Cefn Park
Wrexham

Archaeological geophysical survey

Project No. ARC/3283/1243

May 2022

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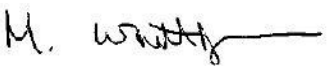
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Date	24/05/22	Date	24/05/22

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1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at a site at Cefn Park, Wrexham. The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS). The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger.

The majority of the anomalies identified by this survey relate to modern material / objects, agricultural activity and geological / pedological variations. Several anomalies are present that are suggestive of infilled features and these could be related to archaeological features, although it is also possible that some of them could be caused by more modern features / activity. There are a number of anomalies of uncertain origin. Generally these do not form any clear patterns or relationships that would indicate an archaeological origin and the majority of them are probably associated with agricultural or other modern activity or natural features / variations. However, as their cause cannot be determined with certainty an archaeological origin for some of them cannot be ruled out.

2. INTRODUCTION

2.1 Overview

Phase Site Investigations Ltd was commissioned by BWB Consulting Ltd to carry out an archaeological geophysical survey at Cefn Park, Wrexham, utilising magnetic gradiometers.

The aim of the survey was to help establish the presence / absence, extent, character, relationships and date (as far as circumstances and the inherent limitations of the technique permits) of archaeological features within the survey area.

The location of the site is shown in drawing ARC_3283_1243_01.

2.2 Site description

The site is situated on the eastern edge of Wrexham and was divided into two parts within the proposed Phase 1 of the Cefn Park development. One part was located in the north / north-west of the site, (approximate centre at SJ 354 510). This encompassed three arable fields and part of a playing field and covered an area of approximately 7 ha. The second part was located to the south-west of the site (approximate centre at SJ 355 505). This section encompassed an arable field, part of another arable field and a small field that was used for manure storage at the time of the survey and covered an area of approximately 10.8 ha.

The site was undulating throughout and was generally bounded by hedgerows and trees. Two sets of goalposts were present in the playing field in the north of the site.

The geology of the site consists of mudstone, sandstone and conglomerate of the Salop Formation overlain by glaciofluvial sheet deposits (British Geological Survey, 2022). The soils of the site are described as freely draining slightly acid sandy soils (Soilscapes, 2022).

2.3 Archaeological background

Archaeological background information was not available at the time of writing this report.

Historic maps (maps.nls.uk, 2022) indicate that the site has been in use for agriculture since before 1913. The large field in the south (Area 5) was formerly sub-divided by a curving field boundary and a field boundary may have crossed the playing field in the north (Area 4).

2.4 Scope of work

The survey areas were specified by the client.

Due to the presence of dense vegetation, trees, manure heaps and internal field boundaries the area accessible / suitable for survey was reduced to approximately 15.1 ha, the extents of which are shown in drawing ARC_3283_1243_02. For the purposes of this survey each area within a field has been given a number, as shown in drawing ARC_3283_1243_02.

No other problems were encountered during the survey which was carried out between 4 and 7 April 2022.

3. SURVEY METHODOLOGY

3.1 Magnetic survey

The survey was undertaken using a Phase Site Investigations Ltd multi-sensor array cart system (MACS).

The MACS comprised 8 Foerster 4.032 Ferex CON 650 gradiometers with a control unit and data logger. The Foerster gradiometers do not require balancing as each sensor is automatically 'zeroed' using the control unit software.

The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN 15 projection. As the survey is referenced direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

3.2 Data processing and presentation

The MACS data was stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

The data was exported as greyscale raster images (PNG files). Data for the entire site is presented at a scale of 1:4000 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown at a scale of 1:1500. All greyscale plots were clipped at -2 nT to 3 nT. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.

The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'013-CFP-NOW-A1 – Overlay Plan.dwg'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar and bipolar responses that will probably be associated with surface / near-surface iron objects. However, X-Y trace plots have not been presented here as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot is provided in the digital archive.

All isolated responses have been assessed using a combination of greyscale and X-Y trace plots. There are a large number of 'iron spike', isolated dipolar anomalies present in the data. There is no evidence to suggest that they are associated with archaeological features and so these have not been shown in the interpretation.

Anomalies associated with agricultural regimes are present in the data but each individual anomaly has not been shown on the interpretation. Instead, the general orientation of the regime is indicated.

The data was examined over several different ranges during the interpretation to ensure that the maximum information possible was obtained from the data.

