measuring only the component of the field parallel to the sensor's axis (Clark 2000:69). They also require calibration (Milsom 2003:2003:61-62). 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 2003:60-62).

Active Geophysical Prospection Techniques

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

Soil Resistivity Surveys

The resistivity/soil 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; David 1995:27-28; Gaffney and Gater 2003:26-36,56-61; Gaffney et al. 1991:2;2002:7; Heimmer and DeVore 1995:29-35,2000:59-60; Kvamme 2001:358-362; Lowrie 1997:206-219; Milson 2003:83-116; Mussett and Khan 2000:181-201; Nishimura 2001:544-546; and Scollar et al. 1990:307-374 for more details on resistivity surveys). It measures the resistance to the flow of an introduced electrical current in the soil. 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). Soil resistance is dependent on several factors, including the soil structure, soil texture, soil water solution conductivity, capillary conductance, the depth of the archeological targets (i.e. features or objects), and the material comprising the archeological target. The differential electrical resistance is primarily dependent on the moisture content in the subsurface matrix (Carr 1982:47-105; Clark 2000:27; Heimmer and De Vore 1995:9,30). Since electricity is easily conducted through water and follows the path of least resistance, the resistivity anomalies are identified as contrasts between the resistance values of the buried features and objects and those of the surrounding soil matrix.

The two types of resistivity surveying techniques used in archeology are the lateral profiling (horizontal) and the vertical electrical sounding (VES). Lateral profiling is done with fixed electrode spacings. Resistance measurements in ohms (Sheriff 1973:156) are collected by moving the electrode array from point to point along fixed traverses. Due to the problem of contact resistance between two electrodes in the ground, a typical soil 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 Gaffney and Gater 2003:29 and Milson 2003:99 for common configurations). The present survey utilizes the twin probe array (Geoscan Research 1996). On the twin probe array, a current and voltage probe are located on a mobile frame that is moved around the site. Two additional probes are located away from the survey area and also consist of a current probe and voltage probe. The probes on the frame are located at a fixed distance apart. A general rule of thumb for the depth investigation of soil resistance survey is the depth is equal to the distance between the probes. This value is not a unique number but an average for the hemispheric volume of soil with a radius equal to the probe separation distance. The probes are connected to the resistance meter, which is also on the frame. The measurement is taken when the mobile probes make contact with the ground and completes the electrical circuit. The measurements are stored in the resistance meter's memory until downloaded to a lap-top computer. The resulting data is integrated to provide areal coverage of the site under investigation.

The VES is done at a location by measuring several resistance values with increasing electrode separation (see Bevan 1998:17-18; Gaffney and Gater 2003:34-35; Lowrie 1997:215-217; Milsom 2003:108-112; and Mussett and Khan 2000:186-194 for additional information for conducting a vertical electrical sounding). As the separation between the electrodes increases, the same proportion of current is disturbed through an increasing depth of soil. This results in a proportionally larger effect of the deeper layers on the apparent resistivity. The Wenner array is most commonly used probe array for VES. In this configuration, the electrodes are evenly spaced with the current electrodes on the ends and the voltage electrodes in the middle (C1 P1 P2 C2). The near surface conditions differ at each electrode for each reading resulting in a relatively high noise level. To produce a smoother sounding curve, the VES is produced by using an offset array where the electrodes are expanded in opposite directions. The two readings for each offset separation are averaged together. This suppresses the local effects at each electrode. The difference between the two readings indicates the significance of these effects. The resistance values using the Wenner probe array obtained are converted to apparent resistivity by the formula $\boldsymbol{\rho_a = 2\pi ar}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **a** is the electrode spacing, and **r** is the measured resistance at each electrode separation. The resulting apparent resistivity values in ohm-meters (Sheriff 1973:156) are plotted by electrode spacing. Variation of the apparent resistivities with each increasing electrode spacing are compared to sounding curves (Orellana and Mooney 1972) or modeled in a computer program (Butler 1999; Interpex 2002). This produces an estimate of the electrical stratification of the soil. This information provides the investigator with basis data that can be used to determine the applicability of the various techniques to the project area (i.e., if the resistivity is high, then ground-penetrating radar should work well on the site, or if the resistivity is extremely high, then a ground conductivity survey may not be practical).

By combining the two methods, one can obtain both lateral profiles at different vertical depths. This requires the use of multiple sets of probes. For this to be achieved, data must be gathered along multiple traverses at a number of different spacings, which are multiples of a fundamental distance. The probes are moved along the traverse at regularly spaced intervals to obtain the horizontal changes. With the different distance spacings between the probes, the vertical changes are also identified during the survey. By combining the two resistivity methods, the resulting data may be displayed as layers at the various depths based on the probe separation or as vertical pseudo-sections (Milson 1996:91-93). The most common probe array used in archeology using this combination is the twin electrode probe array, although multiprobe switching resistivity systems are becoming more common (Geoscan Research 1993; Iris Instruments 1999; Milson 1996:71). Combining the resistance meter, probes, and a multiplexer unit, several probe configurations can be measured at a single location (Geoscan Research 1995). By combining the multiple configurations, pseudo sections or depth information can be collected relatively rapidly over a large area. The conversion of the soil resistance measurements to resistivity is more complicated than in the Wenner probe array (Bevan 2000:2). Like the Wenner probe array, four probes are used to take the resistance measurement; however, instead of having the linear arrangement of potential, current, current, and potential probes set at equal distances apart, in the twin electrode array, one current and one potential set of probes are on the mobile frame and moved about the site collecting readings. The second set of remote probes is set away from the grid. To convert the resistance readings from the multiple sets of probes to comparable apparent resistivity measurements the following formula is used (Geoscan Research 1995: B-1): $\boldsymbol{\rho_a = 2\pi r / G.F}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **r** is the measured resistance at each electrode separation, and **G.F.** is equal to the inverse of the distance between the remote probes plus the distance between the mobile probes minus inverse of the distance between the remote potential and mobile current probes minus the inverse of the remote current and mobile potential probes (**G.F. = 1/C2P2 + 1/C1P1-1/C2P1-1/C2P1** where **C2P2** equals the probe separation distance between C2 and P2, etc.). The resistance measured by the twin electrode probe array is determined by the resistivity below both sets of probes ($\mathbf{R = V/I = (1/2\pi)\ (\rho_1/a_m + \rho_2/a_r\ )}$ where $\boldsymbol{\rho_1}$ is the resistivity of the soil beneath the mobile probes, $\mathbf{a_m}$ is the mobile probe separation distance, $\boldsymbol{\rho_2}$ is the resistivity of the soil beneath the remote probes, and $\mathbf{a_r}$ is the remote probe separation distance). The apparent resistivity can be approximated by the formula $\boldsymbol{\rho_a = \pi a r}$, where the electrode spacing **a** of both the mobile and remote electrodes are equal, or to $\boldsymbol{\rho_a = 2\pi a r}$ (approximate), where the electrode spacing **a** is equal to the mobile probe separation when the remote probe spacing in much greater than the mobile probe spacing. A more accurate method (Bevan 2000) of determining the resistivity measurements from the soil resistance data is to determine the resistivity below the remote, fixed electrodes by taking measurements at two separate probe spacings where $\boldsymbol{\rho_2 = 2\pi\ ((R_1\text{-}R_2)/(1/a_{r1}\text{-}1/a_{r2}))}$. The resistivity below the mobile probes can be computed as $\boldsymbol{\rho_1 = 2\pi a_m R\text{-}\rho_2(a_m/a_r)}$. By combining all the resistivity data, a three dimensional display can be generated of the soil resistivity.

Electromagnetic Conductivity Surveys

The capacity of soil to conduct electrical currents has led to the use of soil conductivity and soil resistivity meters in cultural resource management (Heimmer and De Vore 1995:29-41). Both resistivity and conductivity represent active geophysical techniques. Soil resistivity meters used in archeological surveys typically involve four metal probes placed in contact with the soil. A small alternating current is normally applied to two of the probes and the voltage difference between the other two probes is measured. Variations in soil moisture, chemistry, and structure affect the electrical resistance of the soil. Soil resistivity surveys are particularly well suited to locating high resistance material (e.g. stone or brick) in relatively conductive soil (e.g. clay). Soil conductivity meters provide another method of measuring the soil's ability to conduct electrical current. This survey technique measures the soil conductivity. Theoretically, conductivity represents the inverse of resistivity. High conductivity equates to low resistivity and vice versus. The electromagnetic ground conductivity meter induces an electromagnetic field into the ground through a transmitting coil (see Bevan 1983,1991,1998:29-43; Burger 1992:310; Clark 2000:34-37,171; Clay 2001:32-33; David 1995:20-23; Gaffney and Gater 2003:42-44; Gaffney et al. 1991:5,2002:10; Heimmer and DeVore 1995:35-41,2000:60-63; Kvamme 2001:362-363; Lowrie 1997:222-225; McNiel 1980a,1980b; Milson 2003:129-147; Mussett and Khan 2000:210-227; and Nishimura 2001:551-552; Scollar et al. 1990:520-575 for more details on conductivity surveys). The induced primary field causes an electromagnetic wave flow in the earth similar to the electrical current in a resistivity survey. The materials in the earth create secondary eddy current loops, which are picked up by the instrument's receiving coil. The interaction of the generated eddy loops or electromagnetic field with the earthen materials is directly proportional to terrain conductivity within the influence area of the instrument. The receiving coil detects the response alteration (secondary electromagnetic field) in the primary electromagnetic field. This secondary field is out of phase with the primary field (quadrature of conductivity phase). The in-phase component of the secondary signal is used to measure the magnetic susceptibility of the subsurface soil matrix. Only the quadrature or conductivity phase data have been collected during the present project.

Contrasts result from electrical and magnetic properties of the soil matrix. Contrasts are caused by materials buried in the soil, differences in soil formation processes, or soil disturbances from natural or cultural modifications to the soil. Electromagnetic conductivity instruments are also sensitive to surface and buried metals. Due to their high conductivity, metals show up as extreme values in the acquired data set. On occasion, these values may be expressed as negative values since the extremely high conductivity of the metals cause saturation of the secondary coil. The apparent conductivity data were recorded in units of millisiemens per meter (mS/m). The electrical conductivity unit or siemens represents the reciprocal of an ohm-meter or the unit for resistivity (Sheriff 1973:197). The relationship between conductivity and resistivity is represented by the following formula (Bevan 1983; McNeil 1980): mS/m = 1000/ohm/m.

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

Ground-penetrating Radar Survey

Ground-penetrating radar (gpr) is an active method that has recently achieved popularity in cultural resource management applications (see Bevan 1991,1998:43-57; Clark 2000:118-120,183-186; Conyers and Goodman 1997; David 1995:23-27; Gaffney and Gater 2003:47-51,74-76; Gaffney et al. 1991:5-6,2002:9-10; Heimmer and DeVore 1995:42-47,2000:63-64; Kvamme 2001:363-365; Lowrie 1997:221-222; Milson 2003:167-178;

Mussett and Khan 2000:227-231; Nishimura 2001:547-551; and Scollar et al. 1990:575-584 for more details on ground-penetrating radar surveys). Although Bruce Bevan pioneered the archeological use of gpr a quarter-century ago (Bevan 1977; Bevan and Kenyon 1975), the cost of equipment and problems dealing with the massive amount of data produced by gpr surveys limited the number of archeological applications. Recently, Conyers and Goodman (1997) have published an introduction to gpr for archeologists, and Bevan (1998) has provided an excellent comparison of various radar antennae as applied to a consistent group of archeological features. Reductions in the cost of equipment and improvements in the software available for processing the voluminous data have helped to make gpr surveys more affordable and analysis more efficient.

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

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

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

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

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

7. FIELD SURVEY PROCEDURES

The survey scope-of-work for the Hardscrabble (23SL1223) and the Wish-ton-wish (23SL1222) project called for magnetic, resistivity/conductivity, and ground-penetrating radar surveys of the area associated with the residences in order to identify the extent of the sites and location of the residences. At the Hardscrabble site, the geophysical survey covered an area of 6,400 m^2 in the open area between Ridge Hill Drive and an interior cemetery service road along the southwestern corner of the St. Paul Churchyard cemetery (Figure 7). At the Wish-ton-wish site, the geophysical survey covered an area of 1,625 m^2 in the ostrich and aoudad pens on the southern side of Deer Park at Grant's Farm (Figure 8). The geophysical grid was established at the project locations with a portable Ushikata S-25 Tracon surveying compass (Ushikata n.d.) and 100 meter tape (Figure 9). The surveying compass was used to sight in two perpendicular base lines and the geophysical grid unit corners. Wooden hub stakes were placed at the 20-meter grid corners at both sites with additional stakes placed at the 20-m grid unit corner points and the end points along the five meter extensions at the Wish-ton-wish site. At Hardscrabble, the geophysical grid was aligned on magnetic north. The geophysical grid at the Wish-ton-wish site was aligned parallel to the exterior chain link fence line in the aoudad pen and the interior dividing chain link fence between the aoudad and ostrich pens. The mapping station was offset two meters from the intersecting corner of the interior and exterior pen fences. Magnetic north is located 46° degrees west of the grid north baseline.

Once the geophysical grid was established, a Nikon DTM-730 electronic field station (Nikon 1993) was positioned over the site datum or mapping station (Figure 10). A datum point was established at the southwest corner of grid unit two at the Hardscrabble site. This point was located a couple of meters northwest of the DAR monument. Arbitrary values were assigned to the Northing (N) or y coordinate, Easting (E) or x coordinate, and elevation (Z coordinate). The mapping station for the Hardscrabble survey was established at North 560 meters and East 500 meters (N560/E500) near the turn-around loop of the cemetery service road with an elevation of 500 meter. The backsight reference point for the Hardscrabble project was N500/E500. The datum point at Wish-ton-wish was located at the mapping station for the initial grid baseline stakeout. This point was assigned arbitrary values of North 500 meters and East 500 meters (N500/E500) with an elevation of 500 meters. The backsight reference point for the Wish-ton-wish project was established at an azimuth angle of 180° south of magnetic north in the aoudad pen. Due to the rotated grid orientation at the Wish-ton-wish site, the grid coordinates were assigned arbitrary x and y coordinates with the southeast or lower left hand corner being N0/E0 and the northwest or upper right hand corner being N25/E65.

The site features, geophysical grid points, and topography were mapped with the field station, prism, and prism pole. The data were stored on the memory card of the DTM-730 and subsequently downloaded into a laptop computer. Initially the coordinate data (i.e., survey codes, northing coordinates, easting coordinates, and elevation) and raw field data (i.e., survey codes, horizontal angle, vertical angle, slope distance) files were transferred from the field station to the laptop computer with the Transit software package (Nikon 1996). These data files for each site were then transferred to the WordStar 5.5 software package (MicroPro 1989). The extraneous information in the coordinate data files were removed leaving the northing (Y) coordinates, easting (X) coordinates, elevations (Z coordinates), and point descriptions. This locational information was then converted to an XYZ data (dat) file for processing in the SURFER 8 mapping software (Golden Software 2002). A file folder was created on the laptop computer to hold the mapping and geophysical data (i.e., ulsg). The folder was subdivided into two folders with the project names of hardscrabble and wish-ton-wish. The mapping data from each site were place in the appropriate folders.

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

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

(Golden Software 2002:467-492). A scale bar and north arrow were added to the finished contour map. The project area's natural and cultural features were also labeled. Figure 11 illustrates the natural and cultural features at the Hardscrabble geophysical project area. Figure 12 illustrates the natural and cultural features at the Wish-ton-wish geophysical project area.

Before the start of the geophysical survey at both sites, yellow nylon ropes were laid out on the geophysical grid units (Figure 13). These ropes served as guide ropes during the actual data acquisition phases of the project. Twenty-meter ropes were placed along the top and bottom base lines connecting the grid corners. These ropes formed the boundaries of each grid during the data collection phase of the survey. Additional traverse ropes were placed a one-meter intervals across the grid at a perpendicular orientation to the base lines beginning with the line connecting the two wooden hubs on the left side of the grid unit. These ropes serve as guides during the data acquisition. These 20-meter lengths of ropes are divided into 0.5 meter increments by different colored tape. One color (blue) is placed every meter along the rope with a different colored (red) tape placed at half-meter intervals. The use of different colored tape on the ropes provided a simple way to maintain one's position within the geophysical survey grid unit as data were collected. The geophysical data were therefore recorded in a series of evenly spaced parallel lines with measurements taken at regular intervals along each line resulting in a matrix of recorded measurements (Kvamme 2001:356; Scollar et al. 1990:478-488). Beginning in the lower left-hand corner of the grid, data collection occurred in a parallel (unidirectional) or zigzag (bi-directional) mode across each grid unit until the survey was completed for each technique. Once the survey of the individual grid unit was completed, the ropes were moved to the next grid unit until completion of the survey for each instrument. During the gpr survey, only the two baseline end ropes were used as placement guides for plastic jugs with attached plastic pin flags. The jugs served as sighting reference points during the gpr survey rather than the traverse survey ropes. The use of the jugs avoided any entanglements at the end of the survey lines between the plastic tent pegs used to hold the ropes in place and the gpr survey cart and antenna.

Magnetic Survey Methodology

The magnetic survey is conducted with a Geoscan Research FM36 fluxgate gradiometer with a ST1 sample trigger (Geoscan Research 1987). The instrument is a vector magnetometer, which measures the strength of the magnetic field in a particular direction. The gradiometer consists of a control unit that contains the electronics, menu keyboard pad, power source, operating program, on-off switch, connector for the charger/ data output/external logger, analog output connector, LCD display screen, sounder outlet, balance control, and memory chips (Geoscan Research 1987:8-10). The tubular carrying handle connects the control unit to the vertical sensor housing tube that contains the two fluxgate sensors. N/S and E/W sensor alignment controls are located on the sensor tube. It has a resolution of 0.05 nT with a 0.1 nT absolute accuracy.

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

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

The sensors must be accurately balanced and aligned along the direction of the field component to be measured (Figure 14). The zero reference point at the Hardscrabble site was established at N560/E500 grid corner and the balancing and alignment procedures were oriented to magnetic north. This point was selected where there were no noticeable localized changes in the digital display or by raising the instrument above the ground with the use of a plastic step stool. The readings should vary less than 2 to 3 nT in the area surrounding the zero balance reference point. The balance control on the instrument was adjusted first. The balancing the instrument was conducted in the 1 nT resolution range by first inverting the instrument and zeroing the instrument. The instrument was then rotated 180 degrees about the same horizontal plane of the axis of the handle. The trimming tool was inserted into the balance control slot on the side of the instrument and the reading in the digital display was reduced in half. The procedure was repeated until the reading in the upright and inverted positions was within a range of -1 to 1 nT. With the instrument held vertically at a height where the alignment controls were within easy reach, the two sensors were then aligned. At first, the bottom sensor was aligned. The instrument was pointed to magnetic north and the instrument was zeroed so that the display reading was zero. The instrument was then rotated around the sensor tube 180 degrees until it pointed south. The small aluminum wheel of the N-S alignment control at the bottom of the tube was used to adjust the sensor until the reading was half of the value first observed when it was rotated to the south. The instrument was rotated back 180 degrees until it pointed to magnetic north and rezeroed. The display reading was checked. If the north reading was within the range of -1 to 1 nT, the alignment was considered successful and the bottom sensor was aligned. If the north reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. Once the bottom sensor was aligned, the top sensor was then aligned. The instrument was rotated 90 degrees until it faced east. The instrument was zeroed and then rotated 180 degrees until it faced west. The display reading was noted. The E-W alignment control wheel at the top of the sensor tube was adjusted until the reading was half of the observed reading. The instrument was then returned to its east facing position and rezeroed. If the east reading was within the range of -1 to 1 nT, the alignment was considered successful and the top sensor was aligned. If the east reading was not within the correct range, the procedure was repeated until the readings were within the correct display range. As a final check, the instrument was rotated 360 degrees about the vertical tube axis. If the display reading stayed within the -1 and 1 nT range, the sensor alignment procedures were considered successful. If the observed display readings went over the acceptable range, the balancing and alignment procedures were repeated until successful. The instrument was returned to the 0.1 nT resolution operating range and then zeroed at arms length over the operator's head. The operator's manual (Geoscan Research 1987:29-31) illustrates the steps involved in preparing the instrument for actual field data collection.

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

During the Hardscrabble magnetic survey, data were collected at 8 samples per meter (0.125 m) along each traverse and at one meter traverses across each individual grid unit resulting in 8 samples per square meter. A total of 160 magnetic measurements were recorded for each traverse in the memory of the Geoscan Research FM36 fluxgate gradiometer. A total of 38,400 measurements was recorded during the magnetic survey of twelve 20 m by 20 m grid units (4,800 m^2) before the gradiometer malfunctioned and could not be balanced in the field. Occasionally, the magnetic field strength of an object is extremely high. In these cases, the fluxgate sensors may not be able to recycle or record the high gradient change. In these cases, the dummy value of 2047.5 is inserted into the data string. This value is recognized in the GEOPLOT software as a value that will not be used in the processing algorithms. A total of 112 dummy values were entered into the magnetic data set. The instrument’s memory can hold data acquired from four grid units with the sample density of 8 samples per meter and one meter traverses. At the end of the data acquisition of four grid units, the magnetic data from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research) on a laptop computer. It took approximately 26 minutes to download the data from the instrument’s memory. The site name for the magnetic data from the Hardscrabble site (23SL1223) was ulsghard. Each grid unit data file was assigned the number identifier for the grid unit and the letter “g” to identify the grid file as a magnetic data grid file. The grid files created in GEOPLOT was reviewed in the field prior to the clearing of the gradiometer’s memory and returning for further survey of the project area.

Ground Conductivity Survey Methodology

Due to the malfunction of the fluxgate gradiometer, the Geonics EM38 ground conductivity meter (Geonics Limited 1992) was used to survey an additional four 20 m by 20 m grid units, as well as one selected grid unit in the magnetic survey area at the Hardscrabble site. The extension of the geophysical project area to the west of the initial twelve grid units was dictated by a review of the magnetic data that showed a buried utility line in that direction and the apparent continuation of magnetic anomalies associated with the Hardscrabble residence at the western edge of the initial geophysical grid area. The conductivity instrument is lightweight and approximately one meter in length. The apparent conductivity of the ground is in millisiemens per meter (mS/m) with a measurement precision of ±0.1% of full scale deflection. The meter consists of the transmitting and receiving coils embedded in the case of the instrument, a 9 volt battery, horizontal and vertical digital displays, recorder connector, and control panel. The control panel contains the conductivity range switch with two settings (1000 millisiemens/meter and 100 millisiemens/meter), on/off/battery test switch, a fine and course inphase (I.P) zero controls, a phase adjustment knob, the quadrature phase (Q/P) zero control, and a toggle switch for Q/P and I/P modes. The transmitting and receiving coils are located at opposite ends of the meter with an intercoil spacing of 1 meter. It has an operating frequency of 14.6 kHz in the 100 mS/m range and 40.4 kHz in the 1000 mS/m range. The conductivity meter can collect conductivity data in the quadrature phase operating mode or magnetic susceptibility data in the in-phase operating mode. The present ground conductivity survey is operated in the quadrature phase (Note: the in-phase operating mode measures magnetic susceptibility in parts per thousand or ppt). The EM38 ground conductivity meter has a depth of investigation of approximately 1.5 meters in the vertical dipole mode with optimum resolution at 0.6 meters. An adjustable tubular handle is attached to the meter for carrying during survey. The handle also contains the manual trigger button.

Prior to the start of data acquisition, the meter must be nulled and the battery checked for nominal operating voltage. The battery test is conducted at the beginning of the survey and start of each day or when the voltage is thought to be low. With the range switch in the 1000 mS/m position and the battery test switch to BATT, a good battery should have a display of over -720 units. The battery is replaced if the display is below -720. After the battery check, the instrument is nulled in the inphase mode and then zeroed in the quadrature phase mode. Nulling in conducted at the beginning of the survey at the same zero reference point used to balance and align the fluxgate gradiometer at N560/E500. Since the EM38 measures ground conductivity by inducing very small electrical eddy currents into the ground and measuring the magnetic field that these currents generate, it is important to null the larger primary signal produced by the transmitting coil so that the electronic circuitry is not overloaded by the primary signal. All metal objects must be removed from the operator prior to beginning the initial inphase nulling operation. The range switch is set to the 1000 mS/m position. The instrument is positioned at a height of 1.5 meters above the reference point in the vertical dipole position (upright). The mode toggle switch is set to the I/P position. The meter is nulled by first adjusting the I/P course knob and then the fine I/P knob until the display reads zero. The range switch is then set to the 100 mS/m position and the procedures are repeated. The meter is successfully nulled when the meter reads approximately zero (±10 mS/m) on the 100 mS/m setting at 1.5 meters above the ground. The instrument is then zeroed. The instrument zeroing is conducted at the beginning of the survey and checked two to four times throughout the day. Using the same reference point and with the instrument at a height of 1.5 meters above the ground, the mode toggle switch is set to the normal Q/P position. With instrument in the horizontal dipole position (flat) and the range switch set to 100 mS/m, the Q/P Zero Control knob is adjusted until the meter reads 50 mS/m. This value is referred to as **H**. Without changing the instrument height rotate the EM38 about its long axis to the vertical dipole position. The value in this position is referred to as **V**. Regardless of any layering in the earth at a height of 1.5 meters, **V** should equal twice **H** (**V=2H**). If it doesn't, then the Q/P Zero is not set correctly. To adjust the Q/P Zero, one needs to calculate the correlation **C** value that affects **V** and **H** equally (**C=V-2H**). With the meter in either the horizontal or vertical dipole position, the Q/P Zero Control is adjusted by the correlation value. Adjustment of the displayed value is made by turning the control in the direction of higher conductivity if the value is positive and lower conductivity if the value is negative. The vertical and horizontal dipole measurements are rechecked to insure that the instrument zero is set correctly. If not, the procedures are repeated until the instrument is correctly set. After the Q/P Zero is set, the instrument needs final inphase nulling before commencing the survey. The final inphase nulling is carried out as previously mentioned for the initial inphase nulling procedure, except the EM38 is placed on the ground in the vertical dipole position.

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

The ground conductivity survey was designed to collect 4 samples per meter along one-meter traverses or 4 data values per square meter at the Hardscrabble site project. The data were collected in a parallel fashion with the surveyor returning to the starting side of the grid and maintaining the same direction of travel for each traverse across the grid. A total of 6,654 data values were collected in the extension which included grid units 13 through 16. One thousand seven hundred fifteen data values were collected in grid unit 4 in the magnetic survey area. This grid unit was selected for additional conductivity survey due to the presence of numerous magnetic anomalies that may be related to the location of the Hardscrabble log cabin built by Grant. With four samples per meter and one meter traverses in the parallel mode, it took approximately 25 minutes to complete a 20 m by 20 m grid unit. The data were downloaded to a laptop computer for processing in Geonics DAT38RT software. It took approximately 10 minutes to download the data from the five grid units. The header and data files from the polycorder were converted to a *.g38 file in the DAT38RT software program and then converted to SUFER file format for further processing on the laptop computer. The data should be viewed for any operational errors before the data is deleted from the polycorder. The data files were then placed in the ulsghard file folder in the surferprojects folder on the laptop computer. The file folder names were maintained when the data were transferred to the desk personal computer at MWAC.

