This document is edited and formatted for submission to the Journal of Field Archaeology

The Effectiveness of Historic Human Remains Detection Dog Teams in Locating Historic Unmarked Cemeteries.

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Abstract

Unmarked cemeteries pose a unique set of problems for archaeologists and land managers. Many people have strong opinions on what are appropriate treatments for the dead. In the United States graves are often given special protection under federal and state laws. Identification and verification of historic and prehistoric cemeteries through standard archeological techniques, however, is problematic since traditional excavation techniques is often discouraged or prohibited. Traditionally, archaeologists have used geophysical survey as a noninvasive technique to locate lost cemeteries.

A recent development in noninvasive grave location techniques is the use of Historic Human Remains Detection (HHRD) dogs. These dogs are specially trained to detect the scent of buried human bones. Proponents of this technique claim the dogs can differentiate between human and animal bones and can detect graves exceeding 100 years of age and located up to 6 feet beneath the surface. Determining the effectiveness of HHRD dog surveys is problematic because ground truthing is rarely allowed. This report describes a scientific study testing the effectiveness of HHRD dogs and comparing HHRD dog results against geophysical survey results at multiple, unmarked, burial sites.

The study consisted of three stages. The first stage was a controlled survey where human and animal bones were buried at known depths in a field in Champaign, Illinois. After several months the dogs were tested to determine if they could locate only the human bones. The study's

second stage was a survey conducted at a known cemetery in Urbana, Illinois with standing headstones in portions of the cemetery and open spaces that were known to contain unmarked. At this site, the dog team results were compared to the results of a GPR survey. The third stage was a survey that tested the dogs and geophysical techniques at homestead sites with small cemeteries (or suspected cemeteries) at Fort Gordon, Georgia and comparing the results. This phase utilized geophysical data from Fort Gordon that was collected in 2011 (Hargrave 2012).

Background and previous work

Human burial sites form a unique class of archeological site. Local civilian populations tend to have strong emotional ties to historic cemeteries and Native American cemeteries are deemed places of religious significance and given special protection under federal law (Native American Graves Protection and Repatriation Act of 1990). Standard operating procedures on most (if not all) government installations is to identify and protect insitu all known locations of human burials. The location of many cemeteries, however, is unknown due to a lack of recognizable visual cues, such as grave markers. Identification and verification of historic and prehistoric cemeteries through standard archeological techniques is problematic because the sites must be investigated without excavation. Traditionally, archaeologists have used geophysical survey as a noninvasive technique to locate lost cemeteries.

In 2009, archaeologists at US Army Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL) in Champaign, Illinois, were approached by the Cultural Resource Management Office for Fort Leavenworth, Kansas, to conduct a geophysical survey to locate a historic, unmarked Nez Perce cemetery within the installation (Hargrave 2010). At the request of the Nez Perce Nation, Fort Leavenworth included Historic Human Remains Detection (HHRD) dog teams as one of the methodologies that were to be deployed in the search for the cemetery.

During this work, the archaeology team and the HHRD dog teams were working simultaneously. It was observed that the dogs were able to: (a) cover significantly more ground than the archaeologists, (b) did not alert on the remains of wild animals that were observed on the ground surface, and (c) were alerting on the measuring tapes that ERDC-CERL had used in previous cemetery surveys.

The HHRD dog teams alerted at several locations in the project area, but ground truthing of any suspect areas was prohibited. Post-WWII disturbance of the study area meant that geophysical survey results were inconclusive. As a result, it was not possible to verify the accuracy of the HHRD alerts.

Principles of canine scent detection

The science behind the dog's scent detection ability is not fully understood, but the success of some dog teams have been noted in recent years.

> The ability of HRD [Human Remains Detection] canines to detect these sites, while poorly understood, uncharacterized, and unstandardized, is nevertheless impressive. Their ability to locate as little as 5-15 mg of human tissue, blood, or bone, either buried, on the surface, or elevated above the ground, still exceeds the ability of our best instrumentation. Additional verbal reports of their ability to identify cremains, graves over 100 years old, and minute amounts of human material (even when masked) nearly defy explanation. (Vass *et al.* 2008: 384).

A study conducted by Desert Research Institute (DRI) in 2011 noted that HRD dogs were able to locate individual human teeth with accuracy and false positive rates at 20%-70% (variation by dog) (Cablk and Sagebiel 2011). Lasseter *et al.* (2003) examined the use of dogs trained to detect the generic scent of human decomposition and found that, despite not being trained to alert specifically on dry human skeletal remains, all dog teams involved in the study were able to narrow the search area for this material buried at 1 ft depth for at least one sample, with the overall success rate of 15%. One dog was able to locate, through alert, a single human vertebra buried at 2 ft depth for only two months. A Canadian study (Komar 1999) used eight dog teams to locate dried human bones and fabric soaked in human decompositional fluid to simulate the scent patterns of human remains that had experienced extended postmortem intervals and animal scavenging. In training sessions, where the handlers knew how many items were present, the success rate was 77%–100% in locating all of the dry human bones. In field trials, where the handlers were unaware of the sample size, the dog teams still had a 63%-95% success rate.

Despite reports of HRD dog team success rates, there is ongoing debate and research about what chemicals the dogs are detecting that allows for grave detection and differentiation between human and animal remains. Scientist at the Oak Ridge National Laboratory conducted a two part study to create a Decompositional Odor Analysis Database (DOAD) to attempt to isolate the volatile chemical signature of the decomposing remains of humans and various animals. The first study (Vass *et al.* 2004) focused on the first 1.5 yr of human burial decomposition by utilizing remains buried at depth ranges of 1.5–3.5 ft below the surface and causes of death ranging from accidental to various ailments including cancer (treated with radiation and chemotherapy). The results indicated that the processes of decomposition are not straightforward and can be affected by a variety of environmental conditions. The study identified 424 specific chemicals released from the decomposing human remains. These chemicals were divided into eight classes: (1) cyclic hydrocarbons, (2) noncyclic hydrocarbons, (3) nitrogen compounds, (4) oxygen compounds, (5) acids/esters, (6) halogen compounds, (7) sulfur compounds, and (8) other compounds. With the exception of the halogen compound, environmental factors such as barometric pressure, air temperature, humidity, soil temperature, soil type, and/or soil water content affected not only the dissemination of the scents but the production of the chemicals as well. The depth of the burial, peri-mortem weight and diet also affected the amount and range of chemicals escaping from the grave.

The follow-up study (Vass *et al.* 2008) continued the study from human remains 1.5 –4 yr after burial and included data obtained from a burial 16 yr old, where only skeletal remains were present. In this work, 478 unique chemical compounds were identified radiating from the remains; of these, only 30 were identified as “key markers of human decomposition which were detectable at the soil surface” (Vass *et al.* 2008: 387). There were 11 of the compounds that were only detected in the early stages of decomposition, 5 additional compounds persisted until all soft tissue was fully decomposed, and 14 compounds were detected throughout the decomposition process, including the 16-yr-old burial. A second part of the study examined the chemical vapors released from unburied long bones of human, pig, dog, and deer that had been defleshed 5-9 yr prior to the study. There were 72 compounds detected, and 12 of these were determined to be significant markers of burial decomposition. A final study (Cablk *et al*. 2012) looked at chemical compounds released by separate tissue types from different species of animals and compared them to published results of human decomposition odors. The study focused on eight classes of chemical compounds (acids, aldehydes, ketones, alkanes, alcohols, sulfides, amines, and aromatics) and looked at how the frequency of these compound classes varied in different tissue types (bone, fat, muscle, and skin), instead of looking at whole-body decomposition as previous studies did. The results indicated that not only did the amount of tissue (as a percentage of total body mass) vary from species to species, but the compound class percentages had distinct profiles for each tissue type by species.

These studies demonstrate there are distinct sets of chemicals that are emitted from decaying remains throughout the decomposition process, even after soft tissue is completely gone, and that the total chemical composition of odiferous compounds generated by skeletal remains varied between species of mammals. This finding indicates that there is a scientific basis for HRD dog's ability, by scent alone, to detect graves and differentiate species. In addition to attempts to isolate what the dogs are smelling, studies also have been conducted on which environmental conditions aid or inhibit scent detection by dogs. Debra Komar (1999) looked at dogs' ability to detect various scattered decomposition scents in a temperature range of -22°F to 50°F, with various ground covers including 25 cm of snow and scattered water puddles. She noted that in extreme cold temperatures and deep snow, some dogs either could not or would not work, but the dogs that did work in those conditions did not appear to have lower success rates than they did in better conditions. Other studies have suggested that the effectiveness of the dogs starts to drop off at temperatures exceeding 85°F (Killam 1990; France *et al.* 1997). As the temperature increases, the dogs tire quickly and pant to cool off. As they then are breathing through their mouths and not their noses, their ability to detect scent drops dramatically. A study conducted during July and August in Tuscaloosa, Alabama, found that half the dogs in the trial stopped alerting after the temperatures rose above 90° F (Lasseter *et al.* 2003). Scent vapor radiates away from the decomposing remains through diffusion (Killam 1990; ICF 2013b). Volatile compounds will follow the path of least resistance, and conditions such as bioturbation, variation in vegetation, erosion, water seepage, and man-made ground disturbing events can create paths where the scent will disseminate farther away from the burial site. As a result, HHRD dogs do not necessarily alert immediately over a burial site but may alert within a few meters of a burial.

