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A Controlled Archaeological Test Site Facility in Illinois: Training and Research in Archaeogeophysics

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A Controlled Archaeological Test Site (CATS) facility has been constructed in Champaign, Illinois, by the Cultural Resources Research Center at the U.S. Army Corps of Engineers Construction Engineering Research Laboratory, with funding provided by the National Center for Preservation Technology and Training. The test site will be utilized for research and training with geophysical applications in archaeology. The CATS facility replicates a range of archaeological features commonly encountered in North American archaeological sites and offers a controlled environment for the application of non-destructive investigative techniques. The site provides the opportunity for geophysicists and archaeologists to work with features of known geophysical attributes in a controlled geomorphological setting. In addition to providing a controlled "test bed" for training students in the use of geophysical techniques, the CATS facility will be available for research in a broad range of problems associated with archaeogeophysics, such as the effects of environmental conditions on geophysical expression, sensor type and configuration, data sample density, image processing and pattern recognition, operator variation, and feature variability. This research will contribute to our ability to interpret geophysical data and refine field methods for application in archaeological investigations.

Introduction

While geophysical prospecting and other forms of remote sensing have been in use by archaeologists for nearly a century (Wynn 1986a, 1986b), they have not found general acceptance among archaeologists working in the United States. Although there have been a number of advances in laboratory and other analytical methods over the last few decades, archaeological field methods have remained relatively conservative. The majority of archaeological investigations practiced in the United States are oriented toward cultural resource management compliance under the National Historic Preservation Act of 1966 (NHPA Sec. 106, Public Law 89-665, as amended), which requires federal

land-managing agencies to identify and evaluate sites that may be eligible for inclusion in the National Register of Historic Places (NRHP). The determination of NRHP eligibility involves an assessment of the significance of archaeological sites based in part on evaluations of the site's integrity. It is in this endeavor that archaeogeophysics, the application of geophysics to archaeology, can make a significant contribution to archaeological field methods. Traditionally, site evaluations have relied heavily on the excavation and analyses of a limited number of subsurface tests, usually representing less than 1% of the total site area (Custer 1992; Shott 1987). Since such test excavations provide information from a discontinuous and small sample of the site, potentially significant cultural deposits can

be missed. Basing NRHP eligibility on these statistically small samples can lead to errors in site assessment.

By conducting continuous coverage geophysical surveys at archaeological sites, the distribution of geophysical anomalies, in many cases cultural in origin, can be recorded. Geophysical information about the spatial distribution of cultural features at a site, and in some cases, information about the location and extent of archaeological midden deposits, can be used to optimize the placement of test excavations. Alternatively, information about the lack of such subsurface features can also be used to buttress determinations of NRHP ineligibility. This approach reduces the element of chance inherent in traditional site testing strategies. While geophysical surveys are not appropriate for all sites or under all field conditions, their application can result in significant time and cost savings for the eligibility assessment process.

Although the application of remote sensing techniques is specifically mentioned in *National Register Bulletin 15* as an appropriate investigative method (U.S. Department of the Interior 1995: 23), it has rarely been employed in cultural resource management (CRM) activities in the United States (Schurr 1997). The reluctance of American archaeologists to apply these techniques in archaeological research stems in part from the nature of much of the prehistoric archaeological record in North America. Many archaeological sites lack monumental architecture and contain small features that produce weak geophysical expressions. The ephemeral nature of much of the prehistoric North American archaeological record has led many investigators to believe that geophysical techniques simply do not work on most archaeological sites, especially prehistoric ones (Dalan 1993: 76).

Recent advances in microprocessors, image processing, and instrumentation, however, have increased the efficiency and reduced the costs associated with collecting high resolution geophysical datasets which have an increased probability of detecting small cultural features (Wynn 1986a, 1986b; Weymouth 1986a) typical of many sites in North America. These kinds of spatial data are very useful in addressing questions of "integrity of design" (U.S. Department of the Interior 1995: 44) or intrasite organization that are particularly elusive in traditional test excavation strategies. Therefore, archaeogeophysics can enhance the quality of traditional site testing information and provide data previously available only in large-scale site mitigation projects. Since most NRHP-eligible archaeological sites on federal lands are not excavated, the quality of information pertaining to the national inventory of archaeological sites would be greatly improved if geophysical surveys were routinely employed. Of course, any techniques

that enhance the reliability and reduce the costs for CRM are also of great value to more general archaeological research efforts.