Soil Resistance Survey Methodology

With the malfunction of the fluxgate gradiometer at the Hardscrabble site, the Geoscan Research RM15 advanced resistance meter and PA5 multiprobe array in a twin probe configuration (Geoscan Research 1996) is used at the Wish-ton-wish site (Figure 15). The resistance meter has a resolution of 0.05 ohms with an absolute accuracy of 0.1 ohms. The resistance meter consists of a control unit that contains the electronics, menu pad, power source, operating program, and memory chips. It also contains the on/off switch, expansion ports for the potential and current mobile and remote probes, a LCD display screen, and charger connector. The mobile and remote probe cables are plugged into the back of the RM15 resistance meter. The control unit is attached to the multiprobe array frame by a mounting plate and short and long knoblet screws.

The soil resistance survey is designed with a twin electrode probe array. The stainless steel mobile probes on the frame consist of a set of current and potential probes. The remote probes also consist of a set of stainless steel current and potential probes. The mobile probes on the frame with the resistance meter are moved uniformly across the site. The mobile probes are at a set distance apart on the array frame, which for the present survey was 0.5 meters. The mobile probes are inserted into the ground so the center of the frame is over the center of the traverse point. For acceptable readings, the mobile probes need to be within ±7.5 cm of the center point of the 0.5 meter cell on the traverse line since the reading is of an average volume of a hemisphere with a radius equal to the mobile probe separation distance. This provides some freedom in the placement of the probes, which makes the system fast and easy to use. If an obstacle is in the way of the probes, the frame can simply be moved to one side or the other of the obstacle for the placement of the probes if the displacement will not greatly affect the location of the measurement. The insertion depth for the mobile probes is not critical. With reasonably moist soil, the downward momentum of the frame is enough force to push the probes into the ground to a depth of 3 to 5 cm. The remote probes are stationary, and are set at a distance that is 30 times the twin probe separation distance on the PA5 frame from the survey grid area. At this distance, the background resistance reading is essentially independent of the mobile probes' location. The remote probes were placed approximately 15 meters southeast of N0/E30. The separation distance between the remote probes is not critical since the probes are left in a fixed position throughout the survey. The remote probes were separated by a distance of approximately one-half meter. The remote probes are connected to the resistance meter by means of a 100-meter cable and drum. Although the insertion depth of the remote probes is not critical due to the high contact resistance tolerability of the RM15, it is best to insert the probes as far into the ground as possible to eliminate any offset in background resistance caused by remote probe contact resistance or capacitive coupling of the 100 m cable. This is not generally important in a twin electrode probe survey since one is only looking for changes in an arbitrary background level as the mobile probes are moved along the traverse lines in a grid survey; however, should the remote probe contact resistance change, as in the case of a rain shower, then the offset and background resistance could be beyond acceptable survey levels.

Prior to the start of the survey, the memory of the resistance meter is cleared and the menu settings are checked for the appropriately planned survey. For the present project, the resistance is programmed for a mapping grid size of 20 m, a grid sample interval of

0.5 m, a grid traverse interval of 1.0 m, and the zig-zag grid traverse mode. The range parameters include a gain of 10, a current of 1 mA, and a frequency of 137 Hz. The setup parameters include a medium auto-log speed, an output voltage of 40 v, a high pass filter value of 13 Hz, and a mains frequency equal to the United States standard of 60 Hz. In the array parameters, the PA5 is the selected hardware with the twin configuration. The probe separation was set to 0.5. The communications parameters for downloading the data are set to 9600 baud rate and with a data separator of no space. In the program menu, the meter can be programmed as a single twin array (the default setting), parallel arrays, and multiple arrays. As the word single implies, only one configuration is used during the survey. This is set by the placement of two probes on the array frame. The final menu category contains the battery voltage status.

In order to have an appropriate operating range for data acquisition, the soil resistance system is moved around the grid area to check the dynamic range of resistance values. The gain and current ranges are adjusted so that changes of approximately 1% in the background resistance are observed. Typically this means adjusting the current and/or gain ranges up or down to get a measurement display of three decimal places on the LCD screen. Once the gain and current ranges are set, they are not changed during the survey of the grid. If they require a change because of repeated over-range readings, the data must first be downloaded and the memory cleared. The grid may need to be re-surveyed at the new settings. Once the gain and current ranges are set (x10 for the gain and 1mA for the current) the operator is ready to begin the survey. The Enable Log button is pushed to enable the Logging Display. The LCD screen displays the ohm reading and the initial position location (G1, L1, P1). To take the first reading, the Start button is pushed. The averaged measurement is recorded into memory and the P position values will increment one position. At the end of the line, the L value is advanced one unit, and at the end of the grid, the G value is advanced one unit. An “A” is also displayed on the LCD screen, which indicated the meter, is in the Auto-Log mode and ready for the next measurement. The array frame and meter are picked up, moved to the next location, and the probes are inserted into the ground. At this point in the survey, the readings are automatically recorded. The RM15 detects the completed current when the mobile probes are placed in the ground and the current flows through the system in the automatic method of logging. The instrument provides both an audible warble for the recordation of the averaged resistance value in the instrument’s memory, and advances the position counter to the next point value. When the mobile probes removed from the ground the LCD screen indicates an open circuit (HCR / Open cct.). The survey continues to the end of the grid. At the end of the line, the instrument will provide one beep, and at the end of the grid, it makes two beeps. There are also times when the reading from one of the positions may be over the operating range of the RM15. In those cases, the Dummy Log button is depressed and the dummy value of 2047.5 is inserted into the data set.

During the Wish-ton-wish survey, data were collected at 2 samples per meter (0.5 m) along each meter traverse across the grid resulting in 2 samples per square meter. For each traverse, a total of 40 resistance measurements were recorded in the memory of the

Geoscan Research RM15 resistance meter. A total of 800 measurements were recorded for each complete 20-m by 20-m grid unit during the soil resistance survey. At the end of the data acquisition phase at the site, the resistance data from the survey were downloaded into the Geoscan Research GEOPLOT software (Geoscan Research 2003) on a laptop computer. It took approximately five minutes to download the data from the survey. The grid files were reviewed in the field prior to the clearing of the resistance's memory. The site/file folder name for the resistance data from the Wish-ton-wish site (23SL1222) was ulsgwish. Each grid unit data file was assigned the number identifier for the grid unit and the letter "r" to identify the grid file as a resistance data grid file.

Vertical Electrical Sounding Methodology

The vertical electrical sounding (VES) is conducted with the Gossen Geohm 40D earth tester with a Wenner probe array (see Bevan 1998:7-18; Carr 1982; Gafeney and Gater 2003:34-36; Gossen-Metrawatt GMBH 1995; Lowie 1997:215-217; Milsom 1996:71-73; and Mussett and Khan 2000:186-194 for more details of vertical resistivity soundings). The resistivity meter has four measuring or operating ranges: 1) 0.01 Ω (ohms) to 19.99 Ω, 2) 0.1 Ω to 199.9 Ω 3) 1.0 to 1.999 kΩ, and 4) 10 Ω to 19.99 kΩ. It has an intrinsic error of ±2% of reading ±3 digits; and a service error ±5% of reading ±3 digits.

The VES at the Hardscrabble site was centered at N540/E510 with the offset line oriented east-west. The VES at the Wish-ton-wish site was centered at N15/E20 using the geophysical grid coordinates rather than the mapping coordinates and was oriented along the E20 line from N5 to N25. The offset Wenner array of five electrodes was used to take resistance readings at the following increments: 0.1, 0.15, 0.2, 0.3, 0.4, 0.5, 0.70, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0 meters in both directions from the center probe to obtain data for the offset sounding. The distance between the probes also approximates the depth of investigation. The resistance measurements including the probe separations for both directions along the Wenner array offset were hand recorded in the field notebook for both directions of the offset. A total 26 measurements were recorded at each site. It took approximately 1.5 hours to set up the array and conduct the vertical electrical sounding at each site.

Ground-penetrating Radar Survey Methodology

The Geophysical Survey Systems, Inc. (GSSI), TerraSIRch SIR System-3000 ground-penetrating radar (gpr) system (Figure 16) is used for the Hardscrabble and Wish-ton-Wish geophysical survey projects. The gpr system consists of the digital control unit (DC-3000), a 400 mHz ground coupled antenna (Model 5103), and the GSSI Model 623 survey cart with survey wheel for mounting the antenna and control unit (GSSI 2003a). System hardware contains a 512 mb compact flash memory card as its internal memory. The digital control unit also accepts an industry standard compact flash memory card up to 2 gb. The processor is a 32-bit Intel StrongArm PISC 206 mHz processor with enhanced 8.4" TFT display, 800 x 600 resolution, and 64k colors. The processor produces both linescan and O-scope displays. The gpr system uses one channel. The Model 5103 antenna operates at a nominal frequency of 400 mHz. The 400 mHz antenna has a depth of view of approximately 4 m assuming a ground dielectric constant of 5 with a range of 50 ns, 512 samples per scan, 16 bit resolution; 5 gain points, 100 mHz vertical high pass filter, 800 mHz vertical low pass filter, 64 scans per second, and 100 kHz transmit rate.

The S-3000 control unit was placed on the survey cart and connected to the antenna. The odometer survey wheel attached to the frame of the cart was also connected to the antenna by a small cable. As the cart was moved along on the ground the cart's right rear wheel turned the odometer wheel and the revolutions were translated into distance along the traverse line.

The LCD display on the SIR 3000 control unit provides immediate visual display of the gpr profile data as it is collected. Once the battery is installed into the SIR 3000, the unit boots up (GSSI 2003a:6). The initial screen displays the words TerraSIRch SIR-3000 in the middle of the screen. At the bottom of the screen, there is a set of six buttons positioned over the function keys. The mark button on the right side of the unit allows one to change between English and Metric units of measurement. This is set to metric for the current projects at the Hardscrabble and Wish-ton-wish sites. Selection of the function key below the TerraSIRch button display initiates the gpr data collection program. A set of three screens is displayed with the left window containing the parameter selection tree, the middle window displaying the profile data in linescan format, and the right window showing a single scan in an oscilloscope trace depiction. The command bar at the bottom of the screen allows one to toggle between functions.

Initially, the System menu is opened on the parameter tree. The System menu contains the choices for the system setup. The System menu contains the submenus for Units, Setup, Path, Backlight, Date/Time, Battery, and Version (GSSI 2003a:9-10). Metric units are selected for depth and distance. Time is selected for Vscale (vertical scale) display. Setup contains factory setups for the various antenna configurations, which can not be overwritten, and 16 user setups. The factory default for the 400 mHz antenna (400met) is selected and saved in one of the user setups. The Path submenu allows for the creation of separate folders for the gpr profile files. The Backlight submenu controls the LCD screen brightness. The Date/Time submenu allows one to set the system's internal clock to the correct date and time. The Battery selection provides a check on the remaining charge on the battery in percent of total charge. The Version informs one of the current version of TerraSIRch operating software.

The next step is to configure the SIR-3000 for data collection. The Collect menu is opened (GSSI 2003a:11-16). There are five submenus that need to be configured. The Radar submenu contains the information concerning the antenna frequency selection (400 mHz), the antenna transmit rate (100 kHz), the mode of data collection (distance for survey wheel with value of -1583 for survey cart system), and activation of gps capability (off). The Scan submenu allows for the selection of the number of individual data points or samples collected per scan (512 samples/scan), the data format (16-bit), the time window range (100 ns which is two-way travel time), the Diel or dielectric constant value of the material (generally left at the factory default of 8). The dielectric constant is a measure of the capability of a material to store and pass a charge when an electromagnetic field is applied to the material (Sheriff 1973:51). It reflects the velocity of the radar wave that can pass through a given material. The scan Rate is the number of scans that the SIR-3000 records in its RAM memory per second (100 with a T-RATE of 100 kHz and use of a survey wheel). The scans per unit of horizontal distance is set to 50 scans per meter. This equals 1 scan every 2 cm. The Gain submenu allows for the artificial enhancement of the radar signal in order to offset the natural effects of signal attenuation. During the survey, the Gain is set to the manual mode. The auto mode is used to re-initialize and adjust the antenna's gain values during the initial reconnaissance of the survey area in order to keep from clipping the data. Five separate values are available for the evenly spaced gain points ranging from 1 to 5 (3 is the factory default). The individual gain values can be manipulated are left at the factory default values. The Position submenu controls the position of the time zero setting. Time zero is defined as the location of the beginning of the transmit pulse. During a survey, the Position is set to the manual mode. The offset represents the time lag from the initiation of the radar pulse in the SIR-300 control unit to the transmission of the pulse from the antenna dipole. This is generally represented by the time value where the direct coupling of the signal between the transmitting and receiving antennas. The Surface submenu allows for the display option of setting time zero at the first reflected target or the ground surface. The gpr system was moved around the grid prior to the start of the survey to adjust the gain. If a location caused the trace wave to go off the screen, the gain was set to auto and then back to manual. The position was set to the manual mode with the offset value at the factory default and the surface display option set to zero. The final submenu allows for the manipulation of data collection filters to remove interference and smooth noise. These include low and high pass filters, stacking, and background noise removal filters. These are left at their factor defaults for the specific antenna in use.

The final step prior to the start of the data collection is to return to the System menu and select the path for the profile data. In the Path submenu, a new folder can be named. The folder will contain the radar profile collected in the grid. Once the new path is selected, it is saved in one of the user defined setups. With the setup completed, the run/stop button at the bottom of the display screen is selected and the collect mode is initiated. The gpr unit is moved across the grid and at the end of the traverse, the collect button is selected and data acquisition is halted. The gpr unit is placed at the start of the next line before saving the profile. Once the profile line is saved, the gpr unit is ready to collect the next profile line. The gpr data are recorded on a 512 mb compact flash card and transferred to a lap-top computer at the end of the survey.

The gpr profiles were collected along 0.5 meter traverses beginning in the southwest corner or lower left hand corner of each grid unit or project area. The data were collected in the zigzag or bidirectional mode with the operator alternating the direction of travel for each traverse line. The gpr profiles were collected in the y direction. At Hardscrabble, a total of 41 radar profiles were collected across grid unit 4 oriented along the North or y traverse lines. The data folder containing the profile line data was transferred to the laptop computer via the 512 mb compact flash card used to record the data in the TerraSIRch SIR-3000. The profiles were consecutively labeled beginning with HARD____001 to HARD____041 with the dzt extension. The files were placed in the HARD file folder on the laptop computer before transfer to the HARD file folder on the desk personal computer. At Wish-ton-wish, a total of 131 radar profiles were collected along the 25 m long traverse lines with the lines oriented to the northwest. With one-half meter traverses in the parallel mode, it took approximately 25 minutes to complete a 20m by 20 m grid unit. The data folder containing the profile line data was transferred to the laptop computer via the 512 mb compact flash card used to record the data in the TerraSIRch SIR-3000. The profiles were consecutively labeled beginning with WISH____001 to WISH____131 with the dzt extension. The files were placed in the WISH file folder on the laptop computer before transfer to the WISH file folder on the desk personal computer.

Ground-penetrating surveys generally represent a trade-off between depth of detection and detail. Lower frequency antennae 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 hyperbola matching. Using one of the hyperbolas on a radargram profile (Goodman 2004:76), the velocity was calculated to be approximately 6.3 cm per 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 31.5 cm. With a 100 ns window open, the total depth displayed was approximately 3.15 meters; however, due to noise and signal attenuation, the ability of the radar to detect buried cultural and natural features extended to less than 1.5 meters.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

8. DATA PROCESSING AND INTERPRETATION

Processing of geophysical data requires care and understanding of the various strategies and alternatives (Kvamme 2001:365; Music 1995; Neubauer et al. 1996). Drs. Roger Walker and Lewis Somers (Geoscan Research 2003) provide strategies, alternatives, and case studies on the use of several processing routines commonly used with the Geoscan Research instruments in the GEOPLOT software manual. Dr. Kenneth Kvamme (2001:365) provides a series of common steps used in computer processing of geophysical data:

> ***Concatenation*** *of the data from individual survey grids into a single composite matrix;*
>
> ***Clipping and despiking*** *of extreme values (that may result, for example, from introduced pieces of iron in magnetic data);*
>
> ***Edge matching*** *of data values in adjacent grids through balancing of brightness and contrast (i.e., means and standard deviations);*
>
> ***Filterin****g to emphasize high-frequency changes and smooth statistical noise in the data;*
>
> ***Contrast enhancement*** *through saturation of high and low values or histogram modification; and*
>
> ***Interpolation*** *to improve image continuity and interpretation.*

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

Processing Magnetic Data

Due to the limited memory capacity and changes in the instrument setup of the Geoscan Research FM36 fluxgate gradiometer, the data were downloaded into a laptop computer after the surveying of four grid units at the Hardscrabble site. On the laptop computer, the GEOPLOT software was initialized and the download data routine was selected from the file menu (Geoscan Research 2003:4/1-29). The default input template was then selected. The selection of the gradiometer and FM36 were then made. The grid input template was displayed. For the gradiometer survey, the survey information was entered under the general category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 1). The next step required entering the grid name for downloading data from the FM36. In the grid name for downloading screen, the file name for the grid unit was entered into the laptop computer. The grid file contained the magnetic raw data obtained during the survey. The file name for the grid unit included the grid number and the letter “g” for the gradiometer survey type (i.e., 1g,2g, 3g,…,12g). The download instructions screen was displayed after the file names were checked for duplicate names in the laptop computer and entered into the laptop computer. The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The DUMP key on the FM36 keyboard was depressed and the download process was initiated. Downloading the magnetic data from a typical 40 m by 40 m survey area at 8 samples/m and 1.0 m traverses required approximately 26 minutes to complete the download process. The FM36 was then switched off and disconnected from the laptop computer. The grid files were reviewed in the shade plot display under the graphics menu in the Geoscan Research GEOPLOT processing software (Geoscan Research 2003) for data transfer or survey errors. If no data transfer errors were observed, a composite of the data file(s) was created for further data processing. Generally, while in the field, the composite file was processed with the zero mean traverse routine and viewed on the laptop computer before the memory in the gradiometer was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. Grids actually consist of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the magnetic data, the grid files from the survey must be combined into a composite file. To construct a composite file containing all of the grid files collected at a site, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2003:3/15-21). The master grid file names screen is displayed and the grid files are entered into the mesh template by the grid position in the overall survey of the site. The mesh template defines how the grids fit adjacent to one another within the surveyed area. The grid files are entered into the mesh cells according to their position beginning in the upper left hand corner of the surveyed area. For grids that are in the line of travel or traverse direction (X direction on the template), the grid names are placed from left to right in the mesh cells on the screen display. Grids that are perpendicular to the traverse direction (Y direction on the template) are placed from the top cell to the bottom cell of the mesh template. The GEOPLOT survey directions have the display the line of travel along the traverse on the X axis and the movement across the grid along the Y axis. This format is also followed for the creation of the composite file. Once the grid files have been placed in the correct position in the mesh template, the composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modifications as necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file name included the field acronym for the site (ulsg) and the letter "g" for the gradiometer survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite file for the magnetic data collected at the site, the data is viewed as the numeric data values or the graphic representation of the data (Geoscan Research 2003:5/2-3). In order to continue to analyze the data, the grid or composite files must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window with clip between a minimum value of -3, maximum value of 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Inspection of the background should show the data as bipolar and centered on zero. There should be a broad range in the archeological anomalies with weak anomalies less than 1 nT, typical 1 nT to 20 nT anomalies, strong anomalies greater than 20 nT. If the anomalies are weak then reset the clip plotting parameter to a minimum of -2, a maximum of 2, and units to absolute. Then one should identify weak and strong magnetic anomalies. The strong anomalies often represent modern intrusions into the site such as localized surface iron trash, wire fences, iron dumps, pipelines, and utility lines. Geological trends in the data set should also be identified. Since gradiometers provide inherent high pass filtering, broad scale geological trends are already removed from the data set. If such trends appear to exist, there may be changes in the topsoil thickness, natural depressions, igneous dikes or other geomorphological changes in the landscape. The final step prior to processing the data is to identify any defects in the data. These can range from periodic errors appearing as linear bands perpendicular to the traverse direction, slope errors appearing as shifts in the background between the first and last traverses, grid edge mismatches where discontinuities exist between grids, traverse striping consisting of alternating stripes in the traverse direction which most commonly occurs during zigzag or bi-directional surveys, and stager errors resulting in the displacement of a feature on alternate traverses (Geoscan Research 2003:Reference Card 3).

Initially, the spectrum function (Geoscan Research 2003:6/87-95) was applied to the data. The spectrum function provided analysis of the frequency spectrum of the data, splitting it into amplitude, phase, real, or imaginary components. The amplitude component was selected for the analysis to identify any periodic defects. These defects may have been the effects of cultivation (e.g., plow marks, ridge and furrow) or operator induced defects during data acquisition). It operated over the entire site data set. The spike tolerance was left in the default on position. This had the effect of reducing any broad spectral energy from noise spikes in the data set. No periodic defects were noted in the data set.

The magnetic data were “cleaned up” using the zero mean traverse algorithm (Geoscan Research 2003:6/107-115). This algorithm was used to set the background mean of each traverse within a grid to zero, which removed any stripping effects resulting from “scan to scan instrument and operator bias defects” (Jones and Maki 2002:16). It also was useful in removing grid edge discontinuities between multiple grids. The algorithm utilized the least mean square straight line fit and removal default setting on over the entire composite data set. The letter “z” was added to file name when the composite file was saved to indicate that the zero mean traverse routine had been applied to the data.

The statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire magnetic data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The magnetic data ranged from -199.86 to 211.61 nT with a mean of -0.127 nT and a standard deviation of 11.931 nT.

The data set is interpolated to produce a uniform and evenly spaced data matrix (Geoscan Research 2003:6/53-56). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is an 8 x 1 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinx/x or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements is first expanded using the sinx/x method and then using the linear method. This yields a 8 x 4 data matrix. In the X direction, the number of data measurements are shrunk using the sinx/x method. This yields a 4 x 4 matrix. The letter “i” was added to file name when the composite file was saved to indicate that the interpolation routine had been applied to the data.

The low pass filter was then used to remove high-frequency, small scale spatial details over the entire data set (Geoscan Research 2003:6/57-60). It was also used to smooth the data and to enhance larger weak anomalies. The function scanned the data set with a gaussian weighted, rectangular window set to the default values for the X radius of 1 unit and the Y radius of 1 unit. The letter "l" was added to file name when the composite file was saved to indicate that the low pass filter routine had been applied to the data.

The composite data files were then exported to separate xyz files for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2003:5/4-7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values were 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file names remained the same for all the files. The files were the exported to "expdata" folder in GEOPLOT. The files are then transferred to an appropriately named site folder in the SURFER 8 contouring and 3d surface mapping program's project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The open file command is selected to open the zero mean traverse, interpolate, and low pass filter processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/4** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/4** to provide the correct traverse interval position for the data. The value 440 was added to the East coordinate values and 500 was added to the North coordinate values in order to express the results into the mapped site coordinate system. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. Due to the large ranges of values, the data are also clipped to 20 for data values greater than 20 nT and to -20 for data values less than -20 nT. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 2002). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of lines field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For the present project, the data columns consist of 500 to 560 in the North or Y direction, 440 to 560 in the East or X direction with the X-spacing of 0.25 and the Y-spacing of 0.25. The Kriging gridding method was selected for processing the data. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The operation produces grids that contain more rounded lines in the contour display. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated. The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. The image map is created by selecting the image map operation from the map menu and opening the grid file. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a gradulated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another way to represent geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. Contour maps are useful in determining the strength of the magnetic anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the magnetic data collected at the Hardscrabble site (Figure 17).

Processing Ground Conductivity Data

The ground conductivity data were downloaded into a laptop computer after the completion of survey at each site. On the laptop computer, the DAT38RT software was initialized and the copy files from Polycorder 720 routine was selected from the menu (Geonics 1997:19-25). The default fast mode was selected for copying or downloading the data from the Polycorder to the laptop computer. The fast mode permits the rapid transfer of all data files in the Polycorder's dirfile directory. The dump program is selected on the Polycorder. The Polycorder parameters for communications with the laptop are set to a baud rate of 9600 with 8 data bits, no parity and the mating call equal to <CR>. At the ready prompt on the Polycorder, the Polycorder is driven by the laptop computer. Selecting the enter key on the laptop computer, the fast file copy from Polycorder 720 screen is displayed. The first prompt on the laptop computer asks for the Polycorder's file names. All is entered or the enter key is selected. The second prompt asks for the disk files in the Polycorder format. Two files are created for each site data file (i.e., the header file with H prefix plus file name and the data file with the D prefix plus file name). The third prompt identified the created file in DAT38 format. The Polycorder header and data files (i.e., the DL files) are converted into the DAT38 format with the file name and "g38" extension identifier). The serial port is set to com1. The copy files routine is selected from the menu on the laptop computer. The header file is transferred first followed by the data from each site file from the Polycorder to the laptop computer. Once the files have been transferred to the laptop computer, the next step is to create the data files. The enter data files routine is opened in the DAT38RT program (Geonics 1997:35-37). A list of entered survey files is displayed in the window. The DAT38 (*.g38) file is selected. The screen then displays the profile lines within the file (with Component/Mode/Orientation). Information including the measured component (i.e., conductivity phase), mode (i.e., vertical), and orientation (i.e., 1) are listed next to the line numbers. All of the lines in the file are selected by pressing <ENTER>. The final stage in the preparation of the data files for processing is the creation of the surfer XYZ (*.dat) files in ASCII format. The write file for contour package subroutine is selected from the main DAT38RT menu (Geonics 1997:62-65). The surfer format is selected for the format of the created file. A file name is given to the finished file. The dipoles mode, instrument orientation, component, and survey geometry fields are left in the default values of vertical, 1, conductivity, and arbitrary respectively. The create file command is selected from the submenu. Messages and prompts are provided to enter the beginning and ending X and Y coordinates for each line in the survey grid file. All of the X and Y coordinates with the corresponding conductivity measurements are written to the *.dat file. At the end of the line setup procedure, a window displays the created data file. It can be examined without leaving the program. The file is saved in the DAT38RT folder in the laptop computer. The line setup procedure is required for each grid data file. The *.dat files from the survey are then transferred to SURFER 8.

In SURFER 8 (Golden Software 2002), the data file created in DAT38RT is opened through the open routine in the file menu. The data are presented in the worksheet display. The worksheet contains the East (X) coordinate in the A column, the North (Y) coordinate in the B column, and the data value (Z) in C column. In order to process the data in GEOPLOT (Geoscan Research 2003), the data values must be arranged in ascending order by sorting the X and Y values. All three columns are selected. The sort routine in the data menu is selected and the sort parameters are set with the Column B set for sorting first in ascending order and Column A set for sorting second in ascending order. The data are checked for the correct number of entries based on the number of traverses covered in the survey and by the number of sample intervals per traverses. The conductivity data collected from Hardscrabble project contain 8,369 measurements taken over the 40 m by 40 m and 20 m by 20 m survey areas (sample interval of 0.25 meters or 80 readings along the North axis and traverse interval of 1.0 meter or 20 to 21 lines along the East axis of the individual grid unit). In order to import the data into GEOPLOT, one must make certain that the total number of data values equals the number of measurements taken in the grid unit. For the present survey, a total of 1,600 readings is needed in each grid unit data file (Note: The dummy value of 2047.5 is added at the correct spacing interval to complete the data matrix if needed.). The file is sorted in ascending order in with the X values sorted first and then the Y values sorted next to arrange the data in its correct orientation within the columns of the file's worksheet. The X and Y values are deleted from the file leaving the Z or data values. The data file is saved in SURFER 8 and then copied to GEOPLOT's impdata folder.