Geophysical techniques

Geophysical techniques are gradually being more widely used by archaeologists in the United States. Previous investigations have demonstrated that all of the widely used geophysical methods (including electrical resistance, magnetic gradiometry, ground penetrating radar [GPR], conductivity, and magnetic susceptibility) can—when properly used at suitable sites—be useful in detecting subsurface archaeological features and other deposits (Bevan 1991; Clark 2001; Conyers 2004; Hargrave 2010; Johnson 2006; Witten 2006; Baxter *et al.* 2010; Hargrave and Dunn 2010; Hargrave 2010). All geophysical techniques used in archaeology rely on the (geophysical) contrast between a subsurface target (in this case, historic graves) and the surrounding soil (Clark 2001; Gaffney and Gater 2003; Kvamme 2003). Factors that contribute to these geophysical contrasts include soil moisture, texture (e.g., silt, clay, sand, or loam), iron oxide content, the presence of fired clay (pottery, brick) objects, or ferrous metal artifacts (Clark 2001; Conyers 2006; Gaffney and Gater 2003). Ground penetrating radar (GPR) is particularly effective for identifying interfaces between materials that differ in terms of their absorption and/or reflectance of electromagnetic energy.   Additionally GPR is the only geophysical instrument widely used in archaeology that can measure a target's depth below surface, based on the speed at which the energy moves through the soil (Conyers 2004; Witten 2006).

The amplitude of radar energy reflected back to the surface is influenced by many objects and materials, including tree roots, animal burrows, rocks, soil strata interfaces, architectural remains, pipes, other archaeological features and deposits, and graves. Moist soils tend to absorb radar energy rather than allowing it to pass reducing the depth to which the energy penetrates and thus, the maximum depth at which graves or other features can be detected. Metal pipes and other large metal objects are excellent reflectors and are easily detected, but can obscure objects and deposits below them. Finally, the depth of the radar signal penetration, and the depth to which objects can be detected, depends on the frequency of the antenna being used and the conductivity of the ground.

Effective interpretations of GPR data require some understanding of how energy moves through the soil and is reflected back to the antenna. In some ways, a GPR profile is analogous to a soil profile, but one does not expect objects and features to be recognizable based on their actual shape and discrete objects (described as point sources) are often detected based on the presence of hyperbolas (i.e., inverted V-shapes). Conyers explains the occurrence of hyperbolas as follows: "Point source reflection hyperbolas… are generated because most GPR antennas produce a transmitted radar beam that propagates downward from the surface in a conical pattern, radiating outward as energy travels to depth. The pattern of energy dispersal will therefore spread out and be reflected from buried features that are often not located directly below the transmitting antenna" (Conyers 2014: no page number). The GPR records the location of the source of the reflected energy as if it was directly below the antenna, and this accounts for the hyperbola's "wings" being plotted at greater depth as the antenna moves away from the actual point source.

While some GPR surveys of cemeteries (and other archaeological sites) yield stunning results, many are less successful. Factors that can limit survey success include unfavorable surface conditions (e.g., vegetation, uneven ground, obstacles such as trees and grave markers), soil moisture, and clutter in the data associated with rocks, tree roots, rodent burrows, bedrock, etc. (Bevan 1991; Conyers 2006; Ernenwein and Hargrave 2007). Contrast between grave contents (coffins, partial voids) and the soil characteristics of grave shafts compared to intact soil is highly variable, and interacts with the other factors just described to influence survey outcome.

Data collection and analysis

In 2011, ERDC-CERL conducted GPR and magnetic field gradient surveys were conducted at each of the cemeteries on Fort Gordon (Hargrave 2011). While GPR is not effective in many settings, the sandy soil conditions at Fort Gordon, Georgia, made GPR the most promising technique (Ernenwein and Hargrave 2007). Use of a second technique increases the likelihood of detecting graves and other cultural features (Clay 2001, Kvamme 2006). At the Illinois cemetery, GPR was also considered the best technique. The presence of wrought iron fencing and a significant number of metal decorative items associated with the graves at this site illuminated magnetic gradiometry as a technique.

The GPR surveys were conducted using a GSSI SIR 3000 unit equipped with a 400 MHz antenna. Overall, data quality at Fort Gordon was good but not optimal. Data quality at the Clements Cemetery was poor due to high moisture content of the soil. The magnetic survey was conducted using a Bartington Grad601 dual gradiometer. This system consists of a light weight frame that supports two gradiometers separated by a horizontal distance of one meter. The system was set for its maximum resolution (.1 nanotesla). Data values were collected at .125 m intervals as the surveyor moved slowly along each transect. This strategy resulted in a relatively high-density survey (8 data values per m^2) and reasonably high-resolution maps.

Grave detection

Historic graves can be detected based on their shaft, soil fill, or other contents (typically the casket and or vault) (Burks 2009a, 2009b). The grave shaft and its fill are the most important factors in detecting historic graves, since the casket and body may have decomposed, and no vault may have been used (Bevan 1991). Grave shafts are (in plan) oval to rectangular holes that range in depth from 2–6 ft below the surface. Their plan dimensions vary based on the size of the individual buried and the use of a coffin and/or a burial vault. Historic adult graves are typically expected to be about 6–8 ft (1.8–2.4 m) long and 1.5–2.5 ft wide (approximately .46–76 m) (Burks 2009a: 6).

Soil type plays an important role in grave detection. The grave shaft fill is more mixed and less compact than the surrounding, in situ soil, and will have different moisture retention properties. Graves dug into soil characterized by multiple, distinct strata are more likely to be detected than those dug into a homogeneous soil, since each stratum offers an opportunity for contrast with the fill. Older graves are characterized by greater settling as a result of natural processes as well as the eventual collapse of a wood coffin. In some cases, old graves may be 'topped off' using soil from a different location, increasing the likelihood that the shaft fill will differ markedly from the intact surrounding soil (Burks 2009a).

In addition to human remains, graves may contain a coffin and a vault. Vaults that contain brick, concrete and/or iron rebar, that represent a void, or that retain moisture differently than the surrounding soils are likely to be detected by a GPR survey, and they also may be detected by electrical resistance, conductivity, or magnetometry. Coffin material influences the likelihood that a grave will be detected by a GPR survey. Intact wood coffins that include a void or are associated with a sharp difference in soil moisture within versus outside the coffin may be detected, however most wooden coffins have rotted and collapsed a few decades after burial (depending on soil conditions). Metal is an excellent reflector, meaning that metal coffins are very likely to be detected by GPR. Iron coffins came into use after 1850, although they were probably never widely used in non-urban settings. (Burks 2009a, 7; Crane, Breed, and Co.1858).

In the absence of vault or metal coffin graves may well be characterized by low contrasts with the surrounding soil and anomaly detection may be complicated by the presence of roots of trees and other decorative plantings. Other common historic burial practices can be observed at historic cemeteries that are still well maintained. These common practices include: (1) graves tend to be oriented in a single direction (depending on religious or cultural practice), (2) multiple graves are often arranged in rows or other family clusters, and (3) variability in the nature of grave markers and other cemetery features (e.g., retaining or decorative walls and fences) may reflect socioeconomic status of the deceased (Hargrave 2011).

Several challenges and ironies accompany the use geophysical techniques to detect unmarked graves. There is a great deal of inter-site and sometimes seasonal variation in how soil texture, moisture, rock and bedrock, tree roots, military or other ground disturbance, and grave contents cause graves to contrast with their immediate surroundings. In the absence of historical records, reliable informants, or archaeological ground truthing, interpreting geophysical anomalies as graves has a strong subjective component. Despite one's use of the most sophisticated sensors and rigorous field methods, one ultimately must decide if a particular anomaly "looks like" a grave. In some cases, two equally competent analysts might arrive at different decisions. The best way to reduce the element of subjectivity, and to convincingly convey one's interpretations to non-specialists, is to be explicit about the criteria used to differentiate possible graves from other anomalies.

For this study, graves are/were: oval or rectangular in plan, 6– 8 ft long (children's graves can be smaller), 1.5– 2.5 ft wide (children's graves can be smaller), oriented (long axis) east to west, arranged in rows or clusters (based on family groups), marked using wood or stone (often now absent or displaced), can be outlined using bricks (often now absent or displaced), can be surrounded or otherwise marked by fences or walls (often now absent or displaced), can be characterized by shallow depressions (from natural settling).

It should be noted that on surveys to locate unmarked cemeteries, the goal is almost always to protect the graves from being disturbed. As a result, standard practice is to be very conservative in the interpretation of the data. It is considered preferable to over report the possibility of the presence of graves and to include any anomaly that has “grave like” characteristics.

HHRD dog survey methodology

The dogs used in this study, provided by the Institute for Canine Forensics (ICF), are not cross-trained. In other words, the dogs are trained to detect on the scent of bones and burials, with a focus on burials that are no longer in the active stages of decay. The dogs are trained to notify their handler to a scent through passive alerts (ICF 2013b), typically consisting of the dog moving to a sit or down position while maintaining direct eye contact with their handler at the location where the scent is the strongest. Certification is conducted by a panel of pre-approved evaluators, one of which cannot be affiliated with ICF (ICF 2013b). The tests are scored on success criteria developed for scent detection, and an efficacy score above 75% is required to be certified. The certification is specific to dog and handler as a team. Once certified, teams must recertify annually.

ICF provided four dog teams and a team coordinator to participate in this study. Each team systematically covered the search area in a grid pattern, marking the location of dog alerts with pin flags noting the quality of the alert. Researchers then mapped each alert location and removed the pin flag before the next dog team was allowed into the study area. Pin flags were only used once and then discarded to insure that scent contamination did not occur through reuse of flags. Air and surface temperatures as well as wind speed and direction were recorded periodically during the testing to ensure that each dog team was working under similar conditions to each other. The percentage of the search area where the dogs could get access to the soil surface was determined and recorded as the percentage of accessible terrain. This measurement is equivalent to, and serves the same purpose as, surface visibility observations that archaeologists routinely make during Phase I surface surveys.