Geophysical survey techniques, however, are not appropriate for use in every case and certain techniques may be more reliable than others depending on the project goals and the nature of the site. For instance, it would not be wise to employ ground-penetrating radar on a site thickly covered with vegetation or with exceedingly clayey soils, nor is it recommended to search for small archaeological features on a site littered with metallic debris by using electromagnetic techniques. In order for geophysics to be routinely employed, the feasibility of its application under different conditions and to differing archaeological problems must be clearly understood.

The Need for a Controlled Test Site for Training

With the rapid advances in geophysical methods and technology comes a greater need for the dissemination of information about the capabilities, limitations, and proper use of geophysical techniques for archaeology (Wynn 1986b). Archaeologists have often had unrealistic expectations of geophysics, lacking an understanding of the nature of their application and inherent limitations of the technology. Many of the negative experiences of past geophysical applications in archaeological contexts stem from the application of inappropriate technology for a given site and field conditions (Wynn 1986b), the improper application of geophysical methods by archaeologists themselves, and the difference in site perceptions between archaeologists and technicians hired to conduct geophysical surveys (Dalan 1993).

Frequently, training on geophysical instruments is obtained "on the job" at real archaeological sites where the lack of experience can lead to costly errors and may result in the destruction of resources that might otherwise have been avoided (Schurr 1997). Because each new site represents a unique archaeological record and a unique set of environmental conditions, the effectiveness of training "on the job" is seriously reduced. In addition, verifying geophysical survey results on real sites through excavations affects archaeological resources. Currently, formal training in geophysical techniques for archaeologists in the United States is limited to the National Park Service's annual workshop on archaeogeophysics and remote sensing, which has been conducted since 1990 (De Vore 1992), and to a few university programs such as those at Notre Dame (Schurr 1997) and the University of Nebraska (Weymouth 1986b).

The new CATS facility in Champaign, Illinois, provides

a permanent location at which a variety of training situations can be created to provide experience in designing archaeogeophysical surveys, conducting field exercises with a variety of equipment under a range of site conditions, and carrying out data reduction, analysis, and interpretation without excavation. The CATS environment can be altered to simulate different field conditions ranging from variations in vegetation density and soil moisture content, to proximity to electrical or magnetic interference. The replicated features in the site are designed to represent a mixture of sizes, shapes, and material compositions to produce a variety of geophysical signatures representative of archaeological features common to the midwestern United States.

The features were designed and constructed with careful control over location and composition. The depths and horizontal proximity of different features were varied to create challenges for geophysical detection and interpretation by students. Because the physical characteristics and properties of the features are known, there is no need for excavations.

The Need for Controlled Test Site Experimentation

In addition to its use as a training facility, a controlled archaeological test site is also needed for experimentation with innovative geophysical equipment, software, and interpretive models. Better known remote sensing techniques, such as magnetics and magnetic susceptibility (Clark 1996; Dalan and Banerjee 1996), metal detection (Scott and Fox 1987), electrical resistivity, conductivity, and electromagnetics (Bevan 1983; Dalan 1991; Gaffney, Gater, and Ovenden 1991; Heimner and De Vore 1995), ground-penetrating radar (Bevan 1991; Conyers and Goodman 1997; Vaughan 1986), and self-potential (Wynn and Sherwood 1984), can be tested to refine our understanding of the influences of environmental conditions, site characteristics, sensor type and configuration, data sample density, and operator variability on geophysical expressions. The interaction of these variables is not well understood and therefore interpretations must rely heavily on theoretical and mathematical models of the geophysical expressions of hypothetical features (Clark 1996; Scollar et al. 1990). The CATS facility will allow our prior knowledge of the material composition, density, and dimensions of simulated features to be incorporated into mathematical models. These models will augment our ability to predict the geophysical expression and concise areal extent of archaeological features under field conditions (Tsokas and Tsourlos 1997).