To process the data in GEOPLOT, the data is imported into GEOPLOT using the import data routine under the file menu. The default grid template is selected in the import data screen. The electromagnetic survey type is selected and the user defined category is selected as the instrument. The grid input template screen is displayed on the laptop computer. The ground conductivity survey information is entered under the general category, which contains the settings for the acquisition of the data and the instrumentation used to acquire the data (Table 2). The next step requires the entering of the grid name(s) for importing. The import data screen is displayed after the grid input template parameters are entered. In the import data screen, the import file format is set to Z. The import file parameters are set to top-left reference corner for the start of the grid data acquisition point and the import dummy value equals 2047.5. Unlike the X or East and Y or North directions in the original conductivity data, the X and Y directions in GEOPLOT are reversed with X representing the North direction and Y representing the East direction. Under the import file names, the drive is set to the d drive, the extension is set to the "dat" file extension type, and directory path is set to d:\geoplot\impdata. The correct data file is selected from the list of import file names. The imported grid file is saved to the correct sitename directory. The data file name for the grid unit included the grid number (i.e., 4, 13, 14, 15, and 16) and the letter "c" for the conductivity survey. A notification window indicates the successful completion of the import routine. The grid data set actually consists of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the conductivity data, the grid file from the site must be combined into a composite file. To construct a composite file, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2003:5/2). The master grid file names screen is displayed and the grid file names are entered into the mesh template in the correct location and orientation. The grid file is converted into a single composite. The composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template file is also saved for later modification if necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the file names included the grid unit number (i.e., 4, 13, 14, 15, and 16) and the letter "c" for the conductivity survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite file for the ground conductivity data collected at the Hardscrabble site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2003:5/2-3). In order to continue to analyze the data, the grid or composite file must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window to clip with minimum value of -3, maximum value or 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data is displayed in a shade plot or trace plot. The clip parameters are set to a minimum of -3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing conductivity data begins with the inspection of the data changes on the background signal. These data changes are superimposed on the local geology. There should be a broad range in the archeological anomalies with weak anomalies or archeological features having less than 5% change, typical anomalies with 5% to 20% change, and strong anomalies with greater than 20% change in conductivity values. The data are checked for noise spikes including low level spikes which create a noisy appearance in the data displays, and extremely high anomalous readings which may be as large as ±1000% about the mean. The large background, which underlies the archeology, may have a regional gradient that is dependent on the local geology, drainage, or topography. The regional gradient may change from virtually none to over 300% across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2003:Reference Card 2).

The statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire conductivity data set for each of the sites. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. The original data ranged from -95.34 to 120.60 mS/m with a mean of 29.642 mS/m and a standard deviation of 19.181 mS/m.

The conductivity data were “cleaned up” using the zero mean traverse algorithm (Geoscan Research 2003:6/107-115). This algorithm was used to set the background mean of each traverse within a grid to zero, which was useful in removing grid edge discontinuities between multiple grids. The algorithm utilized the least mean square straight line fit and removal default setting on over the entire composite data set. The letter “z” was added to file name when the composite file was saved to indicate that the zero mean traverse routine had been applied to the data.

The data set is interpolated to produce a uniform and evenly spaced data matrix (Geoscan Research 2003:6/53-56). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is a 4 x 1 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinX/X or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements is first expanded using the sinX/X method and then expanded a second time using the linear method. This yields a 4 x 4 data matrix. The letter “i” was added to file name when the composite file was saved to indicate that the interpolation routine had been applied to the data.

A high pass filter (Geoscan Research 2003:6/49-52) was used to remove the low frequency, large scale spatial detail (i.e., the slowly changing geological “background” response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the X radius and Y radius. The weighting uses the default gaussian setting.

The resulting data is bipolar with the mean centered on zero. The original mean may be restored by using the add function (Geoscan Research 2003:6/11-13). The letter “h” was added to file name when the composite file was saved to indicate that the high pass filter routine had been applied to the data.

The composite data were then exported to separate disk file in a data file format for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2003:5/4-7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension “dat” was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file names remained the same for all the files. The files were the exported to “expdata” folder in GEOPLOT. The files are then transferred to an appropriately named site folder in the SURFER 8 contouring and 3d surface mapping program’s project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The Open File command is selected to open the zero mean traverse, edge match, interpolate, high pass filter processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/4** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/4 t**o provide the correct traverse interval position for the high pass filtered data. A value of 520 was added to the North coordinate values and a value of 440 was added to the East coordinate values. The data are sorted, using the data sort command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing the dummy values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 2002). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of line field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. The data columns consist of 500 to 560 in the North or Y direction, 440 to 560 in the East or X direction with the X-spacing of 0.25 and the Y-spacing of 0.25. The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The spline smoothing operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name. Due to the presence of unsurveyed areas in the Hardscrabble conductivity survey, a blanking file was constructed and applied to the grid file. The blanking file contains the X and Y coordinates used to outline the blanked portion of the grid, as well as, the number of parameter points and whether the blanking operation is located on the interior of the parameter points or on the exterior of these points. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated. The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. Selecting the image map operation from the map menu and opening the grid file creates the image map. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. Contour maps are useful in determining the equal strength of the resistance anomalies as well as their shape and nature. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the ground conductivity data collected at the Hardscrabble site (Figure 18).

Processing Soil Resistivity Data

The soil resistance data were downloaded into a laptop computer after the completion of survey at each site. On the laptop computer, the GEOPLOT software was initialized and the download data routine was selected from the file menu (Geoscan Research 2003:4/1-4/27). The default input template was then selected. The selection of the resistance (instrument type) and RM15 (instrument) was made. The grid input template was displayed. For the resistance survey, the survey information was entered under the general category, which contained settings for the acquisition of the data and the instrumentation used to acquire the data (Table 3). The next step required entering the grid name(s) for downloading data from the RM15. In the grid names for downloading screen, the file name for the grid unit was entered into the laptop computer. The grid file contained the resistance raw data obtained during the survey. The file name for the grid unit included the grid unit number identifier followed by the letter “r” for the resistance survey type (i.e., 1r to 8r). The download instructions screen was displayed after the file name was checked for duplicate names in the laptop computer and entered into the laptop computer. The instrument was connected to the laptop computer via the RS323 serial port and serial cable, switched on, and after waiting approximately one second, the next step was initialized for downloading the data. The display indicated that the laptop computer was waiting for the data from the instrument. The DUMP key on the RM15 keyboard was depressed and the download process was implemented. Downloading the resistance data from a typical 20-m by 20-m grid unit at 2 samples/m and one-meter traverses required approximately 5 minutes to complete the download process. The RM15 was then switched off and disconnected from the laptop computer. The grid file was reviewed in the shade plot under the graphics menu in the Geoscan Research GEOPLOT processing software (Geoscan Research 2003) for data transfer or survey errors. If no data transfer errors were observed, the memory in the resistance meter was cleared. From this preliminary review of the collected data, the geophysical investigator could analyze his survey design and methodology and make appropriate survey decisions or modifications while still in the field. The grid data set actually consists of three files or parts: 1) the grid data file (*.dat), 2) the grid information file (*.grd), and 3) the grid statistics and histogram file (*.grs). The grid data and grid statistics are stored in binary format. The grid information is stored in ASCII (text) format.

In order to process the resistance data, the grid file from the site must be combined into a composite file. To construct a composite file, the master grid routine is selected from the file menu in GEOPLOT (Geoscan Research 2003:3/15-18). The master grid file names screen is displayed and the grid file name is entered into the mesh template. The grid data needs to be converted into a composite file. The composite file is generated by selecting the create composite button on the display screen. The master grid or mesh template is also saved as a file for later modification is necessary. The composite file is also named. Generally, the same prefix is given to both the mesh and composite files. For the present project, the composite file names included the field name for the site (i.e., wish) and the letter "r" for the resistance survey type. Like the grids, composites also consist of three files or parts: 1) the composite data file (*.cmp), 2) the composite information file (*.cmd), and 3) the composite statistics and histogram file (*.cms). The composite data and composite statistics are stored in binary format. The composite information is stored in ASCII (text) format. The mesh file (*.plm) contains a text file used to load several grids into memory at the same time.

After the creation of the composite file for the resistance data collected at the site, the data may be viewed either as the numeric data values or as a graphic representation of the data (Geoscan Research 2003:3/18-21). In order to continue to analyze the data, the grid or composite files must be opened. The open grid/composite command is selected under the file menu. The appropriate grid or composite data file is selected from the correct sitename folder. The default screen display is the shade plot. The shade plot is useful in highlighting subtle changes in the data set. The shade plot represents the data in a raster format with the data values assigned a color intensity for the rectangular area at each measurement station. Data may be presented as absolute numbers, in units of standard deviation, or as a percentage of the mean. Several color and monochrome palettes provide different visual enhancements of the data. Plotting parameters, data histogram, data statistics, processing history, scale and north arrow are provided in sidebars adjacent to the display screen. For the initial shade plot display, the parameter mode is set in the shade plot window to clip with minimum value of -3, maximum value or 3, contrast equal to 1, and units to standard deviation. Set to the normal position, the grey55.ptt shaded palette is selected to represent the changes in the data set. Trace plots of the data represent the data in a series of side by side line graphs, which are helpful in identifying extreme highs and lows in the data. The trace plots show location and magnitude. For the initial trace plot display, the parameter mode is set in the trace plot window to standard with a resolution of 0.5, units to standard deviation, view to front, 0% displacement in the X direction, and 0% expansion in the Y direction.

Up to this point, we have been collecting the data and preparing it for processing and analysis. Initially, the data are displayed in a shade plot or trace plot. The clip parameters are set to a minimum of -3 and a maximum of 3 with a contrast set to 1 and units in standard deviation (SD) for the shade plot. The trace plot is displayed utilizing the standard default parameters with a resolution of 0.1 SD and units set to SD. Processing resistance data from a single twin probe separation distance begins with the inspection of the data changes on the background signal. These data changes are superimposed on the local geology. There should be a broad range in the archeological anomalies with weak anomalies or archeological features having less than 5% change, typical anomalies with 5% to 20%

change, and strong anomalies with greater than 20% change in resistance values. The data are checked for noise spikes including low level spikes which create a noisy appearance in the data displays, and extremely high anomalous readings which may be as large as ±1000% about the mean. The large background, which underlies the archeology, may have a regional gradient that is dependent on the local geology, drainage, or topography. The regional gradient may change from virtually none to over 300% across large sites. Changes may also occur from differences in topsoil thickness, natural depressions, or other topographic conditions (Geoscan Research 2003:Reference Card 2).

Due to a recording glitch in the original data, the search and replace function (Geoscan 2003:6/85-86) was used to remove the erroneously recorded value of 204.7. It was replaced by the dummy value of 2047.5. This removed the high data values in unsurveyed areas of the partial grid units and adjacent to the concrete well cover. The letters “sr” were added to file name when the composite file was saved to indicate that the search and replace routine had been applied to the data.

The statistics function (Geoscan Research 2003:6/101-102) was then applied to the entire resistance data set. The mean, standard deviation, and variance were used to determine appropriate parameters for the subsequent processing steps. A total of 6,400 measurement readings were recorded with 3,119 readings representing the dummy value of 2047.5. The large number of dummy values resulted from the filling of the empty portions of the partial grids with those values. The resistance data ranged from -23.1 to 200.65 ohms with a mean of 22.087 ohms and a standard deviation of 15.866 ohms. The negative value resulted from recordation of faulty values resulting from contact placement errors. This type of erroneous reading occurs when the probe makes temporary contact with a rock such as a foundation stone or concrete.

The noise spikes are removed with the despike function (Geoscan Research 2003:6/35-39). The function locates and removes random, spurious measurements present in the resistance data. The despike parameters are left in the default settings with both the x radius and y radius set to 1, the threshold set to 3.0 standard deviations, and the spike replacement set to the mean. The mean indicates that the noise spike value will be replaced by the window mean value obtained from the surrounding values. The letter “d” was added to file name when the composite file was saved to indicate that the dispiking routine had been applied to the data.

The data set is interpolated to produce a uniform and evenly spaced data matrix (Geoscan Research 2003:6/53-56). Increasing or decreasing the number of data measurements creates a smoother appearance to the data. The original matrix is a 2 x 1 matrix. The interpolate function requires three parameters: direction, interpolation mode and interpolation method. Method may be either sinx/x or linear and the mode is either expand or shrink. In the Y direction, the number of data measurements is expanded using the sinx/x method. This yields a 2 x 2 data matrix. The letter “i” was added to file name when the composite file was saved to indicate that the interpolation routine had been applied to the data.

A high pass filter (Geoscan Research 2003:6/4952) was used to remove the low frequency, large scale spatial detail (i.e., the slowly changing geological "background" response). This is generally used to increase small feature visibility; however, one must be careful since broad features could be removed. The parameters are left in their default settings of 10 for the x radius and y radius. the weighting uses the default gaussian setting. The resulting data is bipolar with the mean centered around zero. The original mean may be restored by using the add function (Geoscan Research 2003:6/11-13). The letter "h" was added to file name when the composite file was saved to indicate that the high pass filter routine had been applied to the data.

The composite data file was then exported to separate disk file in a different file format for use in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). The export batch data routine was selected under the file menu in GEOPLOT (Geoscan Research 2003:5/4-5/7). The export parameters for exported files were set to XYZ-CommaSV (comma separated variables) with the top-left reference corner identifying where the origin point of the X and Y coordinates was located. The X and Y reference coordinates identified the initial starting point in the export data set. The default values are 0,0. The X and Y increment entries identified the sample and traverse intervals of the loaded data set with default values of 1. The export file extension "dat" was selected since it is the extension that SURFER 8 readily recognizes as a data file. The file name remained the same for the data file. The file was the exported to "expdata" folder in GEOPLOT. The file was then transferred to an appropriately named site folder in the SURFER 8 contouring and 3d surface mapping program's project folder (Golden Software 2002).

In SURFER 8 (Golden Software 2002), the initial step is to view the *.dat file. The open file command is selected to open the low pass filter and zero mean traverse processed file found in the sitename folder under the SURFER 8 projects folder. The data is displayed in a worksheet format with the North (Y) coordinated listed in Column A, the East (X) coordinates in Column B, and the data in Column C. Since the X and Y coordinate data from the export function in GEOPLOT are listed in sequential integer values, the North and East coordinate values are corrected to the correct sample interval and traverse interval through the data transform routine. The North coordinate (Column A) is corrected by the formula **A=A/2** to provide the correct sample interval position for the data. The East coordinate (Column B) is corrected by the formula **B=B/2** to provide the correct traverse interval position for the data. The data are sorted, using the DATA SORT command, to check for GEOPLOT dummy values (i.e., 2047.5). The rows of data containing these values are deleted from the file. The data is saved as a new file containing the corrections.

In order to present the data in the various display formats (e.g., contour maps, image maps, shaded relief maps, wireframes, or surfaces), a grid must be generated (Golden Software 2002). The grid represents a regular, rectangular array or matrix. Gridding methods produce a rectangular matrix of data values from regularly spaced or irregularly spaced XYZ data. The grid data command is used to set the parameters of the grid. The data columns are identified. Column A is identified as the Y coordinate and Column B is identified as the X coordinate. The data values (Z coordinate) are found in Column C. The gird geometry is then defined. The minimum and maximum values for the X and Y coordinates are defined. These values represent the beginning and ending coordinates of the surveyed geophysical grid. The sample interval and traverse spacing are defined in the distance between data units under spacing. The # of lines field provides the number of lines in the X and Y directions. The number of lines should correlate with the number of traverses and samples per traverse. For Site 23SL1222, the data columns consist of 0 to 25 in the North or Y direction, 0 to 65 in the East or X direction with the X-spacing of 0.5 and the Y-spacing of 0.5. The Kriging gridding method was selected for processing the data for the two sites. The Kriging method is very flexible and provides visually appealing displays from irregularly spaced data. The Kriging variogram components are left in the default values. The default linear variogram produces a reasonable grid in most circumstances. The grid file (*.grd) is created and named with the same prefix as the data file (*.dat). The next step in the formation of the visual display of the data from the site is to apply the spline smoothing operation to the grid file. The spline smoothing operation produces grids that contain more round shapes on the displays. The default settings for the node method and the number of nodes to insert between the rows and columns of data points are used for this operation. The resulting grid is saved under the same name.

At this point in the process, maps of the data may finally be generated (Golden Software 2002). Typically for geophysical surveys, contour maps, image maps, shaded relief maps, and wireframes may be generated. The image map is a rastor representation of the grid data. Each pixel or cell on the map represents a geophysical data value. Different color values are assigned to ranges of data values. Selecting the image map operation from the map menu and opening the grid file creates the image map. The image map is generated. The map may be edited. The color scale is set with the minimum value assigned the color white and the maximum value assigned the color black. The scale is a graduated scale flowing from white through several shades of gray to black. SURFER 8 has a several predefined color scales including the rainbow scale which is often used for the presentation of geophysical data or the investigator may create an color spectrum suitable for the project data. To complete the image map, descriptive text is added along with a direction arrow, a color scale bar, and map scale bar. Another useful means of displaying the geophysical data is with contour maps. Contour maps provide two dimensional representations of three dimensional data (XYZ). The North (Y) and East (X) coordinates represent the location of the data value (Z). Lines or contours represent the locations of equal value data. The distance or spacing between the lines represents the relative slope of the geophysical data surface. To create a contour map, the new contour map operation is opened under the contour map routine in the map menu. The grid file is selected and the contour map is generated. The contour map may be modified by changing the mapping level values in the levels page of the contour map properties dialog controls. Contour levels can be added or subtracted to the display. The line style, fill colors and hachure shape can be changed. Labeling may also be changed. As with the image maps, descriptive text, including information on the contour interval is added along with a direction arrow and map scale bar. If color fill is used, a color bar is also added. The various types of maps can be overlain on one another and different types of data can be illustrated by stacking the displays within a single illustration. Both the image and contour maps were generated for the soil resistance data collected at the Wish-ton-wish site (Figure 19).

Processing Vertical Electrical Sounding Data

The field measurements were then averaged for each probe spacing along the two offset directions. The resulting average resistance value was used to calculate the resulting apparent resistivity using the formula: $\boldsymbol{\rho_a = 2\pi ar}$, where $\boldsymbol{\rho_a}$ is the apparent resistivity, **a** is the electrode spacing, and **r** is the measured resistance at each electrode separation. The probe spacing and apparent resistivity values were entered into the spreadsheet in the IX1D modeling software package (Interplex 2002). The first step in the IX1D program was to create a new sounding file by selecting the dc resistivity sounding popup under sounding under new under file menu. The Wenner Array was selected under the array type in the new sounding parameters window with apparent resistivity data selected under the type of data. Clicking on the OK button at the bottom of the window opened the apparent resistivity entry/edit menu window. The entry window contained header information fields for the data set name, the Easting coordinate, the Northing coordinate, the elevation, and azimuth angle in degrees where zero is North. The spreadsheet beneath the header information fields contains the identification number for the probe spacing, the probe spacing value, and the apparent resistivity value. These values were entered form the processed data in the field notebook (Table 4). The OK button at the bottom of the screen was selected. The resulting apparent resistivity values in ohm-meters (Sheriff 1973:156) were plotted by electrode spacing. Under the calculate menu, the estimated layered model routine was selected. The forward model of the data was carried out using a 283 point adaptive linear filter (Anderson 1979; Davis et al. 1980). The model used the probe spacings data and the apparent resistivity to generate a synthetic response. A five layer model was created for the Hardscrabble site and a four layer model was created for the Wish-ton-wish site for the approximate subsurface electrical layering (Table 5). The graphic file and the data (Table 5) were saved as an IX1D binary file under the file name “hard.IXR” for the VES data collected at the Hardscrabble site (Figure 20) and “wish.IXR” for the VES data collected at the Wish-ton-wish site (Figure 21). The calculated model values were then hand-transferred to the GRAPHER 5 worksheet for the display of the electrical stratification plot (Golden Software 2003).

In GRAPHER 5, the model data is entered into a new worksheet under the file menu (Golden Software 2003:35-71). The worksheet is saved as a dat file. The next step is to create a 2D line graph under the graph menu in GRAPHER 5 (Golden Software 2003:73-90). The line plot type is selected in the select plot type window under the graph wizard button. The data columns used for the X and Y axis are identified. The depth below the surface is on the Y-axis and the resistivity value is located on the X-axis. Using this ling graph, an electrical stratigraphic block diagram is created by inserting rectangles in the data ranges. The rectangles are subsequently filled and labeled with the appropriate ohm-meter value from the model for the final presentation (Golden Software 2003:127-224).

Processing Ground-penetrating Radar Data

The gpr radargram profile line data is imported into GPR-SLICE (Goodman 2004) for processing. The first step in GPR-SLICE is to create a new survey name in the files menu. The 16-bit GSSI radargrams are converted to 8-bit data for further processing under the filter menu. During the conversion process, the signal may be enhanced by applying gain to the radargrams. Once the conversion process is completed, the next step is to create the info file for the project. The number of profiles are entered (i.e., at Hardscrabble, Site 23SL1223: 41 profiles collected at 0.5 meter traverses and at Wish-ton-wish, Site 23SL1222: 131 profiles collected at 0.5 m traverses), along with the file identifier name, .dzt for GSSI radargrams, the profile naming increment of 1, the first radargram name (generally this is 1), the number of scans per meter (these profiles were collected at 50 scans per meter), the grid direction is set to the y-direction, unit per markers set to 1, a 100 ns time window, and 512 scans per sample (Table 6). Selecting the create info file button completes the information file for the project. Since the radargrams were collected in the zig-zag mode, every even numbered line needed to be reversed. The next step is to insert locational markers into the resample radargrams. The GSSI SIR 3000 and the artificial markers button are selected to apply markers based on the total number of scans in the radargram. The show markers button allows one to view an example of a radargram with the artificial markers in place. The next step is to create the time slices of the 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 set to 20 slices. The slice thickness is set to 50 (.77 ns) to allow for adequate overlap between the slices. The offset value on the radargram where the first ground reflection occurs is viewed in the search 0 ns subroutine. This value is used to identify the first radargram sample at the ground surface. The end sample is 512. The offset value in entered in the samples to 0 ns box. The cut parameter is set to square amplitude with the cuts per mark set to 2. The slice/resample button is selected for processing the radargrams. The final step in the slice menu is to create the XYZ data file. The grid menu is entered next in the processing steps. The beginning and ending values for the x and y coordinates are entered. The grid cell size is set to 0.1 with an x search radius of 0.9 and a y search radius of 0.9. The blanking radius is set to 0.45, the data type is regular, the number of grids equal 20 for the number of slices, and the starting grid number is 1. The Kriging algorithm is utilized to estimate the interpolated data. The covariance and sill are set to 1.2 with the nugget set to 0.2 and a smoothing factor of 1.4. The start gridding button is selected and the gridded dataset is created. A low pass filter may be applied to the combined dataset to smooth noisy time slices in this menu. At this point, one may view the time sliced radar data in the pixel map menu. Figure 22 illustrates the time slices for the ground-penetrating radar data from grid unit 4 at the Hardscrabble site. Figure 23 illustrates the time slices for the ground-penetrating radar data from the Wish-ton-wish site. The gain may be readjusted for any time slice. This is done in the transforms submenu. The interpolations value is set to 5 and the interpolate grids routine is selected. The new interpolated grids are all normalized. The next step is to create the 3D dataset in the grid menu. The number of grids is now equal to 95 ((20-1)*5). The 3D database is created under the create 3D file routine. The 3D data may be displayed as a series of z slices in the creation of a 3D cube with a bitmap output for animating the 3D cube.

The slice option provides the means to specify the number and type of plots either in time slices or depth slices. Times slices are generally used since gpr systems record the time for the radar or radio waves to travel to a target and return to the gpr unit. Depth has to be calculated before it can be used. Depth depends on the velocity of the wave to the target and back. Depth is determined by the following equation: **D = V x T/2** where **D** is depth (meters), **V** is velocity (meters/nanosecond), and **T** is the two-way travel time (nanoseconds). Velocity of the radar wave is determined by the dielectric permittivity of the material (Conyers and Goodman 1997:31-35; Sheriff 1973:51). Other physical parameters that affect the transmission of the radar wave include the magnetic permeability and electrical conductivity of the material. Increases or decreases in these parameters may increase the velocity, slow it down, or attenuate it so there is no reflected signal. In most heterogeneous soils, the various soil layers have differing affects on the velocity of the radar wave. The velocity may be estimated using velocity charts of common materials (GSSI 2003a:49-50) or by identifying reflections in gpr profiles caused by buried objects, artifacts, or stratigraphic soil/sediment layers (Conyers and Goodman 1997:107-135). The depth used in this report was calculated using a value of ca. 0.063 m/ns, which was determined by fitting a hyperbola to radargram reflections in the search submenu in the filtering menu in GPR-SLICE (Goodman 2004:73). The software determines the velocity and the relative dielectric constant for the hyperbola fit. With the time window set to 100 ns which represents two-way travel time, the maximum depth (i.e., indicated by 50 ns) recorded was approximately three meters; however, the relative depth of archeological targets of interest was limited to the upper 1.5 m..

The data were also imported into the GSSI RADAN software (GSSI 2003b) for processing. The software allowed both radargram profile and plan-view (time slice) presentation of the data. Initially, a file containing the radargram profile line data was created in the source directory and an output directory was also selected. A few radargram profile line files were opened for evaluation of the data. The next step was to create a 3D project file in RADAN (GSSI 2003c:13). The grid dimensions from the survey were entered into the RADAN software, including the X/Y directions, the starting coordinates, the X and Y lengths, the number of profile lines, the line spacing, and the line order. The auto load files box was selected and the individual profile lines were combined into one continuous profile line file. The 3D cube button was then selected to run the project. The first step was to set the surface position to time zero at the top of the scan at the point where the ground coupling of the signal occurred. The selected 0-postion will give a more accurate depth calculation. Once the program runs through the entire file, the position setting in the header must also be changed to zero. The second processing step was to removal background noise from the profiles. The FIR filter routine was selected and run over the data. The final step in general processing was to run the migration procedure over the data set. This reduced or eliminated hyperbolic diffraction patterns by taking out the tails of the hyperbolas to more accurately represent the shape and location of the target. The final step was to image the 3D file. The 3D project can be viewed on multiple axes. The Z direction provides time/depth sliced of the profile data. X and Y direction slicing gives profile line views. Multiple axes can be set to display fence displays and cutout cubes. The views can be saved as screen views or as comma delimited files for display in SURFER 8. Figure 24 illustrates the ground-penetrating radar data from the time slice layer from 10 to 20 ns collected in grid unit 4 at the Hardscrabble site. The data from three time slice layers (i.e., from 0 to 10 ns, from 10 to 20 ns, and from 20 to 30 ns) at the Wish-ton-wish site were selected for exporting as comma delimited files for further processing and display in SURFER 8 (Figure 25 to 27).

