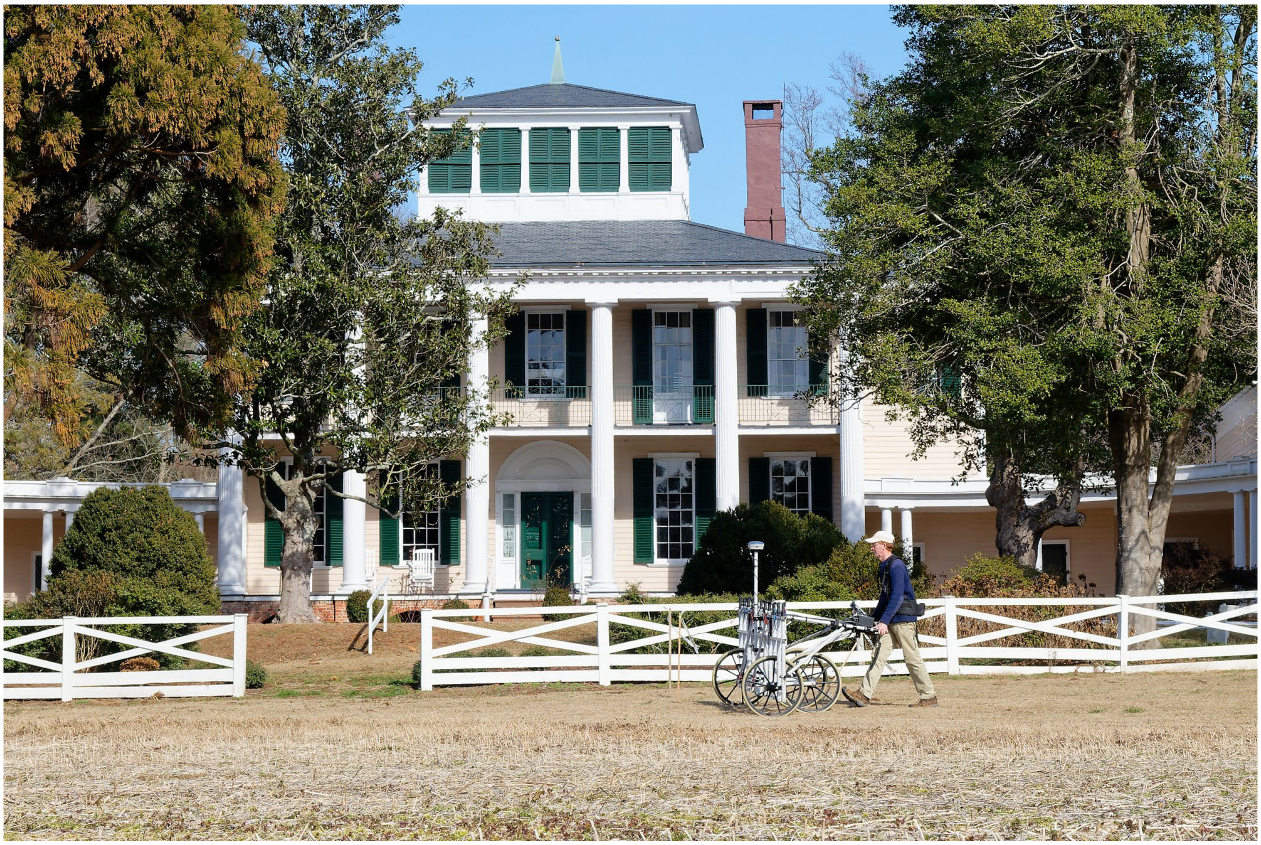
HAYES PLANTATION: SEPTIC AREA, CHOWAN COUNTY, NORTH CAROLINA

Report on Geophysical Surveys, January 26-27, 2025



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Summary

High-resolution magnetometer and ground-penetrating radar (GPR) surveys were undertaken at the Hayes Plantation in Edenton, NC, with the aim of identifying any potentially significant buried cultural remains in an area where a new septic field is proposed to the southwest of the nineteenth-century mansion.