The anomalies have been categorised based on the type of response that they exhibit and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided.

A general discussion of the anomalies is provided for the entire site and then the results are discussed on an area by area basis. A discussion of the general categories of anomaly which have been identified by the survey is provided in Appendix 1.5.

The geophysical interpretation drawing must be used in conjunction with the relevant results section and appendices of this report.

4. RESULTS

4.1 General

The data quality across the majority of the survey area is very good allowing the data to be viewed at a narrow range of readings to better identify weak anomalies.

4.2 Area 1

Basic topography: Relatively level.

Field / area description: Part of an arable field under stubble. The field was firm underfoot and bounded by a mix of fences, hedges and dense vegetation. An area of dense vegetation was present in the north-west of the field and the field was crossed by a track (separating Area 1 and Area 2).

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger / stronger isolated bipolar responses. These will be related to a concentration of, or a larger object or feature of, relatively modern ferrous or fired material. They are not thought to be archaeologically significant but have been shown to indicate where there may be relatively large modern material or features.

Areas of magnetic disturbance associated with relatively modern features / material.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Trends of uncertain origin.

Several isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

Further discussion / additional information:

The majority of the responses in this area will be related to modern material / activity.

The trends within the survey area are all too weak and short to reliably interpret. However, they do not form any patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are simply a product of agricultural or other modern activity on the site or natural variations.

4.3 Area 2

Basic topography: Relatively level.

Field / area description: Arable field under stubble. The field was firm underfoot and bounded by a mix of fences, hedges and dense vegetation. An

area of dense vegetation was present in the north-west of the field and the field was crossed by a track (separating Area 1 and Area 2).

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger / stronger isolated bipolar responses. These will be related to a concentration of, or a larger object or feature of, relatively modern ferrous or fired material. They are not thought to be archaeologically significant but have been shown to indicate where there may be relatively large modern material or features.

An area of magnetic disturbance associated with relatively modern features / material.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Relatively weak linear responses are present associated with modern ploughing regime(s).

Trends of uncertain origin.

Several isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

Further discussion / additional information:

The majority of the responses in this area will be related to modern material / activity.

The trends within the survey area are all too weak and short to reliably interpret. However, they do not form any patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are simply a product of agricultural or other modern activity on the site or natural variations.

4.4 Area 3

Basic topography: Gradual downwards slope to the north.

Field / area description: Arable field under stubble. The field was firm underfoot and bounded by hedgerows and dense vegetation. An area of trees / dense vegetation was present in the eastern part of the field.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger / stronger isolated bipolar responses. These will be related to a concentration of, or a larger object or feature of, relatively modern ferrous or fired material. They are not thought to be archaeologically significant but have been shown

to indicate where there may be relatively large modern material or features.

Two linear bipolar anomalies associated with sub-surface utility apparatus (pipes or cables).

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Relatively weak positive linear responses are present associated with modern ploughing regime(s).

Trends of uncertain origin.

Numerous isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

Further discussion / additional information:

Anomalies A are an alignment of trends that, although weak and fragmented, are suggestive of an infilled feature. The anomalies do not appear to correspond with a historic field boundary and so could be related to an archaeological feature.

There is a slight suggestion that several trends adjacent to Anomalies A may form a sub-circular shape (**Anomalies B**). It is likely that these anomalies are a product of agricultural activity and / or natural variations. However, given their proximity to Anomalies A, which could be related to an archaeological feature, an archaeological origin form Anomalies B cannot be completely ruled out.

Several other trends stand out slightly because they are slightly more coherent or there are several responses in proximity to each other (**Anomalies C**). Some of these anomalies could be related to sub-surface features but it is likely that the majority, if not all, of the responses are related to natural variations, agricultural or other modern activity.

The remaining trends within the survey area are all too weak and short to reliably interpret. They do not form any obvious patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are a product of agricultural activity or natural variations.

4.5 Area 4

Basic topography: Sports pitches were present across the field and the field appeared to have been landscaped with the pitches at a lower level that the surrounding ground.