Interpretation-Magnetic Data

Interpretation of the magnetic data (Bevan 1998:24) from the project requires a description of the buried archeological feature of object (e.g., its material, shape, depth, size, and orientation). The magnetic anomaly represents a local disturbance in the earth's magnetic field caused by a local change in the magnetic contract between buried archeological features, objects, and the surrounding soil matrix. Local increases or decreases over a very broad uniform magnetic surface would exhibit locally positive or negative anomalies (Breiner 1973:17). Magnetic anomalies tend to be highly variable in shape and amplitude. They are generally asymmetrical in nature due to the combined affects from several sources. To complicate matters further, a given anomaly may be produced from an infinite number of possible sources. Depth between the magnetometer and the magnetic source material also affect the shape of the apparent anomaly (Breiner 1973:18). As the distance between the magnetic sensor on the magnetometer and the source material increases, the expression of the anomaly becomes broader. Anomaly shape and amplitude are also affected by the relative amounts of permanent and induced magnetization, the direction of the magnetic field, and the amount of magnetic minerals (e.g., magnetite) present in the source compared to the adjacent soil matrix. The shape (e.g., narrow or broad) and orientation of the source material also affects the anomaly signature. Anomalies are often identified in terms of various arrays of dipoles or monopoles (Breiner 1973:18-19). A magnetic object in made of magnetic poles (North or positive and South or negative). A simple dipole anomaly contains the pair of opposite poles that relatively close together. A monopole anomaly is simply one end of a dipole anomaly and may be either positive or negative depending on the orientation of the object. A linear anomaly is a series of closely connected dipoles. The depth and mass of the archeological object can be estimated by the half-width rule procedure (Bevan 1998:23-24; Breiner 1973:31; Hinze 1990; Milsom 2003:67-70; Telford et al. 1990:87). These measurements represent an approximation of the object's size and depth. It is likely such measurements are too large rather than too small, since the model used in the analysis of the anomalies is based on a compact spherical object made of iron.

Due to the large number of anomalies at the Hardscrabble site, no depth or mass values were calculated for the magnetic anomalies at the Hardscrabble site.

The most noticeable in the magnetic data set from the Hardscrabble site are the two linear anomalies (Figure 28). A very strong linear anomaly occurs across the southeastern quadrant of the geophysical survey grid. It extends from N520/E527 to N519/E560. The anomaly is probably a buried sewer line. The outlet for the line is located along the road ditch to the south of the grid. A second linear anomaly extends through the northwest corner of the magnetic survey area. It enters the survey grid at N539/E480 and exits at N560/E510. The anomaly may represent an unknown buried utility line or the remnants of a buried fence line. The anomaly corresponds to the conductivity anomaly in the four adjacent grid units to the west. A roughly triangular area in the center of the magnetic survey area contains numerous dipole and monopole magnetic anomalies. A few are very strong suggesting highly magnetic material, which is presumed to be historic iron/steel artifacts. The rest of the magnetic anomalies are relatively moderate in strength, which also suggests that these anomalies are caused by smaller magnetic materials, including bricks and small iron/steel artifacts (e.g., nails, screws, bolts and nuts, metal strap fragments, building materials, etc.). Several of the extremely strong magnetic anomalies are located in the area of the depression.

Interpretation-Ground Conductivity Data

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

The conductivity data from the Hardscrabble site revealed a buried fence line or utility line in the western portion of the geophysical survey area in grid units 13 to 16 (Figure 29). This linear conductivity anomaly matches up with the magnetic anomaly noted in the adjacent in the adjacent grid units (Figure 28). The linear anomaly consists of a negative value conductivity low surrounded by conductivity highs. The negative values are the results of the over saturation of the receiving coil on the conductivity meter. The magnitude of the signal did not allow for the receiving coil to obtain reset itself before taking the next measurement. This is a common occurrence in a setting where conductive metals are present such as the buried woven fence wire. The negative dipole conductivity anomalies in other portions of the survey grid appear to represent historic or modern iron/steel artifacts or materials. Grid unit 4 contains numerous conductivity dipole anomalies which may represent historic metallic trash associated with the Hardscrabble residence.

DATA PROCESSING AND INTERPRETATION

Interpretation-Soil Resistance Data

Interpretation of the resistivity data results in the identification of lateral changes in the soil. Since the array parameters are kept constant through out the survey, the depth of penetration varies with changes in the subsurface layers. For each probe separation, the depth penetration is approximately the same as the distance between the current and potential probe for each separation distance. The resistance reading for each separation distance represents the average value for the hemispheric volume of soil with the same radius. If the soil below the survey area was uniform, the resistivity would be constant throughout the area. Resistances of the increasing volumes reflected by the increasing probe separation distances will change, but it is the resistivity, which takes into account the changing depths, remains approximately the same. Changes in soil characteristics (e.g., texture, structure, moisture, compactness, etc.) cause small and large areas to have different resistivities. Large general trends reflect changes in the site's geology whereas small changes may reflect archeological features.

The stone foundation of the Wish-ton-wish residence is indicated by extremely high resistance values between E25 and E47 and N5 and N18 (Figure 30). Several foundation stones are visible on the surface of the mound of earth representing the location of the residence. The geophysical data indicate that the foundation is no longer continuous, but they do suggest the length and width of the residence along with the partially complete outline of the end room on the southeast corner. The residence foundation measures approximately 18 m (60 ft) by 7 m (23 ft). In addition to the foundation outline, isolated resistance highs along the southeastern portion of the southern foundation wall and outside the center of the northern foundation suggest the placement of foundation footer stones for the attached porches on the house. The porch footers extend out approximately one (3 ft) to two (7 ft) meters from the foundation wall. The covered well is located eight (26 ft) meters northwest of the west side of the residence foundation. East of the residence foundation, there is an extremely compacted area, measuring five meters by five meters (16 ft x 16 ft) or 25 m^2 (270 square ft). This area may be the location of an associated outbuilding. A slightly high linear resistance anomaly curves around the foundation and stops at the compacted area east of the residence. This linear anomaly is interpreted as a lane passing around the residence to the outbuilding. It also passes between the well and the west side of the residence. It ranges from 1 to 1.5 meters in width. There is no surface indication of the lane. One other noticeable anomaly is located in the southeast corner of the survey grid. It represents a quarter of the ostrich nest located in the ostrich pen. The nest is approximately 4 m in diameter and approximately 0.25 meters deep at the center.

Interpretation-Vertical Electrical Sounding

The results of the modeling of the vertical electrical sounding data from the Hardscrabble site suggest a five-layer curve for the electrical stratification (Figure 31). The model indicates that the upper 0.035 meters have an apparent resistivity of 7.97 ohm-meters, the second 0.014 m thick layer measures 20.83 ohm-meters, the third 0.18 meter thick layer measures 121.4 ohm-meters, the fourth 3.27 meter thick layer measures 4.60 ohm-meters, and the bottom layer measures 0.31 ohm-meters. This model suggests a highly conductive clayey soil in the upper 40 cms (Bevan 1998:8; McNiel 1980a:16; Telford et al. 1990:289-291). This is underlain with a less conductive loamy soil layer measuring approximately 18 cms in thickness. An extremely highly conductive soil is under the loamy soil layer. The very conductive values in the clayey layers suggest that ground-penetrating radar may have problems with wave attenuation in this area due to the relatively high clay content of the soil. Using this as a basis for antenna selection, a 400 mHz antenna may provide adequate depth penetration from 1.5 to 2.0 meters and better resolution than antennas with low frequencies.

The results of the modeling of the vertical electrical sounding data from the Wish-ton-wish site suggest a four-layer curve for the electrical stratification (Figure 32). The model indicates that the upper 0.06 meters have an apparent resistivity of 31.62 ohm-meters, the second 0.26 m thick layer measures 47.18 ohm-meters, the third 4.4 meter thick layer measures 4.42 ohm-meters, and the bottom measures 9.11 ohm-meters. This model suggests a highly conductive clayey soil in the upper 6 cms (Bevan 1998:8; McNiel 1980a:16; Telford et al. 1990:289-291). This is underlain with a less conductive silty soil layer measuring approximately 26 cms in thickness. An extremely highly conductive soil is under the silty soil layer. The very conductive values in the clayey layers suggest that ground-penetrating radar may have problems with wave attenuation in this area due to the relatively high clay content of the soil. Using this as a basis for antenna selection, a 400 mHz antenna may provide adequate depth penetration from 1.5 to 2.0 meters and better resolution than antennas with low frequencies.

Interpretation-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. Constructing the time slices for the geophysical survey area provides another way of looking at the gpr profile data. The time slices may also be combined to form 3D cubes of the gpr data. In the 20 slices constructed in GPR-SLICE (Goodman 2004; Goodman et al. 1995), the slices provide a planar view of the data at 9.8 ns intervals with an overlap of 4.7 ns.

The gpr time slice data from the Hardscrabble site indicates the presence of numerous moderately high reflections throughout grid unit 4 (Figure 33); however, there does not seem to be any recognizable pattern to these gpr amplitude anomalies. The data suggest the presence of a culturally disturbed area, which corresponds to the disturbed areas identified in the magnetic and conductivity data sets. There is one relatively strong amplitude anomaly centered near N525/E511.5. This anomaly extends through the entire set of time slice layers but is the strongest in the upper 30 ns or 1.89 meters. It is roughly circular in diameter suggesting that the anomaly may represent a well or possible privy. It is located approximately five meters northwest of the northwest corner of the rectangular depression located in grid unit 7.

The composite time slice data from 0 to 30 ns at the Wish-ton-wish site provides complementary data to the resistance data (Figure 34). The stone foundation is indicated by higher amplitude values. The well, possible two-track farm lane, the compacted area related to a possible out building location, and ostrich nest are also suggested by slightly higher amplitude values. A high amplitude circular area centered at N4/E28 represents the area currently used to feed hay to the aoudads. The area is approximately six meters in diameter. During the survey, a substantial amount of uneaten hay was present on the ground along with the heavy metal feeding rack.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

9. CONCLUSIONS AND RECOMMENDATIONS

During the week of April 12th to the 16th of 2004, the Midwest Archeological Center staff conducted geophysical investigations at the two residences associated with Ulysses S. Grant and his family during their stay in St. Louis, Missouri in the 1850 and later during his presidency. The Hardscrabble residence, Site 23SL1223, was a dogtrot style log cabin constructed by Grant in 1856. The cabin was located on land given to Ulysses and Julia Grant by Julia's father. Today the location of the cabin is in a grassy area at the St. Paul Churchyard cemetery. The Wish-ton-wish residence, Site 23SL1222, was a stone residence built by Julia's brother, Lewis Dent. The Grants stayed at the Wish-ton-wish residence between 1855 and 1856. They also used the residence during the presidency of Ulysses S. Grant as a retreat on their visits to her family in St. Louis. The Wish-ton-wish residence is located in the southern portion of Deer Park on the Grant Farm wildlife reserve in St. Louis County, Missouri. The project was conducted as part of the recommendations in the archeological overview and assessment of the Ulysses S. Grant National Historic Site. During the investigations, 6,400 square meters were surveyed at Site 23SL1223 with the Geoscan Research FM36 fluxgate gradiometer, the Geonics EM38 ground conductivity meter and the Geophysical Survey System Inc's TerraSIRch SIR-3000 ground-penetrating radar with a 400 mHz antenna. At Site 23SL1222, 1,625 square meters were surveyed in the aoudad and ostrich pens on Grant's Farm with the Geoscan RM15 resistance meter and PA5 twin probe array and the Geophysical Survey System Inc's TerraSIRch SIR-3000 ground-penetrating radar with a 400 mHz antenna.

The magnetic, ground conductivity, and ground-penetrating radar data collected at the Hardscrabble site provide information of the physical properties (i.e., magnetic, and conductance, and ground-penetrating radar reflections) of the subsurface materials. Numerous small scale magnetic, conductivity, and ground-penetrating radar anomalies are identified in the three data sets. Two linear anomalies are associated with buried fences or underground utility/sewer lines. A triangular concentration of magnetic anomalies in the center of the survey grid suggest the location of the Hardscrabble residence and area of cultural disturbance associated with discard of iron artifacts during the occupation of the residence by the Grant family and subsequent tenants and owners. A shallow depression within the southeastern portion of the geophysical survey area may represent the location of the cabin. The interpretation of the conductivity data also supports the magnetic data interpretations. The negative conductivity anomalies correspond to strong magnetic anomalies indicating that they are composed of iron or steel in grid unit 4. The ground-penetrating radar data from grid unit 4 also suggests the location of a well or privy.

The resistance and ground-penetrating radar data collected at the Wish-ton-wish site provided information on the physical properties (i.e., resistance and ground-penetrating radar reflections). Although earthen mound and numerous limestone foundation blocks were visible on the surface, both data sets provided complementary information of the location, composition, and integrity of the subsurface Wish-ton-wish stone foundation. In addition, the two data sets provided information on the location of a two-track farm lane and a possible out building associated with the residence. Modern intrusions associated with the aoudads and ostriches were also noted in the geophysical data sets.

While these techniques represent extremely valuable methodologies for the initial investigation of the Grant residences, an excavation strategy needs to be developed to verify the identified anomalies. The question could be raised that the use of traditional excavation methods would have been more productive. It is true that the excavations would have allowed a better view of the subsurface materials; however, the amount of time and costs in labor and analysis to conduct such excavations would be substantially higher to cover the same area investigated with the geophysical techniques. With an estimated cost of $3,000.00 per cubic meter of excavation, only one excavation unit could have been placed on the two sites. The chances of placing one excavation over the top of a significant archeological resource would be extremely low. It would still not provide information on the extent of the sites. The geophysical techniques provide virtually 100% coverage of the area under investigation with substantial information on the extent and integrity of the archeological resources. Using the baseline geophysical data, evaluative excavations can be better targeted than through traditional shovel testing and other excavation methods. This allows for better coordination of labor and funds for the evaluation of the National Register of Historic Places status of the site in question. Preliminary shovel, auger, or posthole testing of a site may provide an indication of the artifact concentrations but given the wide spacings generally used and the limited area that is opened to investigation, it is highly possible that major archeological resources would be missed.

This report has provided an analysis of the geophysical data collected during four days at the two residential sites in St. Louis County, Missouri. Both sites contain a high degree of integrity based on the analysis of the geophysical data. Locally significant, both sites are recommended as eligible for inclusion on the National Register of Historic Places under Criterion A for the sites association with the development of agriculture in the mid-1800s, Criterion B for the sites association with Ulysses S. Grant, and Criterion D for the archeological information the sites have yielded and are likely to yield about the history of the Dent and Grant families in 19th Century St. Louis County, Missouri.

Finally, refinement of the archeological and geophysical interpretation of the survey data is dependent on the feedback of the archeological investigations following geophysical survey (David 1995:30). Should additional archeological investigations occur at the sites investigated during this project, the project archeologist is encouraged to share additional survey and excavation data with the geophysical investigators for incorporation into the investigators' accumulated experiences with archeological and geophysical investigations. 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.

TWO RESIDENCES ASSOCIATED WITH ULYSSES S. GRANT

REFERENCES CITED

Aitken, M. J.
1961 *Physics and Archaeology*. Interscience Publishers, New York.

1974 *Physics and Archaeology*. 2nd Edition. Clarendon Press, Oxford.

Anderson, Kenneth B.
1979 *Geological Map of Missouri*. Department of Natural Resources, Jefferson City, Missouri.

Anderson, Walter L.
1989 A Hybrid Fast Hankel Transform Algorithm for Electrical Modeling. *Geophysics* 54(2):263-266.

Benchley, Elizabeth
1976 *An Overview of the Prehistoric Resources of the Metropolitan St. Louis Area*. Cultural Resources Management Studies, National Park Service, Washington, D.C.

Benham, Ken E.
1982 *Soil Survey of St. Louis County and St. Louis City, Missouri* U. S. Government Printing Office, Washington, D.C.

Bevan, Bruce W.
1977 Ground-Penetrating Radar at Valley Forge. Ms. on file, Midwest Archeological Center, Lincoln.

1991 The Search for Graves. *Geophysics* 56(9):1310-1319.

1983 Electromagnetics for Mapping Buried Features. *Journal of Field Archaeology* 10(1):47-54.

1998 *Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration*. Special Report No. 1. Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

2000 *The Pole-Pole Resistivity Array Compared to the Twin Electrode Array*. Technical Report No. 6. Geosight, Weems, Virginia.

Bevan, Bruce W., and J. Kenyon
1975 Ground-Penetrating Radar for Historical Archaeology. *MASCA Newsletter* 11(2): 2-7.

Braun, E. Lucy
1938 Deciduous Forest Climaxes. *Ecology* 19:515-522.

Breiner, Sheldon
1973 *Applications Manual for Portable Magnetometers*. GeoMetrics, Sunnyvale, California.

Browman, David L.
1980 *Cultural Resources Survey of Stupp Memorial Gardens Tower Grove Park, St. Louis City, Missouri*. Land Clearance and Redevelopment Authority, St. Louis, Missouri.

Browman David L., Darwin Horn, and Niki R. Clark
1977 *Interim Report on the Archaeological Survey of Construction Areas in Carondelet, O'Fallon, and Sherman Park, City of St. Louis, Missouri*. Land Clearance and Redevelopment Authority, St. Louis, Missouri.

Brown, David E., Frank Reichenbacher, and Susan E. Franson
1998 *A Classification of North American Biotic Communities*. The University of Utah, Salt Lake City, Utah.

Buchanan, Alan C.
1980 *Mussels (Naiades) of the Meramec River Basin*. Aquatic Series No. 1. Missouri Department of Conservation, Jefferson City.

Burger, H. Robert
1992 *Exploration Geophysics of the Shallow Subsurface*. Prentice Hall PTR, Englewood Cliffs, New Jersey.

Butler, Mark S. (editor)
1999 *RESIX Plus v2 User's Manual: DC Resistivity Data Interpretation Software*. Third Edition. Interpex Limited, Golden, Colorado.

Carr, Christopher
1982 *Handbook on Soil Resistivity Surveying: Interpretation of Data from Earthen Archeological Sites*. Research Series, Volume 2. Center for American Archeology Press, Evanston, Illinois.

Chapman, Carl H.
1975 *The Archaeology of Missouri, I*. University of Missouri Press, Columbia.

1980 *The Archaeology of Missouri, II*. University of Missouri Press, Columbia.

CIN
2004 *About St. Louis: History*. Community Information Network, City of St. Louis, Missouri. <http://stlouis.missouri.org/citygov/planning/research/data/about/history,html>

Clark, Anthony
2000 *Seeing beneath the Soil: Prospecting Methods in Archaeology*. Reprinted. Routledge, London. Originally published in 1990 by B. T. Batsford Ltd., London.

Conyers, Lawrence B., and Dean Goodman
1997 *Ground-Penetrating Radar: An Introduction for Archaeologists*. AltaMira Press, Walnut Creek, California.

Conyers, Lawrence B., and Jeffrey E. Lucius
1996 Velocity Analysis in Archaeological Ground-penetrating Radar Studies. *Archaeological Prospection* 3(1):25-38.

David, Andrew
1995 *Geophysical Survey in Archaeological Field Evaluation*. Research & Professional Services Guidelines No. 1. Ancient Monuments Laboratory, English Heritage, London.

Davis, P. A., S. A. Greenhalgh, and N. P. Merrich
1980 Resistivity Sounding Computations with any Array Using a Single Digital Filter. *Bulletin of the Australian Society of Exploration Geophysicists* 11:54-62.

Dice, Lee R.
1943 *The Biotic Provinces of North America*. University of Michigan Press, Ann Arbor.

Fenneman, Nevin M.
1938 Physiography of Eastern United States. McGraw-Hill Book Company, New York.

Foth, Henry D., and John W. Schafer
1980 *Soil Geography and Land Use*. John Wiley & Sons, New York.

Fuller, Michael
2004 *The Archaeology of Missouri: Missouri Time Periods*. Missouri Archaeological Society, Columbia, Missouri. <http://coas.missouri.edu/mas/articles/ articlemotimeperiods.html.>

Gaffney, Chris, and John Gater
2003 *Revealing the Buried Past: Geophysics for Archaeologists*. Tempus Publishing, Stroud, Great Britain.

Gaffney, Chris, John Gater, and Sue Ovenden
1991 *The Use of Geophysical Techniques in Archaeological Evaluations*. Technical Paper Number 9. Institute of Field Archaeologists, University of Birmingham, Birmingham, England.

2002 *The Use of Geophysical Techniques in Archaeological Evaluations*. IFA Paper No. 6. Institute of Field Archaeologists, University of Birmingham, Birmingham, England.

Geonics
1992 *EM38 Ground Conductivity Meter Operating Manual for EM38 Models with Digital Readout*. Geonics Limited, Mississauga, Ontario, Canada.

1997 *Computer Program manual (Survey Data Reduction Manual) DAT38, Version 3.40*. Geonics Limited, Mississauga, Ontario, Canada.

1998 *DL720/38 Data Logging System Operating Instructions for EM38 Ground Conductivity Meter with Polycorder Series 720, Version 3.40*. Geonics Limited, Mississauga, Ontario, Canada.

Geoscan Research
1987 *Fluxgate Gradiometer FM9 FM18 FM36 Instruction Manual, Version 1.0*. Geoscan Research, Bradford, England.

1996 *Resistance Meter RM15 Instruction Manual, Version 2.4*. Geoscan Research, Bradford, England.

2003 *Geoplot Version 3.00 for Windows Instruction Manual, Version 1.95*. Geoscan Research, Bradford, England.

Golden Software
2002 *Surfer 8 User's Guide: Contouring and 3D Surface Mapping for Scientists and Engineers*. Golden Software, Golden, Colorado.

2003 *Grapher 5 2D and 3D Graphing for Scientists and Engineers Getting Started Guide: Gain the Power behind Superior Graphing*. Golden Software, Golden, Colorado.

Goodman, Dean
2004 *GPR-SLICE – Ground Penetrating Radar Imaging Software Ver. 4.0 User's Manual*. Geophysical Archaeometry Laboratory, Woodland Hills, California.

Goodman, D., Y. Nishimura, and J. D. Rogers
1995 GPR Time Slices in Archaeological Prospection. *Archaeological Prospection* 2(2):85-89.

Gossen
1995 *Geohm 40D Earth Tester Operating Instructions*. Gossen-Metrawatt GMBH, Nurnberg, Germany.

Grant, Ulysses S.
1999 *Personal Memoirs of Ulysses S. Grant*. Reprint. Random House, New York. Originally published in two volumes (Volume I in 1885, and Volume II in 1886) by Charles Webster & Company, New York.

GSSI
2003a *TerraSIRch SIR Sytem-3000 User's Manual*. Geophysical Survey Systems, Inc., North Salem, New Hampshire.

2003b *RADAN for Windows Version 5.0 User's Manual*. Geophysical Survey Systems, Inc., North Salem, New Hampshire.

2003c *3D QuickDraw for RADAN 5.0 User's Manual*. Geophysical Survey Systems, Inc., North Salem, New Hampshire.

Harl, Joseph L.
1995 *Master Plan for the Management of Archaeological Resources within St. Louis City and County, Missouri*. Research Report No. 203. Archaeological Services, Department of Anthropology, University of Missouri, St. Louis.

Heimmer, Don H., and Steven L. De Vore
1995 *Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archeological Investigations*. Revised Edition. Interagency Archeological Services, National Park Service, Denver, Colorado.

2000 Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations. In *Science and Technology in Historic Preservation*, edited by Ray A. Williamson and Paul R. Nickens, pp. 53-73. Advances in Archaeological and Museum Science, Volume 4. Kluwer Academic/Plenum Publishers, New York.

Hinze, William J.
1990 The Role of Gravity and Magnetic Methods in Engineering and Environmental Studies. In *Geotechnical and Environmental Geophysics, Volume 1: Review and Tutorial*, edited by Stanley H. Ward, pp. 75-126. Society of Exploration Geophysicists, Tulsa, Oklahoma.

Interpex
2002 *IX1D Version 2.05*. Interpex Limited, Golden, Colorado. <hppt://www.interpex.com/ix1d.htm>.

Iris Instruments
1999 *Syscal Kid – Switch 22 Compact Resistivity Meter Multi-Electrode Switching System Operating Manual*. Iris Instruments, Orleans, France.

King, Julia A., Bruce W. Bevan, and Robert J. Hurry
1993 The Reliability of Geophysical Surveys at Historic-Period Cemeteries: An Example from the Plains Cemetery, Mechanicsville, Maryland. *Historical Archaeology* 27(3): 4-16.

Kvamme, Kenneth L.
2001 Current Practices in Archaeogeophysics: Magnetics, Resistivity, Conductivity, and Ground-Penetrating Radar. In *Earth Sciences and Archaeology*, edited by Paul Goldberg, Vance T. Holliday, and C. Reid Ferring, pp. 353-384. Kluwer Academic/Plenum Publishers, New York.

Little, Kimberly
1993 *Ulysses S. Grant's White Haven: A Place Where Extraordinary People Came to Live Ordinary Lives, 1796-1885*. Historic Resource Study. Ulysses S. Grant National Historic Site, St. Louis, Missouri.

Lowrie, William
1997 *Fundamentals of Geophysics*. Cambridge University Press, Cambridge, United Kingdom.

McNiel, J. D.
1980a *Electrical Conductivity of Soils and Rocks*. Technical Notes TN-5. Geonics Limited, Mississauga, Ontario, Canada.

1980b *Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers*. Technical Notes TN-6. Geonics Limited, Mississauga, Ontario, Canada.

MicroPro
1989 *WordStar 5.5*. MircoPro International Corporation, San Rafael, California.

Milsom, John
2003 *Field Geophysics*. Third Edition. John Wiley & Sons, Chichester, England.

Missouri Cooperative Soil Survey
2003 *MLRA 115 Central Mississippi Valley Wooded Slopes*. Curators of the University of Missouri, Columbia. Site is hosted by the Center for Agricultural, Resource and Environmental Systems, University of Missouri, Columbia. <http://soils.missouri.edu/mo_mlra/mlra115.htm>

Moore, Bob
1994 *Jefferson National Expansion Memorial Administrative History, 1980-1991*. Jefferson National Expansion Memorial, National Park Service, St. Louis, Missouri.

Morris, Ann
1999-2000 *St. Paul's Churchyard, Area C-4: A Survey of Cemeteries in St. Louis County, Phases I and II*. Ms. on file, Missouri State Historic Preservation Office, Department of Natural Resources, Jefferson City, Missouri.

Moxom, Walter J.
1941 Climate of Missouri. In *Climate and Man: 1941Yearbook of Agriculture*, edited by Grove Hambridge, pp. 945-954. House Document No. 27, 77th Congress, 1st Session. U. S. Government Printing Office, Washington, D. C.

Music, B.
1995 On-Site Prospection in Slovenia: The Case of Rodik. *Archaeological Computing Newsletter* 43:6-15.

Mussett, Alan E., and M. Aftab Khan
2000 *Looking into the Earth: An Introduction to Geological Geophysics*. Cambridge University Press, Cambridge, United Kingdom.

MWAC
1998 *Ulysses S. Grant National Historic Site: Cultural Sites Inventory*. Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

Neubauer, W., P. Melichar, and A. Eder-Hinterleitner
1996 Collection, Visualization, and Simulation of Magnetic Prospection Data. In *Interfacing the Past: Computer Applications and Quantitative Methods in Archaeology, CAA95, Volume 1*, edited by H. Kamermans and K. Fennema, pp. 121-129. Analecta Praehistorica Leidensia No. 28. University of Leiden, Leiden, The Netherlands.

Nickel, Robert K.
2001 Ground Penetrating Radar Studies of Three Areas at Ulysses S. Grant National Historic Site. Ms. on file, Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

Nikon
1993 *Field Station DTM-700 Series DTM-750/DTM-730/DTM-720 Instruction Manual*. Nikon Corporation, Tokyo.

1996 *TransIt Version 2.1 User's Guide*. Nikon Inc. Instrument Software Department, Melville, New York.

Nishimura, Y.
2001 Geophysical prospection in Archaeology. In *Handbook of Archaeological Sciences*, edited by D. R. Brothwell and A. M. Pollard, pp. 543-553. John Wiley & Sons, Ltd., Chichester, England.

