Appendix 7.4

Geophysical Survey Interim Report
Summary

A geophysical (magnetometer) survey, covering approximately 58 hectares, was carried out on land around Preesall, Lancashire, that will be impacted by the proposed construction of a new gas storage facility and its associated supply pipelines and utilities connections. The survey covered approximately 60% of the total land within the application boundary that is suitable for survey. Anomalies caused by pipes, field drains, modern agricultural activity and geological variation predominate in the data. Only at one location (Fields 45, 46 and 47) have anomalies been identified that cannot be confidently interpreted as either being modern or geological in origin and on this basis they have been interpreted as possibly archaeological. A pilot ground penetrating radar survey carried out at a single location has identified one target of unknown origin. On the basis of the geophysical survey carried out to date the archaeological implications of the proposed project would seem to be low.
Report Information

Client: Hyder Consulting (UK) Ltd.
Address: The Mill, Brimscombe Port, Stroud, Gloucestershire, GL5 2QG
Report Type: Geophysical survey
Location: Preesall
County: Lancashire
Grid Reference: SD 625 465 (centred on Gas Storage Facility)
Period(s) of activity represented: ?
Report Number: 2257
Project Number: 3761
Site Code: PGS11
Planning Application No.: Pre-application
Museum Accession No.: n/a
Date of fieldwork: June – September 2011
Date of report: October 2011
Project Management: Sam Harrison BSc MSc AIFA/Alistair Webb BA MIfA
Fieldwork: Alex Harrison BSc
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David Williams BA PIIfA
Report: Alistair Webb
Illustrations: Alex Harrison, David Harrison, Sam Harrison
Photography: Site Staff
Research: n/a

Authorisation for distribution: -------------------------------------
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1 Introduction

Archaeological Services WYAS (ASWYAS) were commissioned by Jenny Wylie, Senior Archaeologist at Hyder Consulting (UK) Ltd, on behalf of their client, Halite Energy Group Limited, to undertake a geophysical (magnetometer) survey on land around Preesall that is likely to be affected by a proposed industrial development comprising a gas storage facility, NTS interconnector pipeline and brine outfall pipeline and associated infrastructure to the east of Fleetwood, Lancashire (see Fig. 1). The scheme of work was undertaken in accordance with the requirements of Planning Policy Statement 5 and to a Written Scheme of Investigation submitted to, and approved by, Peter Iles, Development Control Archaeologist for Lancashire County Council.

Site location, topography and land-use

The application area covers approximately 284 hectares, extending from the Irish Sea coast immediately south of Fleetwood, in the west, to Garstang in the east (see Fig. 2). Of this overall area approximately 105 hectares was identified as suitable for evaluation by geophysical survey.

The project comprises four separate elements, three corridors of a minimum 30m width and a single large block of land covering the Gas Storage Facility (GSF). To the west is the corridor for a brine outfall pipe which extends from the Gas Storage Facility on the eastern side of the Wyre estuary, at SD 340 367, to the outfall point on the beach south of Fleetwood at SD 310 355 (see Fig. 3). To the east of the river Wyre estuary is the GSF (see Fig. 4) which is centred at SD 625 465 and which covers a single block of land of approximately 179 hectares. Extending south from the storage area is a second corridor for the route of the Electricity Connection (see Fig. 5) that terminates at an electricity sub-station at Stanah on the western side of the Wyre estuary. Extending east from the storage area is a much longer corridor (approximately 12km) for the NTS Interconnector (see Figs 6, 7 and 8) which runs from the GSF at SD 363 460 to SD 468 454, just west of Garstang.

Land usage varied over the application being predominantly under agricultural production with mainly arable crops of wheat and barley but with a large area of potatoes in the GSF. Some areas were laid to grass for either hay or silage.

The topography was generally flat and low lying at less than 5m above Ordnance Datum (aOD) to the east of the Wyre estuary. To the west of the estuary the land is slightly higher at nearly 20m aOD near Stanah but again generally less than 10m aOD.

Soils and geology

The bedrock geology of the survey area is predominantly of the Sidmouth Mudstone and Sherwood Sandstone formations. These are overlain by superficial (drift) deposits comprising of peat, till and tidal flat deposits of clay and silt (BGS 1991).
The soils throughout the survey area are interchangeable and are classified as being in the Salop, Downholland 1 and Turbary Moor soil associations. These soils are characterised as seasonally waterlogged, reddish fine loams over clay, deep stoneless clays or silts and deep earthy peats respectively.

2 Archaeological and Historical Background

The following archaeological background is summarised from baseline information provided by the client. A more detailed and comprehensive assessment of the archaeological background will be contained within the Environmental Impact Assessment (EIA), currently in preparation. Preliminary data from the EIA does, however, indicate more than 170 archaeological records (as entered on the Lancashire Historic Environment Record) within the defined search area. More than half of the records relate to post-medieval activity but with a significant number (42) relating to prehistoric activity. The vast majority of the catalogue entries are recorded within the wider search area with relatively few within the application area itself.

The wetland environment across which the scheme traverses is thought to be rich in prehistoric archaeology, particularly from the Neolithic period and Bronze Age, as suggested by a wealth of finds from the immediate area. Neolithic stone axes have been found at Bone Hill, Blacklane Head Farm and at Pilling Moss. At Kate’s Pad, Out Rawcliffe, Neolithic or Bronze Age trackways were found under 4m of peat and other finds from the Bronze Age include stone axes, spearheads, dagger sheaths and hoards. Evidence for Bronze Age settlement is known from Pilling Moss where several stray finds and a ritual bog burial have also been located. An Environmental Statement from 2005 identified significant potential for the presence of earlier Neolithic and Mesolithic remains, preserved within the waterlogged peats and marine and estuarine silts.