Field / area description: Playing pitches with adjacent trees and areas of denser vegetation. The survey area covered one full rugby pitch, which included two sets of goalposts, and part of a second rugby pitch. The field was relatively firm underfoot. The survey area was bounded by hedgerows and dense vegetation to the north-east and west with no fixed boundary to the south.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger / stronger isolated bipolar responses. These will be related to a concentration of, or a larger object or feature of, relatively modern ferrous or fired material. They are not thought to be archaeologically significant but have been shown to indicate where there may be relatively large modern material or features.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Diffuse negative linear anomalies that appear to correspond with the position boundaries of the rugby pitches. These responses are probably related to these features, or possibly associated drainage, and will not be archaeologically significant.

Trends of uncertain origin.

Numerous isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

Further discussion / additional information:

There are a number of weak trends in this field. The majority, if not all of these, are probably caused by modern activity or natural variations but several of them may form alignments or regular shapes (**Anomalies D**). Some of these could be related to sub-surface features but they are too short and weak to reliably interpret.

There are a number of trends in the south of the area that are broadly aligned north-east to south-west (**Anomalies E**). These are probably related to the remnants of agricultural activity, although some of them could be associated with drainage features.

The remaining trends within the survey area are all too weak and short to reliably interpret. They do not form any obvious patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are a product of agricultural activity or natural variations.

4.6 Area 5

Basic topography: Undulating.

Field / area description: Arable field under immature crop. The field was relatively firm underfoot and bounded by hedgerows.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

Several larger / stronger isolated bipolar responses. These will be related to a concentration of, or a larger object or feature of,

relatively modern ferrous or fired material. They are not thought to be archaeologically significant but have been shown to indicate where there may be relatively large modern material or features.

Two linear bipolar anomalies associated with sub-surface utility apparatus (pipes). A third linear (much weaker) bipolar response is suggestive of a drainage feature.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Relatively weak positive linear responses are present associated with modern ploughing regime(s).

A diffuse, positive curvi-linear anomaly corresponds with the position of a former field boundary and will be related to this feature.

Broad areas of positive and negative responses associated with natural features or variations

Trends of uncertain origin.

Numerous isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

Further discussion / additional information:

Anomaly F stands out but this corresponds with a former field boundary shown on historic maps and will be related to this feature.

The broad, diffuse areas visible in this field will be related to natural features / variations and are not archaeologically significant.

The strong linear bipolar responses in the south-east of the area are suggestive of two adjacent metal pipes. A linear, much weaker bipolar response (**Anomaly G**) is suggestive of a ceramic drainage feature.

There are a number of weak trends in this field. The majority, if not all of these, are probably caused by modern activity or natural variations. Several trends stand out slightly because they are slightly more coherent or there are several responses in proximity to each other (**Anomalies H**). Some of these anomalies could be related to sub-surface features but it is likely that the majority, if not all, of the responses are related to natural variations.

The remaining trends within the survey area are all too weak and short to reliably interpret. They do not form any obvious patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are a product of agricultural activity or natural variations.

4.7 Area 6

Basic topography: Relatively level.

Field / area description: Small field, predominantly used for manure storage. The field was bounded by hedgerows. The area that could be surveyed was relatively firm underfoot but uneven as it contained vehicle ruts. Manure heaps were present in the west of the field.

Summary of anomalies: Several isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

A larger / stronger isolated bipolar response. This will be related to a concentration of, or a larger object or feature of, relatively modern ferrous or fired material. It is not thought to be archaeologically significant but has been shown to indicate where there may be relatively large, modern material or a feature.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Trends of uncertain origin.

Several isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

Further discussion / additional information:

The area contains a relatively high number of linear trends but the small size of the survey area makes it difficult to interpret them. **Anomalies I** are two broadly parallel alignments of trends. It is possible that these are related to archaeological features, although it is worth noting that they do not appear to continue into Area 5 to the south, but they could also be a product of agricultural activity. The trends in the south-east of the area are suggestive of agricultural activity but several trends either run oblique to these or are slightly more coherent (**Anomalies J**) and it is possible that these could have a different cause, although it is not possible to determine if these could, potentially, be related to archaeological features or other agricultural activity or natural variations.

4.8 Area 7

Basic topography: Gradual downwards slope to the east.

Field / area description: North-western part of an arable field under immature crop. The survey area was relatively firm underfoot and bounded by hedgerows to the north and west with no fixed boundaries to the south and east.

Summary of anomalies: Numerous isolated dipolar and small bipolar responses, that are all thought to be associated with modern material. These have not been shown on the interpretation.