Nixon, Joseph M., M. Colleen Hamilton, and Laura E. Kling
1982 *A Prehistoric, Protohistoric, and Historic Overview of the River des Peres Drainage Basin, St. Louis County, Missouri*. Research Report No. 4. Archaeological Survey, University of Missouri, St. Louis.

Nixon, Joseph M., Laura E. Kling, and Joseph Harl
1982 *Phase I Cultural Resource Survey of Gravois Creek Drainage Basin, St. Louis County, Missouri*. Research Report No. 9. Archaeological Survey, University of Missouri, St. Louis.

Nobel, Vergil E.
1997 *A Report on the 1991 Excavations at Ulysses S. Grant National Historic Site, St. Louis, Missouri*. Technical Report No. 49. Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

NPS
n.d. Hardscrabble: The House that Grant Built. Brochure on file, Ulysses S. Grant National Historic Site, St. Louis, Missouri.

1993 *Resources Management Plan Ulysses S. Grant National Historic Site*. Ulysses S. Grant National Historic Site, National Park Service, St. Louis, Missouri.

O'Brien, Michael J., and W. Raymond Wood
1998 *The Prehistory of Missouri*. University of Missouri Press, Columbia.

O'Bright, Alan W., and Kristen R. Marolf
1999 *The Farm on the Gravois: Historic Structures Report, Ulysses S. Grant National Historic Site, St. Louis, Missouri*. Ulysses S. Grant National Historic Site, St. Louis. Missouri.

Orellana, Ernesto, and Harold M. Mooney
1972 *Two and Three Layer Master Curves and Auxiliary Point Diagrams for Vertical Electrical Sounding Using Wenner Arrangement*. Interciencia, Madrid, Spain.

Ott, Leonard C.
2002 *Phase One Cultural Resource Survey, Estates at Sappington Pointe, Crestwood, Missouri*. SCI Engineering, St. Charles, Missouri.

Peddie, Norman W.
1992 *The Magnetic Field in the United States, 1990, Total Intensity Chart*. U.S. Geological Survey Geophysical Investigations Map GP-1002-F. U.S. Geological Survey, Reston, Virginia.

Peddie, Norman W., and Audronis K. Zundie
1988 *The Magnetic Field in the United States, 1985, Inclination Chart*. U.S. Geological Survey Geophysical Investigations Map GP-986-I. U.S. Geological Survey, Reston, Virginia.

Pflieger, William L.
1971 *A Distributional Study of Missouri Fishes*. Museum of Natural History Publication 20. University of Kansas, Lawrence.

Phillips, Jan
1979 *Wild Edibles of Missouri*. Missouri Department of Conservation, Jefferson City.

Post, Jas. L. (compiler)
1904 *Reminiscences by Personal Friends of Gen. U. S. Grant and the History of Grant's Log Cabin*. J. L. Post, St. Louis, Missouri.

Price, James E.
1996 *Limited Archeological Investigations at the Ulysses S. Grant National Historic Site, 23SL857: A Brief Report on Subsurface Excavations in the Winter Kitchen Conducted October 10-13, 1995*. Southeast Missouri Archaeological Research Facility, American Archaeology Division. University of Missouri-Columbia, Naylor.

1997 *Archeological Investigations at the Ulysses S. Grant National Historic Site, 1997*. Southeast Missouri Archaeological Research Facility, American Archaeology Division, University of Missouri-Columbia, Naylor.

Price, James E., and Mary Jane Hastings
1998 *A Report on the 1995 Excavations at Ulysses S. Grant National Historic Site, St. Louis, Missouri*. Southeast Missouri Archaeological Research Facility, American Archaeology Division, University of Missouri-Columbia, Naylor.

Primm, James N.
1981 *Lion of the Valley: St. Louis. Missouri*. Pruett Publishing Company, Boulder, Colorado.

Reichenbacher, Frank, Susan E. Franson, and David E. Brown
1998 *North American Biotic Communities*. The University of Utah, Salt Lake City, Utah.

Richardson, Albert D.
1885 *A Personal History of Ulysses S. Grant*. Reprint. Park Publishing Company, Hartford, Connecticut. Originally printed in 1868 by American Publishing Company, Hartford, Connecticut.

Schwartz, Charles W., and Elizabeth R. Schwartz
1959 *The Wild Mammals of Missouri*. Missouri Department of Conservation, Jefferson City.

Scollar, I., A. Tabbagh, A. Hesse, and I Herzog
1990 *Archaeological Prospection and Remote Sensing*. Topics in Remote Sensing 2. Cambridge University Press, Cambridge, England.

Scott, Douglas D.
2001a *Archeological Investigations of the Ice House and Summer Kitchen/ Stone Building at Ulysses S. Grant National Historic Site, St. Louis, Missouri*. Technical Report 69. Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

2001b Searching for the Elusive Latrine: Archeological Investigations in the Backyard of the Summer Kitchen, Ulysses S. Grant National Historic Site, St. Louis, Missouri. Ms. on file, Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

2002a *Archeological Investigations for the Barn Relocation at Ulysses S. Grant National Historic Site, St. Louis, Missouri*. Technical Report 78. Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

2002b Documentation of a Foundation at the North End of the Summer Kitchen (HS2), Ulysses S. Grant National Historic Site, St. Louis, Missouri. Ms. on file, Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

2003 Archeological Monitoring of the Initial Visitor Center Construction Episode, Ulysses S. Grant National Historic Site, St. Louis County, Missouri. Ms. on file, Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

Scott, Douglas D., Karin M. Roberts, and Vergil E. Nobel
2004 *Under White haven: An Archeological Overview and Assessment of Ulysses S. Grant National Historic Site, St. Louis, Missouri*. Technical Report No. 89. Midwest Archeological Center, National Park Service, Lincoln, Nebraska.

Sharma, Prem V.
1997 *Environmental and Engineering Geophysics*. Cambridge University Press, Cambridge, United Kingdom.

Shelford, Victor E.
1963 *The Ecology of North America*. University of Illinois Press, Urbana.

Simon, John Y. (editor)
1975 *The Personal Memoirs of Julia Dent Grant (Mrs. Ulysses S. Grant)*. Reprint. Southern Illinois University Press, Carbondale. Originally published in 1975 by G. P. Putnam's Sons, New York.

Steyermark, Julian A,
1963 *Flora of Missouri*. Iowa State University Press, Ames.

Sutton, Ann, and Myron Sutton
1985 *Eastern Forests*. Alfred A. Knopf, New York.

Telford, W. M., L. P. Geldart, and R. E. Sheriff
1990 *Applied Geophysics*. Second Edition. Cambridge University Press, Cambridge, United Kingdom.

Thornthwaite, C. W.
1948 An Approach toward Rational Classification of Climate. *Geographical Review* 38:55-94.

Tite, M. S.
1972 *Methods of Physical Examination in Archaeology*. Seminar Press, New York.

USDA
1981 *land Resource Regions and Major Land Resource Areas of the United States*. Agriculture Handbook 296. U. S. Government Printing Office, Washington, D.C.

Unklesbay, A. G., and J. D. Vineyard
1992 *Missouri Geology: Three Billion Years of Seas, Sediments and Erosion*. University of Missouri Press, Columbia.

Ushikata
n.d. *Tracon & Surveying Compasses*. Ushikata Manufacturing Company, Tokyo.

Weymouth, John W.
1986 Geophysical Methods of Archaeological Site Surveying. In *Advances in Archaeological Method and Theory, Volume 9*, edited by Michael B. Schiffer, pp. 311-395. Academic Press, Orlando, Florida.

1993 *An Analysis of magnetic and Resistance Surveys on the Ulysses S. Grant National Historic Site*. Department of Physics and Astronomy, University of Nebraska, Lincoln.

Williams, Scott K.
2001 *History's Time Portal to Old St. Louis: Three Flags over St. Louis: The Colonial Heritage of St. Louis, Missouri*. Scott K. Williams, Florissant, Missouri. <http://www.usgennet.org/usa/mo/county/stlouis/colonial.html>

Wright, Christopher A.
1987 Part B; Study Units. In *Master Plan for Archaeological Resource Protection in Missouri*, edited by Donald E. Weston and Michael S. Weichman, pp. Bi/1-B26/5. Archaeological Associates and Environmental Systems Analysis, Kansas City, Missouri. Prepared for Division of Parks, Recreation and Historic Preservation, Missouri Department of Natural Resources, Jefferson City, and the National Park Service, Washington, D.C. Survey and Planning Grant Number 29-85-9310-009-B

Table 1. Acquisition and instrumentation information for the gradiometer survey used in the grid input template at Site 23SL1223.

GENERAL			
Acquisition	Value	Instrumentation	Value
Sitename	ulsghard	Survey Type	Gradiometer
Map Reference		Instrument	FM36
Dir. 1st Traverse	N	Units	nT
Grid Length (x)	20 m	Range	AUTO
Sample Interval (x)	0.125 m	Log Zero Drift	Off
Grid Width (y)	20 m	Baud Rate	2400
Traverse Interval (y)	1.0 m	Averaging	Off
Traverse Mode	zig-zag	Averaging Period	16

Table 2. Acquisition and instrumentation information for the ground conductivity survey used in the grid input template at Site 23SL1223.

GENERAL			
Acquisition	Value	Instrumentation	Value
Sitename	ulsghard	Survey Type	EM
Map Reference		Instrument	EM38
Dir. 1st Traverse	N	Units	mS/m
Grid Length (x)	20 m		
Sample Interval (x)	0.25 m		
Grid Width (y)	20 m		
Traverse Interval (y)	1.0 m		
Traverse Mode	Parallel		

Table 3. Acquisition and instrumentation information for the resistance survey used in the grid input template at Site 23Sl1222.

GENERAL			
Acquisition	Value	Instrumentation	Value
Sitename	ulsgwish	Survey Type	Resistance
Map Reference		Instrument	RM15
Dir. 1st Traverse	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	Zig-zag	High Pass Filter	13 Hz
ACCESSORIES			
	Accessories	value	
	Array Hardware	PA5	
	Interface	AD1	
	Log Mode	Single	
	Configuration	Twin	
	Probe Spacing	0.5	

Table 4. Offset Wenner array resistivity data.

Center at N540/ E510				**$\rho_a = 2 \pi R d$**
Probe spacing (m)	Left (East) offset resistance reading (ohms)	Right (West) offset resistance reading (ohms)	average resistance reading (ohms)	Apparent resistivity (ohm-meters)
0.1	26.9	26.5	26.7	16.776
0.15	35.8	35.1	35.45	33.411
0.2	31.1	30.4	30.75	38.642
0.3	21.95	21.5	21.725	40.451
0.4	15.82	15.83	15.825	39.778
0.5	12.84	12.87	12.855	40.385
0.7	6.18	6.17	6.175	27.159
1.0	3.05	3.09	3.07	19.289
1.5	1.035	1.045	1.04	9.802
2.0	0.56	0.54	0.55	6.912
3.0	0.27	0.24	0.255	4.807
4.0	0.115	0.12	0.1175	2.953
5.0	0.07	0.05	0.06	1.885

* at Site 23SL1223

Table 4. Continued.

Center at N15/ E20				**$\rho_a = 2 \pi R d$**
Probe spacing (m)	Left (South) offset resistance reading (ohms)	Right (North) offset resistance reading (ohms)	average resistance reading (ohms)	Apparent resistivity (ohm-meters)
0.1	54.6	54.5	54.55	34.275
0.15	44.2	44.1	44.15	41.610
0.2	33.1	33.0	33.05	41.532
0.3	17.61	17.9	17.755	33.467
0.4	11.12	11.20	11.16	28.048
0.5	7.10	7.17	7.135	22.415
0.7	3.36	3.49	3.425	15.064
1.0	1.34	1.40	1.37	8.608
1.5	0.54	0.6	0.57	5.372
2.0	0.305	0.4	0.3525	4.430
3.0	0.215	0.2	0.2075	3.911
4.0	0.18	0.1	0.14	3.519
5.0	0.16	0.17	0.165	5.184

* at Site 23SL1222

Table 5. Vertical electrical sounding models.

Number of layer	apparent resistivity (ohm-meters)	thickness of layer (m)
1	7.97	0.0353
2	20.83	0.0145
3	121.47	0.176
4	4.60	3.27
5	0.311	

* Hardscrabble (23SL1223) site.

Table 5. Continued.

Number of layer	apparent resistivity (ohm-meters)	thickness of layer (m)
1	31.62	0.058
2	47.18	0.248
3	4.42	4.40
4	9.11	

* Wish-ton-wish (23SL1222) site.

Table 6. Acquisition and instrumentation information for the ground-penetrating radar surveys.

GENERAL			
Acquisition	Value	Instrumentation	Value
File Nam	hard	Survey Type	GPR
Number of Profile Lines	41	Instrument	GSSI TerraSIRch SIR 3000
Dir. 1st Traverse	N	Samples/scan	512
Grid Length (x)	20 m	Bits/sample	16
Scans/meter	50	Scans/second	100
Grid Width (y)	20 m	Meters/mark	2
Traverse Interval (y)	0.5 m	Diel Constant	8
Traverse Mode	zig-zag	Antenna	400 mHz
ACCESSORIES			
	Channel(s)	1	
	Range Gain (dB)	-20.0 26.0 31.0 43.0	
	Position Correction	0 ns	
	Vertical IIR LP N = 1F	800 mHz	
	Vertical IIR HP N = 1F	100 mHz	
	Position (ns)	0	
	Range (ns)	100	

* at Site 23SL1223

Table 6. Continued.

GENERAL			
Acquisition	Value	Instrumentation	Value
File Nam	wish	Survey Type	GPR
Number of Profile Lines	131	Instrument	GSSI TerraSIRch SIR 3000
Dir. 1st Traverse	N	Samples/scan	512
Grid Length (x)	65 m	Bits/sample	16
Scans/meter	50	Scans/second	100
Grid Width (y)	25 m	Meters/mark	2
Traverse Interval (y)	0.5 m	Diel Constant	8
Traverse Mode	Zig-zag	Antenna	400 mHz
ACCESSORIES			
	Channel(s)	1	
	Range Gain (dB)	-20.0 26.0 31.0 43.0	
	Position Correction	0 ns	
	Vertical IIR LP N = 1F	800 mHz	
	Vertical IIR HP N = 1F	100 mHz	
	Position (ns)	0	
	Range (ns)	100	

* at Site 23SL1222

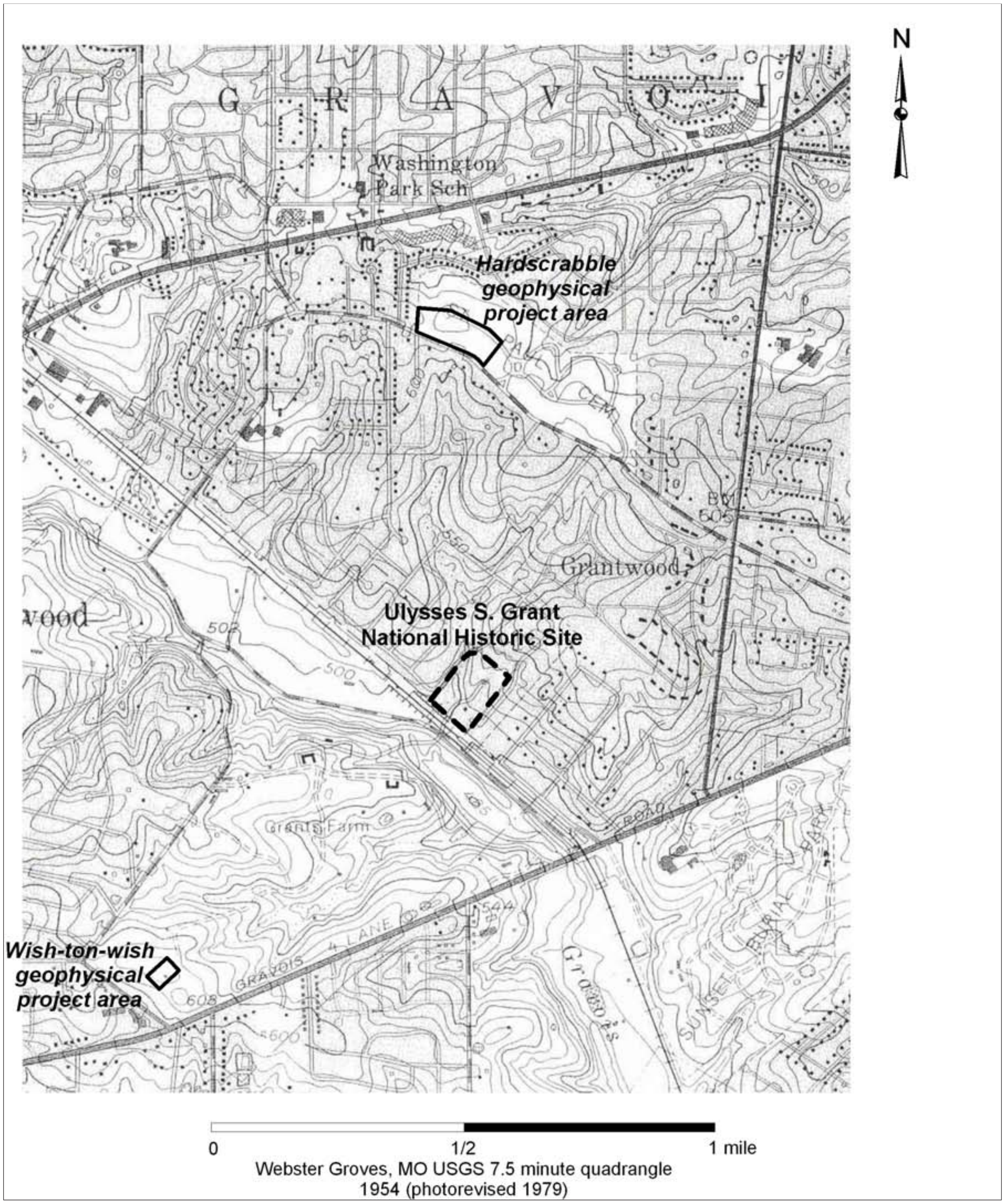


Figure 1. Location of the Hardscrabble (Site 23Sl1223) and Wish-ton-wish (Site 23SL1222) geophysical project areas in St. Louis County, Missouri.

a) Wish-ton-wish residence in 1856 (Richardson 1885: engraving opposite page 139).

b) Wish-ton-wish ruins after 1873 fire (O'Bright and Marolf 1999:2.11).

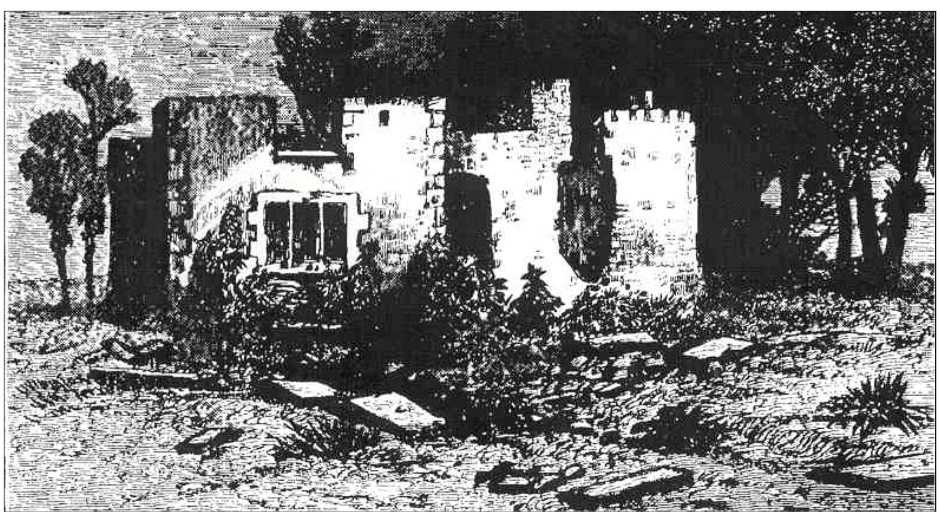


Figure 2. Historic engravings of Wish-ton-wish residence.

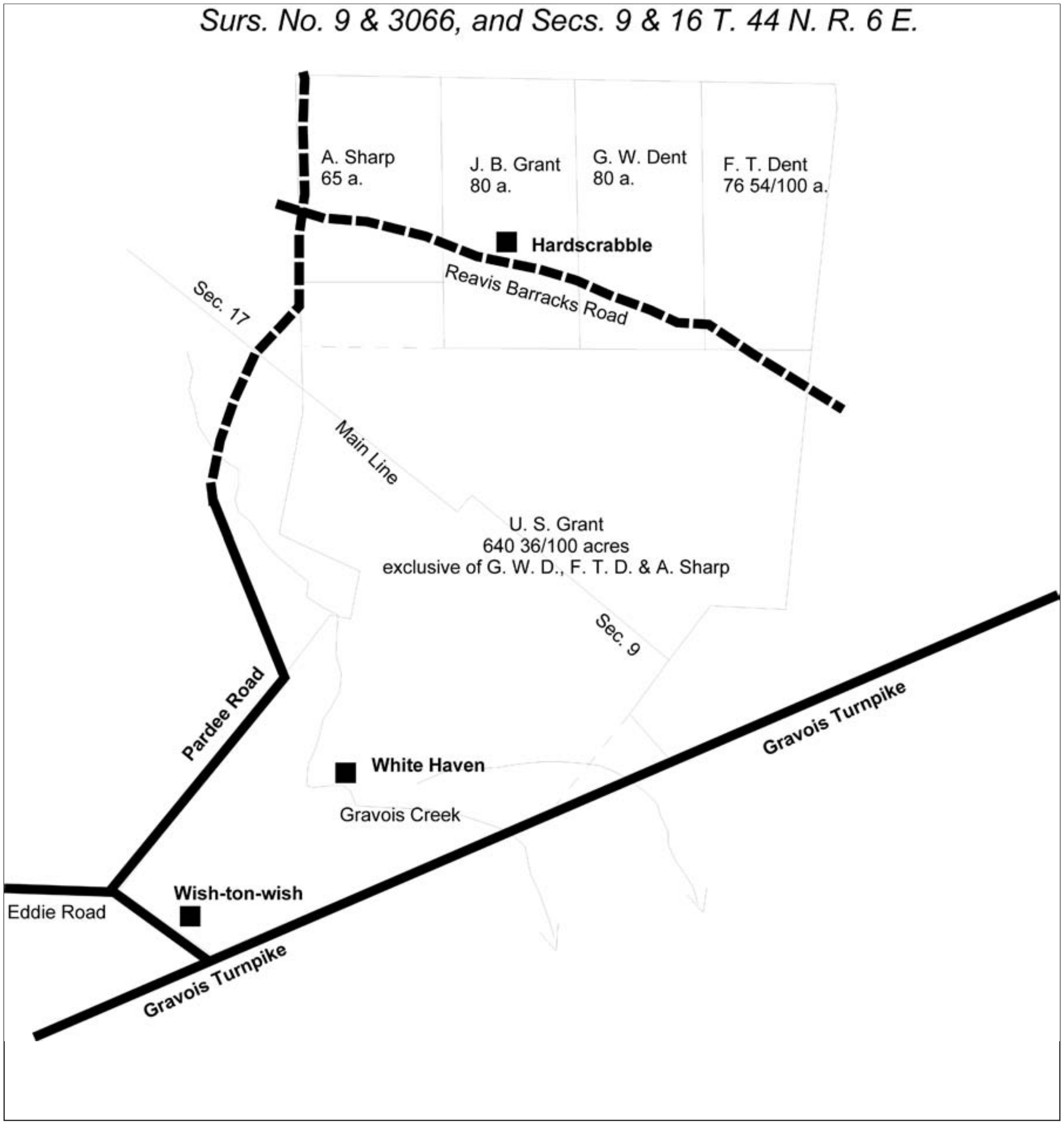
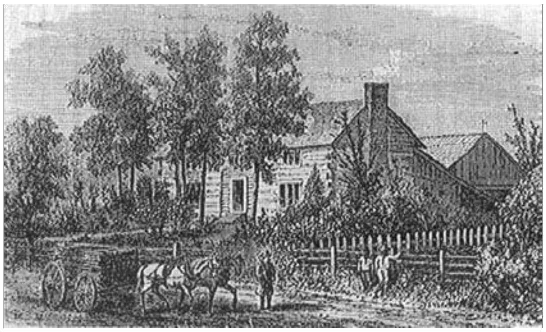
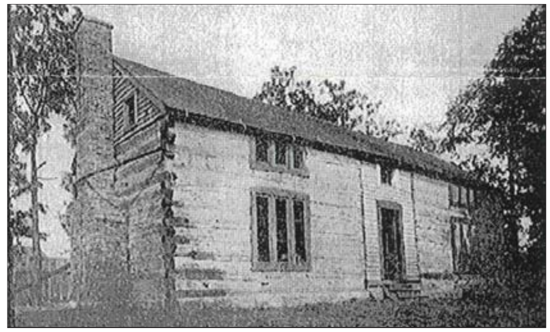


Figure 3. Survey map of the White Haven farm prepared for President Ulysses S. Grant (adapted from hand drawn map in O'Bright and Marolf 1999:2.60).

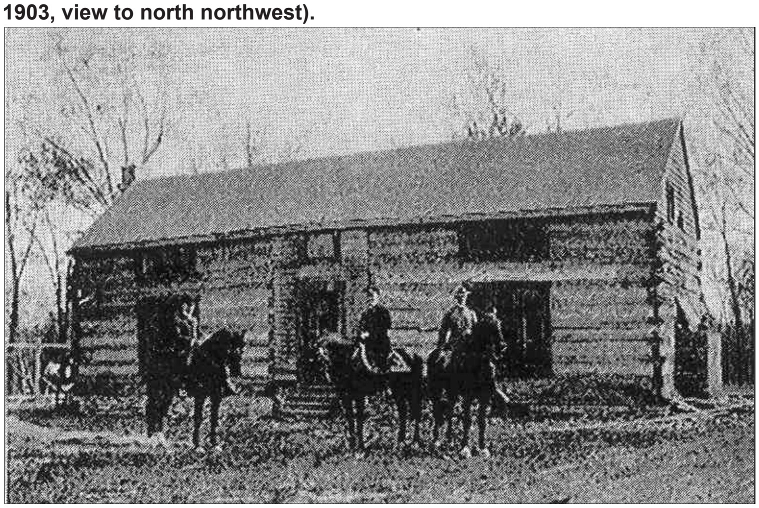
a) Hardscrabble residence in 1869 (Richardson 1885: engraving opposite page 141).



b) Hardscrabble in 1891 (Post 1904:5; photograph taken by Edward Joy in 1891, view to north-east).



c) Hardscrabble in 1903 (Post 1904:25; photograph taken by C. F. Blanke in 1903, view to north northwest).



d) Hardscrabble on Grant's Farm today (view to northwest).