Each dog handler recorded the alert quality of each dog alert on a scale of 1–3. A Quality 1 alert indicated a strongly committed alert, where the dog alerted immediately to a specific location. A Quality 2 alert indicated the dog is committed to an area but needed to work the area to determine the alert location. A Quality 3 alert indicated the presence of a scent pool. This type of alert is where the dog indicates by their body language that they are detecting the scent of human decomposition, but that they cannot determine the source of the scent to the degree needed to trigger a higher-quality alert. Therefore, the handler's experience with their dog and their ability to communicate effectively with the animal plays more of a role in Quality 3 alerts. Specific teams are referenced here by the initials of the team handler.

The Control Study Area Survey

The control study survey area was created as a test to determine the rate of false positive alerts as well as the ability of the dogs to differentiate between human and animal bones within the same search area. This site consisted primarily of bones that had been buried after soft tissue decomposition had ended. The dogs are trained to locate graves where decomposition had once occurred or where human bones are scattered on the surface. It was recognized, therefore, that the nature of the burials themselves was not what the dogs were trained to detect, but it was hoped that having multiple bones buried at each location and a long burial period of 11 months would help mitigate these potential problems.

Skeletonized human (*homo sapien sapien)* and coyote (*canis latrans)* bones were purchased from The Bone Room in Berkeley CA. This store sells human skeletal remains that were legally exported from the People's Republic of China between 1987 and 2008 (The Bone Room 2014). None of the human remains used in this study derived from Native American populations, either domestically or abroad. Bare whitetail deer (*odocoileus virginianus*) bones of recent origin were obtained from a local taxidermist. The study area also incorporated an experimental archaeological site where three entire domesticated pig (*sus scrofa domestica)* carcasses have been decomposing undisturbed insitu since 1998. The control test site was located in an enclosed, mowed grass divided into three survey blocks (Figure 1, Table 1). Wooden posts from a preexisting rope fence provided the separation boundaries between the three study blocks. Study Block A contained five human burials, five deer burials, and three coyote burials. Study Block B contained the preexisting experimental archaeological site. All three domestic pig burials were located within this block. No human, deer, or coyote were buried with this block. Study Block C contained five human burials, five coyote burials, and one deer burial. ICF dog handlers were not informed how many burials were present, that both animal and human bones had been buried, or that a preexisting experimental site was situated within the study areas.

Bones were buried from 10-12 December 2012. Locations were selected to create single burials as well as clusters of single species. Each location contained multiple bones spread out in a horizontal layer at the bottom of each excavation. Depth of the burials varied from 6–100 cm below surface. Topsoil depths were measured between 14–18 cm below surface with the topsoil consisting of silty clay loam with clay loam subsoil.

HHRD dog testing at this site occurred on 11 November, 2013. Testing began at 09:30 and continued until 13:55. The soil surface was 80-100% accessible to the dogs at the time of the survey. Temperature ranged from 49.2^0 F to 53.7^0 F during testing. Ground temperature ranged from 56.1^0 F to 55.1^0 F throughout the testing day. Humidity ranged from 53.7% to 61.3%. The wind ranged from 3.8mph to 11.1 mph. At the beginning of the day the wind was blowing on an azimuth of 235 degrees and then switched direction at around noon to a direction of 346 degrees. The day was overcast and rain moved into the area immediately after testing concluded.

Results and conclusions

The findings in this experiment produced mixed results (Table 2). Several patterns in the data, however, are readily observable.

The first is that no HHRD team alerted within 2 m of a burial site. This result could be explained by the fact the wind was blowing at 11.1 mph by the end of testing, and occasional gusts were stronger still. It is possible that the prevailing wind caused the scent to disperse more quickly. Alerts were, however, occurring upwind as well as downwind of the burial site nearest to the alert, so the role of the wind in affecting alert location is not clearly defined. Additionally, the detection of bones buried after decomposition is not specifically what the dogs were trained for, which may explain a wider range of scent detection. There is also a clear pattern of alerts along the fence posts that separate the three study blocks. It is extremely likely that the fence posts were acting as chimneys and funneling the scent to the surface and the majority of the fence-post alerts were occurring in proximity to burial sites. In this experiment, depth and the amount of skeletal material did not seem to affect the quality of the dog alerts. Three of the four dog teams had alerts in the vicinity of Burials 10 which was the second deepest of all human burials and it also had the smallest amount of bone (with four vertebra). Burial 11, which had four ribs at the second-shallowest depth, had no alerts associated with it at all.

Study Block B was intended to test the possibilities of false positives. There should have been no dog alerts within this area. However, only one team (Team BP) did not have any alerts in that area. The majority of the alerts were focused, however, along the fence posts when there were human burials on the other side of the fence. If we discard the alerts related to the fence posts, then Team JG had only one alert in Study Block B, and that alert was 11 m downwind of Burials 1-3 (the densest concentration of human bones on the site) located in Study Block C. Two dogs produced three alerts, including a Quality 1 alert, in the northwest corner of Study Block B. This area was a depression, at least 30 cm in depth, located immediately over a feature in the experimental archaeological site sitting under Study Block B. The turf in this area was cracked and disrupted by the soil's subsidence. The area is almost equidistant from Burial 6 (with five human ribs) to the northwest and the two pig carcasses to the southeast. Possible explanations for this alert are: (1) the disruption in the turf could have provided an easy conduit for the scent from either burial to escape, (2) the depression might have caused any scents blowing along the ground surface to pool and concentrate, or (3) the dogs or their handlers might have cued on the depression as a visual cue for ground disturbance activity. A second cluster of false positive alerts occurred in the southwest corner of Study Block A. Two dogs produced three false positives in this area, although this grouping was not as compact and distinct as the false positive cluster in Study Block B. Visual inspection of the site verified that there were no depressions, slight mounds, or turf disturbance in this area.

Another aspect of this control portion of the study was to determine if the dogs could differentiate between animal and human bones. The answer to this question is that they clearly can. In all three blocks, there were significantly more alerts associated with human burials than animal burials. In fact, there is a higher rate of alerts that are not within 10 m of any burial location (false positives) than there are alerts within 10m of an animal burial. The areas that should have produced the strongest scent associated with animal bones were the cluster of three deer burials in the south east corner of Study Block A, the cluster of two coyote burials in the south central portion of Study Block A, the three pig burials in Study Block B, and the loose cluster of two coyote burials in the northwest corner of Study Block C. There were no dog alerts associated with any of these areas. The pig burials had the potential to be very problematic for the dogs, since those burials were the only cases of insitu decomposition. Additionally, as domesticated animals, their diet would have been corn and/or soy based, resulting in a ratio of bodily compounds more similar to humans (who also have a diet rich in corn and soy products) than wild deer or coyote. Despite this, there were no dog alerts in the vicinity of the pig burials.

Clements Cemetery Surveys

Clements Cemetery is moderately sized, private cemetery in Champaign County, Illinois. The earliest legible tombstones date to 1810–1820. Evidence from the tomb stones indicate that one Revolutionary War veteran and multiple Civil War veterans are buried in this cemetery. Burials appear to have occurred once every few years throughout the last half of the 19th century and much of the 20th century. The rate of burials seemed to slow in the 1980s and 1990s. Personal communication with Mr. Cecil McCormick (2012 and 2013), the currently appointed trustee of the Clements Cemetery Association, indicated that during those two decades, the cemetery became overgrown and many of the stones suffered damage. Maintenance of the site resumed in the late 1990s and continues to this day. Much effort had been put towards repairing or replacing damaged stones, and there are at least a dozen examples of new marble stones placed immediately next to the stubs of earlier headstones broken off at the ground.

The names on stones indicate there are several family clusters within the cemetery. The southeastern quarter of the cemetery is the older portion and, in addition to the family clusters, there are multiple open spaces where there is the strong possibility of unmarked graves being present.

Only a portion of this cemetery was surveyed. Four 20x20 m blocks (labeled A-D) were selected based on the presence of grave stones and significant open areas that had a high possibility of unmarked graves. Blocks A and D were continuous in the southeastern portion of the cemetery and Blocks B and C were continuous in the southwestern portion of the cemetery.

When the Clements GPR data were processed and analyzed, it became apparent that soil moisture was a limiting factor. Numerous hyperbolas are visible in the GPR profiles but in most cases, these are characterized by low amplitudes and modest dimensions. Importantly, the apexes of most of the hyperbolas are located near the top of the GPR profiles, suggesting that their sources are located at very shallow depths. The position of the hyperbolas in the GPR profiles seems inconsistent with their being associated with caskets that are presumably located - approximately 1.5– 2 m below the surface. However, Conyers (2012, 134–137) illustrates a number of hyperbolas associated with caskets whose apexes are plotted at approximately .6 m below surface (but none apparently as near the surface as those at Clements Cemetery). It is possible that our hyperbolas are reflections associated with the corners of upper portions of grave shafts. The caskets and lower portions of the shafts may not be manifest in the data because soil moisture has attenuated the signal.

We assumed soil moisture and resultant poor radar penetration caused the hyperbolas detected at Clements Cemetery to be small (in horizontal dimensions) and weak (low amplitude). However, Conyers also notes that reflections from graves not located directly under the antenna often exhibit low amplitudes (2012). Two possible alternative sources for the hyperbolas at Clements Cemetery were considered. First, there are naturally occurring rocks and, in a few cases, displaced grave marker stones located immediately below the humus layer. In addition, several large trees are located in the two eastern survey areas and their roots may explain some of the hyperbolas in those areas. However, no trees are present in the two western survey areas, suggesting that roots are an unlikely explanation for the hyperbolas located there.