A larger / stronger isolated bipolar response. This will be related to a concentration of, or a larger object or feature of, relatively modern ferrous or fired material. It is not thought to

be archaeologically significant but has been shown to indicate where there may be relatively large, modern material or a feature.

Very strong responses associated with strongly magnetic relatively modern features / material. These responses can extend for some distance beyond the feature and in some cases the feature causing the strong response may be located beyond the survey area.

Relatively weak positive linear responses are present associated with modern ploughing regime(s).

Trends of uncertain origin.

Several isolated positive responses, the majority of which are probably related to relatively modern deeper buried ferrous / fired material or are geological / pedological in origin.

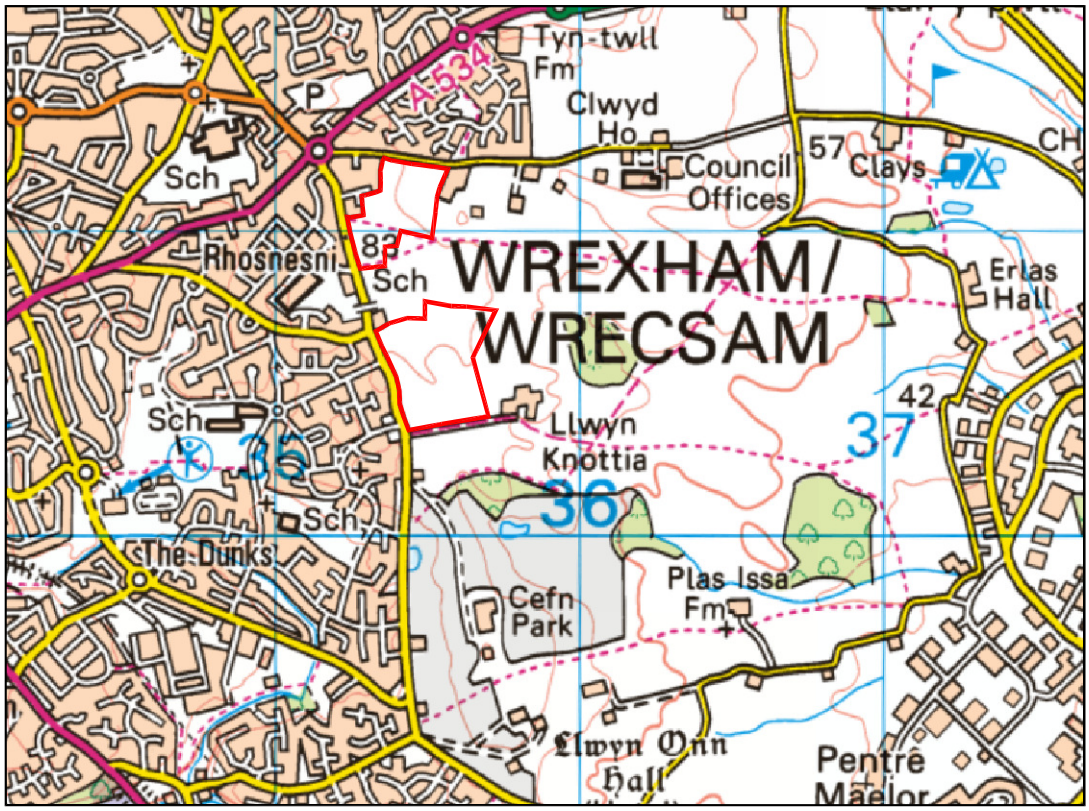
Further discussion / additional information:

Several weak trends are present that are too weak and short to reliably interpret. They do not form any obvious patterns or relationships that would suggest they are associated with sub-surface features and it is likely that they are a product of agricultural activity or natural variations.

5. DISCUSSION AND CONCLUSIONS

The majority of the anomalies identified by this survey relate to modern material / objects, agricultural activity and geological / pedological variations. Several anomalies are present that are suggestive of infilled features and these could be related to archaeological features, although it is also possible that some of them could be caused by more modern features / activity. There are a number of anomalies of uncertain origin. Generally, these do not form any clear patterns or relationships that would indicate an archaeological origin and the majority of them are probably associated with agricultural or other modern activity or natural features / variations. However, as their cause cannot be determined with certainty an archaeological origin for some of them cannot be ruled out.