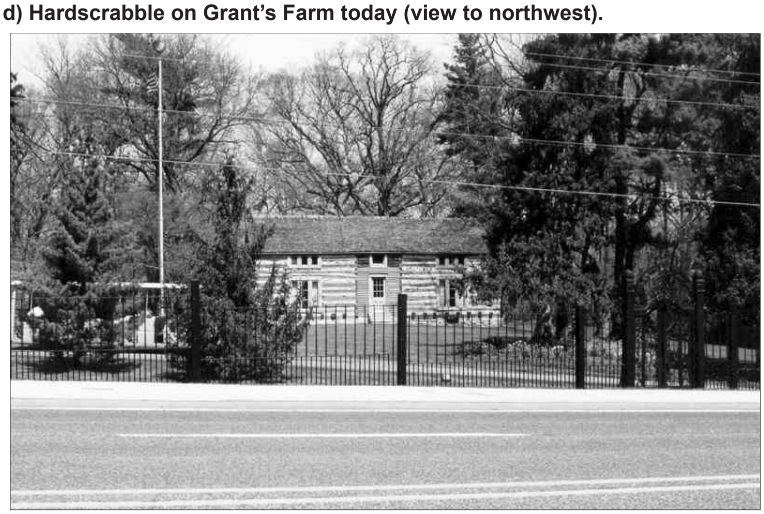
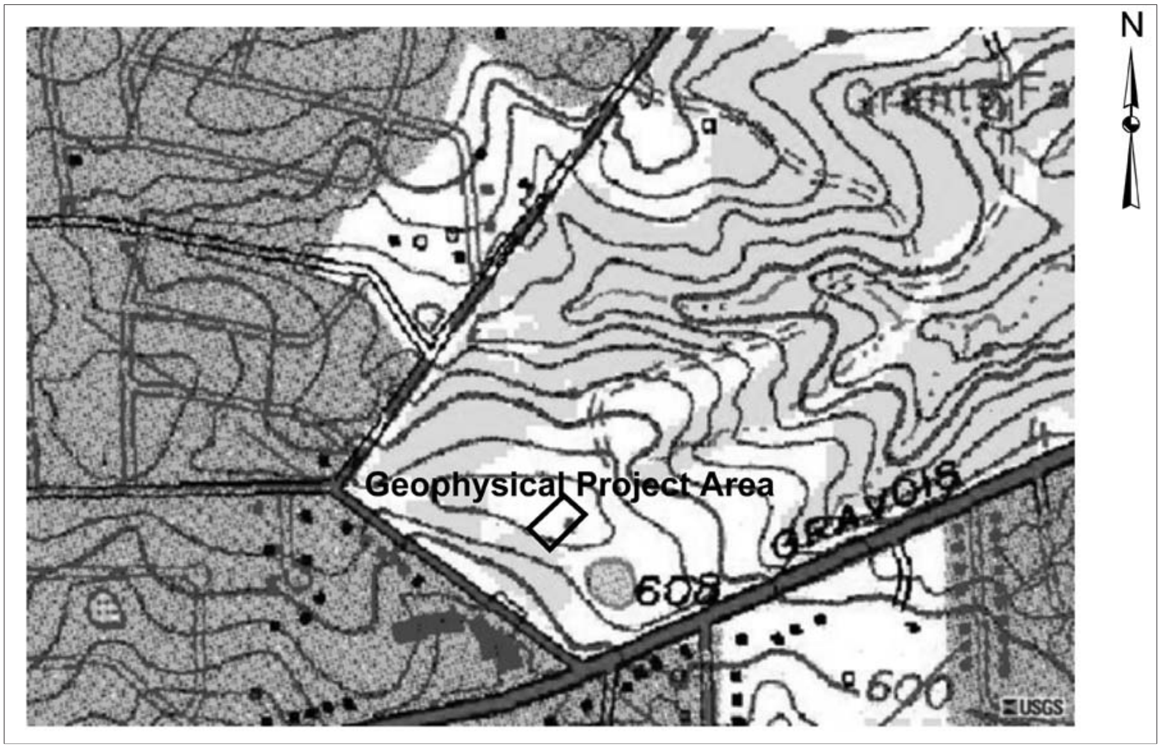


Figure 4. Historic and modern views of the Grant's Hardscrabble cabin.

a) topographic map (USGS, St. Louis, Missouri, 01 July 1996).



b) aerial photograph (USGS, St. Louis, Missouri, 22 March 2002).

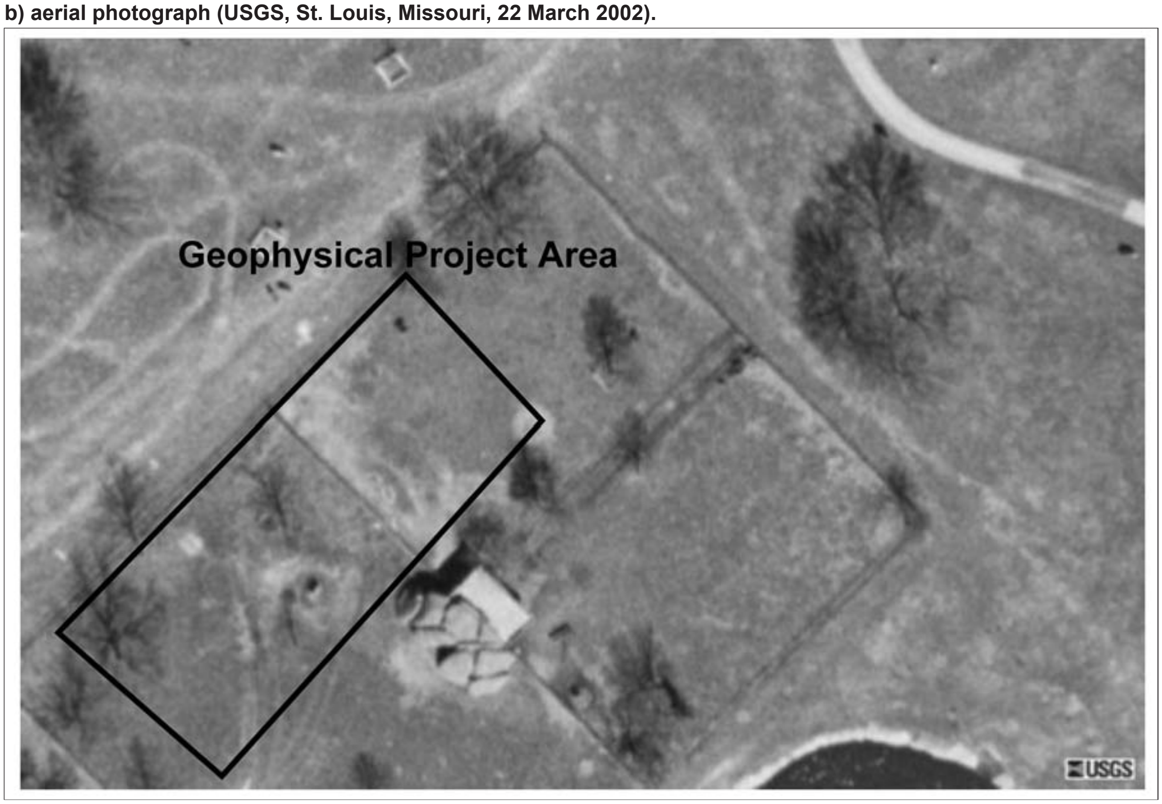
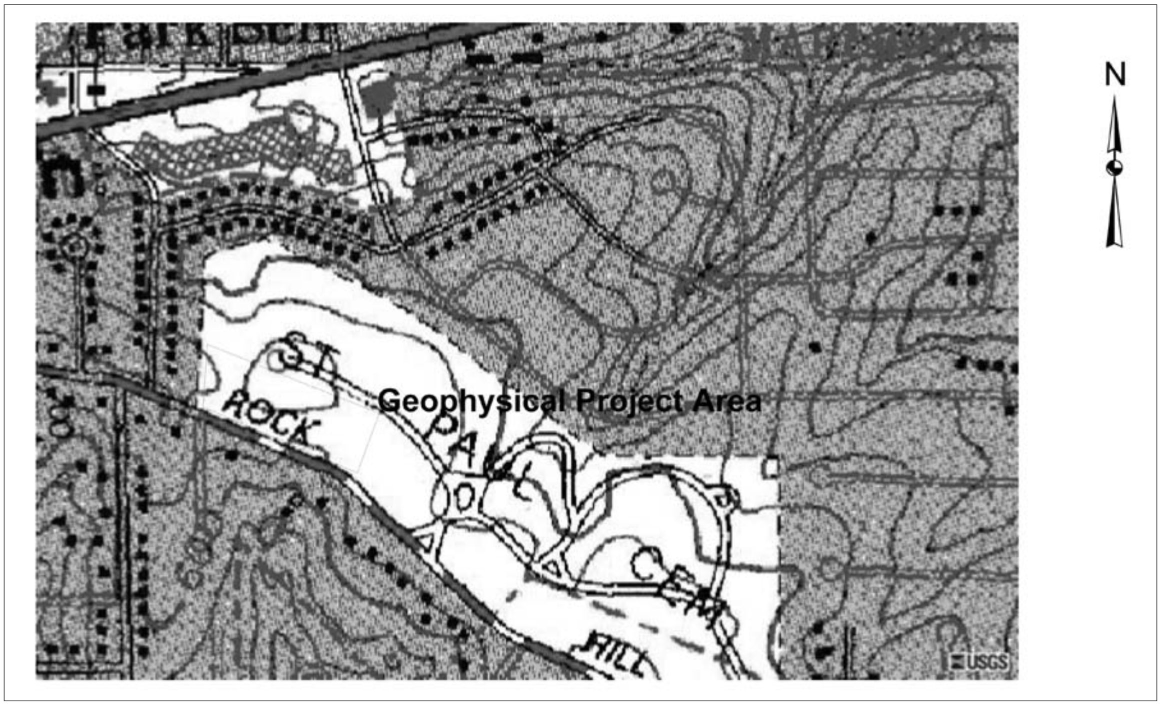


Figure 5. Geophysical project area at the Wish-ton-wish residence of Ulysses S. Grant and family (Site 23SL1222) on Grant's Farm.

a) topographic map (USGS St. Louis, Missouri, United State, 01 July 1996).



b) aerial photograph (USGS St. Louis, Missouri, United States, 22 March 2002).

Figure 6. Geophysical project area at the Hardscrabble residence of Ulysses S. Grant and family (Site 23SL1223) on St. Paul Churchyard cemetery.

a) General view of the Hardscrabble geophysical project area (view to the west).

b) Location of the DAR marker in St. Paul Churchyard lawn near Grant's Hardscrabble cabin (view to the northwest).

Figure 7. Two views of the Hardscrabble geophysical project area.

a) Geophysical grid in the aoudad pen (view to the north).

b) Wish-ton-wish residence foundation stones in the ostrich pen (view to the south).

Figure 8. Two views of the Wish-ton-wish geophysical project area.

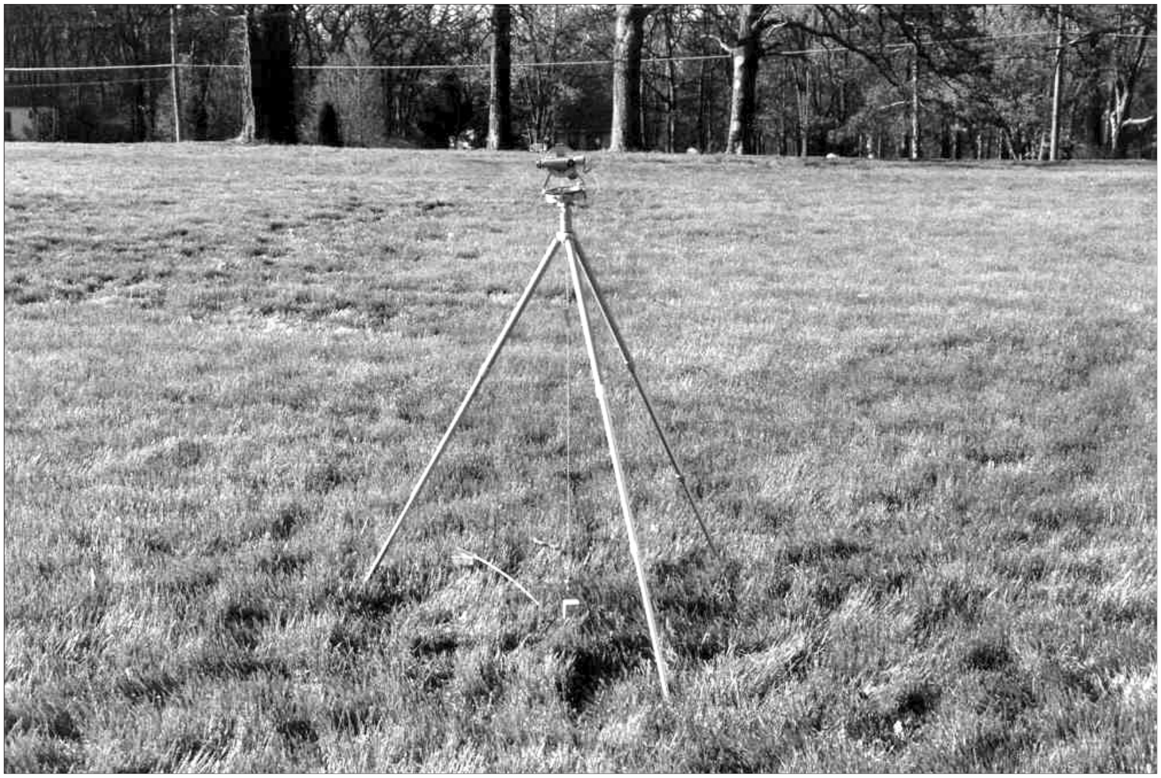


Figure 9. Pocket transit set over grid unit corner stake (view to the south).

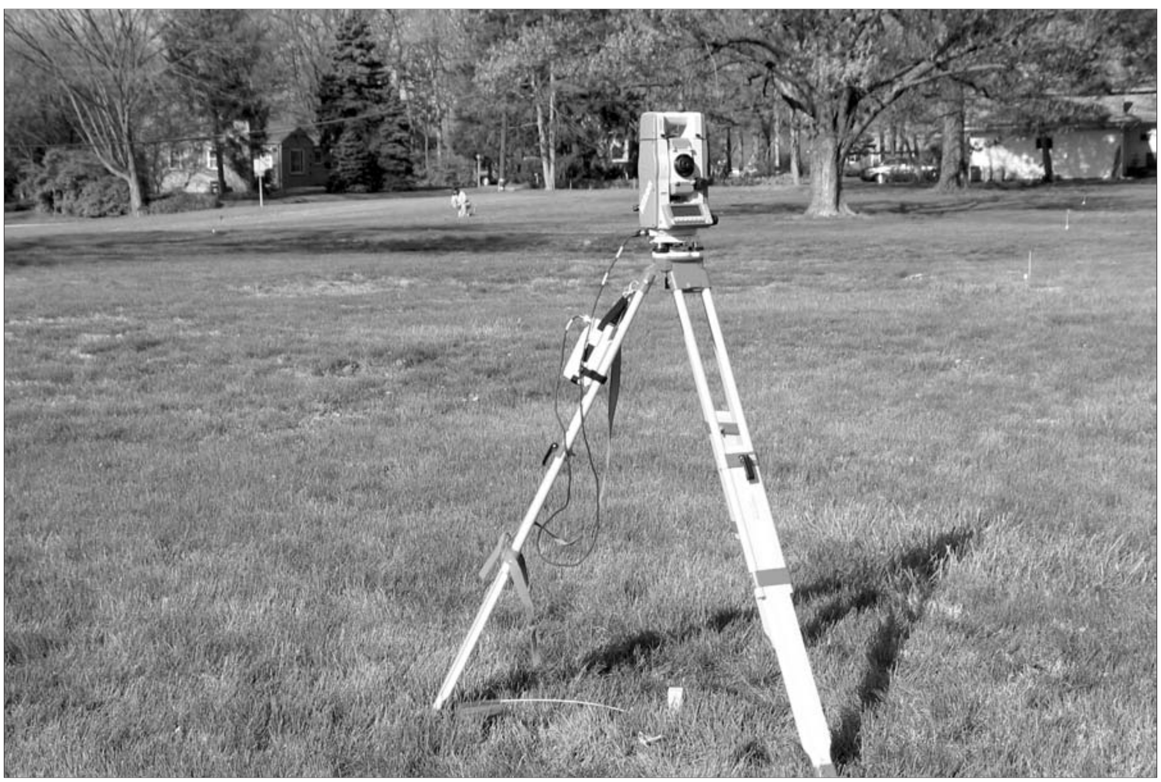


Figure 10. Field station set over mapping station at Site 23SL1223 (view to the west southwest).

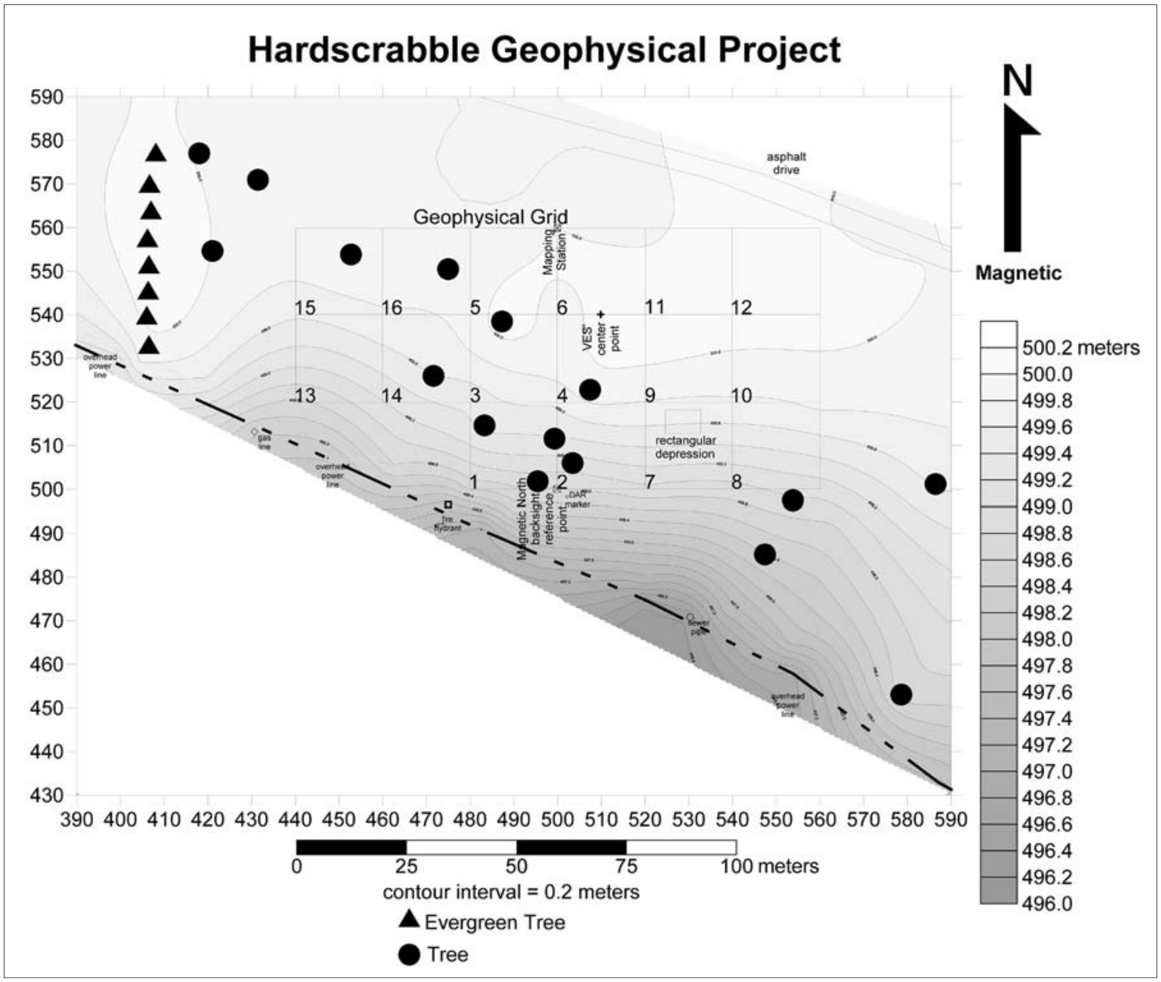


Figure 11. Geophysical grid layout at the Hardscrabble residence, Site 23SL1223.

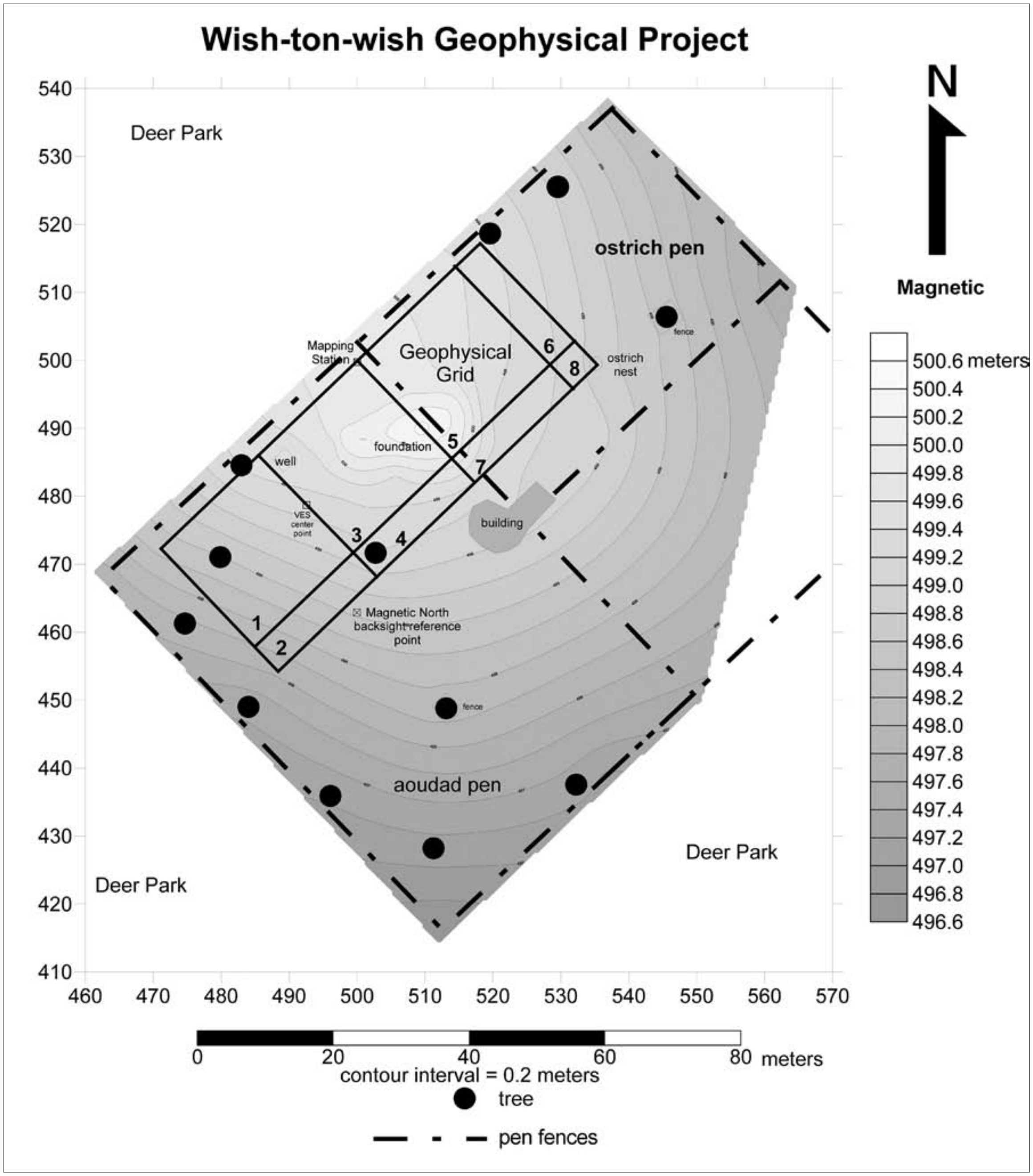


Figure 12. Geophysical grid layout at the Wish-ton-wish residence, Site 23SL1222.

Figure 13. Volunteers and park staff laying out grid ropes at Site 23SL1223 (view to the west).

Figure 14. Balancing the fluxgate gradiometer before starting magnetic gradient survey at Site 23SL1223 (view to the south).

Figure 15. Using the resistance meter and twin probe array at Site 23SL1222 (view to the north northwest).

Figure 16. Conducting the ground-penetrating radar survey with a 400 mHz antenna mounted on a cart system (view to the north northwest).

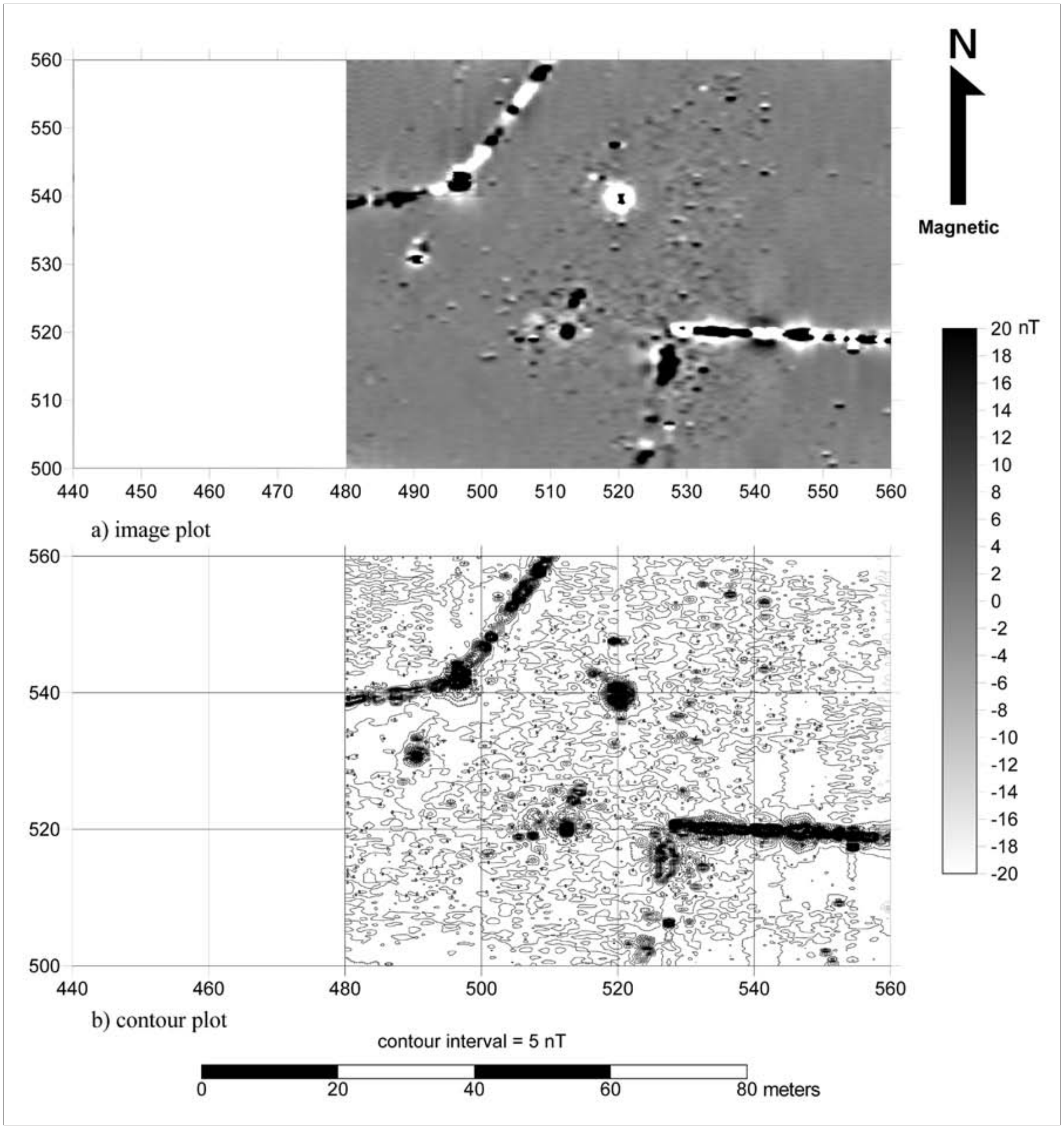


Figure 17. Magnetic gradient data image and contour plots at Site 23SL1223.