The CATS facility also provides a context for research

and development of new geophysical technologies. For example, U.S. Army Construction Engineering Research Laboratory (USACERL) is conducting basic research on two new techniques which may have archaeological applications: nuclear quadrupole resonance and phased array ultrasonic detection. Experimentation with these systems in a controlled environment, such as CATS, with a set of simulated archaeological targets provides a realistic assessment of their potential for archaeological fieldwork.

The CATS Facility

The site comprises 2500 sq m and is located on the property of USACERL in NW Champaign, Illinois. It is situated on an almost level plot of prairie-developed Drummer silty clay loam and Catlin silt loam soils in a former agricultural field. The natural soil profiles generally display a black, firm silty clay loam A horizon ca. 36 cm thick. The B horizon usually appears as a dark gray (upper profile) and a yellowish brown (lower profile) silty clay loam about 84 cm thick. Preliminary surveys of the site, archaeological and historical records, air photographs, and maps revealed no indications of previous disturbance other than farming and some possible surface disturbances resulting from the construction of the USACERL parking lot located 200 m to the south. The site is free of obstacles and interference from traffic or utility lines.

A baseline geophysical survey using resistivity (Geoscan RM15 Resistance Meter) and magnetics (Geoscan FM36 Fluxgate Gradiometer) was performed at the site by the Institute for Minnesota Archaeology (Mathys 1996) before CATS construction was initiated. This survey was conducted to provide baseline geophysical data for comparison with later surveys and to determine if subsurface anomalies are present within the testing area. The 50 × 50 m site area was divided into 25 grid units for the high resolution surveys, each measuring 100 sq m (FIG. 1).

The resistivity survey showed that the site lacks concentrations of discrete geophysical anomalies but contains three large areas which grade from low to high resistance that cover the entire site. The NW quarter of the site exhibits slightly higher resistance than the southern half of the site, while the NE quarter exhibits relatively low resistance values. No discrete anomalies were identified and the low resistivity readings in the NE part of the site appear to be the result of a thin (< 10 cm thick) deposit of clayey soil overlaying the plowzone of that area. Magnetic results showed eight isolated bipolar anomalies indicative of ferrous objects, probably small pieces of discarded farm machinery. Three larger weak magnetic anomalies were identified that correspond to the location of the redeposited clayey soils with low resistance values. Since the anomalies