Hyperbolas whose lowermost extent spanned a horizontal distance of at least 1 m were determined to be most likely to represent graves. This selection resulted in a total number of hyperbolas for all four grids at165 (29 in Block A, 36 in the Block B, 47 in Block C, and 53 in Block D). For this study, an important question is whether these hyperbolas relate to historic graves. As noted, their tendency to be located very high in the profiles would seem to argue against this association, but they could conceivably be associated with portions (most likely corners) of the upper portions of grave shafts. Several other lines of evidence were considered to further assess if the hyperbolas are associated with graves. Inspection of Clements Cemetery indicates that most of the existing grave markers are arranged in north-south rows. Visible grave outlines and the information inscribed on the grave markers indicates that most of the actual graves are located west of the in-situ markers, but inscriptions are located on the east side of some markers. Additionally, some of the marker stones whose locations were recorded within the survey areas are small and may represent footstones rather than headstones. These observations raise the possibility that some graves could be located east of their associated marker. If the hyperbolas are associated with graves, many of them may be aligned with the marked graves. A little more than one-half of the alignments of marker stones exhibit a roughly consistent north-south orientation while a smaller number (particularly those located between the survey areas) are oriented a little more northeast-southwest.

Closely spaced hyperbolas could be associated with different parts of a relatively large object (e.g., grave, rock). Also, any portion of a grave or other object could be the actual source for the hyperbola. To allow for this, hyperbolas are counted as being near a grave (and therefore associated with an alignment of marked graves) if they are located within 1 m of the north-south transect lines of existing graves. Using these criteria about 50% (n=88) of the 165 hyperbolas are located near the alignments of marked graves (Figure 2). This reasonably high number seems to suggest that the hyperbolas tend to be associated with the apparent alignments of marked graves.

A second way to evaluate the likelihood that the hyperbolas are associated with historic graves is to assess their locations relative to individual marker stones. If the hyperbolas are associated with graves, some of them should be located near a marker. However, one might not expect too many such cases of proximity. If the hyperbolas are in fact associated with graves, most of the markers have clearly been removed. Here, we again use a proximity criterion of 1 m. 14 hyperbolas are located within a meter of one of the 38 marker stones that are located within the survey area. This includes two cases where pairs of contiguous hyperbolas are located near the same stone. In most of the 14 cases, the hyperbola is located northeast, southwest, southeast, or southwest of a marker. These locations relative to stones might seem less likely than the expected situation where a grave is located east or west of a stone. They could conceivably represent situations where two graves (e.g., husband and wife) share a single marker stone (and only one grave is manifest by a hyperbola). Overall, 36.8 % of the stones are located within 1 m of a hyperbola. Again, this seems like a reasonably high occurrence rate given the relatively small number of stones inside the survey areas.

Soil moisture limited the success of our GPR survey of Clements Cemetery. The amplitude slices yielded unreliable results, and we relied on information from the GPR profiles (which was standard practice before the development and wide use of amplitude slicing). We plotted the location of the hyperbolas with maximum widths of at least 1 m. The hyperbolas appear to be associated with apparent alignments of existing marker stones, suggesting that they are associated with graves. Similarly, the occurrence of hyperbolas in close proximity (within 1 m) of marker stones may also support the interpretation that the hyperbolas are associated with graves. Nevertheless, we are far from certain of this interpretation. A conservative interpretation of all of the available evidence leads us to view the results of the Clements Cemetery GPR survey as inconclusive.

HHRD dog survey

The ICF team survey took place at Clements Cemetery on 12 November 2013. Early on that morning, the temperature dropped significantly, and snow was falling. Survey work was delayed to 13:00 and while conditions improved, there was still snow on the ground in portions of the site during testing. The handlers indicated that this was the first time any of the dogs had been asked to work in snow and the first time that some of the dogs had ever seen snow.

The survey began at 13:13 and continued until 15:39. Air temperatures started at 35.2 ^{0}F and fell to 31.5 ^{0}F. Ground temperatures ranged from 53.5 ^{0}F to 31.1 ^{0}F throughout the afternoon and site (depending on snow cover). Humidity was at 47.1%–54.6%, and the winds were 3.7–4.3 mph from 40-42 degrees azimuth. The ICF team coordinator determined the ground visibility at 80%–100%.

Buffers of 1 m and 2 m were generated around each GPR hyperbola anomaly. The buffers were added to approximate the size of grave shafts around the anomaly features. HHRD team results were plotted on top of these layers (Figure 3). Alert quality designations by the HHRD dogs were collected but not utilized in the analysis as each dog produced alerts that were consistently at the same level. The first item the data shows is that not every team worked in all four blocks. The second item is that a large number of dog alerts correspond directly to headstones. This is most obvious in the Team LA's alerts in the Blocks A. The handlers stated that there were so many graves in this cemetery that it was producing a general aura of human decomposition; the dogs were being overwhelmed and were unable to pick out specific alert locations. Combined with factor of the snow on the ground, and the dogs became distracted and did not want to work. The handler for team JG stated that his dog wasn't smelling, she was just alerting on the site of grave stones. The handlers tried to rest their dogs and then refocus their efforts, but this attempt met with varying degrees of success. As a result, by the end of the day not all dogs had completed each of the search blocks.

This event highlights an area of cemetery searches where HHRD dogs may not be an effective method. The handlers stated that the pervasive scent would have been a problem even without the snow. This demonstrates that HHRD dogs are not well suited to find individual graves within a group of graves. It also highlights that the ability to work field dog teams may be as dependent on environmental conditions as some geophysical techniques. Finally, this effort demonstrated that the dogs are intelligent enough to associate the scent of decomposition with the presence of a headstone. When they were unable to produce alerts on scent alone, some of them were utilizing visual cues to alert on and receive their reward. The handlers, however, were able to determine after a period of time what some of these dogs were doing and modified their interpretation of the dog alerts accordingly.

Fort Gordon Cemeteries Surveys

Five cemeteries (9, 20, 26, 31, and 34) that predate the 1940 establishment of Fort Gordon, Georgia, were surveyed with HHRD dogs as part of this effort. These sites were believed to be small family cemeteries associated with rural farmsteads. The same five cemeteries were previously surveyed with GPR and four of the five (excluding Cemetery 20) were previously surveyed with magnetic gradiometer in 2010 (Hargrave 2011). Geophysical survey anomalies with the potential to be graves were marked with 1x2 m rectangles (average grave shaft size). These shapes correspond to the center point plus 1 m radius buffer used at the Control Site and Clements Cemetery Site surveys. The 1 m radius buffer on Fort Gordon cemetery maps corresponds to the 2 m radius buffer zones at the Control Site and Clements Cemetery sites. Finally, the 4 m buffer at Fort Gordon cemeteries corresponds to the 5 m buffer used at the previous survey sites. Due to the proximity of the geophysical survey anomalies, use of the 10 m buffer created buffer overlaps that were so large as to be unsuitable for analysis and so the 10 m buffer was discarded for the analysis. The same HHRD dog alert quality criteria utilized in the control site and Clements Cemetery were utilized at all Fort Gordon Cemeteries.

Cemetery 9

Cemetery 9 is bordered on the southeast by an unnamed one-lane dirt road and on the other three sides by a dirt track that appears to be used as a turn-around location for the dirt road. Three sides of the cemetery are surrounded by a wooden post and barbed wire fence, and the area is designated by signage. The soil at this site consisted of loose, fine sand that was, within the fence line of the cemetery, anchored by grass that is regularly mowed.

Both GPR and magnetic data were collected from this site. Strong anomalies in both sets of data indicate the possibility of at least six graves located in the northern corner of the survey area. The anomalies occur in parallel lines orientated on a northeast-southwest axis. This somewhat conforms to historic burial practice in this region of orientating the lengths of the graves on an east-west axis. Based on geophysical survey, this cemetery was evaluated as having a high likelihood of containing actual graves (Hargrave 2011).

Interestingly, the potential graves are not located in the center of the fenced area now designated as the cemetery boundary (Figure 4), but are located in the north eastern corner of the area, with one extending under the fence line into the dirt track that circles the cemetery. It is very likely that the fence line for the cemetery was historically larger and included the dirt track that is now used as a turn-around site. If the dog handlers were influencing the interpretation of the dog alerts based on what they thought should be there, one would expect to see multiple alerts in the center of the fenced-off area and not in the dirt track outside the fence.

The results of this survey were extremely positive (Table 3). Three of the four teams alerted at locations on or outside of the fence line on the northern corner of the site. Only one dog team had the majority of their alert in the center of the fenced area indicating that this team had perhaps fallen for the preconceptions of the cemetery layout based on the fence line. Interestingly, the same team produced the alert closest to the suspected graves. Thirty percent of all dog alerts were located within 4 m of potential graves.

Cemetery 20

Cemetery 20 was located in a wooded area approximately 10 m from a multi-lane paved road. GPR was the only geophysical technique deployed at this site (Hargrave 2011) due to undergrowth in the project area that would have prevented accurate magnetic data collection. No grave markers were observed. Some architectural debris was observed, but it appeared to be the result of a dumping event and not in situ debris.

There were 15 geophysical anomalies identified, based on their size and shape. These anomalies were assessed as less likely to be real graves than some anomalies seen at other cemeteries, due to a continuous range of variability between these 15 selected anomalies and other anomalies that were identified as not grave-like. Additionally, there were a series of perpendicular anomalies observed on slices more than 1 m below surface. Perpendicular patterns typically do not correspond to small cemetery layouts (Hargrave 2011).