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SITE LOCATION

SCALE

0m 500m 1000m

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Scale [A4 Sheet]	Drawing	Status
AS SHOWN	ARC_3283_1243_01	FINAL

Client: BWB CONSULTING LTD LEEDS

Site: CEFN PARK WREXHAM

Title: SITE LOCATION MAP

Job No: ARC_3283_1243

		Drawn	RS
Chk.	MW	Date	09/05/2022



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EXTENT OF SURVEY AREAS

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Scale [A3 Sheet]	Drawing	Status
1:4000	ARC_3283_1243_02	FINAL

Client
BWB CONSULTING LTD
LEEDS

Site
CEFN PARK
WREXHAM

Title
LOCATION OF SITE SHOWING MAGNETIC GRADIENT DATA

Job No
ARC_3283_1243

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	07/04/2022



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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3283_1243_03	FINAL

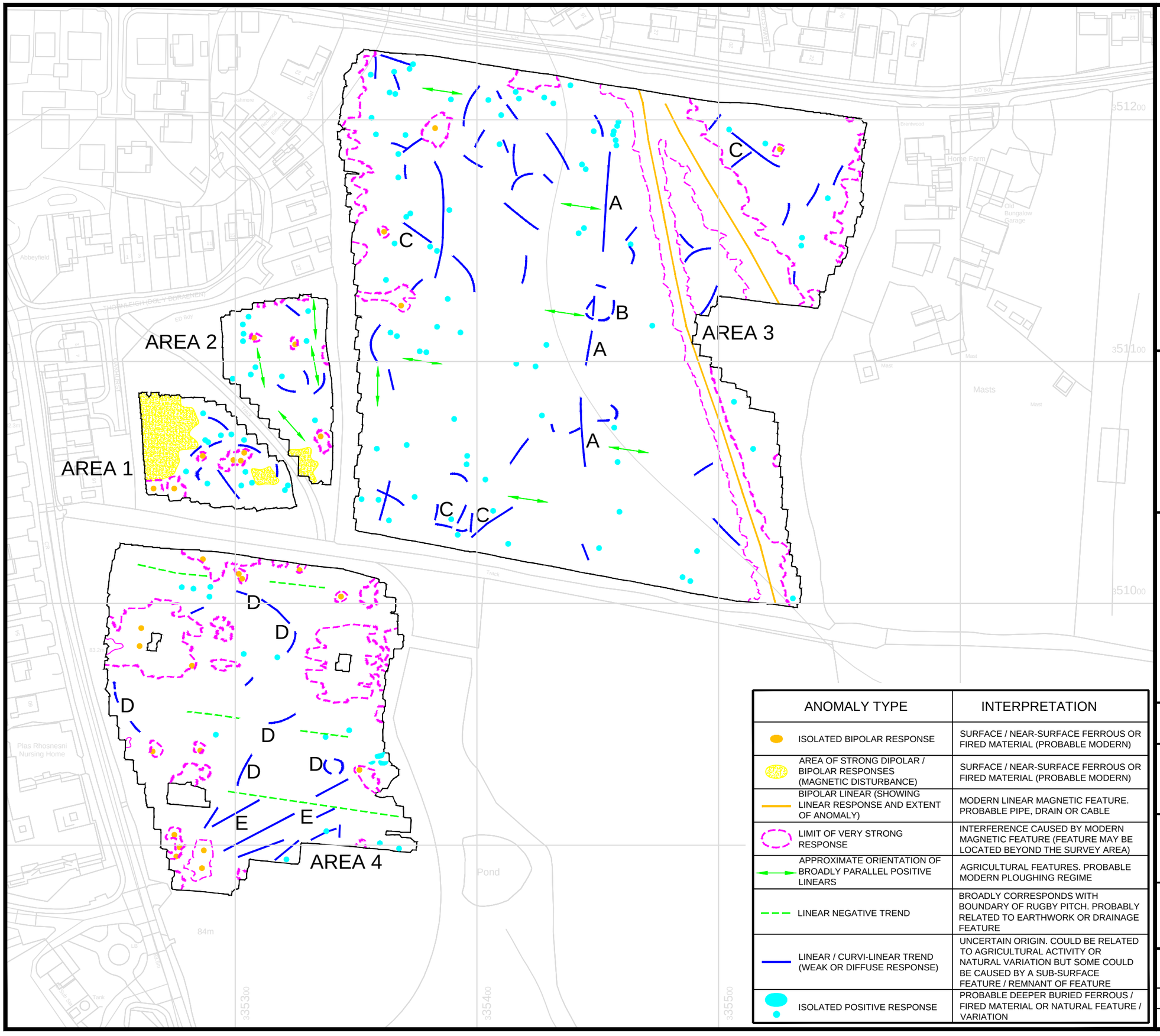
Client
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Site
CEFN PARK
WREXHAM

