DOCUMENT 6.10.5

Geophysical Survey Part 15

The Yorkshire and Humber (CCS Cross Country Pipeline) Development Consent Order

Under Regulation 5(2)(a) of the Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Application Reference: EN070001

June 2014

ARCHAEOLOGICAL SERVICES WYAS

Yorkshire and Humber Carbon Capture Scheme (CCS) Cross Country Pipeline Dalton to Skerne

Geophysical Survey

Report no. 2600

April 2014

Client: AECOM

REGISTERED · IfA · ORGANISATION

Yorkshire and Humber Carbon Capture Scheme (CCS) Cross Country Pipeline Dalton to Skerne

Geophysical Survey

Summary

A geophysical (magnetometer) survey, covering approximately 123.5 hectares, was carried out along the Dalton to Skerne section of the preferred route of the Yorkshire and Humber Carbon Capture Scheme Cross Country Pipeline. A single area (Site 1) of high archaeological potential has been located approximately 1km west of Lund where anomalies indicative of an enclosure complex with evidence of settlement activity have been identified. The anomalies correspond with a previously identified but undated cropmark site. Linear anomalies located to the north-east and south-west (Site 1a and Site 1b) of Site 1 are also interpreted as archaeological, probably forming part of an outlying system of fields/land division associated with the main complex. Several other linear anomalies have been identified on the higher ground at the western end of this section of the corridor and ascribed a possible archaeological origin. Elsewhere along the corridor numerous anomalies locating former field boundaries, extensive ridge and furrow cultivation, land drains, infilled chalk extraction pits and variation in the superficial deposits have been identified. On the basis of the survey, the archaeological potential of this section of the pipeline corridor is assessed as locally very high but generally moderate to low.

ARCHAEOLOGICAL
SERVICES
WYAS

Report Information

Client:	AECOM
Address:	5th Floor, 2 City Walk, Leeds, LS11 9AR
Report Type:	Geophysical Survey
Location:	Dalton to Skerne
County:	East Yorkshire
Grid Reference:	SE 9529 4736 to TA 056 549
Period(s) of activity:	Iron Age?/Roman, medieval, post-medieval, modern
Report Number:	2600
Project Number:	3992
Site Code:	DVC12
OASIS ID	archaeol11-177930
Planning Application No.:	
Date of fieldwork:	November 2012 – May 2013
Date of report:	August 2013
Project Management:	Sam Harrison BSc MSc AIfA
Fieldwork:	David Harrison BA MSc MIfA
	James Lawton BSc Msc PIfA
	Orlando Prestidge BA MA PIfA
	Christopher Sykes BA MSc
	Louise Felding BA Mag. Art
	Marina Rose BA
	Kieron Power BA
	Kieron Kinninmont BSc
	Thomas Fildes BA
	Alexander Schmidt BA
	Daniel Waterfall BA
Report:	Alistair Webb BA MIfA
Illustrations:	David Harrison
	Sam Harrison

Authorisation for distribution: ---

PO Box 30, Nepshaw Lane South, Morley, Leeds LS27 0UG
Telephone: 0113 383 7500.
Email: admin@aswyas.com

Contents

List of Figures

1 Introduction

Archaeological Services WYAS (ASWYAS) was commissioned by AECOM, on behalf of their client, National Grid, to undertake a programme of geophysical (magnetometer) survey along the proposed route of the Yorkshire and Humber Carbon Capture Scheme (CCS) Cross Country Pipeline also covering any areas of associated infrastructure. The proposed route runs from Drax Power Station, in North Yorkshire, to the east coast near Barmston, in East Yorkshire (see Fig. 1), a distance of 74 kilometres. The route is divided into four sections – Camblesforth to Tollingham, Tollingham to Dalton, Dalton to Skerne and Skerne to Barmston.