The HHRD results at this cemetery were also more ambiguous than at other survey sites (Figure 5, Table 3). One team had only one alert, and that was more than 4 m away from the possible grave anomalies. A second team had 2 alerts closer than 4 m to an anomaly, and two that were more than 4 m distant. In total, 64.3% of all alerts were located farther than 4 m from any geophysical anomaly. No Quality 1 alerts were recorded at this cemetery, and there did not appear to be a clear pattern to the alerts between teams. However there was one alert directly over an anomaly and four more alerts within the 1 m buffer zone, comprising 35% of the total alerts for the site.

Cemetery 26

Cemetery 26 is located in a wooded area accessible only on a fire-break road. Several thin slabs of limestone were present that could be interpreted as grave markers. Two stones were lying on the ground surface, but one stone that had been broken off at ground level had once been orientated vertically. All of these stones, however, were less than 10 cm thick (much thinner than one would expect for a tombstone), and there was no evidence of smoothing or inscriptions on the surface of the slabs. There was evidence on site of heavy vehicular activity on the site, possibly related to logging activity in areas near the survey site.

A series of linear anomalies radiating from a point near the center of the survey area were observed in the GPR data. Due to their length, these anomalies were interpreted as the result of vehicle activity. The GPR anomaly near the stones is sitting over one of those linear features and therefore, is therefore suspect as a grave. A series of magnetic dipoles (both positive and negative components in close proximity) of various sizes occurred throughout the survey area. This pattern is typical of a scattering of small metal objects that indicate transitory use more typical of a bivouac, training, or logging area instead of a habitation site. Two weaker monopoles and one dipolar magnetic anomaly are aligned on the eastern side of the survey area. Also in this area, GPR results show a cluster of grave-like anomalies and a lone grave-like anomaly that are not associated with the linear features. While the GPR and magnetic anomalies do not correspond to each other, the presence of multiple unexplained anomalies in a single portion of the site raises the possibility that these features may be graves, despite the improbability of so many graves being placed in such a tight cluster. All things considered, geophysical survey indicated a moderate likelihood that the anomalies on the east side of this cemetery site represent historic graves.

All four dog teams surveyed this cemetery, but only two teams registered any alerts (Figure 7, Table 3). Both alerts were Quality 2 and within 1 m of a geophysical anomaly. Only the alert by team JG, however, was in proximity to one of the anomalies determined by Hargrave as more likely to be an historic grave; the other alert (Team LA) was located on an anomaly that was associated with the linear features determined as likely the result of vehicular activity. No dog teams alerted in the vicinity of the limestone slabs.

Cemetery 31

The center of the area of Cemetery 31 had a scatter of bricks at the surface that did not appear aligned or arranged. Visits to other cemeteries in the region (not part of this study) demonstrated that occasionally bricks were used to outline graves. A lone cedar tree was also present at the site. Fort Gordon CRM staff indicated that in this region, cedar trees were often planted in cemeteries.

Approximately 18 GPR anomalies are identified as possible graves, with the majority orientated near northwest to southeast (Figure 7). Several of the anomalies overlap so only 12 distinct areas occur in this survey area. The magnetic data is characterized by a number of large, strong, dipolar anomalies that are consistent in size and shape, indicating that they may have a similar source or cause. A number of the magnetic anomalies roughly correspond in location and orientation to GPR anomalies described as grave like. It is possible (but unlikely given the socio-economic setting of the historic region) that the strong magnetic reading within graves could represent metal-lined coffins or vault lines from vaults made of metal or reinforced with rebar. An alternate possibility is that a grave outlined by fired bricks could also produce the geophysical signatures seen at Cemetery 31. This possibility may also explain the scattering of loose brick on the surface. All of the evidence indicates that it is highly likely that historic graves are present at Cemetery 31.

HHRD dog surveys resulted in 29 total alerts including five Quality 1 alerts (Table 3). Three of the four dogs had alerts within 1 m of the central anomalies that had correlation between magnetic and GPR data. Of all the alerts, 62% were located within 4 m of grave-like anomalies. The tight clustering of alerts around the central portions of the site correlates well with the geophysical data. The presence, however, of multiple strong alerts by multiple dogs some meters away from the buffer zones does raise some issues with the interpretation. One possible cause would be that the cemetery is larger than currently assumed and an expanded geophysical survey should be conducted. A second possibility is that the dog alerts sites had been influenced by the presence of subsurface disturbance that channeled the scent away from the grave site to more distant locations.

Cemetery 34

Cemetery 34 is located near Cemetery 31, approximately 0.3 km west of a major, multilane dirt road. Two depressions and an earthen berm studded with pieces of concrete, brick, and stone are situated on the northern portion of the survey area. Two cedar trees were located 30 m north of the survey area.

Approximately 30 GPR anomalies were identified as possible historic graves (Figure 8). Many of the possible graves are in clusters but there appears to be an apparent northwest southeast alignment of 7 or 8 anomalies along the north central portion of the site. There are several large magnetic anomalies, but these anomalies do not appear to be associated with GPR anomalies as we saw at Cemetery 31. The GPR anomalies also are not as spatially discrete as the anomalies seen in Cemeteries 9 and 31. At Cemetery 34, there is more of a continuous range of variation in anomaly dimensions. As a result, it is moderately likely that the anomalies seen as Cemetery 34 are historic graves.

HHRD dog survey produced 41 total alerts. It is interesting to note that only Team BP alerted in the area of the north central cluster of anomalies highlighted in Hargrave 2011 as the anomalies most likely to be graves. Three of the four dogs' alert patterns were focused on a cluster of anomalies west of the center of the survey area. The GPR data, however, does show that these anomalies are fairly consistent to the deepest data slice at 2.29 m below surface. Two of these anomalies are orientated north-south, with only one orientated east-west. This cluster may be an example a subsurface feature creating a conduit where the scent is being brought to the soil surface. An alternative explanation is that this a case of the archaeologists privileging the cultural norms of east-west grave orientation and ruling this area out as grave like due to the north south orientation of some of the anomalies.

Summary and conclusions on Fort Gordon cemetery surveys

The results from this portion of the study were very promising. The dogs alerted directly over the GPR anomalies described as potential graves at 60% of the cemeteries and alerted within 1 m of the anomalies at least once at 100% of the cemeteries. More than half of all alerts (58.5%) we located within 4 m of possible grave locations.

The dogs also performed well at cemeteries where the visual cues were misleading. At Cemetery 9, three of the four teams alerted in the dirt tract outside of the cemetery fence line, which corresponds to the results of the geophysical survey that indicated the graves extended under and outside of the fence line. Geophysical survey also indicated that the broken stone slabs at Cemetery 26 had a very low probability of being a grave and no dogs alerted on this feature. One handler stated that if she was the one generating alerts, she would have alerted on the slabs but her dog showed no interest in it, and she trusted her dog.

Conclusions and Recommendations

The study detailed in this report was intended to determine the effectiveness of HHRD dog teams in locating unmarked human burials. The study demonstrated that use of the dog teams has some advantages over traditional geophysical survey techniques but there are other scenarios where use of the dogs would not be advisable.

The first question of HHRD dog accuracy that should be addresses is whether or not the dogs can differentiate between human and non-human animal remains. Unmarked cemeteries are often located in areas that are overgrown or wooded and there is a probability that naturally occurring decomposed faunal remains may be present in any study area. The dogs performed well in the controlled portion of the study with alerts located within 10m of buried non-human animal remains being the least common of all alert types.

The second question of accuracy concerns whether or not the dogs can pinpoint the exact location of a grave. The answer to this question would be that the dogs achieve this degree of accuracy infrequently. In the control study portion of this experiment, where defleshed bones had been buried for 1 year, no dog alerts were recorded closer than 2 m of the burial location. Additionally, at the control study site, the presence of fence posts and a depressed area with broken sod in the general area of the burials created a conduit for the scent to rise to the surface at a spot some distance away from the burial locations, further reducing the accuracy of the results. At the five Fort Gordon cemeteries, where the remains had been in place for at least 50 years and insitu decomposition had occurred, 5% of the dog alerts were located immediately over potential grave sites and 19% of the alerts were located within 1 m of the potential grave sites. The Fort Gordon survey demonstrated, however, that 61% of the dog alerts were located within 4 m of geophysical anomalies described as likely graves and very few alerts were located more than 10m away from suspected grave locations. It is recommended, therefore, that any HHRD dog alert not be interpreted as the location of a grave but as the center of a 4-5 m radius circle that may contain a grave.

Finally, whether or not the dogs and/or handlers are utilizing visible cues to generate alerts was also examined in this study. At the Fort Gordon cemeteries, sites were selected where visual cues were deliberately misleading. At Cemetery 9, potential graves were identified under and outside of the cemetery perimeter fence and not in the center of the fenced area. Only one team had the majority of their alerts located in the center of the fenced area and three teams had alerts outside of the fence in the area of the grave anomalies. At Cemetery 26 there were broken limestone slabs that strongly resembled gravestones. Geophysical surveys indicated that the ground beneath the slabs had a low probability of containing graves. No HHRD dog team alerted in the vicinity of these stones despite the fact that one handler commented that the stones looked suspiciously grave like. At Clements Cemetery, where unmarked graves were interspersed with marked graves, one handler reported that his dog was not smelling, but instead alerting at tombstones. The handler did not record those alerts and did not continue the survey. This indicates that the dogs are smart enough to key in on visual cues but that the handlers are often aware of their dogs working methods and can identify when the dogs are not working the study area properly. The conclusion is that while both the dogs and handlers are identifying visual cues at study locations, the teamwork between dog and handler tends to nullify the effects of visual observation of the study area.