Evidence for Roman activity within the environs of the scheme is known from several coin finds within the west of scheme. Roman pottery, bone and glass were found at Broadfleet Stream, near Stakepool, and a Roman road and an associated Romano-British building was identified in the 19th century at Fleetwood.

Therefore, on the current evidence base, the application area is considered to have a moderate to high archaeological potential.

3 Aims, Methodology and Presentation

The primary objective of the geophysical (magnetometer) survey was:

- to provide information about the nature and possible interpretation of any magnetic anomalies identified and thereby to determine the presence or absence of buried archaeological remains.

Extremely large and/or linear developments are complicated by the large and extended area of land affected and by the variety of geological and soil conditions through which the route
may pass. Due to the size, mixture of superficial geology and rural location of the application area, a magnetometer survey covering the ground that will be destroyed or damaged by the development was deemed to be the most cost-effective method of evaluation at this stage although it was recognised at the outset that certain types of archaeological activity, particularly unenclosed, transient, activity dating to the earlier prehistoric periods, may not be readily identifiable by magnetometry. Nevertheless, a detailed magnetometer survey of all of the land that will be impacted by the construction of the gas storage facility and supply infrastructure, an area of approximately 103 hectares was proposed for survey. However, access has not been agreed in some areas and other areas, where access was granted, also remain unsurveyed at the present time due to project deadlines. To date an area of 58 hectares has been surveyed.

A secondary objective was to identify an area/s where ground penetrating radar (GPR) survey may be able to locate archaeological features or deposits not normally identifiable by magnetometer survey. Additional GPR survey may be required depending on the results of the magnetometer survey and of the pilot survey, depending on ground conditions.

**Magnetometer survey**

Bartington Grad601 magnetic gradiometers were used during the survey, taking readings at 0.25m intervals on zig-zag traverses 1m apart within 30m by 30m grids, so that 3600 readings were recorded in each grid. These readings were stored in the memory of the instrument and later downloaded to computer for processing and interpretation. Geoplot 3 (Geoscan Research) software was used to process and present the data. Further details are given in Appendix 1.

**Reporting**

A general site location plan, incorporating the 1:50000 Ordnance Survey (OS) mapping is shown in Figure 1 whilst Figure 2 shows the extent of the application area at the same scale. Figures 3 to 8 are more detailed (1:10000) plots of the various elements of the project. The processed (greyscale) data, minimally processed (XY trace) data, together with interpretation plots are presented in Figures 9 to 113 inclusive.

Further technical information on the equipment used, data processing and survey methodologies are given in Appendix 1 and Appendix 2. Appendix 3 describes the composition and location of the site archive. The GPR survey results are presented in Appendix 4.

The survey methodology, report and any recommendations comply with the approved Project Design (Harrison 2011), with guidelines outlined by English Heritage (David *et al* 2008) and by the IfA (Gaffney, Gater and Ovenden 2002). All figures reproduced from Ordnance Survey mapping are with the permission of the controller of Her Majesty’s Stationery Office (© Crown copyright).
The figures in this report have been produced following analysis of the data in ‘raw’ and processed formats and over a range of different display levels. All figures are presented to most suitably display and interpret the data from this site based on the experience and knowledge of Archaeological Services staff.

4 Results (see Figs 9 to 113 inclusive)

Due to the dispersed nature of the survey areas the results will be reported in six sections (see Fig. 2) which relate to the corridors for the brine outfall pipe, electricity connection and the NTS Interconnector (three sectors) and the single large area of the gas storage facility itself.

Brine Outfall Pipe Corridor (see Fig. 3 and Figs 9 to 14 inclusive)

Fields 1 to 4 inclusive

Only the western end of this corridor was surveyed (Fields 1, 2, 3 and 4). A massive area of ferrous disturbance at the western end of Field 1 locates a dump of modern, highly magnetic material.

In Field 2 a herringbone pattern of linear dipolar anomalies locates a system of field drains and in Field 3 and Field 4 much stronger linear dipolar anomalies locate other pipes and/or drains.

No anomalies of archaeological potential have been identified in along this section of the corridor.

Gas Storage Facility Area (see Fig. 4 and Figs 93 to 113 inclusive)

Fields 71 to 75 inclusive

These five fields are criss-crossed with dipolar linear anomalies caused by pipes almost certainly associated with the nearby brine wells.

Field 76

Anomalies due to variations in the soils and superficial deposits are noted, particularly to the eastern half of the field. Other linear anomalies and areas of magnetic disturbance are due to the ubiquitous network of pipes and drains and to modern activity.

Fields 81 to 84 inclusive

The data from Field 81 and Field 82 is characterised by a mass of individual ‘iron spike’ anomalies which results in the data having a speckled appearance. These anomalies are caused by the practice of spreading a mulch of organic waste across these fields. The anomalies are either due to ferrous material incorporated within the organic waste or possibly to the concentration of magnetic mineral by bacteria during the decomposition process.
would not be possible to identify any anomalies of archaeological origin, if present, against this magnetic background.

Elsewhere discrete patches of magnetic disturbance indicative of the deliberate tipping or infilling of magnetic material in Fields 83 and 84 are noted together with geological anomalies and other anomalies caused by modern activity.

**Electricity Connection Corridor (see Fig. 5 and Figs 15 to 26 inclusive)**

**Field 9**
A pipe aligned east/west.

Broad, low magnitude, anomalies are due to variation in the superficial deposits.