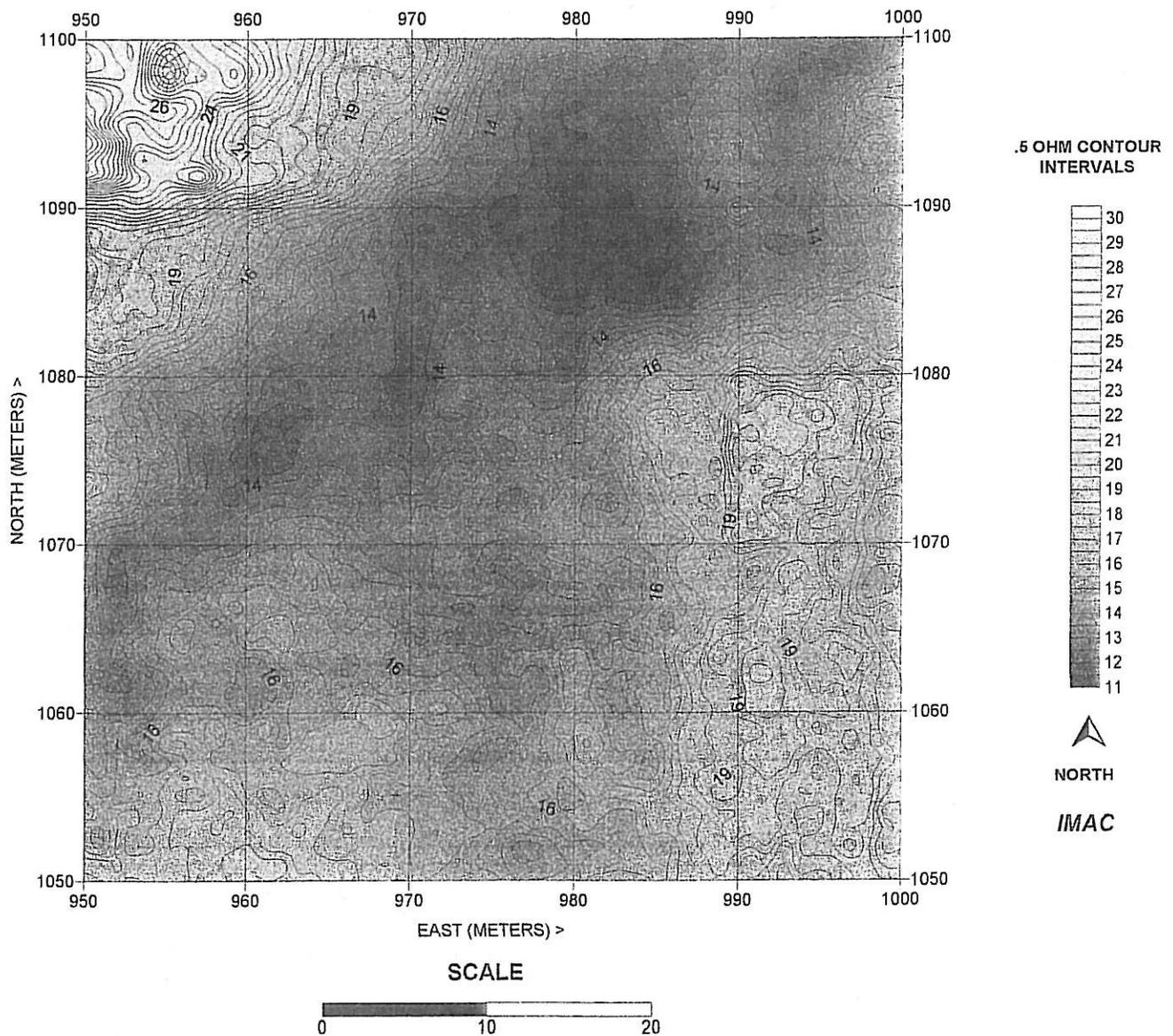


Figure 1. Baseline resistivity composite map of the CAT site showing a lack of discrete resistance anomalies (from Mathys 1996: fig. 2).

detected by the geophysical surveys were not significant enough to alter the design of the site, they are viewed as part of the background data typical of most archaeological sites and will be taken into consideration during all future CATS projects.

Background research was conducted in the fall of 1996 by students of the University of Illinois, Department of Anthropology, to develop models of prehistoric and historical cultural features commonly associated with archaeological sites in the midwestern United States. Representative samples of archaeological features from real sites

were selected to guide the development of modeled feature designs. Individual features and target clusters were then designed to take into consideration material composition, proximity to other features, and feature configurations. Materials ranging from on-site soils to clam shells from the Mississippi River were incorporated to provide the diversity of geophysical attributes that might be found in cultural features. A range of depths, target shapes, and horizontal positions challenge the capabilities of different geophysical techniques and data processing routines.