This report relates to the Dalton to Skerne section, which runs from near Dalton in the west (SE 9529 4736) to a point approximately 1.5km south-east of Skerne, at TA 056 549, in the east. During the course of the survey the route of the pipeline corridor and location and extent of infrastructure was revised. Waterlogging and access issues also restricted access in certain areas. The scheme boundary shown on all figures represents the current proposals; previous boundaries are not displayed. Any apparent 'gaps' in the survey or areas surveyed 'outside' the displayed corridor are due to the reasons outlined above. The scheme of work was undertaken in accordance with guidance contained with the National Planning Policy Framework (2012) and to a Written Scheme of Investigation (WSI), produced by AECOM and approved by Humber Archaeology Partnership. The geophysical survey was carried out between November 27th 2012 and May 21st 2013.

Site location, land-use and topography

The Dalton to Skerne section starts just west of Lund and south of Middleton-on-the-Wolds (SE 9529 4736) and runs in a north-easterly direction around the village of Hutton before heading due east until the end of the section just to the north of Skerne (TA 0565 5488 - see Fig. 2). The pipeline corridor crosses mixed arable farmland with an occasional field of permanent pasture. The topography is gently undulating gradually falling from a height of about 40m aOD at the western end of the section to about 20m aOD at Hutton and then gradually levelling out to about 10m aOD after crossing Skerne Beck about 1km from the eastern end of the section. Part of a single field (Area 44 – see Fig. 21) was unsuitable for survey as it contained a potato crop.

Geology and soils

The underlying bedrock geology along all of this section comprises White Group Chalk. To the south-western end of the section, to the west and north of Lund, Burnham Chalk Formation prevails with Flamborough Chalk predominating from Bracken and north-eastwards around Hutton and through to the end of the section. There are superficial deposits recorded in most sections of the corridor except at the western end of the section where none is recorded around SE 953 473 and 970 493. Quaternary deposits of till and diamicton are commonly present throughout except at TA 000 527 and at TA 056 545 where river terrace sands and gravels are recorded.

The soils along this section are described as deep, well-drained fine and coarse loams, sometimes slowly permeable and prone to seasonal waterlogging that are classified in the Hunstanton, Burlingham and Holderness soil associations. (Soil Survey of England and Wales 1983).

2 Archaeological Background

The following archaeological background is summarised from draft 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 (AECOM 2013) does, however, indicate 189 archaeological records within the Dalton to Skerne search area (as entered on the Humber Archaeological Partnership Sites and Monuments Record, and the National Monuments Record). An additional ten assets were identified during a review of aerial photographs, while fifteen sites or find spots were recorded during an archaeological walkover survey undertaken by the client. Nearly 60% (110 assets) of the archaeological records date to the post-medieval period. The remaining assets break down as 46 from the prehistoric, seven Roman, fifteen medieval and eleven from the modern period. Only a single Scheduled Monument (Sunderlandwick deserted medieval village – DS47) is recorded with 23 listed buildings, five of which are churches. However, with the exception of findspots recorded during the walkover, very few assets, are recorded actually within the corridor itself or even within 200m of it.

Of the assets dating to the prehistoric period, 21 are identified as Bronze Age in date with three Neolithic and a single Mesolithic asset. Nine are classified as Iron Age/Roman with the remainder not assigned to a specific period. All but one of the Iron Age sites are associated with settlement and land ownership and include enclosures identified on air photographs, such as DS5 and DS46, west of Lund, and DS63 and DS65 north of Rickle Pits. Two possible round barrows, also north of Rickle Pits, DS64 and DS65, are also identified as cropmarks.

The paucity of Roman period assets is partly attributable to the fact that is difficult to discriminate between those sites/assets that are Iron Age and those which are Roman. Therefore it is possible that some of the assets categorised as Iron Age, or of no specific period, may in fact be Roman. Of the seven Roman assets four relate to spot finds and three relate to settlement activity most notably near Big Bustard Field (DS175).

Many of the medieval and post-medieval assets are related to settlement and land-use including listed buildings and churches in the villages of Lund, Hutton and Skerne. A deserted settlement is recorded at Bracken (DS54) just to the east of the corridor but generally, whilst medieval and post-medieval assets are numerous, they are primarily located in current settlements and not in proximity to the pipeline corridor.

Several post-medieval heritage assets that fall within or close to the pipeline corridor appear to be agricultural in origin, for example the ridge and furrow earthworks west of Hornhill Top (DS207) or chalk or marl pits, such as the chalk pit west of Horn Hill (DS52).