**Field 10**
Another pipe aligned north/south.

**Field 11**
Only discrete anomalies interpreted as due to geological variation.

**Field 12**
Data in this field is characterised by extensive areas of magnetic disturbance almost certainly related to the brine well located just to the north of the survey corridor. A pipe leading to/from the well is also noted.

**Field 15**
The strong response from another pipe aligned north/south, running parallel with Back Lane, masks the data over the majority of the survey corridor in this field.

**NTS Interconnector – Sector 1 (see Fig. 6 and Figs 27 to 50 inclusive)**

**Field 16 and Field 17**
Only anomalies and trends in the data caused by geological variation, modern disturbance and recent agricultural activity have been noted in these two fields.

**Field 22 and Field 23**
Again anomalies due to drainage or modern activity predominate. The route of a former field boundary is located as series of intermittent dipolar anomalies.

**Fields 24 to 27 inclusive**
This stretch of the corridor is characterised by a complex pattern of very strong linear and curvilinear anomalies. There is no coherent pattern to these anomalies and the irregularity of the majority of them strongly suggests these anomalies are due to changes in the geology and
soils and reflects the fact that this section of the corridor crosses Stalmine and Preesall Moss where there are expected to be deposits of peat. In Field 26 and Field 27 the anomalies are much broader and are definitely characteristic of geological variation.

**Fields 32 to 35 inclusive**

Only linear anomalies indicative of a system of field drains have been identified in these fields.

**Fields 37, 38 and 39**

Field drains, pipes and a small area of magnetic disturbance are noted in these three fields.

**NTS Interconnector – Sector 2 (see Fig. 7 and Figs 51 to 59 inclusive)**

**Fields 45 to 49 inclusive**

A system of field drains is clearly distinguished in Field 45 and a pipe crossing Field 46 and 47 is also noted.

In addition a series of linear anomalies extending from the eastern end of Field 45 and across the whole of Field 46 are also noted. The form and alignment of these anomalies is clearly different from the anomalies caused by the field drains and they are also more regular than those anomalies interpreted as geological further to the west in this corridor. A confident interpretation is difficult due to the narrow nature of the survey corridor but it is considered that these anomalies could potentially be archaeological in nature.

**NTS Interconnector – Sector 3 (see Fig. 8 and Figs 60 to 92 inclusive)**

**Fields 57 to 61 inclusive**

This section of the corridor crosses the eastern side of Pilling Moss and Nateby Moss (see Fig. 2) and the data reflects this change in geology with a plethora of curvilinear and sinuous anomalies and broader areas of magnetic variation across this series of adjoining fields. The more coherent anomalies probably reflect the presence of former water courses, particularly striking in Field 60, with the broader areas of magnetic enhancement due to the accumulation deposits in this former waterlogged landscape. The western side of Field 61 seems to mark the limit of this wetland environment.

The eastern end of Field 61 has a massive area of magnetic disturbance around the edge of a small gas pumping station with a pipe heading from the station on a north-easterly bearing.

**Fields 64, 65, 66 and Fields 69 and 70**

Only a series of pipes and drains are noted in this easternmost section of the corridor.
5 Discussion and Conclusions

The magnetometer survey undertaken to date has identified anomalies due to variation in the soils and superficial deposits, particularly in the areas of Pilling and Nate Moss, field drains and pipes. Some of the pipes are also associated with land drainage but there are several that probably serve the numerous brine wells in the vicinity. There are also several areas where the tipping or dumping of strongly magnetic modern material has impacted on the data. The recent spreading of bio-waste at the northern end of the GSF has also had an adverse effect on the potential for identifying any relatively weak anomalies in this area, if present, that may have an underlying archaeological cause.

The survey has not identified any anomalies of definite archaeological potential so far and very few of any potential at all. Even those that have been ascribed some potential could equally easily have a non-archaeological origin. It is not yet clear whether the apparent absence of archaeological anomalies is an accurate reflection of the absence of archaeological activity in this landscape. As noted earlier, geophysical (magnetometer) survey is perhaps most successful in identifying areas of enclosed settlement and less so at locating activity associated with a more transient or seasonal utilisation of land that is likely to have been fairly marginal prior to drainage in the recent past.

*The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological remains. Confirmation of the presence or absence of archaeological remains can only be achieved by direct investigation of sub-surface deposits.*
Appendix 1: Magnetic survey - technical information

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the Earth’s crust and is mostly present in soils and rocks as minerals such as maghaemite and haemite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. The magnetic susceptibility of a soil can also be enhanced by the application of heat and the fermentation and bacterial effects associated with rubbish decomposition. The area of enhancement is usually quite large, mainly due to the tendency of discard areas to extend beyond the limit of the occupation site itself, and spreading by the plough. An advantage of magnetic susceptibility over magnetometry is that a certain amount of occupational activity will cause the same proportional change in susceptibility, however weakly magnetic is the soil, and so does not depend on the magnetic contrast between the topsoil and deeper layers. Susceptibility survey is therefore able to detect areas of occupation even in the absence of cut features. On the other hand susceptibility survey is more vulnerable to the masking effects of layers of colluvium and alluvium as the technique, using the Bartington system, can generally only measure variation in the first 0.15m of ploughsoil.

Types of Magnetic Anomaly

In the majority of instances anomalies are termed ‘positive’. This means that they have a positive magnetic value relative to the magnetic background on any given site. However some features can manifest themselves as ‘negative’ anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a ‘?’ is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.
The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

*Isolated dipolar anomalies (iron spikes)*

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic ‘spiky’ trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being present as a consequence of manuring.