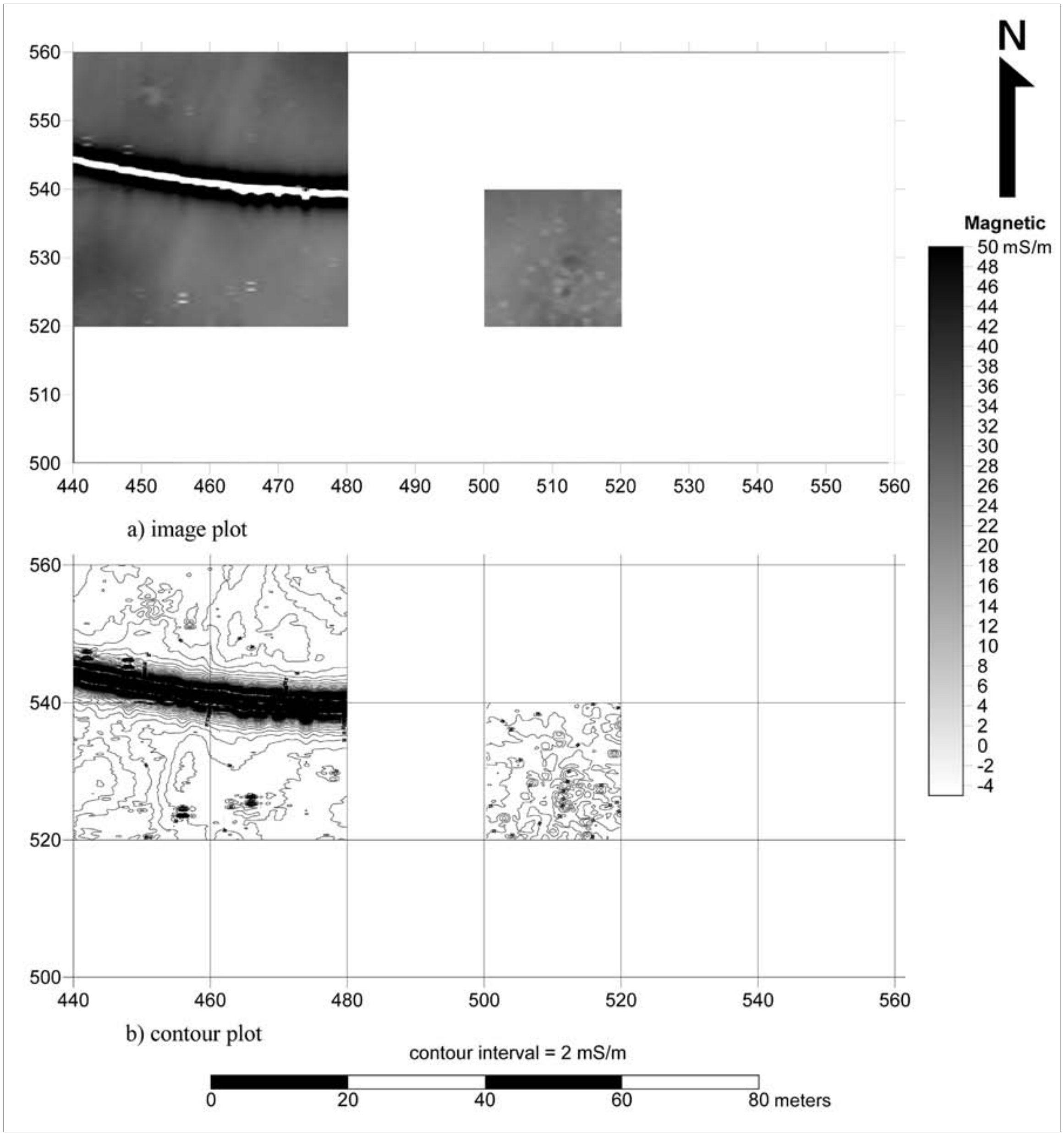


Figure 18. Conductivity data image and contour plots at Site 23SL1223.

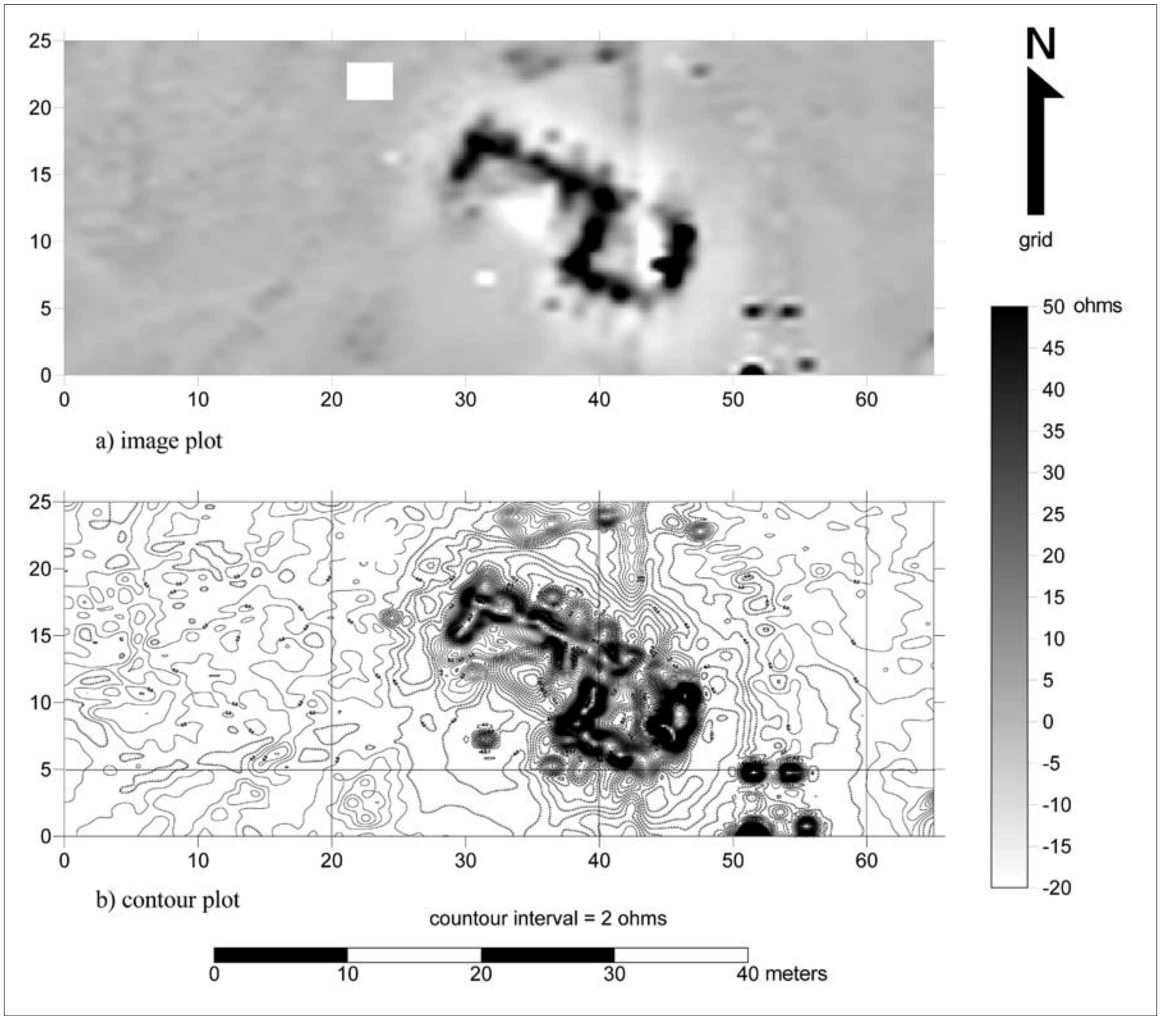


Figure 19. Resistance data image and contour plots at Site 23SL1223.

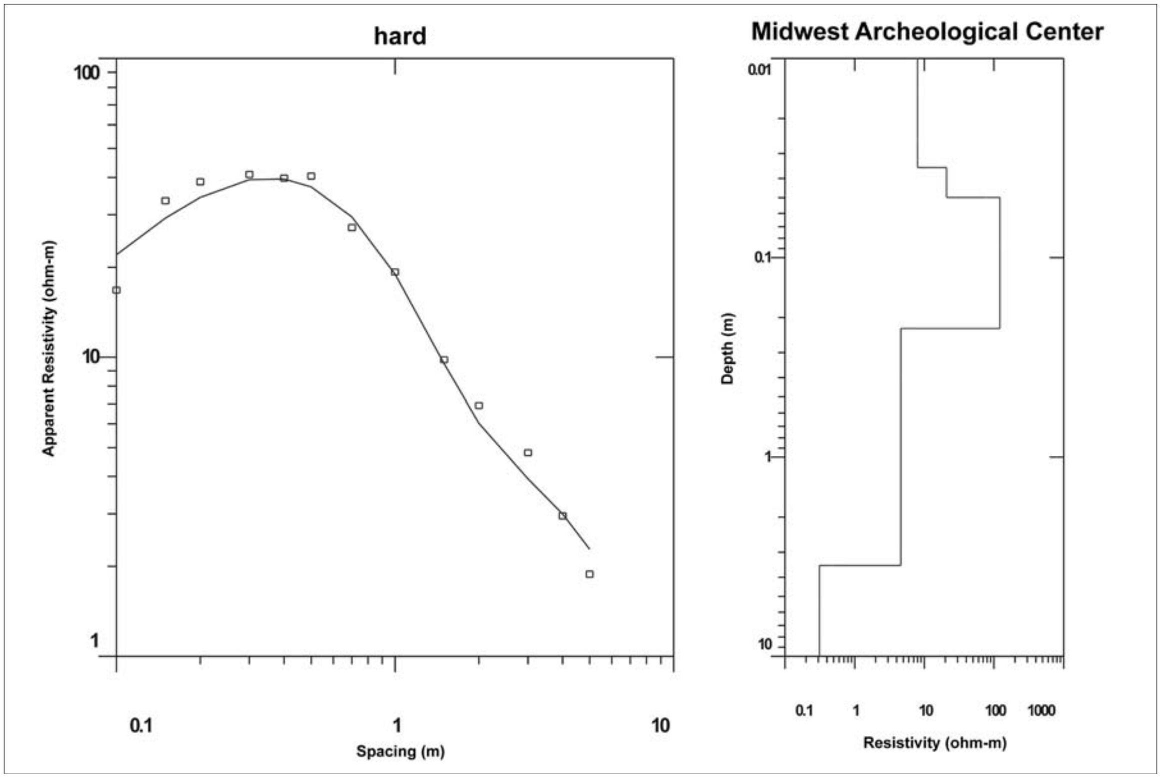


Figure 20. Resistivity data and model for vertical electrical sounding at Site 23SL1223.

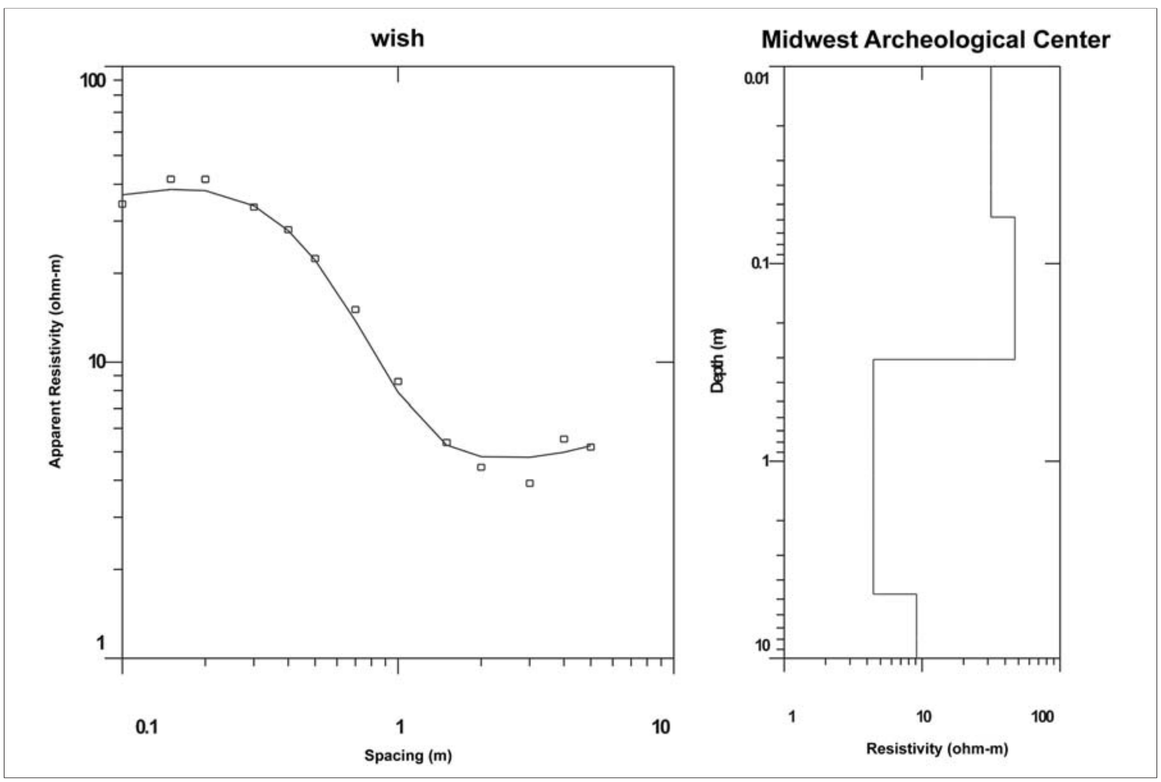


Figure 21. Resistivity data and model for vertical electrical sounding at Site 23SL1222.

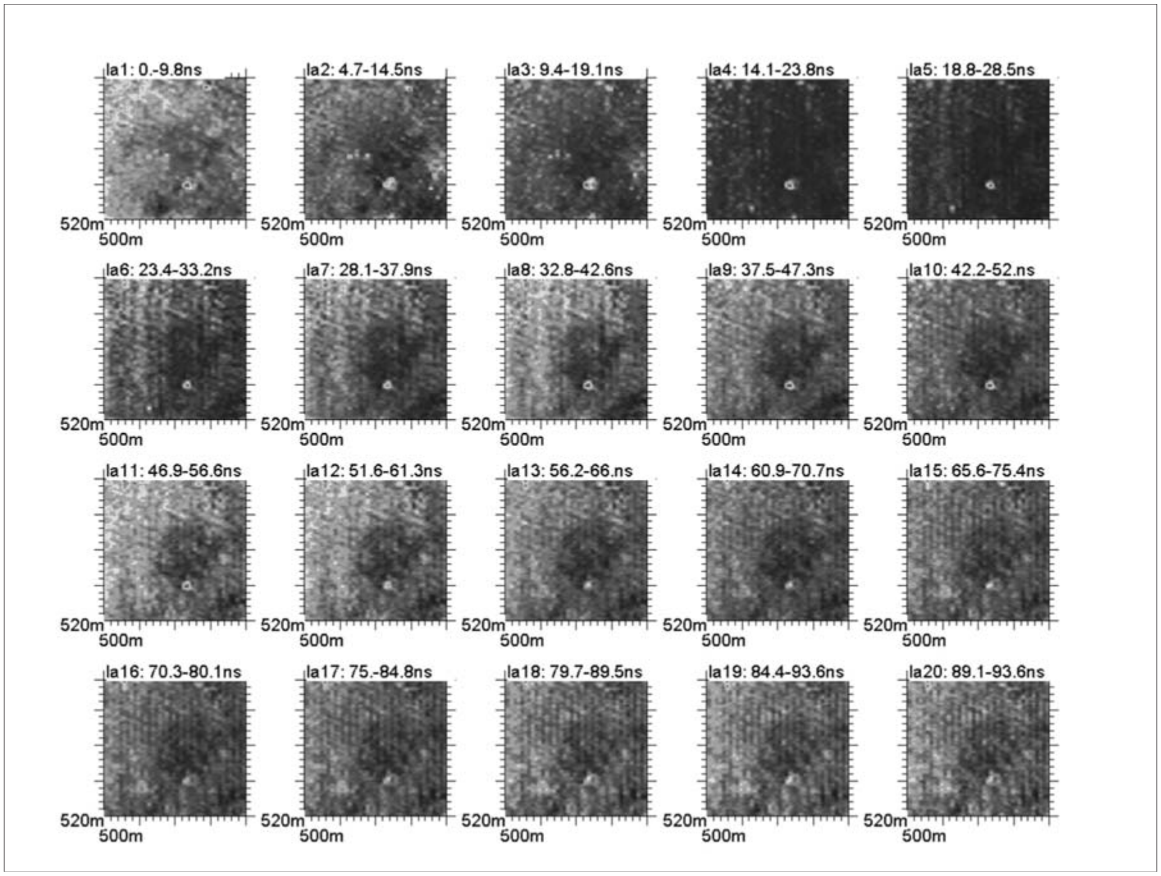


Figure 22. Ground-penetrating radar time slices in grid unit 4 at Site 23SL1223.

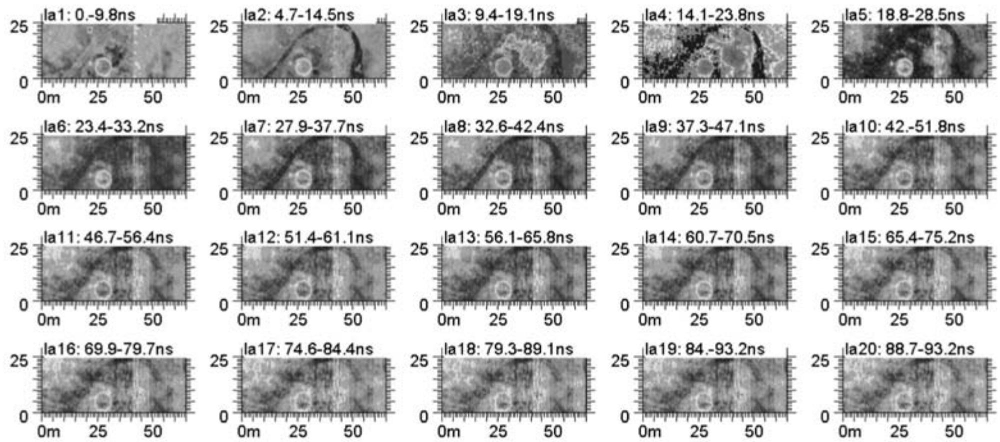


Figure 23. Ground-penetrating radar time slices at Site 23SL1222.

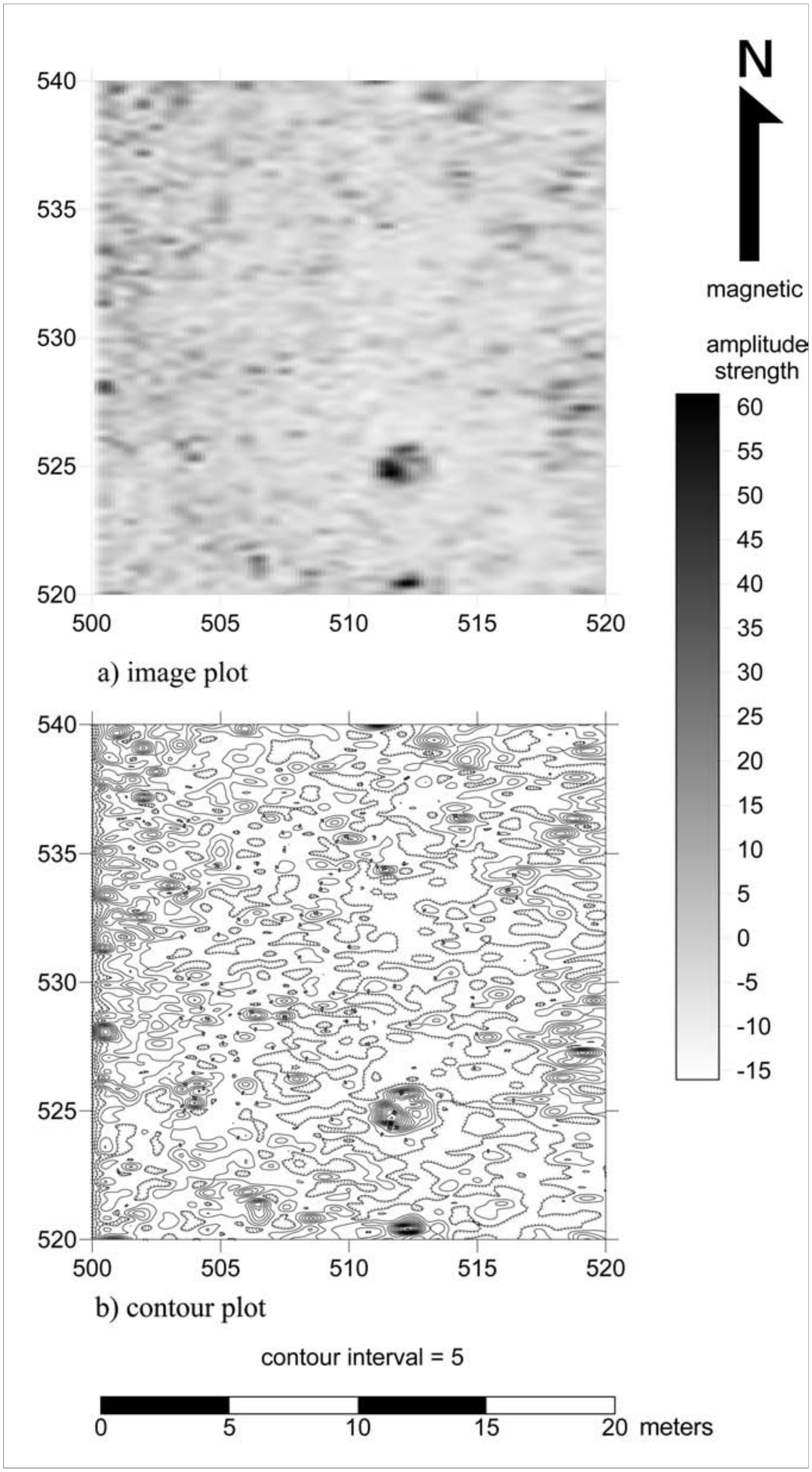


Figure 24. Ground-penetrating radar time slice data from 10 to 20 ns, Site 23SL1223.

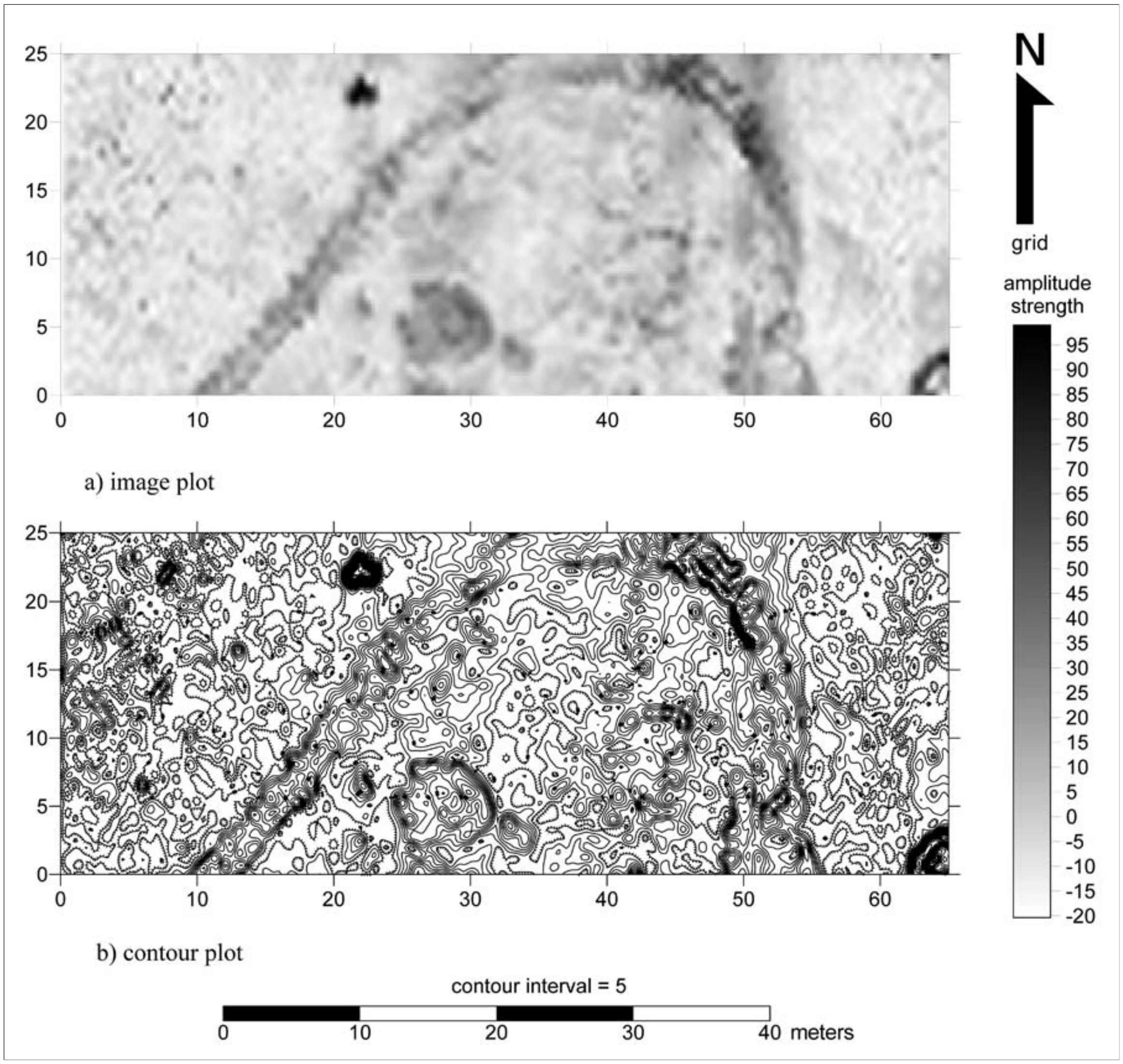


Figure 25. Ground-penetrating radar time slice data from 0 to 10 ns, Site 23SL1222.