Therefore, whilst numerous heritage assets and find spots are recorded within the wider landscape, the current evidence base indicates that the application area itself has a low to moderate potential for the presence of unrecorded archaeological features.

3 Aims, Methodology and Presentation

The main aim of the geophysical survey was to provide sufficient information to enable an assessment to be made of the impact of the proposed development on any potential archaeological remains and for mitigation proposals, if appropriate, to be recommended. To achieve this aim a magnetometer survey covering the whole of the pipeline corridor was carried out, a total of 123.5 hectares.

The general objectives of the geophysical survey were:

- to provide information about the nature and possible interpretation of any magnetic anomalies identified;
- to therefore determine the presence/absence and extent of any buried archaeological features; and
- to prepare a report summarising the results of the survey.

Magnetometer survey

The site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble 5800 model). 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 Ordnance Survey map and showing the four overall sections, is shown in Figure 1 at a scale of 1:250000. Figure 2 is a large scale (1:50000) overview of the Dalton to Skerne section showing the extent of the pipeline corridor and associated infrastructure. At this scale this section of the pipeline has been divided into eight blocks. Figures 3 to 26 inclusive show the processed greyscale magnetometer data, the first edition Ordnance Survey mapping (1855) and the overview interpretation of the data along the route at a scale of 1:5000. Detailed data plots ('raw' and processed) and full interpretative figures are presented at a scale of 1:2000 in Figures 27 to 80 inclusive with the route split into twenty sectors. The survey area numbers which are depicted on Figures 3 to 80 inclusive were assigned prior to the fieldwork to aid communications with the client. Archaeological identifier numbers, depicted on the same figures correspond to those in the baseline information provided by the client.

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.

Archaeological Services WYAS is registered with the Online Access to the Index of archaeological investigations project (OASIS). The OASIS ID for this project is archaeol11-177930.

The geophysical survey methodology, report and any recommendations comply with guidelines outlined by English Heritage (David *et al.* 2008) and by the Institute for Archaeologists (IfA 2013). 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 and Discussion (see Figs 3 to 80 inclusive)

The anomalies identified by the survey fall into a number of different types and categories according to their origin and these are discussed below and cross-referenced to specific examples and locations along the proposed pipeline route.

Ferrous/Modern Anomalies

Ferrous responses, manifesting either as individual 'spike' anomalies or more extensive areas of magnetic disturbance, are typically caused by modern ferrous (magnetic) debris, either on the ground surface or in the plough-soil, or are due to the proximity of magnetic material in field boundaries, buildings or other above ground features. Little importance is normally given to such anomalies, unless there is any supporting evidence for an archaeological interpretation. Ferrous debris or material is common on rural sites, often being present as a consequence of manuring or tipping/infilling. Where specific reasons for the strong ferrous responses are apparent more detailed descriptions are given below. However, throughout the route iron ‘spike’ anomalies are common and if there is no obvious pattern or clustering to their distribution it is assumed that the anomalies are caused by a random background scatter of ferrous debris in the plough-soil or in the adjacent field boundaries.

In Area 82 (see Figs 30, 31 and 32), at the southern end of the field, an arc of magnetic disturbance around the edge of the surveyed area is almost certainly caused by recent disturbance associated with the radar beacon, identified as DS8, located immediately to the south. Seven high magnitude ‘spikes’ (labelled **A**) to the north of the beacon and two to the south in Area 83 are interpreted as being caused by the buried footings or foundations for other infrastructure associated with the radar beacon. A tenth ‘spike’ at the extreme north-eastern corner of Area 82 may have a similar origin.

In Area 81 a small rectangular anomaly, **B**, probably locates a former (but unmapped) chalk pit. In Area 73 and 74 (see Figs 42, 43 and 44) two sub-circular clusters of high magnitude responses locate infilled features. The more extensive anomaly, **C**, also locates a former chalk pit that is shown on the first edition mapping and identified as DS52. The smaller anomaly, **D**, locates a small, now backfilled, pond, also shown on the first edition mapping.