An area of 0.68 hectares (1.70 acres) was investigated using a Sensys MX3 magnetometer system with 11 gradiometer sensors spaced 25 cm (~10 inches) apart. A subsequent GPR survey was conducted across a smaller area of 0.24 ha. (0.60 acres) using a MALA MIRA HDR multichannel GPR system with 22 channels separated by just 6.5 cm (~2.5 in). These complementary non-invasive methods are capable of detecting and characterizing a wide range of cultural features, including walls and foundations, cellars and various pits, hearths and post holes.

The results of this investigation reveal numerous buried pipes, seven buried septic tanks, and multiple leach fields, mostly confined within 20 m (65 ft) of the fence, with one pipe and small tank extending to around 30m (100 ft) from the fence. Two of the tanks had previously been located by probing, but this survey provides detailed maps of all tanks and the complex network of pipes in this area, and reveals the extent of recent ground disturbances. A small number of possible archaeological features have also been identified, including hearths and pits. These suggest pre-contact activity in this area, although all evidence for these is located away from the proposed septic system.

The geophysical results do not reveal any significant historic or pre-contact features and deposits in the area of proposed septic field.

This report includes a description of the methodology and the results, plus plots of the magnetometer results and GPR time-slice images to illustrate the findings. Interpretation maps are also provided to assist with future management and investigations in this area.

Cover photo: The magnetometer survey in progress, January 26, 2026. Photo: author.

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1. Introduction

1.1 Horsley Archaeological Prospection, LLC, (HAP), has conducted non-invasive geophysical surveys across the site of a proposed septic system at the Hayes Plantation in Edenton, North Carolina. It was hoped that a combination of magnetometry and ground-penetrating radar (GPR) would be able to identify and map the presence – or absence – of any significant buried cultural remains in this area located some 40 m or 130 ft to the southwest of the early nineteenth century mansion. The work was undertaken in response to a request from the Edenton Historical Commission.

1.2 The proposed septic field at the Hayes Plantation is centered on 355,665 E, 3,900,695N (WGS84, UTM coordinates, zone 18N [meters]) or 2,708,710E, 845,715N (NAD83 [2011], State Plane North Carolina [US feet]). While the area of potential disturbance measures only around 0.06 hectares or 0.15 acres it was decided to encompass a much larger area to (i) better understand and distinguish potential naturally occurring geophysical anomalies, and (ii) allow for alternative locations of the septic field to be proposed should archaeological remains be discovered. Magnetometry was conducted first across an area of 0.68 ha. (1.70 acres), followed by a more focused GPR survey over 0.24 ha. (0.60 acres). These areas are shown in Figure 1.

1.3 The soil underlying this location is the *State loamy fine sand* (USDA-NRCS, n.d.). The typical soil profile is described as an 18 cm-thick (7 in) loamy fine sand *Ap* layer, over a loamy fine sand *E* horizon between 18-33 cm (7-13 in); a sandy clay loam *Bt1* horizon between (13-38 in); a fine sandy loam *Bt2* horizon between (38-42 in); with a sand *C* horizon between (42-80 in). This soil forms on sandy and loamy fluviomarine deposits and/or marine deposits (*Ibid.*, n.d.). Such soils provide excellent conditions for both magnetometry and GPR.

1.4 Hayes Plantation is situated on Quaternary deposits composed of unconsolidated sand, clay, gravel, and peat deposited in marine, fluvial, eolian, or lacustrine environments (Rhodes and Conrad, 1985). In general, such deposits are also conducive to geophysical methods. HAP's previous work in the region (e.g., at the nearby Newbold-White House in Perquimans County, [Horsley 2018]) has shown that the natural magnetic anomalies are produced by variations in the underlying deposits, although in general it is possible to distinguish these from those associated with cultural features – especially when the results are combined with GPR data.

1.5 The survey area is bounded to the east by the fence between the agricultural field and the garden around the main house. Surveys extended west from this fence across an area of maintained lawn and into the field to the southwest. Ground conditions were ideally suited to geophysical survey, being flat and without obstacles. (The few wooden stakes that had been placed to mark the recently identified probable buried septic tanks were temporarily removed during the survey. These markers were also recorded with GPS and their locations are included in Figure 1).