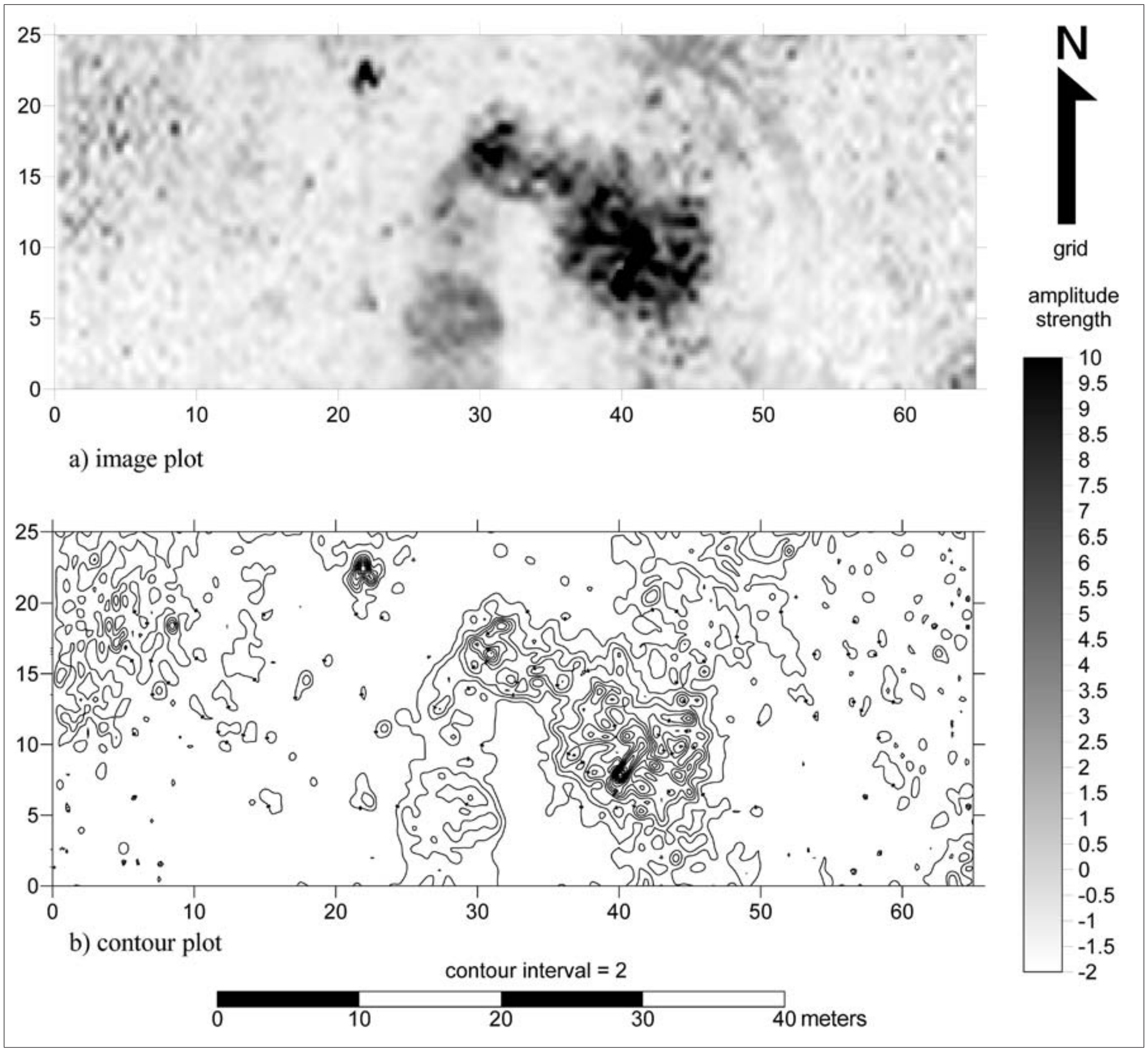


Figure 26. Ground-penetrating radar time slice data from 10 to 20 ns, Site 23SL1222.

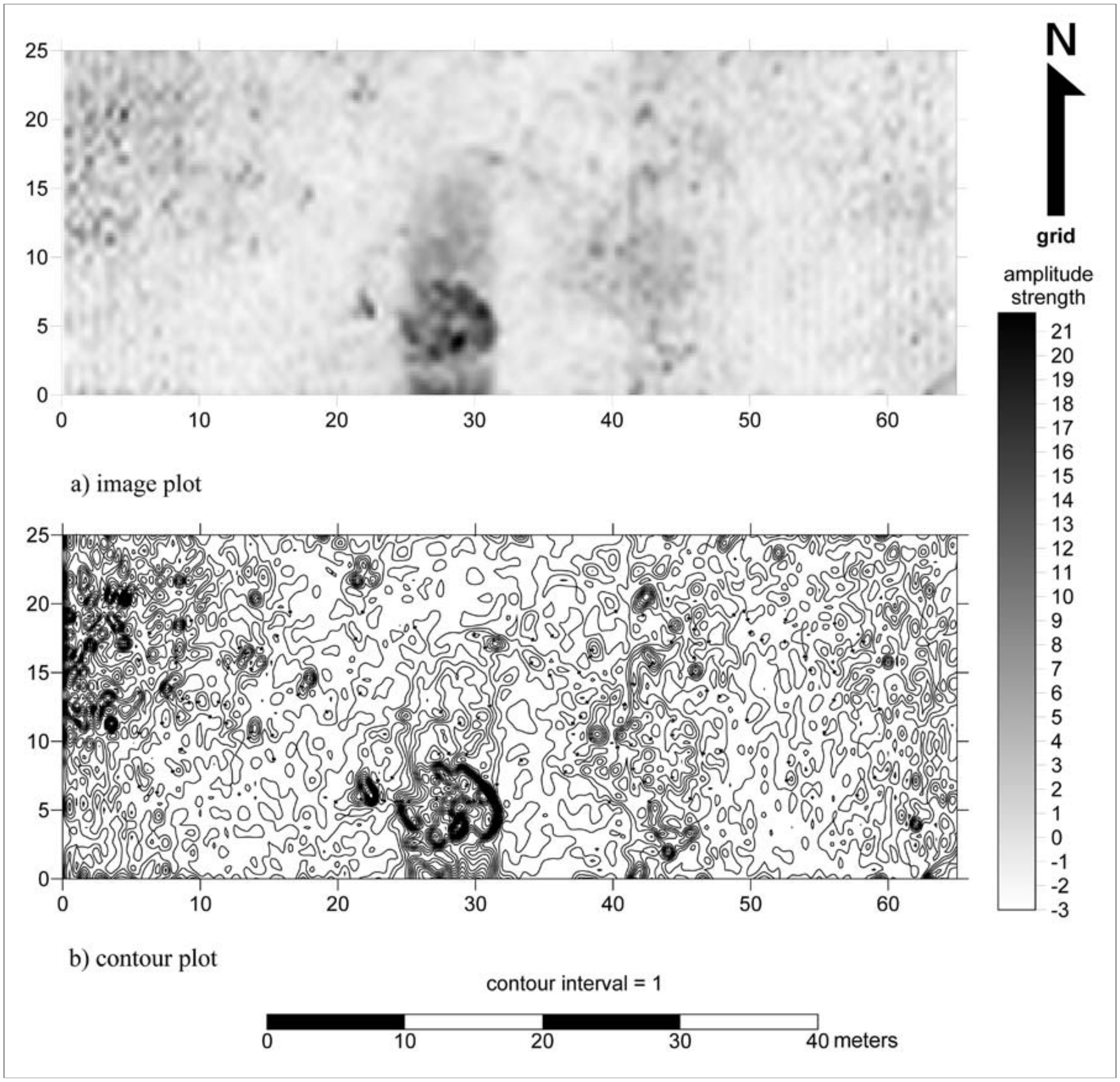


Figure 27. Ground-penetrating radar time slice data from 20-30 ns, Site 23SL1222.

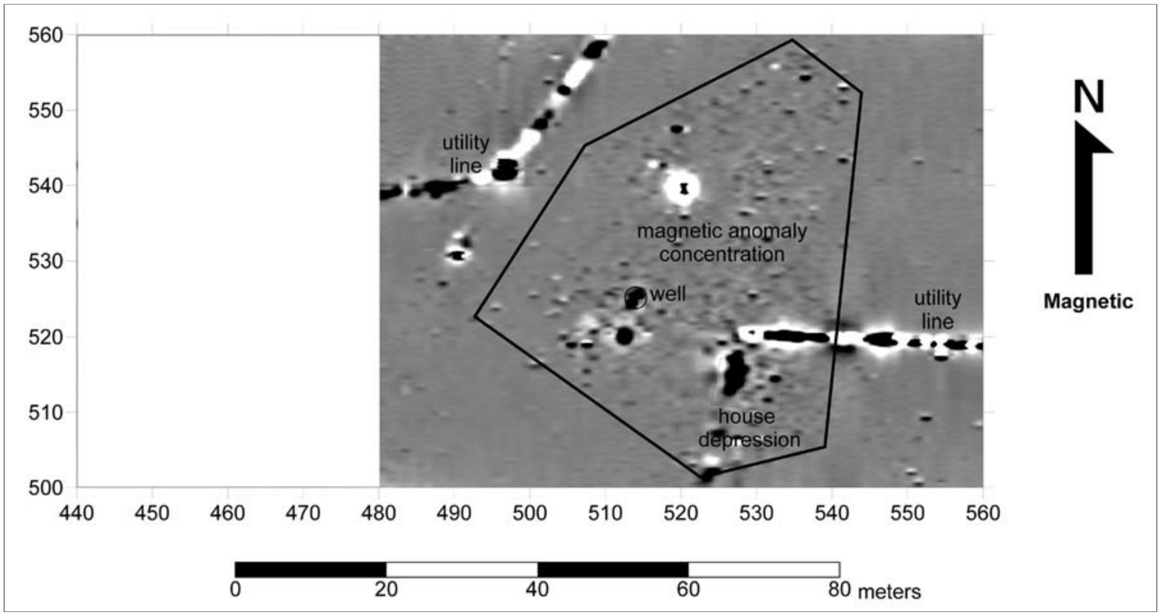


Figure 28. Magnetic gradient data interpretations at the Hardscrabble residence project location, Site 23SL1223.

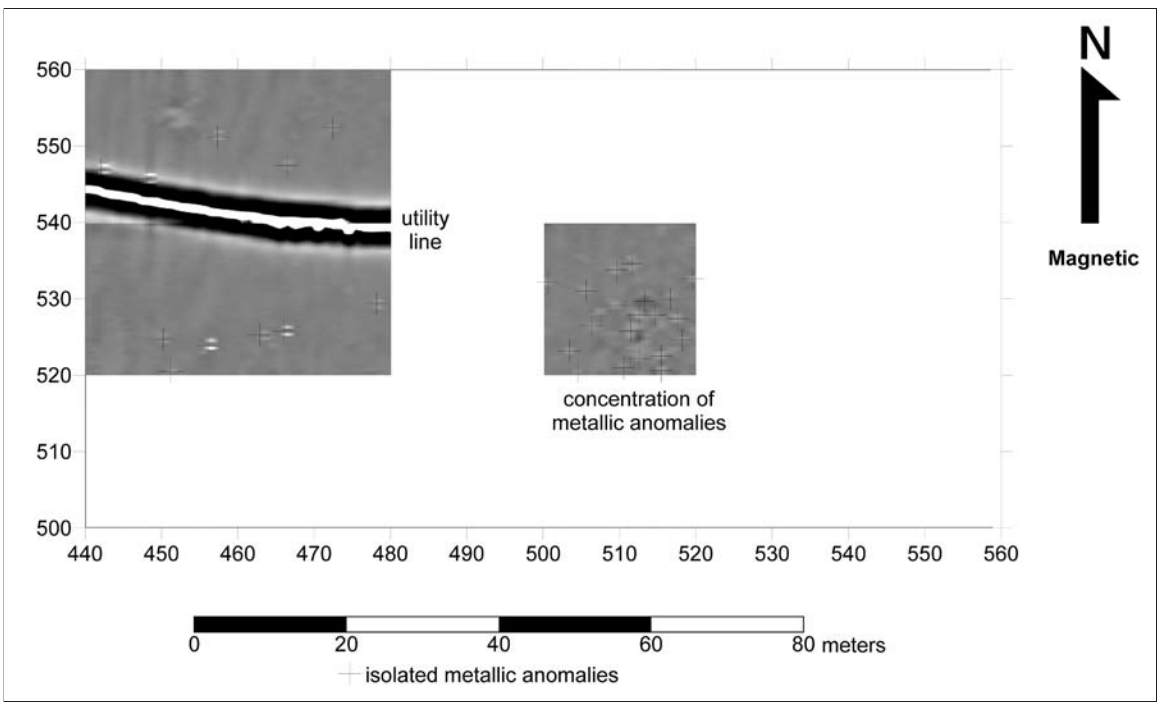


Figure 29. Conductivity data interpretations at the Hardscrabble residence project location, Site 23SL1223.

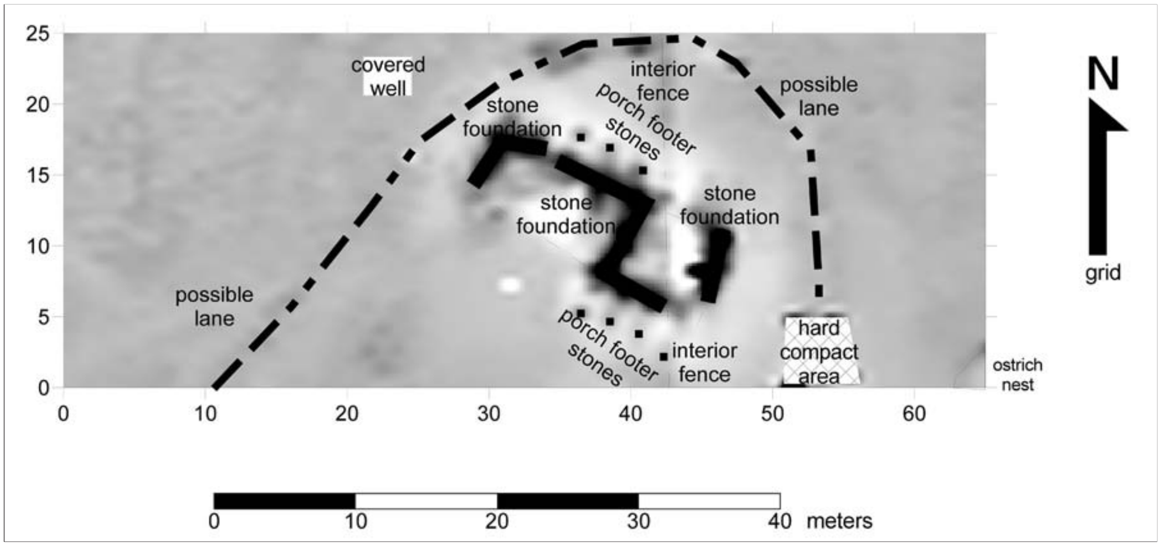


Figure 30. Resistance data interpretations at the Wish-ton-wish residence project location, Site 23SL1222.

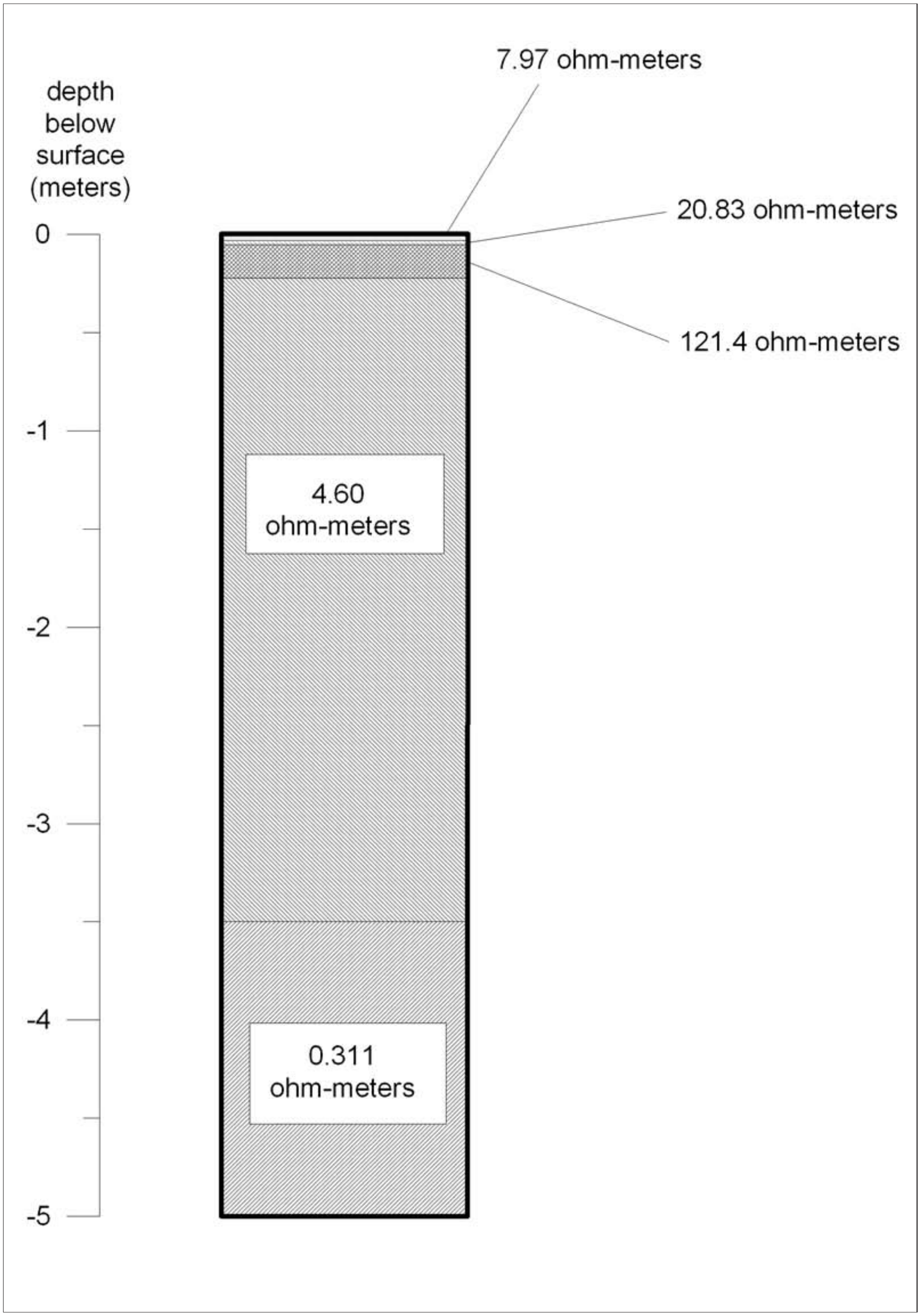


Figure 31. Electrical stratification of soil at Site 23SL1223.

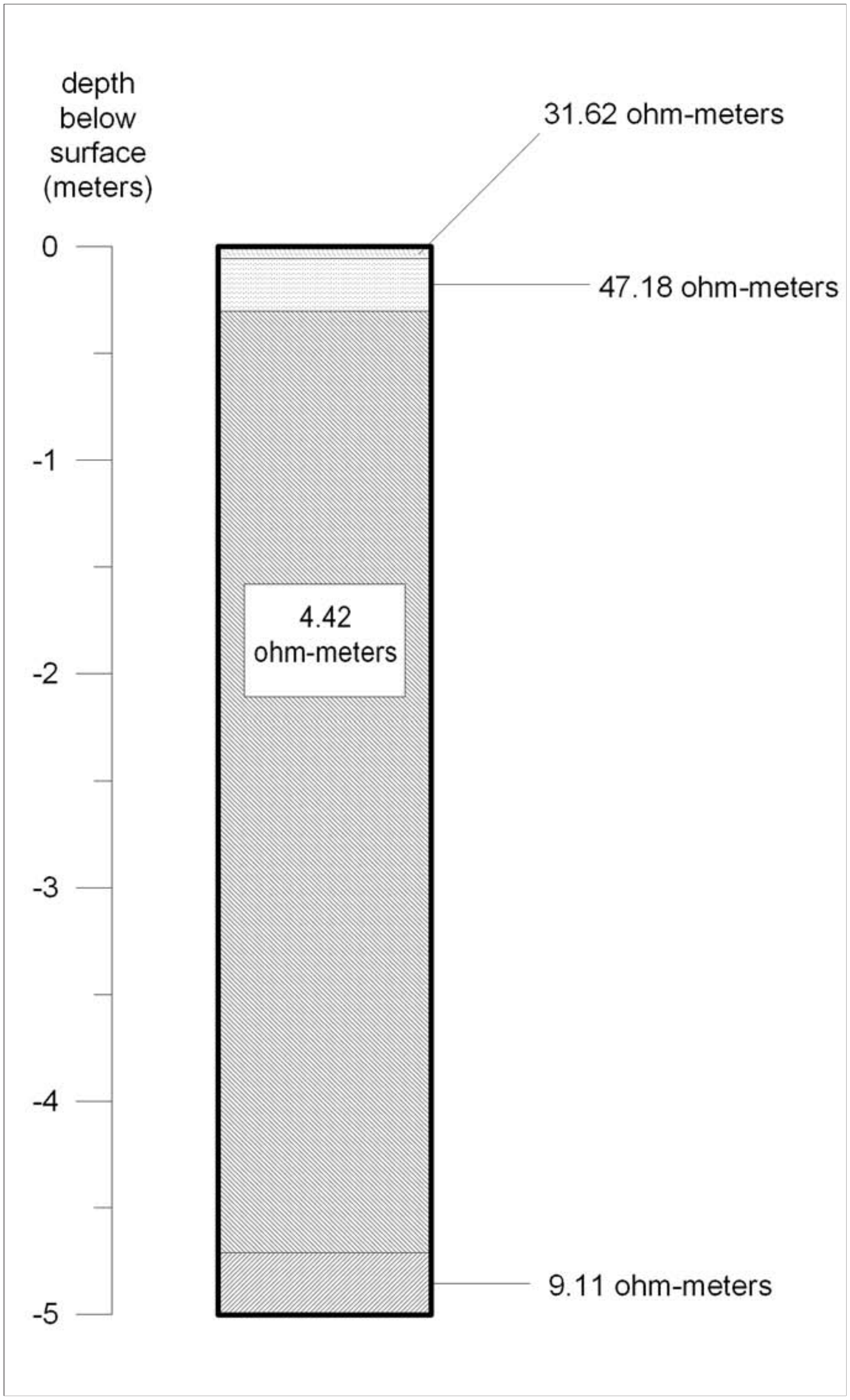


Figure 32. Electrical stratification of soil at Site 23SL1222.

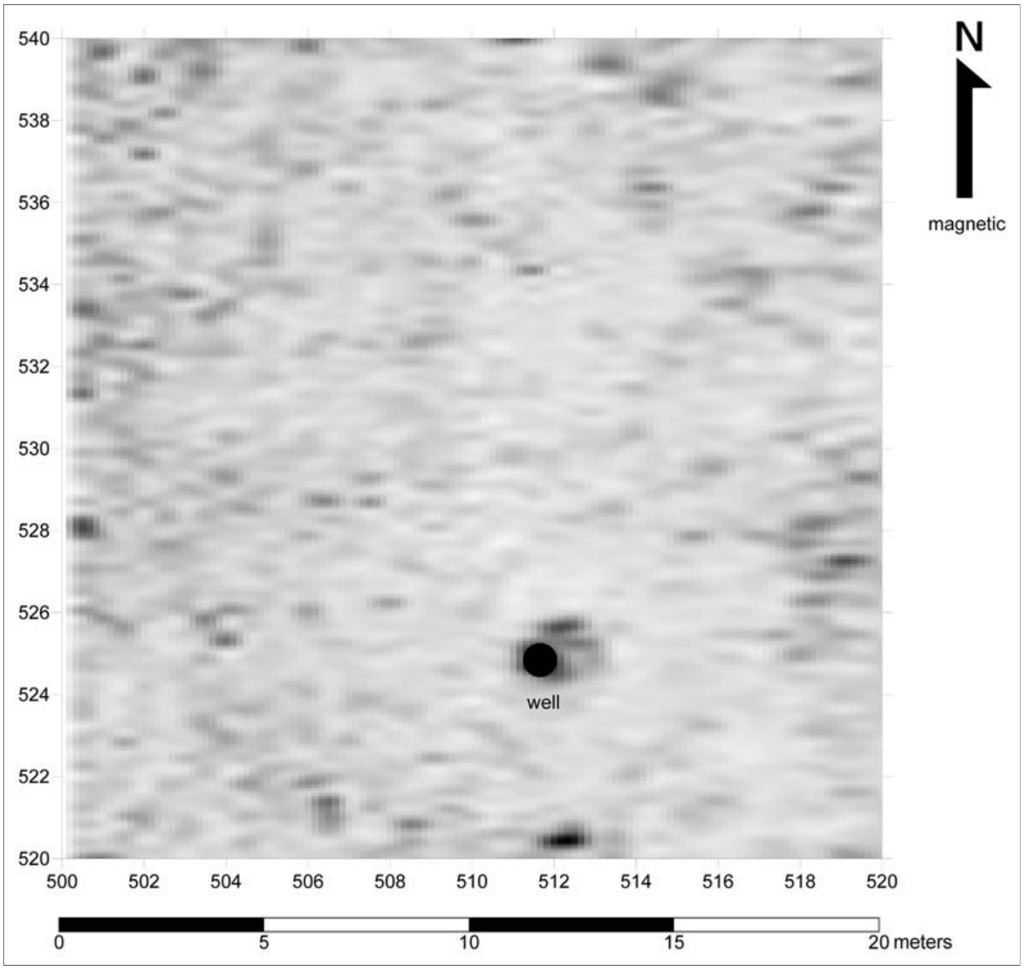


Figure 33. Ground-penetrating radar time slice data interpretations from grid unit 4 at the Hardscrabble residence project location, Site 23SL1223.

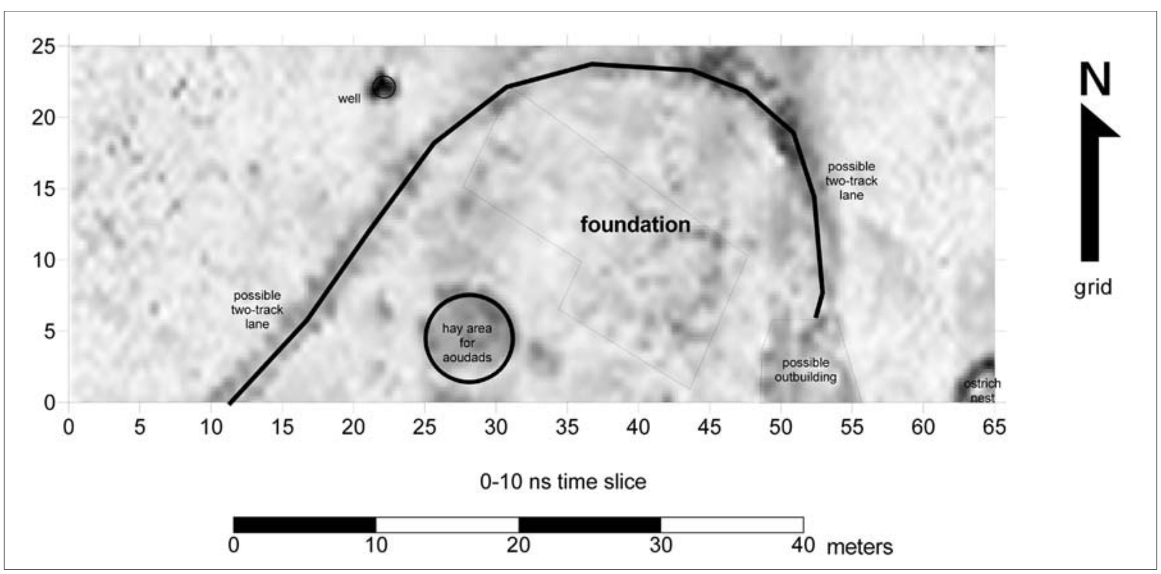


Figure 34. Ground-penetrating radar time slice data interpretations at the Wish-ton-wish residence project location, Site 23SL1222.