The portion of the study where the dogs struggled was in the search for unmarked graves within a sizable cemetery that included some marked graves. The dogs appeared overwhelmed by the number of graves. The handlers reported that the large number of graves would have created a general aura of scent and made the identification of specific alert locations very difficult. Environmental conditions were problematic at this location with both the geophysical survey and the HHRD dog team survey. The archaeologists conducting the geophysical survey stated that better results might have been obtained with better conditions. The dog handlers, however, stated that it was unlikely that better results would have been obtained had the weather been different. Combined with the HHRD teams low success rate in identifying the exact location of graves, it is not recommended that HHRD dogs be utilized to located exact graves within a larger cemetery.

Geophysical survey techniques proved superior to HHRD dog surveys in the amount of detail and transparency of the data analysis. Dog alerts resulted in a single GPS coordinate location (that might have been located several meters away from the potential grave) and a description on the strength of the dog alert. No other information about the potential grave could be provided. Geophysical survey techniques were not only able to pinpoint the exact location of anomalies, but were also able to determine the count, size, shape and orientation of those anomalies. These characteristics were used to determine the likelihood that each one of the anomalies could or could not be described as a potential grave.

Geophysical survey data can be stored and reproduced digitally and pictorially, making it possible for the customer (or a third party) to evaluate the criteria used to identify grave-like anomalies and repeat or redo the data analysis. In the dog team surveys, the alerts result from a series of communications between the dog and the handler. HHRD dog teams are certified as a team; handlers cannot switch dogs with each other and expect to get accurate results. As a result, a third party dog handler at the study location would not be able to observe an HHRD dog team working and come up with an independent analysis of the dog's behavior. The only way to repeat or verify the analysis is to bring additional dog teams to the site and repeat the entire study.

Both geophysical and HHRD dog studies were improved by overlapping multiple data sets. The geophysical survey in this study utilized GPR and magnetic gradiometer. Additional geophysical techniques, such as electrical resistance, were not utilized due to soil types at the study locations but might be deployed elsewhere. The areas where graves were deemed most likely to be present were the areas where anomalies appeared in both sets of data. Likewise in the HHRD dog study each survey area was worked independently by multiple dog teams and the data was most compelling when all or most of the dogs alerted in the same area. Additionally, dog team accuracy was not consistent by teams. The data demonstrated that at one cemetery a particular dog team could alert right over a potential grave and at the next site generate alerts that were the furthest away from burial locations. It is strongly recommended, therefore, that regardless of what techniques are utilized, multiple techniques or surveys be conducted wherever possible.

The results of this study indicate that there is a scientific basis for the claims that HHRD dog teams can detect decomposing skeletal remains and differentiate between human and animal bones. At locations of insitu decomposition, the teams consistently generated alerts in the proximity of suspected or known graves at a much higher statistical rate then if they were doing it by chance. The speed and reduced cost of HHRD dog team surveys make this a very attractive technique to land managers. It should be noted, however, that the dog teams perform some tasks better than others. They struggled in this study with identifying unmarked grave locations within cemeteries of a significant size. The difficulty the dogs had in pinpointing exact grave locations and the inability to provide any information on the characteristics of the potential graves is also problematic for generating a definitive understanding of the unmarked cemeteries being studied.

It is the opinion of the authors that the best utilization of HHRD dog teams is in conjunction with, and not in place of, traditional geophysical survey techniques. Geophysical survey is expensive and time consuming but it provides a great deal of information about potential cemetery sites. A CRM confronted with an area many hectares in size that is rumored to contain an unmarked cemetery may find that it is cost prohibitive to a conduct geophysical survey of the entire area. An HHRD dog team survey could be conducted at relatively little cost (compared to geophysical techniques) to provide information about which portion of the suspect area to focus geophysical survey efforts on. By significantly reducing the area needed to be examined by geophysical survey techniques, HHRD dog team investigations can provide a meaningful cost benefit to Cultural Resource Managers.

Acknowledgements

This study was conducted for the Legacy Program under Project 12-510, “Guidance on the Use of Historic Human Remains Detection Dogs for Locating Unmarked Cemeteries.” The technical monitor was Kelly Merrifield, Cultural Resources Specialist, Legacy Program.

The authors would like to thank the following for the assistance provided to the researchers during the fieldwork at Fort Gordon, Georgia: Mr. Robert Drumm, Chief, Natural Resources Branch DPW and Ms. Renee Lewis, Archaeologist. The authors would also like to thank the staff of the Institute for Canine Forensics including Ms. Lynne Angeloro, Ms. Adela Morris, Ms. Barbara Pence, Mr. John Grebenkemper and Mr. Jerrold Christensen. The authors would also like to thank Mr. Cecil McCormick, Clements Cemetery Association Trustee for allowing the cemetery to be used as a test location.

The work was performed by the Land and Heritage Conservation Branch of the Installations Division (CN-C), US Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL). At that time field work was performed, Dr. Christopher White was Chief, CEERD-CN-C; at the time of publication, Dr. Michael Hargrave was Chief, CEERD-CN-C. Ms. Michelle Hanson was Chief, CEERD-CN. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel. COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

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Tables

Table 1. Burial descriptions at control test site.

Burial Number	Species	Bones	Depth
1	Human	3 Scapula	50 cm
2	Human	3 Scapula	50 cm
3	Human	3 Scapula	50 cm
4	Coyote	3 Ulna	6 cm
5	Human	3 Scapula	80 cm
6	Human	5 Ribs	30cm
7	Human	13 Carpal/Tarsal	15cm
8	Human	4 Vertebra	30 cm
9	Human	3 Scapula	25 cm
10	Human	3 Ribs	70 cm
11	Human	4 Ribs	20 cm
12	Human	4 Vertebra	50 cm
13	Deer	4 Ribs	50 cm
14	Deer	3 Lower Limb Bone	50cm
15	Deer	4 Ribs	50cm
16	Pig	Entire Carcass	100cm
17	Pig	Entire Carcass	100cm
18	Deer	3 Lower Limb Bone	70cm
19	Deer	4 Ribs	10cm
20	Deer	4 Ribs	50cm
21	Coyote	3 Ulna	10cm
22	Coyote	3 Ulna	30cm
23	Coyote	3 Ulna	120cm
24	Coyote	3 Ulna	50cm
25	Coyote	3 Ulna	20cm
26	Coyote	3 Ulna	40cm
27	Pig	Entire Carcass	100cm

Table 2. Summary for dog surveys Control Study Area.

Results	Team				
	AM	BP	JG	LA	Totals
# of alerts less than1 m from human burial	-	-	-	-	0
# of alerts 1–2 m from human burial	-	-	-	-	0
# of alerts 2–5 m from human burial	3	-	-	-	3
# of alerts 5–10 m from human burial	4	4	4	7	19
# of alerts less than 1 m from animal burial	-	-	-	-	0
# of alerts 1–2 m from animal burial	-	-	-	-	0
# of alerts 2–5 m from animal burial	-	-	-	-	0
# of alerts 5–10 m from animal burial	2	-	2	1	5
# of alerts not in any buffer zone	6	3	1	8	18

Table 1. Summary of all HHRD dog alerts at Fort Gordon cemeteries.

Cemetery	Alerts over Possible Graves	Alerts within 1 m of Possible Graves	Alerts within 1–4 m of Possible Graves	Alerts more than 4 m from Possible Graves
9	2	1	3	8
20	1	4	6	3
26	0	2	0	0
31	0	6	12	11
34	3	6	15	17
Totals	6	19	36	39

Figures

Figure 1: Burial locations and HHRD Dog Team results at Control Survey Area, Champaign, IL.