1.10 The geophysical survey was undertaken between January 26^{th}-27^{th}, 2025. Despite snow a few days prior to fieldwork, weather conditions were well suited to both GPR and magnetometer survey.

2 Geophysical prospection methods

2.1 Geophysical methods include a range of non-invasive techniques for detecting subsurface disturbances associated with buried remains. It is important to note that these techniques do not detect the features themselves, but rather physical variations – or *anomalies* – that require interpretation. For a buried feature to be detected there must therefore be some degree of physical contrast between it and the natural soil and subsoil that surrounds it; if no such contrast exists, that feature will effectively be invisible. It should also be noted that different subsurface situations may give rise to very similar, if not identical, above-ground geophysical anomalies. The interpretation of such results therefore requires experience working with shallow geophysical data, and familiarity with archaeological and natural features and deposits. Interpretation may also draw on excavation and other archaeological evidence that can aid in the identification of specific feature types, materials, and depths. Only through investigation using more intrusive methods can datable artifacts and material be obtained, and causative features be accurately determined.

2.2 Many archaeological features exhibit physical contrasts to natural soils and sediments, either through the addition of foreign material into the soil (e.g., building materials such as bricks and rocks), or by altering the soils and subsoils (e.g., conversion of magnetic properties through heating, or the silting up of cut features such as pits and ditches). A selection of geophysical techniques is available for archaeological prospection, including magnetometry, electrical resistance, and GPR. Each method measures a different physical property and therefore a particular method or combination of methods may be chosen that will be best suited to the conditions at a given site.

2.3 Magnetometry is currently the most rapid geophysical method for detailed survey and can detect a broad range of both prehistoric and historic archaeological features on account of contrasts in magnetic susceptibility (MS) and/or the presence of a permanent magnetization. MS is the ability of a material to become magnetized when placed in a magnetic field. In soils, this is related to the naturally occurring iron minerals present. These minerals can be converted to more magnetic forms through many anthropogenic activities, such as heating and the decomposition of organic material. In addition to pits, ditches, larger postholes, and many burnt remains, it is often possible to identify areas of occupation using a magnetometer by their increased 'noise' levels. Heating soils to high temperatures can cause a strong, permanent magnetization to be retained, such that kilns and furnaces can be detected, as well as accumulations of brick and tile. Historic sites are therefore usually more easily identified on account of the higher concentration of magnetic material in the form of brick, tile and ceramics, in addition to iron objects. Due to the speed with which measurements can be made this method is well suited to characterize magnetic anomalies over large areas at high resolution. Further information on this technique may be found in Appendix 1.

2.4 In contrast to most other methods, GPR has the potential to provide information on the depth of subsurface remains by recording energy reflections from sub-horizontal features (such as cultural layers, soil horizons); vertical features (e.g., trenches, foundations); and discrete bodies (such as rocks and boulders). Where conditions allow different features to be resolved it can be possible to identify vertical relationships between them. Since the energy reflections occur where there is a change in the velocity of the emitted GPR energy, such as between different materials, soil textures, or water content, it may not be possible to detect features where there is a gradual transition or no contrast from one material to another.

Of the range of archaeological features commonly encountered, burials present difficult targets for geophysical prospection methods as there may be little contrast to allow their detection. Bones are too small to be detected with any method and, despite digging of the grave and interment of a casket, wrapped body, or other human remains, the grave is usually immediately backfilled with the same material that was removed, reducing the potential for a geophysical contrast. Despite this, previous investigations have shown that graves may be located by: (i) identifying disruptions in the natural stratigraphy of the soil; or (ii) by detecting the less-compact soil of the grave fill; or (iii), if present, by detecting an air-filled cavity. In general, however, over time this contrast is reduced such that older burials may be impossible to distinguish. Successful results therefore depend on a number of factors, including the nature of the soils and sediments at a site, the age of the burials, and the surveyor's experience in analyzing such data.

One of the most useful aspects of GPR for archaeological investigations is the ability to produce *amplitude time-slices* – horizontal plans that correspond to different depths below the ground surface that more closely resemble archaeological plans. When used in combination with the individual radar profiles, interpretations can be produced for different depth ranges. Further details on this method are provided in Appendix 1.