Title
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: AREAS 1, 2, 3 AND 4

Job No
ARC_3283_1243

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	07/04/2022



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ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR RESPONSE	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
AREA OF STRONG DIPOLAR / BIPOLAR RESPONSES (MAGNETIC DISTURBANCE)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
BIPOLAR LINEAR (SHOWING LINEAR RESPONSE AND EXTENT OF ANOMALY)	MODERN LINEAR MAGNETIC FEATURE. PROBABLE PIPE, DRAIN OR CABLE
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. PROBABLE MODERN PLOUGHING REGIME
LINEAR NEGATIVE TREND	BROADLY CORRESPONDS WITH BOUNDARY OF RUGBY PITCH. PROBABLY RELATED TO EARTHWORK OR DRAINAGE FEATURE
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	UNCERTAIN ORIGIN. COULD BE RELATED TO AGRICULTURAL ACTIVITY OR NATURAL VARIATION BUT SOME COULD BE CAUSED BY A SUB-SURFACE FEATURE / REMNANT OF FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE DEEPER BURIED FERROUS / FIRED MATERIAL OR NATURAL FEATURE / VARIATION

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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3283_1243_04	FINAL

Client
BWB CONSULTING LTD
LEEDS

Site
CEFN PARK
WREXHAM

Title
INTERPRETATION OF MAGNETIC GRADIENT DATA: AREAS 1, 2, 3 AND 4

Job No
ARC_3283_1243

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	07/04/2022



NOTES

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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3283_1243_05	FINAL

Client
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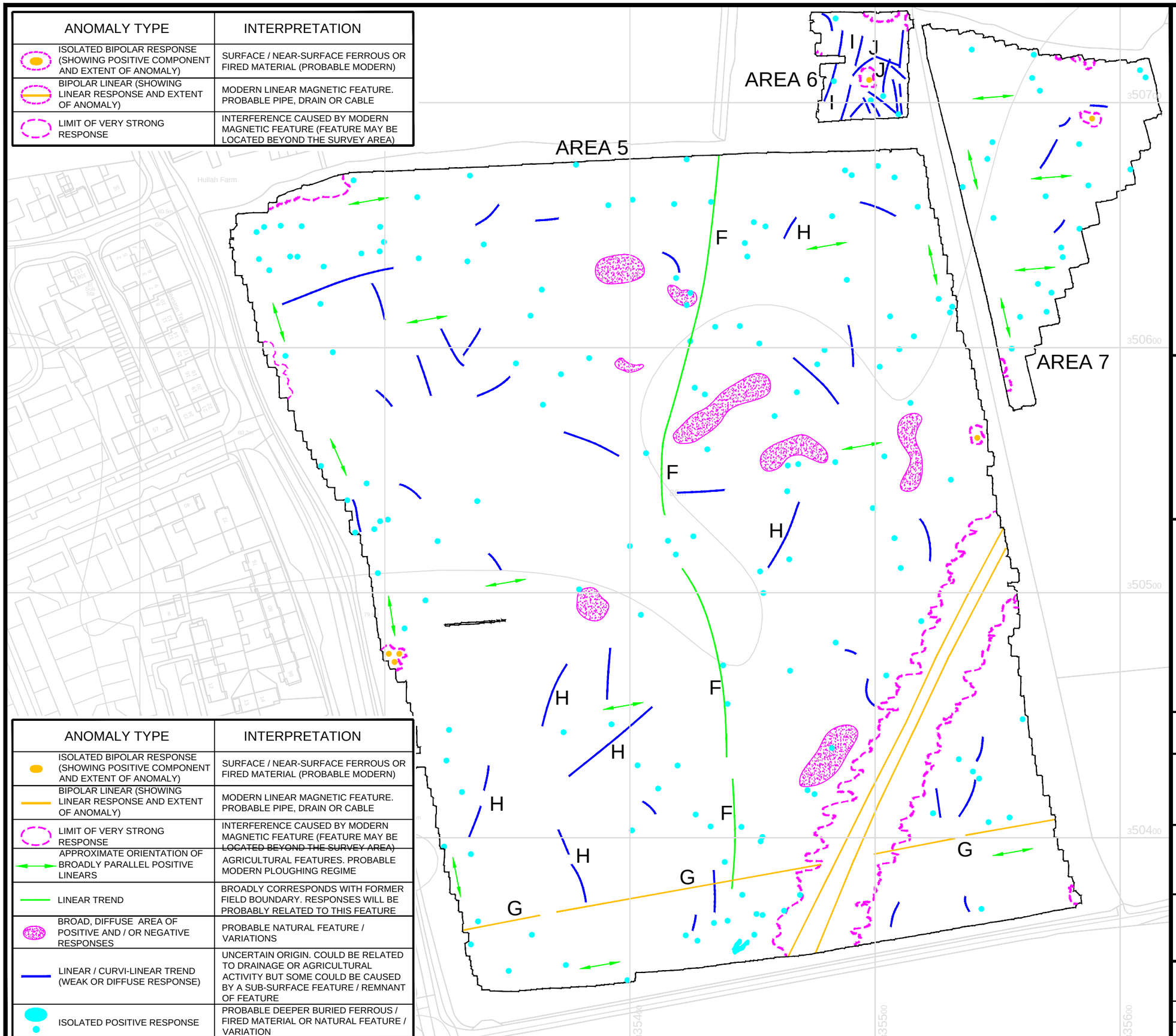
Site
CEFN PARK
WREXHAM