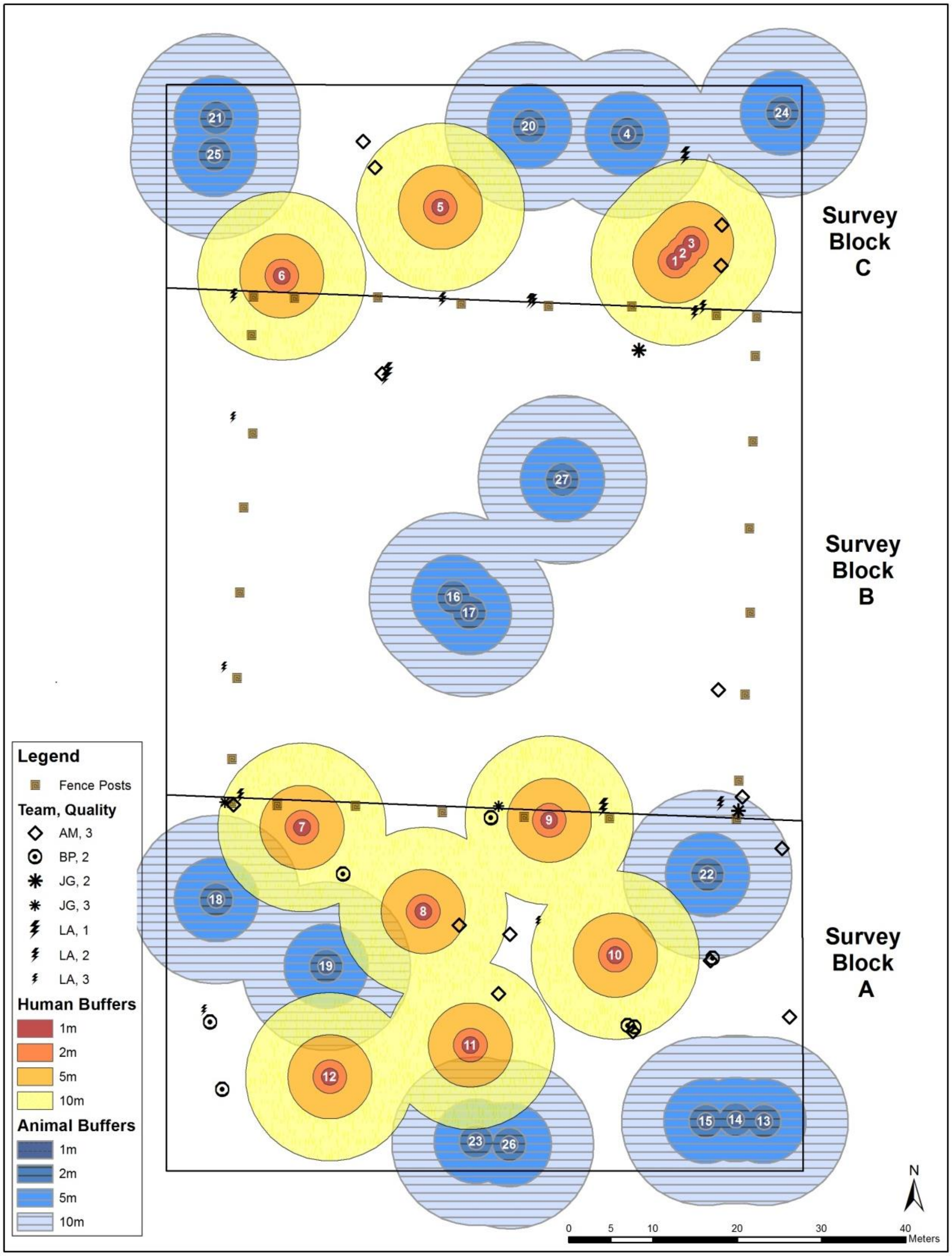

Figure 2. Alignments of observed grave marker stones and GPR hyperbolas possibly associated with graves, Clements Cemetery.

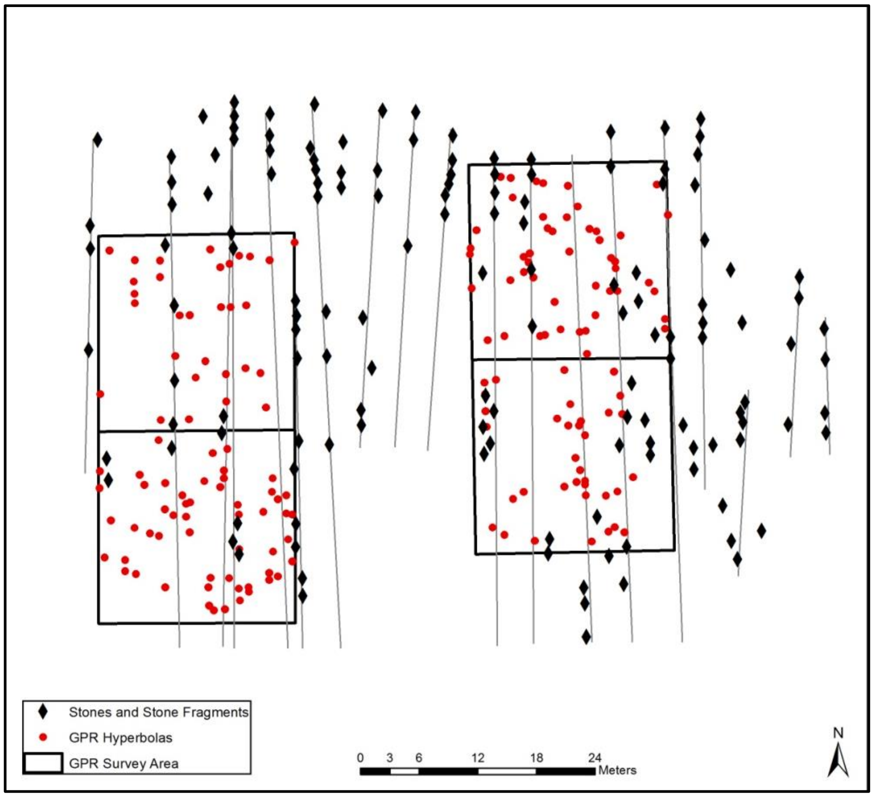

Figure 3: HHRD dog Alerts at Clements Cemetery

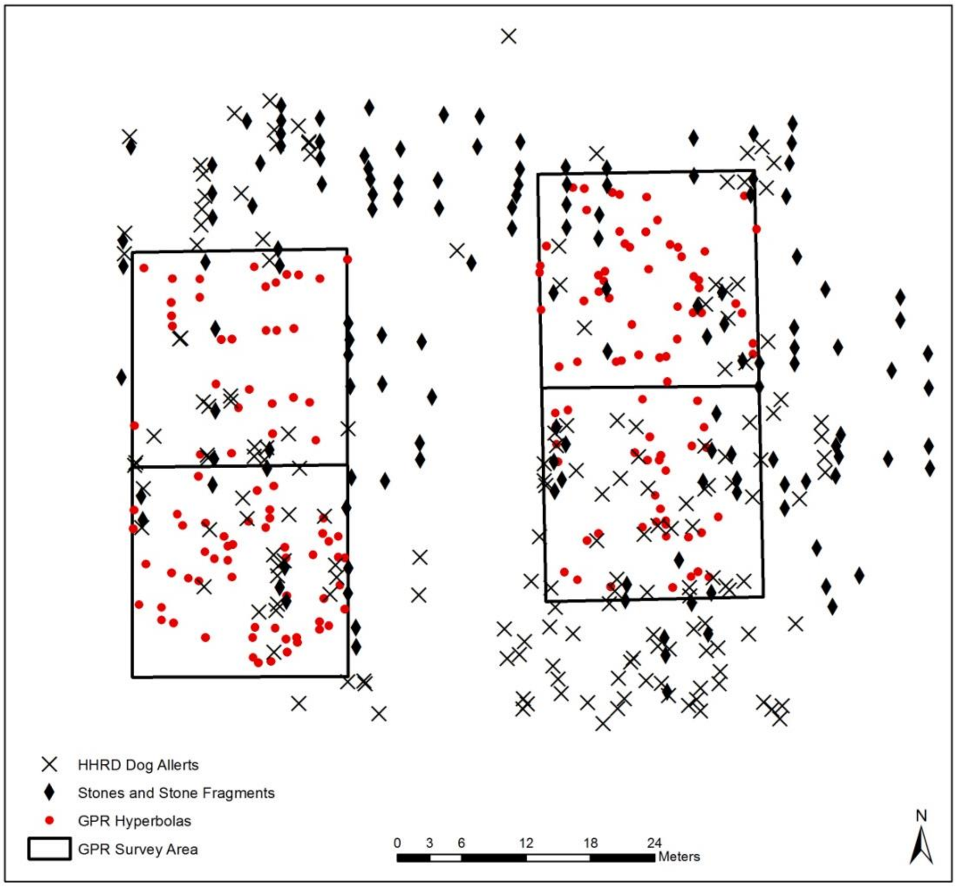

Figure 4: HHRD Dog alerts at Cemetery 9, Fort Gordon, GA.

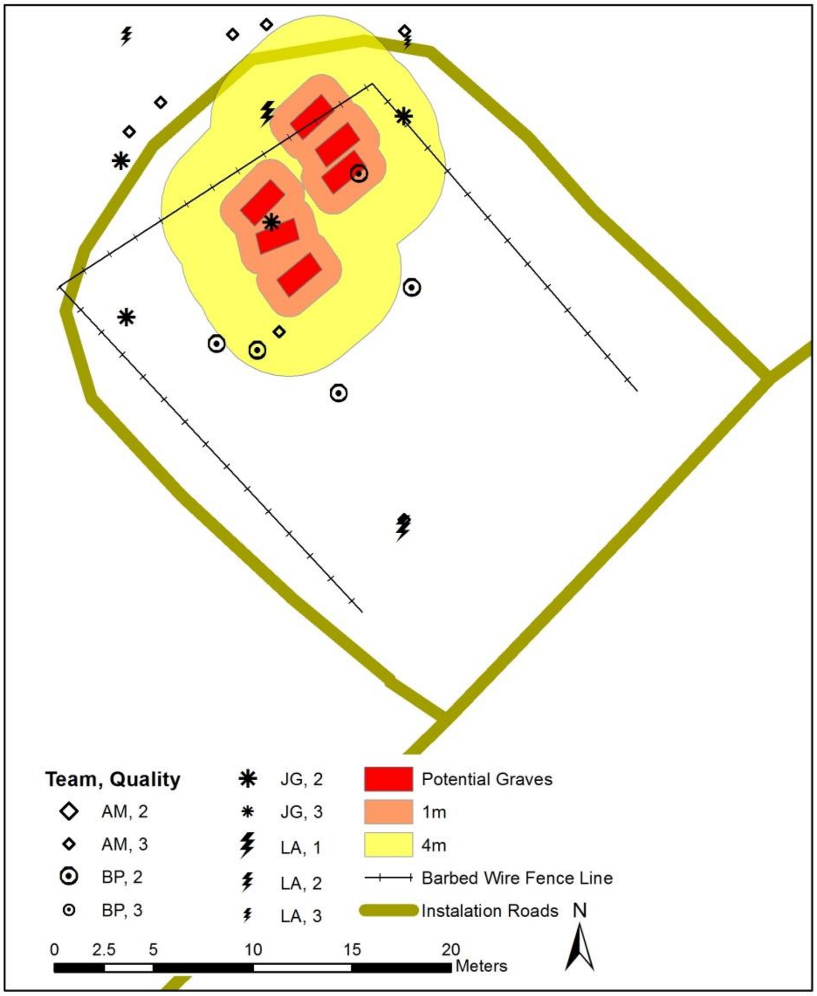

Figure 5: HHRD Dog alerts at Cemetery 20, Fort Gordon, GA.