*Areas of magnetic disturbance*

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

*Linear trend*

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

*Areas of magnetic enhancement/positive isolated anomalies*

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an ‘iron spike’ anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

*Linear and curvilinear anomalies*

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

**Methodology: Magnetic Susceptibility Survey**

There are two methods of measuring the magnetic susceptibility of a soil sample. The first involves the measurement of a given volume of soil, which will include any air and moisture that lies within the sample, and is termed volume specific susceptibility. This method results
in a bulk value that it not necessarily fully representative of the constituent components of the sample. For field surveys a Bartington MS2 meter with MS2D field loop is used due to its speed and simplicity. The second technique overcomes this potential problem by taking into account both the volume and mass of a sample and is termed mass specific susceptibility. However, mass specific readings cannot be taken in the field where the bulk properties of a soil are usually unknown and so volume specific readings must be taken. Whilst these values are not fully representative they do allow general comparisons across a site and give a broad indication of susceptibility changes. This is usually enough to assess the susceptibility of a site and evaluate whether enhancement has occurred.

**Methodology: Gradiometer Survey**

There are two main methods of using the fluxgate gradiometer for commercial evaluations. The first of these is referred to as **magnetic scanning** and requires the operator to visually identify anomalous responses on the instrument display panel whilst covering the site in widely spaced traverses, typically 10m apart. The instrument logger is not used and there is therefore no data collection. Once anomalous responses are identified they are marked in the field with bamboo canes and approximately located on a base plan. This method is usually employed as a means of selecting areas for detailed survey when only a percentage sample of the whole site is to be subject to detailed survey.

The disadvantages of magnetic scanning are that features that produce weak anomalies (less than 2nT) are unlikely to stand out from the magnetic background and so will be difficult to detect. The coarse sampling interval means that discrete features or linear features that are parallel or broadly oblique to the direction of traverse may not be detected. If linear features are suspected in a site then the traverse direction should be perpendicular (or as close as is possible within the physical constraints of the site) to the orientation of the suspected features. The possible drawbacks mentioned above mean that a 'negative' scanning result should be validated by sample detailed magnetic survey (see below).

The second method is referred to as **detailed survey** and employs the use of a sample trigger to automatically take readings at predetermined points, typically at 0.25m intervals, on zig-zag traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation. Detailed survey allows the visualisation of weaker anomalies that may not have been detected by magnetic scanning.

During this survey a Bartington Grad601 magnetic gradiometer was used taking readings on the 0.1nT range, at 0.25m intervals on zig-zag traverses 1m apart within 30m by 30m square grids. The instrument was checked for electronic and mechanical drift at a common point and calibrated as necessary. The drift from zero was not logged.

**Data Processing and Presentation**

The detailed gradiometer data has been presented in this report in XY trace and greyscale formats. In the former format the data shown is 'raw' with no processing other than grid biasing having been done. The data in the greyscale images has been interpolated and
selectively filtered to remove the effects of drift in instrument calibration and other artificial
data constructs and to maximise the clarity and interpretability of the archaeological
anomalies.

An XY plot presents the data logged on each traverse as a single line with each successive
traverse incremented on the Y-axis to produce a ‘stacked’ plot. A hidden line algorithm has
been employed to block out lines behind major ‘spikes’ and the data has been clipped. The
main advantage of this display option is that the full range of data can be viewed, dependent
on the clip, so that the ‘shape’ of individual anomalies can be discerned and potentially
archaeological anomalies differentiated from ‘iron spikes’. Geoplot 3 software was used to
create the XY trace plots.

Geoplot 3 software was used to interpolate the data so that 3600 readings were obtained for
each 30m by 30m grid. The same program was used to produce the greyscale images. All
greyscale plots are displayed using a linear incremental scale.
Appendix 2: Survey location information

The site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble 5800 model). The accuracy of this equipment is better than 0.01m. The locations of the survey grid and anomalies are available as a DXF file. The internal accuracy of these markers is better than 0.01m. Reference Objects were established at suitable locations around the site boundary. The survey grids were then super-imposed onto a base map provided by the client to produce the displayed block locations. However, it should be noted that Ordnance Survey positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if co-ordinates are measured off hard copies of the mapping rather than using the digital co-ordinates.

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.
Appendix 3: Geophysical archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Microsoft Word 2000), and graphics files (Adobe Illustrator CS2 and AutoCAD 2008) files.

- a full copy of the report

At present the archive is held by Archaeological Services WYAS although it is anticipated that it may eventually be lodged with the Archaeology Data Service (ADS). Brief details may also be forwarded for inclusion on the English Heritage Geophysical Survey Database after the contents of the report are deemed to be in the public domain (i.e. available for consultation in the Gloucestershire Historic Environment Record).
Appendix 4: Ground Penetrating Radar Survey
GPR Survey at Preesall
Lancashire

Geophysical Survey
Project No. ARC/637/271

October 2011
GPR Survey at Preesall, Lancashire

Geophysical Survey
Project No. ARC/637/271

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APPENDIX 1 Ground penetrating radar; technical information 7

DIGITAL COPY OF REPORT CAN BE FOUND ON CD ATTACHED TO BACK COVER
1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a ground penetrating radar (GPR) survey at a site near Preesall, Lancashire. The survey covered two areas; Grid 55 and Grid 56.

The survey was undertaken to identify potential archaeological features, which may include the remains of a wooden track, underlying a layer of peat.

A GSSI SIR3000 with a 200 MHZ antenna was utilised with data collected on profiles spaced 0.5 m apart. Profiles were surveyed in two directions, parallel with a baseline and then perpendicular to it. A reading was collected every 0.02 m along each profile.