2.5 Recent years have seen several significant developments in GPR systems. One of these involves combining multiple transmitter and receiver antennas within a single array, thereby allowing the collection of several transects of high-resolution data in a single pass. By closely spacing the antennas, these so-called multi-channel devices are capable of collecting true-3D GPR data at efficient rates. Currently available systems operating at center frequencies of around 450-500 MHz provide data along transects spaced around 6.5-8.0 cm apart, significantly closer than the 25cm or 50cm more commonly employed in archeological investigations. This increased resolution has the potential to allow much smaller cultural features to be imaged and identified.

3. Methodology

3.1 The magnetometer survey was conducted using a Sensys MXV3 multichannel fluxgate gradiometer system. Eleven gradiometer sensors spaced 0.25m apart were mounted onto the pushcart. When pushed at a comfortable walking pace (between 1-2 meters per second), data collected at 100Hz results in an on-ground resolution of 1-2cm x 25cm, or >200 readings per square meter.

3.2 Magnetometer data were collected along parallel transects oriented east-west. To ensure careful and consistent collection in the field, these transects were guided by digital guidelines uploaded to the onboard data acquisition computer as a shapefile. Integrating a real-time kinematic global positioning system (RTK-GPS) onto the pushcart allows real-time display of these lines, as well as the current position and heading. This helps to guide the operator in the field and simultaneously collects accurate positioning information for georeferencing of the geophysical data. Consequently, detailed notes about survey grid positions and start/stop coordinates of data transects are not necessary as the entire survey is part of a single grid, and each data position has its own unique coordinates.

Flags were also used in the field to mark the ends of the transects and provide an additional visual aid for walking straight lines. The location of the magnetometer survey is shown in red in Figure 1. This larger, 0.68-hectare (1.7-acre) area was investigated first to both investigate the primary Area of Interest and place it in its setting, thereby allowing for alternate locations for the proposed septic system to be sited should that have been necessary.

3.3 Following collection and downloading of the raw data to a desktop computer, the magnetometer data are exported from *MonMX* before the results can be reviewed using *MAGNETO*, both proprietary software programs from *Sensys*. During the export from *MonMX*, minimal data treatment was applied to help match the outputs from each gradiometer sensor. This is achieved by applying a moving median filter (length = 20m).

MAGNETO allows the data to be exported in various formats, including georeferenced raster images (e.g., TIFFs) and ASCII files. The latter was used for additional interpolation using Surfer from *Golden Software*.

3.4 The GPR survey was undertaken using a MALÅ MIRA HDR multichannel system. This system operates at a center frequency of 500 MHz to collect 22 GPR profiles spaced just 6.5cm apart in a single swath. This high resolution allows a true 3-dimensional view of the subsurface to be obtained. This antenna is towed behind a UTV, and the operator uses a laptop to collect and monitor data. This system can also be integrated with RTK-GPS to assist with careful coverage of the Area of Interest and real-time georeferencing of he GPR data.

GPR survey was conducted across a smaller area of 0.24 ha. (0.60 acres) to encompass the primary Area of Interest and also to obtain additional information about the two buried tanks that had previously been located by probing (see Figure 1).

3.5 GPR data were collected and recorded onto a dedicated field computer and later downloaded onto a PC. Subsequent data processing was undertaken using MALÅVision. Minimal treatment was undertaken prior to the production of time-slices, limited to a standard procedure of *time-zero correction* and *gain correction*. These steps shift the start of the signal (time-zero) to coincide with the ground surface rather than when the pulses are transmitted, and boost the weaker signal returned from greater depths. Following initial analysis of the time-slices, additional processing steps included: the application of a *band-pass filter* (to reduce or remove external sources of electromagnetic noise); a *median background removal* to help reduce differences between the antennas (for data collected with the multichannel system); *Kirchoff migration* to collapse hyperbolic reflections back into point source reflections; and applying a *Hilbert transform* to convert the sinusoidal radargram pulses to simpler positive pulse envelopes. These additional steps aided analysis of the results, and reference was made to all processed data during analysis and interpretation.