High magnitude linear dipolar anomalies have been identified at several locations along the corridor. These anomalies are probably caused by drainage pipes, such as recorded in Area 72, west of Bracken, **E**, laid along an existing boundary (see Figs 42, 43 and 44), or along the line of a former boundary, such as in the north-western corner of Area 62, **F** (see Figs 57, 58 and 59). At other locations the extent of magnetic disturbance along the line of the former boundary suggests the boundary has been backfilled with strongly magnetic materials such as building waste; an example of this latter type is in Area 70 (see Figs 45, 46 and 47) where anomaly **G** locates the corner of a former field.

The data within Area 37 (see Figs 78, 79 and 80, is characterised by a mass of individual ‘iron spike’ anomalies which results in the data having a dense ‘speckled’ appearance. This effect is typical where a mulch of organic waste has been spread on the field. The strong magnetic responses are either due to ferrous material incorporated within the organic waste and/or possibly to the concentration of magnetic minerals by bacteria during the decomposition process. The net result is that it can be difficult to identify any anomalies of archaeological origin, if present, against this magnetic background and indeed the line of a former field boundary shown on the first edition mapping crossing this area on a south-west/north-east alignment cannot be detected against this elevated magnetic background. If the effect is due to natural decomposition processes it might be expected that the effects decrease over time. The data has a similar appearance in Area 76 (see Figs 39, 40 and 41), although in this area the effect is only noticeable across a part of the field and therefore on balance it is considered more likely that the magnetic disturbance has an underlying geological cause.

Agricultural Anomalies

Linear trend anomalies have been identified in all blocks along the survey corridor. These anomalies are all interpreted as of agricultural origin being caused by ploughing or field drains or by the removal and infilling of former field boundaries.

By far the most numerous agricultural anomalies are those due to ploughing, particularly to the medieval and post-medieval practice of ridge and furrow ploughing. The characteristic striped appearance of the data in the areas of ploughing is due to the magnetic contrast between the infilled (or partially filled) furrows and former ridges. Evidence of ridge and furrow ploughing is extensive along the entire length of this section of the pipeline corridor being particularly prominent in fields immediately west of Hornhill Top (see Figs 6, 7 and 8), where the fields are under pasture and earthwork remnants of the ploughing are still visible, and in the fields to the west and north of Hutton (see Figs 18, 19 and 20).

Over the last 150 years the size of the fields has been increased by the removal of many of the boundaries that are shown on the first edition Ordnance Survey map; these boundaries are indicated on the 1:5000 overview figures (see Figs 4, 7, 10, 13, 16, 19 and 22). This trend is most clearly noticeable in the fields around Hutton (see Figs 18, 19 and 20) where more than ten boundaries have been removed. Analysis of the first edition mapping indicates that linear anomalies locating former boundaries are identified at 24 locations. A further six boundaries shown on the 1855 map have not been identified by the survey. The reasons why these particular boundaries have not been detected is not clear. Some may have been relatively ephemeral and may have been removed by modern deep ploughing. However, it is noticeable that four out of the six boundaries not identified by the survey are located where the magnetic background is particularly 'noisy' raising the possibility that there may be insufficient contrast for the response from a shallow cut feature, such as would be left from a grubbed out hedge-line, to be visible against a fluctuating magnetic background. In Area 37, at the eastern end of this section of the pipeline corridor, the effects of the organic waste account for the non-detection of a fifth former boundary (see Figs 24, 25 and 26).

A number of linear anomalies interpreted as being caused by field drains have been identified. These anomalies are all towards the eastern end of the corridor, on the very low lying land to the east of Rickle Pits and are identified in Areas 39, 40 ,41 and 42 (see Figs 75, 76 and 77).

Geological Anomalies

The magnetic background varies constantly along the length of this section of the corridor. This is considered to be mostly a reflection of the undifferentiated nature of the superficial Quaternary till deposits that predominate along this section; the bedrock is chalk throughout and the soils all fine loams.

Against this background several areas of significantly enhanced responses are noted at several locations and these are described in further detail below.

In Area 84 (see Figs 27, 28 and 29) a broad anomaly, **H**, aligned roughly north/south may be caused by an accumulation of soil within a fissure in the chalk geology; no superficial deposits are recorded at this location.