Although peat soils are often waterlogged the mineral content in these soils is usually very low which means that the GPR signal is not attenuated. This means that GPR can be effective at locating features or variations within peat deposits. The propagation velocity (based on the dialectic constant of the soil) of peats can however be low which can mean that although the signal strength is good through the soils the time taken for a response to return is relatively slow which means that the effective depth penetration can be reduced.

The dialectic constant of the soils at the survey areas is not known and so the propagation velocity must be assumed. A hyperbolic curve based on a velocity of 0.08 m/ns fitted a response from a possible field drain near to the survey area and so this value was used to assess the data. However that if the sub-surface conditions and moisture content change beneath this level then the estimate depth values may no longer hold true.

Several possible horizons in the data could indicate geological boundaries or variations. It is possible that the lower horizon, indicates the base of the peat with the other horizons indicating changes in soil type or variations within the peat.

A high amplitude anomaly was present in Grid 55. Assuming a propagation velocity of 0.08 m/ns this response is located at a depth of between 2.2 m and 2.7 m below ground level. However if there is peat above this response and the peat is waterlogged then the actual depth to the feature that produced this response could be much shallower (as shallow as 1.1 m to 2.6 m). The cause of the anomaly is not known; it could indicate the presence of a broadly linear feature but it could also be caused by a natural localised variation in the sub-surface.

Grid 56 did not show any significant variations or anomalies of interest.

The GPR survey has not identified any anomalies that indicate the presence of possible or probable archaeological features. There is one anomaly of unknown origin and it is possible that there are features present which are located beyond the effective depth penetration of the GPR or which do not have a sufficient dielectric contrast to the surrounding material to allow their detection by GPR.

It should be noted that features smaller than the profile spacing of 0.5 m will not have been identified by the GPR survey.
2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by Mr Sam Harrison of Archaeological Service WYAS to carry out a geophysical survey, comprising ground penetrating radar (GPR), at a site near Pressall (NGR SD 439 464). The survey was carried out in two areas.

The survey was undertaken to identify potential archaeological features, notably the remains of a wooden track underlying a layer of peat.

The location of the site is shown in drawing ARC_637_271_01.

2.2 Site description

The site is adjacent to Bone Hill Lane near Pressall, Lancashire. The two survey areas were located on a relatively level wheat field that had recently been harvested. The edges of the field were waterlogged at the time of the survey but the areas themselves were reasonably dry.

A borehole record held by the British Geological Survey\(^1\) located approximately 230 m from the survey area indicates the site to be underlain by approximately 3 m of peat which in turn is underlain by layers of clay, gravels and sand which in turn are underlain by the New Red Sandstone of Permian and Triassic age.

2.3 Scope of work

The position of each survey area was established by Archaeological Services WYAS relative to their existing grid system, using a RTK GPS, and were located in Grid 55 and Grid 56.

For the purposes of this survey the GPR survey grids are referred to by the existing grid number in which they are located; namely Grid 55 and Grid 56.

Grid 55 was 120 m long by 5 m wide and Grid 56 was 90 m long by 5 m. A plan showing the location of the GPR survey areas is shown in drawing ARC_637_271_02.

A GSSI SIR3000 with a 200 MHZ antenna was utilised for the survey with data collected on profiles spaced 0.5 m apart. Profiles were surveyed in two directions, parallel with a baseline and then perpendicular to it. A reading was collected every 0.02 m along each profiles.

An initial assessment of the data quality and potential depth penetration was carried out prior to the commencement of the survey. The data quality appeared to be good and data was returned over a high time range, indicating that the depth penetration was also good. Based on this initial assessment the survey was carried out over both areas.

No problems were encountered during the survey, which was carried out between 3 October and 4 October 2011.
3. **SURVEY METHODOLOGY**

3.1 **Ground penetrating radar (GPR)**

A GSSI SIR-3000 with a 200 MHz antenna was used for the ground penetrating radar survey. The GPR system was calibrated for distance and the gain was modified for the site specific conditions. The calibration and gain were regularly monitored and if required were modified to account for variations in the site conditions.

The survey grids were set-out by the client and intermediate points were established using tape measures. All grid points were marked out using semi-permanent spray paint. To obtain a comprehensive assessment of the site the data was collected in two directions parallel to the baseline and then perpendicular to it at 0.5 m intervals.

The survey data was stored in the instrument and downloaded at the end of the survey.

The position of points on the survey grids were tied in to the existing site survey by the client.

A more detailed survey methodology and technical summary of GPR can be found in Appendix 1.

3.2 **Data processing and presentation**

The GPR data were processed, analysed and interpreted using Sandmeier Software Reflex-win v6.0. As a minimum the data is processed to improve the gain, to remove the effects of background noise and to ensure that all possible anomalies are identified. Details of the processing, analysis and interpretation can be found in Sections 1.4 and 1.5 of Appendix 1.

The survey results have been superimposed onto drawing ‘Preesall GPR Map.dwg’ provided by the client.

‘Timeslice’ analysis of the data was carried out over a range of time windows between 10 ns and 85 ns. A selected timeslice for Grid 55 has been displayed in drawing ARC_637_271_03 which shows the data at a time range of 61 to 64 ns.

A number of GPR profiles were individually inspected and two selected radargrams are shown in drawing ARC_637_271_04 to highlight the type of variations and anomalies in the data.

To obtain estimated depth information for the GPR data an assumed value for the propagation velocity of the sub-surface must be used. This value normally lies between 0.07 m/ns and 0.1 m/ns. A value of 0.08 m/ns was used for the initial assessment of the data on site and also for the estimated depths shown in the drawings. However, it is worth noting that waterlogged peat deposits can have a propagation velocity as low as 0.04 m/ns. If these conditions are present beneath the site then the estimated depths indicated in this report could be significantly different to the actual depth to a feature or horizon, which may be shallower than indicated.