Among the features that have been constructed at the

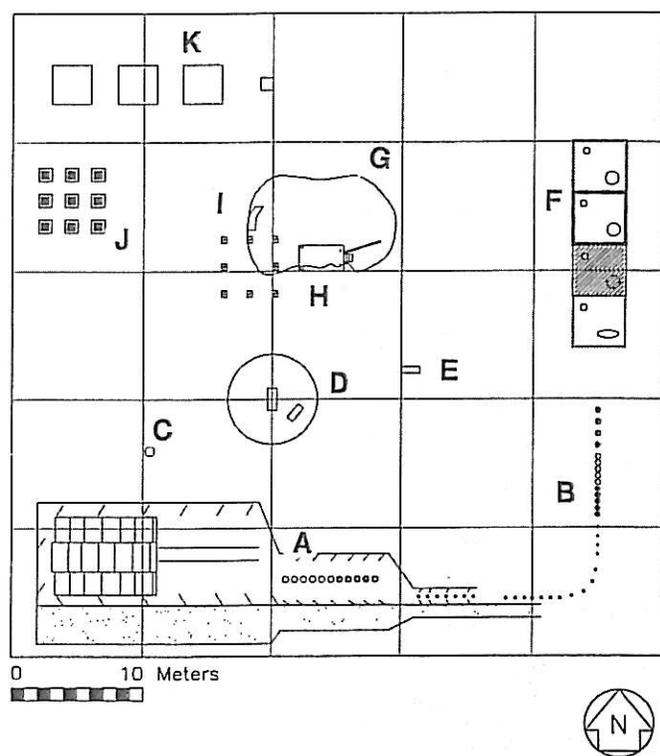


Figure 2. Map of the CATS facility showing feature layout. A) ditch and embankment complex; B) palisade; C) roasting pit; D) mound; E) isolated burial; F) house complex; G) midden; H) historical cellar; I) limestone picrs and brick sidewalk; J) brick matrix; K) matrix of wood and metal objects.

CATS facility (FIG. 2) are: 1) monumental architecture in the form of ditches, embankments, mounds, and palisades; 2) domestic architecture in the form of four contiguous house floors and associated features; 3) mortuary or forensic features in the form of pig and dog burials in mounds, under house floors, and as isolated pits; 4) hearths, roasting pits, refuse pits, and artifact clusters; 5) a matrix of bricks of varying composition and depth; and 6) a matrix of wooden rods, metal pipes, and other objects in various configurations and depths.

The CATS field, in common with a large number of sites in the eastern United States, has been disturbed by agricultural activity, so all constructions were designed to represent sub-plowzone features. This enabled the post-construction plowing of the site to reconstitute the surface geophysical characteristics of the Ap horizon (plowzone) soils typical of a plowed prairie site. The plowzone was stripped from the large areas of construction and then replaced after the sub-plowzone portions had been completed.

Although a small front-end loader assisted stripping and replacement of plowzone, all other excavations were by hand to reduce the effects of compaction and disturbance

from heavy equipment. All stages of construction were photographed and mapped using a Sokkia SET2CII total station. Representative profiles of the natural soil horizons were also recorded as a reference for comparisons.

The largest construction at the site is a ditch and embankment complex that measures 11 m at its widest and 39 m in length. At its deeper end, the ditch is 1.4 m below the ground surface and 3 m wide (FIG. 3) but decreases in size to 1 m wide and 0.5 m deep. The embankment ranges from 1.5–7 m in width and 0.5–1.5 m in height. The structure is built in segments of differing dimensions and composition to generate a variety of geophysical expressions. The embankment was composed primarily of soils removed from the adjacent ditch sections, and the ditch was filled with a combination of sand, off-site A horizon soils, and clays from on site.

A variety of smaller internal features were constructed within the embankment and ditch. These include concentrations of limestone and igneous rocks at varying density and configuration beneath the embankment wall, and postholes of differing size and fill intruding into parts of the embankment. The ditch contains smaller, or nested, features including whole and broken ceramic flower pots, igneous rock and shell concentrations, a wood log section, and three burned surfaces or hearths. Soil temperature readings were recorded every 15 minutes during the controlled burns using Omega Engineering, Inc. thermocouples (FIG. 4) placed at various locations within the hearths and burned house floor (described below).

A series of postholes extends from those in the embankment, beyond the ditch and embankment structure, to form a replicated palisade. Here, too, changes in the dimensions and material contents of the postholes occur every few meters. Postholes were filled with sand, limestone, igneous rock, clay, or local A horizon soils. Several postholes were filled with burning wood to simulate a burned palisade.