In Block 5 (see Figs 57 to 63 inclusive) two discrete clusters of enhanced responses stand out. In Area 61 the enhanced responses appear to lie within the corner of a former field (the former boundaries were not identified as magnetic anomalies, possibly as a consequence of the elevated magnetic readings in this field). It is conjectured that these responses may be due to the deposition of flood deposits from the drain located 100m to the north of the corridor; the superficial deposits at this location are also recorded as river terrace deposits of sand and gravel which are highly likely to contain clusters of (particularly) magnetic gravels.

The cluster of enhanced responses in Area 59 are located immediately west of a drain and the anomalies are interpreted as being caused by the deposition of silt/alluvium following episodes of flooding.

In Area 56 (see Figs 63, 64 and 65) vague curvilinear trends in the data are noted. Again these anomalies are located immediately adjacent to a drain and hence they too are accorded a geological origin, probably again to deposition of silt/alluvium following episodes of flooding. Similar flood related anomalies are located to the east of the drain in Area 54 (see Figs 66, 67 and 68).

At the eastern end of the corridor in Area 38 (see Figs 78, 79 and 80) the magnetic background is again very ‘noisy’. River terrace sand and gravel superficial deposits are again recorded at this location and therefore the ‘noise’ is interpreted as being caused by the presence of magnetic material (probably magnetic gravels) within the fluvial deposits.

Possible Archaeological Anomalies

Unless otherwise stated, anomalies of possible archaeological origin are thought to be caused by infilled cut features such as ditches, often forming part of a system of land division and settlement, and by discrete features such as pits.

Across the corridor in the Dalton to Skerne section a number of anomalies have been ascribed a possible archaeological interpretation. Whilst these anomalies do not manifest in any coherent archaeological pattern, they cannot be readily explained as being caused by modern boundary features, ploughing or other agricultural activity. They may be located relatively close to areas of known archaeological potential. For these reasons they have been interpreted as being of possible archaeological origin.

In Area 84 (see Figs 27, 28 and 29) a linear anomaly, **I**, is identified approximately 100m north of the anomalies classed as Site 1b (see below). The anomaly is on the same broad east/west axis as the principal feature in Site 1b and therefore is ascribed a possible archaeological origin.

Five hundred metres to the north a short curvilinear anomaly, **J**, and a short linear anomaly, **K** in Area 82 (see Figs 30, 31 and 32) are located just to the south of the enclosure complex identified as Site 1 (see below).

In Area 78 linear anomalies, **L**, **M** and **N** are identified. All three fall within a 200m long section of the corridor and are only 300m north-east if Site 1a. Of the three **L**, looks the most convincing; all are aligned at an oblique angle to the current field layout.

The final anomaly of possible potential, **O**, comprises a pair of linear anomalies forming a right angle. These anomalies are located in Area 73 (see Figs 42, 43 and 44) within a field of extant ridge and furrow earthworks. The anomalies are aligned obliquely to the current field layout.

Archaeological Anomalies

The following sites have been assigned an archaeological interpretation based upon their clarity, their discernible form and their proximity to one or more known heritage assets.

Site 1 (see Figs 30, 31 and 32)

A plethora of interconnecting linear anomalies at the northern end of Area 82 locates a site of high archaeological potential comprising enclosures, many sub-divided, appended on the northern side of a spinal ditch or ditch flanked trackway with a probable associated field system. This site correlates with an area of cropmarks of unknown date recorded as DS46 (see Fig. 4). A large number of discrete anomalies within the enclosures are indicative of features such as larger pits, hearths or areas of burning, which are clearly indicative of settlement activity.