*The GPR interpretation drawing must be used in conjunction with the relevant results section and appendices of this report.*
4. **RESULTS**

4.1 **Ground penetrating radar (GPR)**

When the GPR was scanned across the site to determine the gain and offset values that should be used at the site several near-surface hyperbolae responses, possibly associated with field drains, were present in the data. These anomalies ‘fitted’ a hyperbolic curve based on a velocity of 0.08 m/ns and so this velocity was used to determine estimated depths for the GPR profiles.

However, it is worth noting that waterlogged peat deposits can have a propagation velocity of as low as 0.04 m/ns. It is possible that the sub-surface conditions could change beneath the layer where field drains may be present and the peat deposits could become more waterlogged. If these conditions are present beneath the site then the estimated depths indicated in this report could be significantly different to the actual depth to a feature or horizon, which may be shallower than indicated.

Based on an assumed propagation velocity the GPR has obtained a depth penetration of between 3.7 m and 4.0 m below ground level. The data below approximately 3.7 m was slightly distorted indicating that data quality was reduced and no data were obtained below 4.0 m.

Timeslice analysis of both survey grids revealed the data to be generally uniform with only an occasional localised variation. An exception to this were a series of parallel linear anomalies aligned broadly north to south visible in Grid 55 at a depth of between 0.05 and 0.10 m. These are probably associated with a ploughing regime and are not thought to be archaeologically significant.

Visual analysis of selected GPR radargrams showed there to be several discontinuous horizons present in the data. Possible horizons were present at approximately 0.3 m, 1.0 m and more consistent horizons were present at 1.9 m to 2.1 m and 2.2 m to 2.9 m. These horizons could indicate changes in sub-surface soils or variations in moisture content. Other than these responses there was an occasional high amplitude response but the majority of these were only present on a single profile and are assumed to be caused by an isolated feature or variation. There was no discernable pattern to these responses and they are not thought to be archaeologically significant.

The only response that was visible over a range of timeslices and was also consistently visible on adjacent radargrams was a high amplitude response present in Grid 55 at a depth of approximately 2.2 m to 2.7 m. The response stands out very well in the timeslices (see Profile A on drawing ARC_637_271_03) and also appears as an isolated response on some of the radargrams. However on other radargrams it appears to lie on a possible horizon in the data (see Profile B on drawing ARC_637_271_03). It is possible that this anomaly is caused by a variation in a geological horizon and may simply be a natural feature was has a localised increased moisture content or other variation compared to the surrounding material. It is also possible that the anomaly is caused by a feature that lies on a geological horizon. The exact cause of the anomaly cannot be determined from the GPR data.

The data in Grid 56 was more uniform than Grid 55 and there were suggestions of horizons in the data similar to Grid 55 but no other anomalies stood out over several timeslices or on adjacent profiles.
5. DISCUSSION AND CONCLUSIONS

Although peat soils are often waterlogged the mineral content in these soils is usually very low which means that the GPR signal is not attenuated. The propagation velocity (based on the dialectic constant of the soil) of peats can however be low which can mean that although the signal strength is good through the soils the time taken for a response to return is relatively slow which means that the effective depth penetration can be reduced.

The dialectic constant of the soils at the survey areas is not known and so the propagation velocity must be assumed. A hyperbolic curve based on a velocity of 0.08 m/ns fitted a response from a possible field drain near to the survey area and so this value was used to assess the data. However if the sub-surface conditions and moisture content change beneath this level then the estimate depth values may no longer hold true. It should be recognised that the actual depth to a feature or sub-surface variation may be significantly shallower to that indicated in this report.

Near-surface variations probably associated with a ploughing regime were observed in Grid 55.

Several possible horizons in the data could indicate geological boundaries or variations. It is possible that the lower horizon, indicates the base of the peat with the other horizons indicating changes in soil type or variations within the peat.

A high amplitude anomaly was present in Grid 55. Assuming a propagation velocity of 0.08 m/ns this response is located at a depth of between 2.2 m and 2.7 m below ground level. However if there is peat above this response and the peat is waterlogged then the actual depth to the feature that produced this response could be much shallower (as shallow as 1.1 m to 2.6 m). The cause of the anomaly is not known; it could indicate the presence of a broadly linear feature but it could also be caused by a natural localised variation in the sub-surface.

Grid 56 did not show any significant variations or anomalies of interest.

It is possible that there are features present which are located beyond the effective depth penetration of the GPR or which do not have a sufficient dielectric contrast to the surrounding material to allow their detection by GPR.

It should be noted that features smaller than the profile spacing of 0.5 m will not have been identified by the GPR survey.

*It should be noted that a geophysical survey does not directly locate sub-surface features - it identifies variations or anomalies in the background response caused by features. The interpretation of GPR anomalies is often subjective and it is rarely possible to identify the cause of all such anomalies. Not all features will produce a measurable anomaly and the effectiveness of a GPR survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a GPR survey will identify all sub-surface features. Confirmation on the identification of anomalies and the presence or absence of sub-surface features can only be achieved by intrusive investigation.*
6. REFERENCES

APPENDIX 1

1. Ground penetrating radar: technical information

1.1 Theoretical background

1.1.1 GPR instruments work by transmitting electromagnetic pulses (waves) into the sub-surface at specific frequencies using an antenna. Each pulse is affected by the material that passes through, notably its dielectric properties and conductivity, and can undergo interactions such as attenuation (signal loss), reflection and scattering.