3.6 To allow conversion of two-way travel time to real depth, the average velocity of the ground was found by matching computer-generated hyperbolae to the data. This velocity is specific to different sediments and water content, and for this dataset it was found to be around 0.104 m/ns. It is worth noting that this is the average velocity for the entire profile, and the component velocities will be different for different materials, topsoil, subsoil, feature fill, as well as variations in water content. Therefore, the calculated depths given here should be taken as approximations but are expected to be within 10-20% of the actual depths.

3.7 Following processing, the individual radargrams were combined to produce a 3-dimensional block of data. This was then 'sliced' horizontally to produce the amplitude time-slices corresponding to different depths within MALÅVision. Slices of 0.1m (4") thickness were produced from the ground surface down to 2.0 meters below surface (m.b.s.), corresponding to around 6 feet and 6 inches. These time-slices allow the horizontal relationships between reflections to be more easily identified, and both radargrams and time-slices were consulted to produce the interpretation presented here.

3.8 GPR time-slices were subsequently imported into *ArcView*, a Geographical Information System (GIS) package to allow the results to be georeferenced and integrated with maps of surface features, as seen in the accompanying figures.

4 **Magnetometry results** – Figures 2-3

4.1 The results of the magnetometer survey are presented in Figure 2, and a summary of the significant anomalies, with interpretations, is provided in Figure 3. Brief descriptions of the general findings of this magnetometer survey are provided in the following sections.

4.2 *Intense ferrous anomalies*

The magnetometer results are dominated by the intense positive and negative responses caused by iron metal. A band of these bipolar responses is visible running alongside the wooden fence (see also Section 4.2), as well as two larger, more intense anomalies some distance into the field, and several smaller, discrete bipolar responses randomly distributed across the survey area. The most intense anomalies (in excess of ±25 nT) are highlighted as dark and light gray in Figure 3. Iron metal is commonly encountered in magnetometer surveys, caused by small pieces of debris or trash that become incorporated in the topsoil. Consequently, these isolated, discrete anomalies can be ignored as they do not indicate any significant past activity. In contrast, the larger intense responses and clusters of such anomalies indicate more significant and concentrated activities that could be either modern or historical in origin. While magnetic anomalies are generally much larger than their causative objects or features, larger anomalies indicate larger or longer features. Comparison of the locations of the wooden stakes marking the two buried septic tanks shows that they coincide with two of the larger intense anomalies (at [i] and [ii]), but the results reveal that additional buried tanks are also present. In Figure 3, a third tank is suggested some 13 m (45 ft) to the southeast of one tank (at [iii]), and a fourth tank at [iv] – these are all confirmed by the GPR survey (see Section 5). The anomalies at [v] may indicate some other buried iron object(s) located under the plastic cover labeled “irrigation valve” near the entrance through the fence to the field.

4.2 *Magnetic “noise”*

In addition to the large, bipolar anomalies described above, clusters of smaller-scale, less intense responses have been detected. These are highlighted in yellow in Figure 3. A long band of such magnetic “noise” can be seen within around 5-6 m of the wooden fence, indicating a concentration of iron objects in this area. In two places the distinctive alternating pattern of positive-negative responses suggests a buried iron pipe or conduit, although the large number of anomalies makes it difficult to be certain or follow their full course. The GPR results, described in Section 5, confirm the presence of several buried pipes running parallel to the fence in this area, which may partly or fully explain the magnetometer results.

Immediately to the southeast of one of the two larger ferrous responses likely indicating a buried iron tank is a rectangular area of magnetic noise. Its location suggests that it is likely related to the tank, and therefore also modern in origin. While not considered significant, this anomaly does help to define the extent of potential recent ground disturbances in this area.

4.3 *Other intense, positive magnetic anomalies*

A small number of intense positive anomalies have been identified, with a notable group near [vii] in Figure 3. Such responses may be produced by fired material, such as brick or tile, although they can also be caused by iron-rich metal or rock. The GPR results indicate that these appear to be associated with a leach field, helping to rule out any archaeological significance.

4.4 *Discrete positive magnetic anomalies*

Several discrete, strong positive magnetic responses can be seen across much of the survey area. They measure between 0.4-1.0 m in diameter and up to 12 nT in strength. Such anomalies are consistent with those produced by burned deposits, such as hearths or pits containing burned soils. These could represent pre-contact hearth and pit features, although further work would be required to better understand their cause. None have been identified in the area of the proposed septic field.