The next largest construction is a series of four contiguous house floors with associated internal features (FIG. 5). This complex measures 12 × 4 m and is divided into four house compartments simulating different configurations of attributes. Each house contains a hearth (FIG. 6) and one additional pit feature. The pits in three of the houses simulate deep storage or refuse features (FIG. 7) and contain layers of clay, manure, sand, and local loamy soils. A fourth structure contains a simulated human burial using a pig carcass (see, for example, France et al. 1992). A series of small postholes line the walls of two of the houses and are filled with either sand or local silt. The earthen floor of one of the structures was burned to replicate the effects of a house destroyed by fire (FIG. 8).



Figure 3. West-facing view of the ditch and embankment feature showing nested smaller features within the ditch.

A circular earthen mound constructed in the central portion of the site simulates a mortuary feature common to the eastern United States. The mound measures 7 m in diameter and 1.5 m in height. The plowzone soil was stripped from the area and a large central crypt was excavated below the mound floor. The crypt was lined with wooden logs and an extended pig carcass was deposited in the tomb. An additional shallow burial pit containing a pig carcass was constructed below one side of the mound slope. Replicated ceramic vessels and clam shells were added to the burial pits as nested features. The earthen mound was then built using on-site and off-site A horizon soils.

Additional isolated pits in open areas of the site, away from the larger complexes, include a deep roasting pit, a shallow dog burial and a larger pig burial. The roasting pit is a deep cylindrical hole in which a series of fires was built



Figure 4. Attaching thermocouples for a controlled burn in a hearth.



Figure 5. North-facing view of house floors showing hearths and storage pit features.

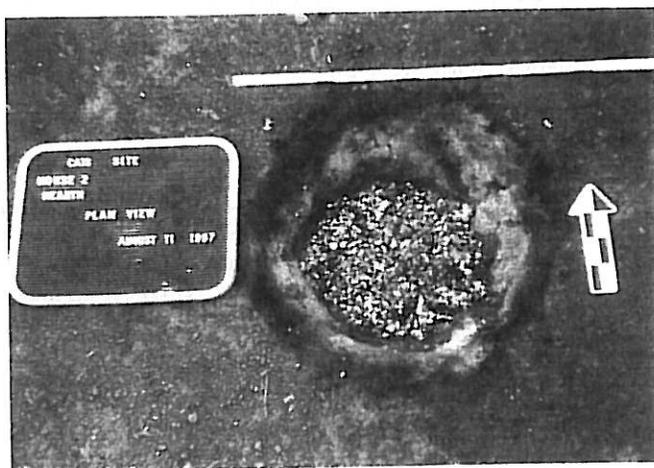


Figure 6. Newly burned hearth showing soil discolorations.

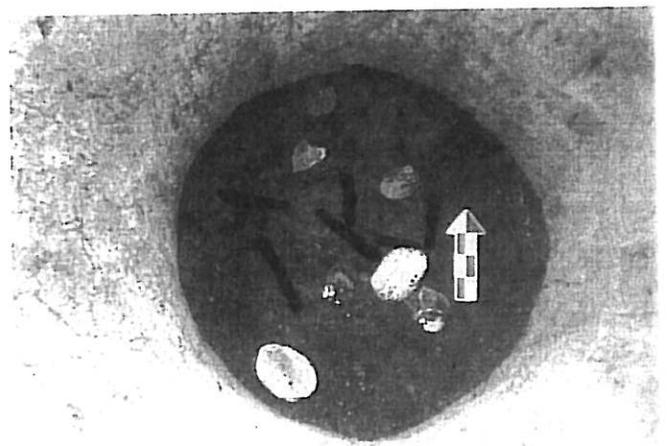


Figure 7. Deep bell-shaped pit feature containing clam shells and charred corn cobs.



Figure 8. House floor during controlled burn.

to cook food for student crews working on the site using a Tonganese earth oven cooking technique employing heated stones. The resulting feature has layers of burned earth, charcoal, and fire-cracked igneous rock, and was allowed to silt up naturally for a year before being completely refilled.

The animal burials in isolated pits were both skeletal and "in-the-flesh." The canine burial consisted of a shallow basin-shaped pit containing a skeletonized partial carcass of a road-killed dog. The isolated pig carcass was interred in a narrow, oval pit and represents an isolated burial or forensic case (cf. France et al. 1992).