1.1.2 How well a material conducts (its dielectric properties) determines the velocity of the wave. A change in the dielectric properties results in a concurrent change in velocity that in turn causes some of the wave’s energy to be reflected. In general the ground material will have a different dielectric constant to the material of man-made objects producing an anomaly in the observed response. By measuring the travel-time and amplitude of reflected signals received back at the antenna it can be possible to obtain approximate depths to the anomaly. In cases where the target feature and the surrounding ground have matching or similar dielectric constants the target cannot be resolved.

1.1.3 A material’s conductivity is the most important factor in determining a wave’s rate of attenuation. A high conductivity will cause the energy to be dissipated throughout a material and so there will be a reduction in the signal strength and the distance that the wave will propagate is reduced. Signal loss is therefore greatest in conductive metals and water rich soils, such as clay. If the material through which the wave is passing is varied in its composition (heterogeneous) then this can result in scattering of the waves. As well as attenuating the signal and reducing its depth penetration the scattering of the waves can produce anomalies that do not relate to true features (phantom anomalies).

1.1.4 The antenna frequency utilised in a survey is selected based on the depth and size of a target feature. Higher frequency waves are attenuated more easily than lower frequency ones and do not have a reduced depth penetration. Selection of antenna frequency is therefore a trade off between depth penetration and target resolution with high frequency (greater than 1 GHz) antennae being used for shallow, high resolution surveys, such as locating reinforcement and low frequency (250 MHz or lower) antennae used for identifying deeper larger features, such as drains, buried obstructions and geological boundaries. Medium frequency antennae (400 MHz to 700 MHz) can obtain reasonable depth penetration and resolution and are often used for utility tracing.

1.1.5 The interpretation of GPR anomalies is often subjective and it is rarely possible to identify the cause of all such anomalies. Not all features will produce a measurable anomaly and the effectiveness of a GPR survey is also dependant on the site-specific conditions. The main factors that may limit whether a feature can be detected are the composition of a feature, its depth and size and the surrounding material. It is not possible to guarantee that a GPR survey will identify all sub-surface features.

1.1.6 There are a wide range of features that can be located using GPR including metallic and non-metallic utility apparatus, rebars in concrete, buried structures or foundations, depth or thickness of materials, archaeological features, mineshafts and depth to bedrock.

1.2 Instrumentation

1.2.1 There are a number of different types of instrument available and each one is built to a different specification. Some systems transmit energy in pulses, others in a continuous wave (CW). The form and duration of the energy, the frequency of operation, and the strength of
reflected signal that can be detected, the antennae design, and whether the antennae can be moved apart or interchanged with different frequency antennae all vary from system to system. The majority of the systems that are currently on the market have digital recording facilities and a number of them have built in odometers so that data can be linked to an exact point on a traverse line. An experienced operator who has been fully briefed on the likely site conditions can best assesses whether a particular instrument and antennae frequency is suitable to achieve the desired aims of an individual project.

1.3 Survey methodology

1.3.1. A detailed GPR survey is usually carried out as a regular grid of parallel profiles. To obtain a comprehensive assessment of a site the data is collected in two directions, parallel with a baseline and then perpendicular to it. If the target feature is linear and its approximate orientation is known then data can be collected in one direction aligned to intersect the feature at right angles. The distance between the profiles is determined by the likely target size, shape and orientation. High resolution structural surveys can have profile intervals of 0.5 m or less whilst brownfield or utility tracing surveys usually have a spacing interval of between 1 m and 2 m.

1.3.2. At this site data was collected on profiles spaced 0.5 m apart. Profiles were surveyed in two directions, parallel with a baseline and then perpendicular to it. A reading was collected every 0.02 m along each profiles.

1.3.3. The GPR survey grids were established on site by the client using a GPS system. Intermediate grid points were established using tape measures. The grid points were marked out using semi-permanent spray paint.

1.3.4. The survey grids were tied-in by the client.

1.3.5. A GSSI SIR3000 GPR system with a 200 MHz antennae was used on this site. This equipment has a maximum depth penetration of between 3 m and 5 m in good ground conditions. The higher the frequency of the antenna the better the resolution but the lower the depth penetration.

1.3.6. The GPR system was set-up and calibrated on site relative to the site specific conditions. The set-up was regularly monitored and is adapted if the site conditions change.

1.4 Data reduction and processing

1.4.1. The GPR data were processed and analysed using Sandmeier Software Reflex-win v6.0. The data were depth corrected to allow for the gap between the antenna and the ground surface and then filtered to highlight anomalies. This filtering involved performing a high and low band pass filter to eliminate unwanted low and high frequency signals, background noise reduction to remove horizontal background noise and noise added by the GPR system. The final stage of processing was to increase the gain of responses proportional to their depth.

1.4.2. ‘Timeslice’ analysis of the data was carried out by importing the GPR profiles within the X and Y co-ordinate system used on site. A GPR timeslice effectively sums the reflected energy within a time ‘window’ (pseudo-depth - where time is the two-way travel time between transmitter and receiver and relates to an equivalent depth where a known velocity is used) and produces an amplitude contour plot to enable a relative comparison of surveyed areas. In this way areas of high amplitude, usually indicative of ground disturbance such as poor compaction or voiding, can potentially be identified. It should be noted that in the generation of GPR timeslices a degree of both interpolation between adjacent GPR profiles and extrapolation from GPR profiles takes place. The analysis of the data was carried out over a range of time windows between 10 ns and 85 ns.
1.5  Presentation and interpretation

1.5.1. The results of the GPR survey have been superimposed onto drawing ‘Preesall GPR Map.dwg’ provided by the client.

1.5.2. ‘Timeslice’ analysis of the data was carried out over a range of time windows between 10 ns and 85 ns. A selected timeslice for Grid 55 has been displayed which shows the data at a time range of 61 to 64 ns.