4.5 *Weak linear trends*

Several weakly magnetic linear trends have been identified. One group, near [viii] in the northern part of the survey coincides with some slight linear depressions noted on the ground surface. These measure between ±2 nT in strength, with the negative portion of each response coinciding with the depression. The cause of these is unclear and they could be recent in age, produced by farming or garden beds. Further, more intrusive work would be necessary to determine their age and any significance; however, this area is far from the proposed septic system and no further work is recommended at this time.

Three very weak trends, less than ±0.5 nT, can be seen in the southeastern end of the survey area, highlighted at [ix] in Figure 3. One trend is aligned NW-SE and lies close to the boundary between the mown grass area and agricultural field; the other two are aligned SW-NE which matches historic plow scars visible in the GPR data (compare with the GPR time-slice from 0.3-0.4 m.b.s. in Figure 7). All three are interpreted as being due to plowing and relatively recent in origin.

4.6 In summary, the magnetometer survey reveals several modern features relating to existing septic systems in this part of the field, and highlights areas of recent disturbance. A small number of possible hearths and/or pits are suggested that could indicate pre-contact activity in this area, although no significant features have been identified in the area of the proposed new septic system.

5 **GPR results** – Figures 4-19

5.1 Figures 4-18 present a selection of *amplitude time-slices* to illustrate the results obtained by the GPR surveys at different depths. Each plot corresponds to a 10cm-thick (4”) horizontal slice through the ground, and they are shown from the surface to a depth of around 1.5 m.b.s. (meters below surface), roughly 5 feet. The only anomalies identified below a depth of around 1.5 m.b.s. appear to be natural variations in the subsoil. The data in these images are shown after processing described in Section 3.5 above, including both migration and Hilbert transformation.

5.2 As the time-slices illustrate, the GPR survey has detected numerous geophysical anomalies caused by a range of surface and subsurface disturbances. Many of these have distinctive characteristics that help to identify their origins (e.g., buried pipes, tree roots, etc.), while others require analysis of both time-slices and the individual radargrams.

As is commonly seen in such data, these anomalies lie at a range of depths below the ground surface and therefore do not all appear in a single time-slice. Figure 19 presents an interpretation of all significant GPR anomalies between 0.0 – 1.5 m.b.s. (approximately 0-5 ft) to combine all relevant findings in one image.

The following sections describe the findings of this investigation, grouped according to feature type.

5.3 *Buried pipes, tanks, and leach fields indicating several former septic systems*

Almost immediately below the ground surface, at a depth of around 0.05 m.b.s., it is possible to distinguish high amplitude linear reflections that reveal buried pipes. Numerous pipes can be seen, with several running parallel to the fence, others leading to square tanks, and others leading to wider leach fields. The base of the deepest pipe appears to be around 1.0 m.b.s. All identified pipes are shown in the interpretation provided in Figure 19.

Seven buried tanks have been identified, (see [a] to [g] in Figure 19), some of which coincide with those seen in the magnetometer survey (see Section 4.2 above, and anomalies [i], [ii], and [iv] in Figure 3). The tanks that do not have associated magnetic responses are non-ferrous, possibly constructed of concrete or plastic. Associated with these pipes and tanks are several broader reflections that often extend deeper, and are consistent with leach field anomalies

5.4 *Tree roots*

While not significant, tree root reflections have been identified throughout the time-slices from the ground surface to a depth of around 0.9-1.0 m.b.s. These are included in Figure 19 as they complicate the interpretation of data in the area alongside the fence, and it is possible that some short sections of pipe have been mis-interpreted as tree roots, or vice versa – especially in the narrow survey section near [a]. Their presence may also be relevant when considering the siting of the new septic system.

5.5 Possible pit

One possibly significant archaeological feature has been identified in the GPR results. At [h] is an oval feature detected between 0.4-1.3 m.b.s. It measures around 1.8 m across and may extend beyond the survey boundaries to the west. Such an anomaly indicates a cut-and-filled feature, such as a pit. In the absence of any dating evidence it is impossible to determine if this feature is modern, historical or pre-contact in date, although the fact that the upper level has been detected below the plow zone suggests that it may represent pre-contact activity. This is the only potentially significant feature identified in the GPR data.