Title
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA: AREAS 5, 6 AND 7

Job No
ARC_3283_1243

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	07/04/2022

ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR RESPONSE (SHOWING POSITIVE COMPONENT AND EXTENT OF ANOMALY)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
BIPOLAR LINEAR (SHOWING LINEAR RESPONSE AND EXTENT OF ANOMALY)	MODERN LINEAR MAGNETIC FEATURE. PROBABLE PIPE, DRAIN OR CABLE
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)



ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR RESPONSE (SHOWING POSITIVE COMPONENT AND EXTENT OF ANOMALY)	SURFACE / NEAR-SURFACE FERROUS OR FIRED MATERIAL (PROBABLE MODERN)
BIPOLAR LINEAR (SHOWING LINEAR RESPONSE AND EXTENT OF ANOMALY)	MODERN LINEAR MAGNETIC FEATURE. PROBABLE PIPE, DRAIN OR CABLE
LIMIT OF VERY STRONG RESPONSE	INTERFERENCE CAUSED BY MODERN MAGNETIC FEATURE (FEATURE MAY BE LOCATED BEYOND THE SURVEY AREA)
APPROXIMATE ORIENTATION OF BROADLY PARALLEL POSITIVE LINEARS	AGRICULTURAL FEATURES. PROBABLE MODERN PLOUGHING REGIME
LINEAR TREND	BROADLY CORRESPONDS WITH FORMER FIELD BOUNDARY. RESPONSES WILL BE PROBABLY RELATED TO THIS FEATURE
BROAD, DIFFUSE AREA OF POSITIVE AND / OR NEGATIVE RESPONSES	PROBABLE NATURAL FEATURE / VARIATIONS
LINEAR / CURVI-LINEAR TREND (WEAK OR DIFFUSE RESPONSE)	UNCERTAIN ORIGIN. COULD BE RELATED TO DRAINAGE OR AGRICULTURAL ACTIVITY BUT SOME COULD BE CAUSED BY A SUB-SURFACE FEATURE / REMNANT OF FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE DEEPER BURIED FERROUS / FIRED MATERIAL OR NATURAL FEATURE / VARIATION

NOTES

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Scale [A3 Sheet]	Drawing	Status
1:1500	ARC_3283_1243_06	FINAL

Client: BWB CONSULTING LTD LEEDS

Site: CEFN PARK WREXHAM

Title: INTERPRETATION OF MAGNETIC GRADIENT DATA: AREAS 5, 6 AND 7

Job No: ARC_3283_1243

Surveyed	JW, RS	Drawn	JW
Chk.	MW	Date	07/04/2022

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APPENDIX 1

Magnetic survey: technical information

1.1 Theoretical background

1.1.1 Magnetic instruments measure the value of the Earth's magnetic field; the units of which are nanoTeslas (nT). The presence of surface and sub-surface features can cause variations or anomalies in this magnetic field. The strength of the anomaly is dependent on the magnetic properties of a feature and the material that surrounds it. The two magnetic properties that are of most interest are magnetic susceptibility and thermoremnant magnetism.