The settlement is aligned on a south-west/north-east axis on Lund Wold. A central double-ditched trackway, **Tr1**, extends 300m from south-west/north-east across the full width of the surveyed area. Linear (ditch) anomalies **D1, D2 and D3** extend at right angles north-westwards from the trackway with interconnecting ditches aligned south-west/north-east linking to form two large enclosures **E1**, to the west and adjoining it to the east, **E2**. **E1** is rectangular and measures 60m by 30m. Within it numerous discrete anomalies locate features indicative of settlement activity. Enclosure **E2** is broadly square-shaped measuring 50m by 40 to 45m and is sub-divided with at least two major internal divisions. Weaker linear anomalies hint at further sub-division. Again discrete anomalies are clearly identified within **E2**. North of **E1** and north and east of **E2** further, mostly weaker and discontinuous, linear anomalies indicate the continuation of the enclosure complex. To the west of **E1 Tr1** continues for 70m before turning to the north-west at the edge of the surveyed area, anomaly **D5**. The area enclosed by **D1** and **D5** does not appear to be sub-divided or to contain and significant number of discrete features and is therefore considered to be a field, **F1**, attached to the main complex to the east.

Site 1a (see Figs 33, 34 and 35)

Approximately 0.5km to the north-east of Site 1 anomalies defining another small enclosure, **E3**, again attached to the north side of a trackway, **Tr2**, are identified. The alignment of the trackway strongly suggests that these features are part of the same system of enclosure and field division described as Site 1 (see above).

Site 1b (see Figs 27, 28 and 29)

Approximately 0.75m km to the south-west two interconnecting linear ditch type anomalies are identified. About 150m to the north-east three other fragmentary linear anomalies are also noted. It is not certain whether these anomalies form part of more enclosures/fields associated with Site 1 to the north, or whether they are indicative of more recent agricultural activity. It is worth noting that identifier DS5 0.4km to the north-west records cropmarks interpreted as indicative of Iron Age enclosures, perhaps lending weight to an archaeological origin for the anomalies recorded within the pipeline corridor.

5 Conclusions

The geophysical survey has identified only a single site of definite archaeological activity along the Dalton to Skerne section of the pipeline corridor. This site is located on Lund Wold and correlates with a previously identified, but undated, area of cropmarks. The site comprises a trackway with enclosures appended to the north and large fields in the surrounding landscape. Discrete anomalies within the enclosures suggest activity associated with settlement. The survey has successfully defined the extent of the archaeological activity within the proposed development area and identified an outlying part of the (presumed) same system of enclosure/field division to the north-east. Less coherent anomalies to the south-west may also form part of the same system.

Several other linear anomalies have been ascribed a possible archaeological cause on the basis that they cannot be definitely be interpreted as being due to more recent field systems or agricultural practice. Proximity to other known heritage assets has also been taken into account when making the interpretation. It is worth noting that all the identified anomalies of probable and possible archaeological origin are located on the higher ground of the Wolds at the western end of this section of the corridor.

Magnetic vestiges, evidence of the former practice of ridge and furrow ploughing, have been identified throughout this section of the corridor; low earthworks also survive in areas of pasture. Virtually all the fields around the village of Hutton, a village of medieval or earlier origin, bear evidence of this former ploughing technique.

Throughout the corridor the survey has also located the line of many former field boundaries removed since the production of the first edition of the Ordnance Survey map in 1855; only a few leave no trace in the data. Other modern features identified include drains, sub-surface pipes and footings for unknown features that are thought likely to be associated with a radar beacon on Lund Wold. Large areas of magnetic disturbance or enhancement locate backfilled chalk pits and ponds, some of which are shown on first edition mapping, others are not.

Based on the magnetometer survey only a single area of high archaeological potential has been identified, with two other areas of moderate potential to the north-west and south-east. Elsewhere along the corridor the overall potential is assessed as low to moderate.

Disclaimer

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 haemetite. 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 then 0.01m. 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; and
- 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 East Yorkshire Historic Environment Record).

Bibliography

AECOM, 2013. *Dalton to Skerne Section* AECOM Draft Baseline Information

British Geological Survey, 2013. http://maps.bgs.ac.uk/geologyviewer/ (Viewed July 28th 2013)

David, A., N. Linford, P. Linford and L. Martin, 2008. *Geophysical Survey in Archaeological Field Evaluation: Research and Professional Services Guidelines (2nd edition)* English Heritage

IfA, 2013. *Standard and Guidance for archaeological geophysical survey*. Institute for Archaeologists

Old-Maps, 2013. www.old-maps.co.uk (Viewed July 28th 2013)

Soil Survey of England and Wales, 1983. Soils of Northern England, Sheet 1.