5.6 In summary, the GPR results provide a clear map of relatively recent activities relating to former septic systems that mostly lie within 20 m (65 ft) of the fence, with one pipe and small tank extending to around 30m (100 ft) from the fence. Multiple pipes and leach fields are present, as well as seven probable septic tanks. Only one possible pit feature has been detected that may be culturally significant; however, this is located away from the proposed septic system.

6 Conclusions

6.1 Combined magnetometer and GPR surveys have been very successful in detecting several buried features in the Area of Interest; however, the majority relate to former septic systems, and no significant archaeological features or deposits have been identified in the area of the proposed septic field.

6.2 Images of the geophysical results are enclosed, along with interpretation plots to accompany the written descriptions of the results. Figure 20 combines the findings of the two survey techniques, and Figure 21 shows the proposed septic system overlaid onto the results, which also highlights the extent of previous ground disturbances in this area.

6.3 Ground conditions proved very well-suited to geophysical survey, with the sandy soils being particularly favorable for GPR. In addition to this improving confidence in these findings, it also demonstrate the potential for their use in archaeological prospection in similar environments in this region.

The results and subsequent interpretation of geophysical surveys should not be treated as an absolute representation of the underlying features. It is normally only possible to prove the nature of anomalies through intrusive means, such as trial excavations.

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Fieldwork: T.J. Horsley | **Dates of survey**: 1/26 – 1/27/2024

Report: T.J. Horsley | **Date of report**: 3/23/2025

Bibliography *(This also refers to material cited in the appendix)*

Bevan, B.W. (1991). The search for graves. *Geophysics*, 56(9): 1310-1319.

Conyers, L.B. (2004). *Ground-Penetrating Radar for Archaeology*. Altamira Press, Walnut Creek.

Conyers, L.B. (2006). Ground-Penetrating Radar, in J.K. Johnson (Ed.) *Remote Sensing in Archaeology: An Explicitly North American Perspective*. The University of Alabama Press, Alabama. 131-159.

Gaffney, C. and Gater, J. (2003). *Revealing the Buried Past. Geophysics for Archaeologists*. Tempus Publishing Ltd., Stroud.

Goodman, D., Nishimura, Y. and Rogers, J.D. (1995). GPR time-slices in archaeological prospection. *Archaeological Prospection*, 2: 85-89.

Goodman, D. and Piro, S. (2013). *GPR Remote Sensing in Archaeology*. Springer, New York.

Horsley, T.J. (2018). *Newbold-White House, Hertford, Perquimans County, North Carolina. Report on Geophysical Surveys, April 23-27, 2018*. Horsley Archaeological Prospection, LLC, Report no. HAP2017-49.

King, J.A., Bevan, B.W. and Hurry, R.J. (1993). The reliability of geophysical surveys at historic-period cemeteries: an example from the Plains Cemetery, Mechanicsville, Maryland. *Historical Archaeology*, 27(3): 4-16

Rhodes, T.S., and Conrad, S.G. (1985). *Geologic Map of North Carolina*. Department of Natural Resources and Community Development, Division of Land Resources, and the NC Geological Survey, compiled by Brown, Philip M., et al, and Parker, John M. III, and in association with the State Geologic Map Advisory Committee, scale 1:500,000.

USDA-NRCS (n.d.). *WebSoilSurvey*. U.S. Department of Agriculture: Natural Resources Conservation Service. Available online at: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Appendix 1 - Magnetometry

It can be possible to detect subtle anomalies in the Earth's magnetic field caused by buried archaeological remains using a magnetometer. Variations in the magnetism, (the magnetic susceptibility), between a feature and the surrounding soil can arise owing to weakly magnetic oxides present in the soil. Past human activities may have redistributed these minerals or converted them into more magnetic forms, so that buried features may be detected and identified by their resulting magnetic anomalies. In this way, it is possible to identify and map buried pits, house basins, ditches, hearths and, depending on their size and degree of magnetic contrast, postholes. Based on patterns and alignments of pits and postholes, it may be possible to identify structural remains.