1.5.3. A number of GPR profiles were individually inspected and two selected radargrams have been shown to highlight the type of variations and anomalies in the data.

1.5.4. To obtain estimated depth information for the GPR data an assumed value for the propagation velocity of the sub-surface must be used. This value normally lies between 0.07 m/ns and 0.1 m/ns. A value of 0.08 m/ns was used for the initial assessment of the data on site of and also for the estimated depths shown in the drawings. However, it is worth noting that waterlogged peat deposits can have a propagation velocity of as low as 0.04 m/ns. If these conditions are present beneath the site then the estimated depths indicated in this report could be significantly different to the actual depth to a feature or horizon, which may be shallower than indicated.

1.5.5. The interpretation has been superimposed onto the available map detail and an accompanying technical report has been produced. The report and drawings have been provided in both hardcopy and digital formats

1.6  Limitations of ground penetrating radar

1.6.1. The GPR survey method requires the equipment to be pushed on a cart or dragged across a site. The presence of an uneven ground surface, dense, high or mature vegetation or surface obstructions may mean that some areas cannot be surveyed.

1.6.2. The depth penetration and quality of data of a GPR survey is limited by the presence of conductive material in the sub-surface. Surface water, reinforced concrete and moisture rich soils (particularly clays) can all have a negative impact on data quality. The presence of made ground also can have a detrimental effect on the GPR data quality as this usually contains conductive material in the form of metallic scrap and brick. The effectiveness of GPR is therefore dependant on the site specific conditions.

1.6.3. A GPR survey does not directly locate sub-surface features - it identifies variations or anomalies in the background response caused by features. It can be possible to interpret the cause of anomalies based on the size, shape and strength of response but the reliability of this interpretation can vary significantly from site to site. Not all features will produce a measurable GPR response and the effectiveness of a GPR survey is also dependant on the site-specific conditions. It is not possible to guarantee that a GPR survey will identify all sub-surface features. A GPR survey is usually most-effective at identifying sub-surface features when used in conjunction with other complementary geophysical techniques.

1.6.4. The profile spacing has a major impact on the size of the feature that can be detected. Features of a similar size or smaller than the profile interval are unlikely to be detected even if they can produce a measurable response.

1.6.5. Anomalies identified by a GPR survey are located on individual profiles. The location of possible features in plan is based on the extrapolation of points on adjacent profiles.

1.6.6. Approximate depth information can be obtained but it should be recognised that these values are based on average wave velocities for a given medium. Depths are therefore only estimated and the accuracy of the depth will decrease in heterogeneous materials.
NOTE

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SCALE

0m  500m  1000m

SITE LOCATION

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ARCHAEOLOGICAL SERVICES WYAS MORLEY

GPR SURVEY AT PREESALL LANCASHIRE

SITE LOCATION MAP

Scale [M Sheet] Drawing Status
AS SHOWN ARC_637_271_01 FINAL

Client

Site

Title

Job No

UTL_637_271

Chk.

MW

Date

04/10/2011
HIGH AMPLITUDE RESPONSE. POSSIBLE SUB-SURFACE FEATURE OR VARIATION. DEPTH MAY VARY FROM 2.2-2.7 mbsgl TO 1.1-1.3 mbsgl DEPENDING ON MOISTURE CONTENT OF SUB-SURFACE.
RADARGRAM A: SECTION OF PROFILE Y3.5, GRID 55

RADARGRAM B: SECTION OF PROFILE Y2.5, GRID 55

NOTES
1. THIS DRAWING MUST BE USED IN CONJUNCTION WITH THE ACCOMPANYING TECHNICAL REPORT (ARC_637_271_RPT.DOC) WHICH PROVIDES DETAILS OF THE TECHNIQUES EMPLOYED, THEIR INHERENT LIMITATIONS AND ANY SITE SPECIFIC ISSUES.
2. THIS DRAWING IS BASED UPON DRAWING "Preesall GPR Map.dwg" PROVIDED BY THE CLIENT.
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5. NB. DEPTHS ARE ESTIMATED BASED ON ASSUMED PROPAGATION VELOCITIES. FOR WATERLOGGED PEAT BOGS THESE CAN BE HALF THE VALUES OF THOSE USED FOR THIS DRAWING. FEATURES MAY BE SIGNIFICANTLY SHALLOWER TO THE ESTIMATED DEPTHS SHOWN HERE (POSSIBLY AS MUCH AS HALF THE DEPTH). DEPTHS CAN ONLY BE CONFIRMED BY INTRUSIVE INVESTIGATION.

ALWAYS EXERCISE CAUTION WHEN EXCAVATING

KEY
- HIGH AMPLITUDE RESPONSE. POSSIBLE SUBSURFACE FEATURE OR VARIATION
- BROADLY CONTINUOUS LAYER IN DATA. POSSIBLE GEOLOGICAL INTERFACE OR CHANGE IN MOISTURE CONTENT

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Scale: 1.500
Drawing: ARC_637_271_04
Status: FINAL

Client: ARCHAEOLOGICAL SERVICES WYAS MORLEY
Site: GPR SURVEY AT PREESALL LANCASHIRE
Title: GRID 55 - SELECTED GPR RADARGRAMS
Job No: ARC_637_271

Surveyed: NF, DP
Drawn: NF
Date: 04/10/2011
Bibliography