A matrix of nine cylindrical postholes containing three types of ceramic bricks was constructed in the western part of the site. The matrix is arranged in three rows of three postholes each. Each row of three postholes contains bricks of the same type buried at different depths, generating subtle differences in magnetic readings.

Complex arrangements of different materials were assembled in four large pits in the NW corner of the site primarily for experimentation with phased array ultrasonic detection technology. One pit measures 1.2 m sq and 1.2 m in depth and contains metal cans arranged at varying depths. Another pit measuring 2.4 m sq and 2.4 m in depth contains metal paint cans arranged at different depths and at differing angles. A third pit measuring 1.8 m in depth and 2.4 m sq contains wood, metal pipe, and ceramic brick at various depths. Each set of these materials was arranged to form the letters "CERL" for experimentation with imaging methods. The fourth pit, measuring 20

× 60 × 13 cm deep, contains ten wooden dowels arranged at increments of depth and horizontal spacing that increase at 1 cm intervals.

Additional feature complexes planned for future construction include a simulated midden, historical house piers, a brick sidewalk, and a matrix of varying gravel densities. The midden will include various lenses of shell, chert, and pottery that become increasingly ephemeral toward the margins. The house piers will be constructed of small clusters of limestone slabs arranged at 2 m intervals just below the plowzone. The brick sidewalk will increase in depth toward one end. The gravel matrix will vary in density with every 2 m of length simulating roadbed sections and degraded wall foundations.

Discussion

A number of experimental archaeological sites have been constructed to examine problems specific to site formation processes (Crabtree 1990; Fowler 1980; Nash and Petraglia 1987; Riley and Freimuth 1979) or excavator effectiveness (Chilott and Dectz 1964). Similarly, artificial test sites have been constructed for geophysics training in forensics (France et al. 1992; Davenport et al. 1988) and testing technologies for detecting unexploded ordnance (PRC Environmental Management, Inc. 1994). A similar site is currently under planning by the Department of Energy in Richland, Washington and will also contain experimental, control, and simulated cultural features. Additionally, two individual experimental features have been

constructed for comparisons with real site data in north-central Texas (Martin, Bruseth, and Huggins 1991). The CATS facility is, however, the first complete site to be constructed and available specifically for archaeogeophysical training and experimentation.

Control features of uniform geophysical properties and dimensions will be added at the CATS and other similar facilities around the country (Darby Stapp and G. Clark Davenport, personal communications 1997) allowing the study of environmental effects on geophysical signals. With the foreknowledge of the spatial and geophysical characteristics of the targets, the site provides an ideal context for experimentation and training with geophysical technologies and field methods under controlled conditions.

The site provides the opportunity for geophysicists and archaeologists to work as interdisciplinary teams toward advancing the understanding and acceptance of geophysical capabilities in archaeological research. It is our hope that these specialists will recognize the CATS facility as ideal for advancing cooperative efforts of the two disciplines. Toward this goal, USACERL invites archaeologists and geophysicists to submit proposals for training and experimentation at the site.

Future Research Directions

USACERL has recently acquired two geophysical instruments, a Geoscan FM36 Fluxgate Gradiometer and a Geoscan RM15 Resistivity meter with a multiplexer array. Available software includes the suite of analytical and visual tools contained in the Geoplot software package and a commonly used PC-based mapping package, Surfer. A National Center for Preservation Technology and Training Applied Research Grant has been awarded to investigate refinements in geophysical prospection to increase the dependability of archaeological site testing for National Register of Historic Places (NRHP) eligibility with a minimum of site disturbance. Smaller more limited excavations could then be used to document intact subsurface features. This approach, which USACERL archaeologists have applied in the past with varying degrees of success, has been hampered by the spatial imprecision of geophysical data. The benefits of such an approach are clear; smaller excavations produce less material for long-term curation, are faster and less expensive to complete, and produce defensible data for NRHP eligibility assessments. For a federal land managing agency with thousands of archaeological sites awaiting testing, such an approach makes good sense.

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