Features associated with high temperature processes can also be detected on account of a permanent, so-called thermoremanent magnetization that is retained when a material containing iron oxides is heated to above around 600-800°C (1000-1400°F) and then cooled. In this way, kilns, furnaces, pit ovens, and often deposits containing bricks, tiles and fire-cracked rocks, can be identified from the more intense magnetic anomalies associated with them.

Burials are not usually identified using a magnetometer since neither the cutting and backfilling of the grave shaft, nor the inhumation itself, creates a magnetic contrast that can be measured at the ground surface. Bones are too small to be detected with any geophysical technique and, despite digging of the grave and interment of a body or human remains, the grave is usually immediately backfilled with the same material that was removed and so there may be no difference between the grave fill and the surrounding soil. In some instances, notably historic graves where coffins were used, an air-filled void may be left after the body has decayed; however, this feature is often only detectable using GPR.

Magnetometers are highly sensitive to iron metal and consequently surface or buried iron objects can be detected as very intense responses. While this iron may be archaeological in origin, it is often from modern fences, farm machinery and trash, and it is impossible to distinguish between different sources.

Many magnetometers allow readings to be collected at regular and closely-spaced time intervals, (defined by the operator), such that data may be recorded at regular distance intervals by walking along a marked guide rope at a constant pace guided by a beep. The quality and accuracy of the data is therefore dependent on the operator's ability to walk smoothly and at a constant speed throughout the survey area. Standard practice for such data collection is to establish a grid of 20m or 30m squares that are each surveyed in turn. Within each grid, data may be collected at 0.125m or 0.25m intervals along traverses spaced either 0.5m or 1.0m apart. Decisions about the resolution at which to collect geophysical data are based on factors including the size and nature of expected archaeological features, and the time available for survey.

For more information on this technique, see Aspinall et al. (2008), Clark (1990: 64-98), Gaffney and Gater (2003: 36-42) and Kvamme (2006).

Appendix 2 **- Ground-penetrating RADAR**

Ground-penetrating RADAR, or GPR, involves the transmission of high-frequency radar pulses into the ground from a surface antenna. Where this energy meets discontinuities in the soil, such as a change in soil types and buried remains, some pulses are reflected back to a receiving antenna while others continue down to be reflected by more deeply buried changes. The elapsed time between the energy transmission and reflection provides information on the depth of buried targets, and is used to produce a vertical slice through the ground – a *radargram*. Unlike other geophysical prospection techniques, such as magnetometry or earth resistance, this profile allows vertical relationships between deposits to be investigated. Furthermore, many closely-spaced transects may be combined to form a three-dimensional block of data that can be re-sampled horizontally. This is used to produce a series of subsurface plans for increasing depths, referred to as *amplitude time-slices*. The depth penetration of the radar pulses is dependent on both the frequency of the antennas employed and the electrical conductivity of the soils and sediments. Lower frequencies may be used to provide deeper penetration, but at the expense of resolution.

Radargrams are measured in terms of time (two-way travel time of the radar pulse); however, it is possible to calculate real depth values if the velocity of the material through which the radar energy is travelling is known. This can either be achieved in the field or by fitting computer-generated hyperbolae to the data after data collection. Further information on this technique may be found in Conyers (2004; 2006), Gaffney & Gater (2003: 47-51, 74-76), Goodman et al. (1995), and Goodman and Piro (2013).

Whilst previous investigations have shown that GPR can often detect later historic graves (e.g., Conyers 2006; King et al. 1993), early historic and prehistoric graves are far more difficult to identify. If the fill of the grave itself is less compact than the surrounding sediments, the sides and base of the grave may be detected using GPR; however, the inhumations themselves are unlikely to produce any clear reflection. It is therefore not usually possible to distinguish between any detected pit anomalies and graves.

Historic features such as foundations, floor layers, and rubble spreads, produce clearly identifiable radar reflections. Lenses and deposits of sand, gravel, or boulders will produce similar reflections, and distinguishing between natural and anthropogenic features may be difficult and require additional information from other geophysical techniques or intrusive methods.