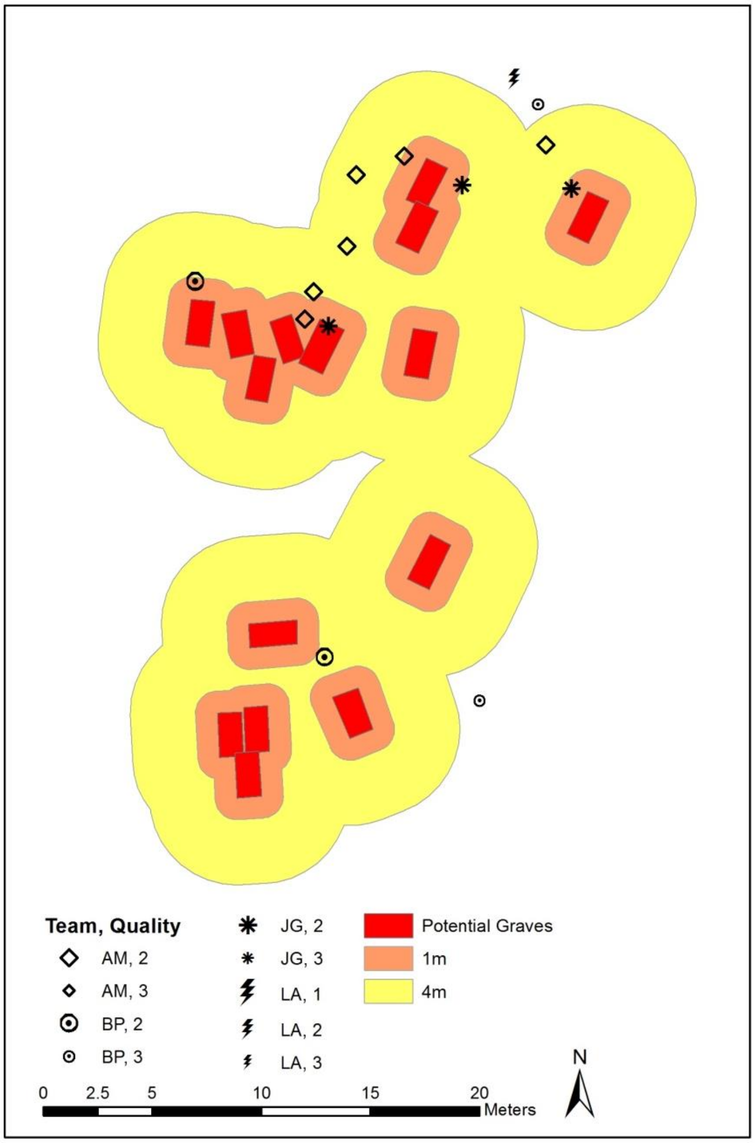

Figure 6: HHRD Dog alerts at Cemetery 26, Fort Gordon, GA.

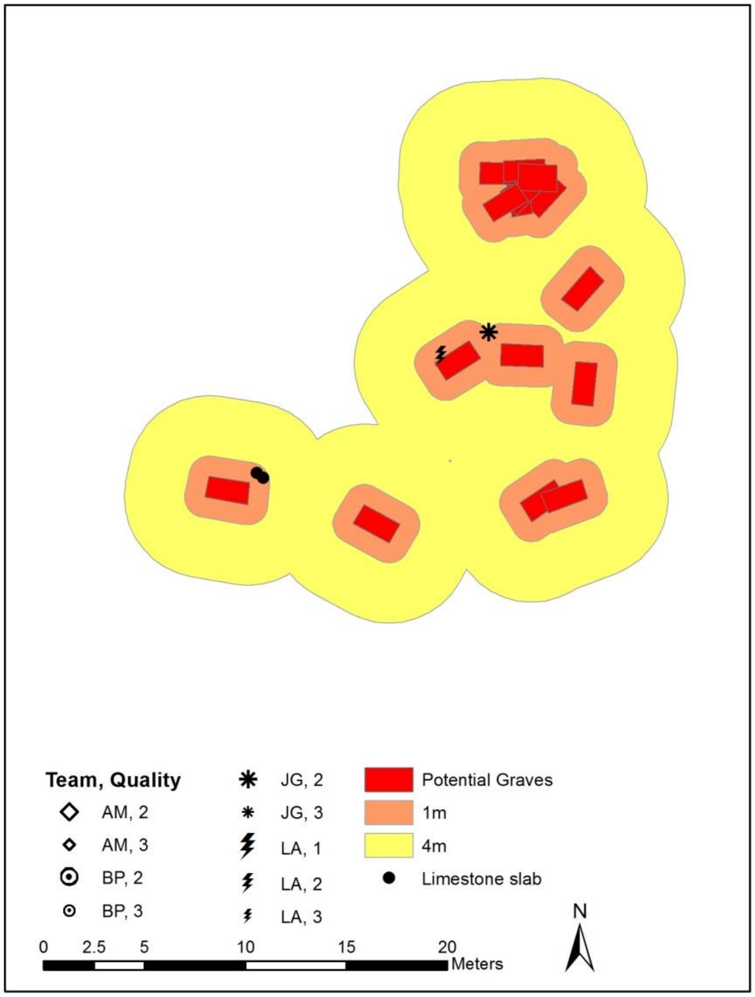

Figure 7: HHRD Dog alerts at Cemetery 31, Fort Gordon, GA.

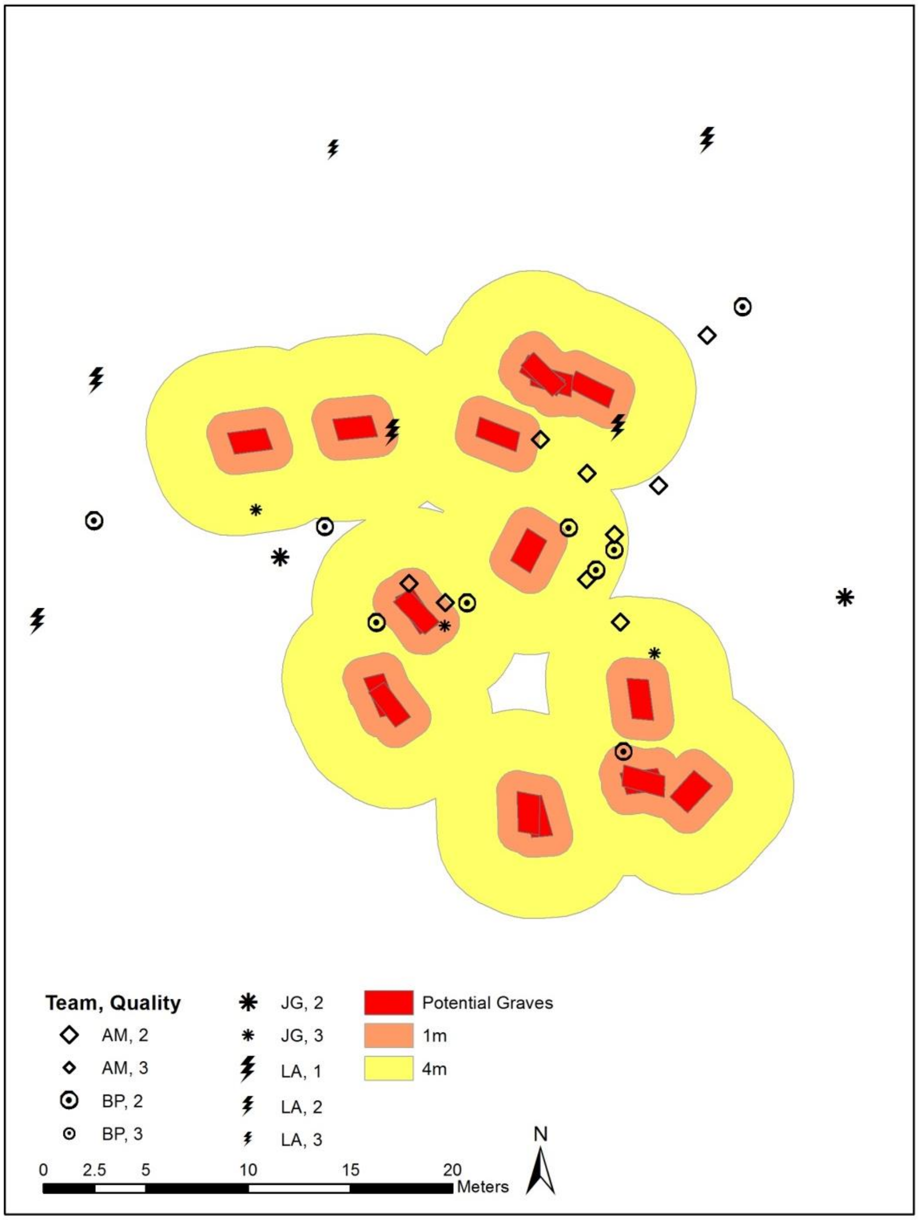

Figure 8: HHRD Dog alerts at Cemetery 34, Fort Gordon, GA.