1.1.2 Magnetic susceptibility indicates the amount of ferrous (iron) minerals that are present. These can be redistributed or changed (enhanced) by human activity. If enhanced material subsequently fills in features such as pits or ditches then these can produce localised increases in magnetic responses (anomalies) which can be detected by a magnetic gradiometer even when the features are buried under additional soil cover.

1.1.3 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. Less magnetic material such as masonry or plastic service pipes which intrude into the topsoil may give a negative magnetic response relative to the background level. The strength of magnetic responses that a feature will produce will depend on the background magnetic susceptibility, how rapidly the feature has been infilled, the level and type of human activity in the area and the size and depth of a feature. Not all infilled features can be detected and natural variations can also produce localised positive and negative anomalies.

1.1.4 Thermoremnant magnetism indicates the amount of magnetism inherent in an object as a result of heating. Material that has been heated to a high temperature (fired), such as brick, can acquire strong magnetic properties and so although they may not appear to have a high iron content they can produce strong magnetic anomalies

1.1.5 The magnetic survey method is highly sensitive to interference from surface and near-surface magnetic 'contaminants'. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult, or even impossible, in the vicinity of surface magnetic features. The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.

1.1.6 The interpretation of magnetic anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Not all features will produce a measurable magnetic response and the effectiveness of a magnetic 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 magnetic survey will identify all sub-surface features.

1.1.7 Most high resolution, near surface magnetic surveys utilise a magnetic gradiometer. A gradiometer is a hand-held instrument that consists of two magnetic sensors, one positioned directly above the other, which allows measurement of the magnetic gradient component of the magnetic field. A gradiometer configuration eliminates the need for applying corrections due to natural variations in the overall field strength that occur during the course of a day but it only measures relative variations in the local magnetic field and so comparison of absolute values between sites is not possible.

1.1.8 Features that are commonly located using magnetic surveys include archaeological ditches and pits, buried structures or foundations, mineshafts, unexploded ordnance, metallic pipes and cables, buried piles and pile caps. The technique can also be used for geological mapping; particularly the location of igneous intrusions.

1.2 Instrumentation

1.2.1 A multi-sensor array cart system (MACS) utilising 8 Foerster 4.032 Ferex CON 650 gradiometers, spaced at 0.5 m intervals, with a control unit and data logger was used for the magnetic survey to survey part of the site.

1.3 Survey methodology

1.3.1 The MACS utilises an RTK GNSS system which means that survey grids do not have to be established. Instead an area is surveyed over a series of continuous profiles and the position of each data point is recorded using an RTK GNSS system. The sensors have a separation of 0.5 m which means that data was collected on profiles spaced at 0.5 m apart. Readings were taken at between 0.1 m and 0.15 m intervals.

1.3.2 Data is collected on zig-zag profiles along the full length or width of a field, although fields can be sub-divided if they are particularly large. Marker canes are set-out along field boundaries at set intervals and these are used to align the profiles. The survey profiles are usually offset from field boundaries, buildings and other metallic features by several metres to reduce the detrimental effect that these surface magnetic features have on the data. The location of the MACS data is converted direct to Ordnance Survey co-ordinates using the UK OSTN 15 projection. As the data is related direct to Ordnance Survey National Grid co-ordinates temporary survey stations are not established.

1.3.3 The Foerster gradiometers have a resolution of 0.2 nT but the stability of the cart system significantly reduces noise caused by instrument tilt and movement when compared with a traditional hand-held gradiometer system and the increased data intervals provide a higher resolution data set. The sensors have a range of ± 10,000nT and readings are taken at 0.1 nT resolution.

1.4 Data processing and presentation

1.4.1 The MACS data is stored direct to a laptop using in-house software which automatically corrects for instrument drift and calculates a mean value for each profile. A positional value is assigned to each data point based on the sensor number and recorded GNSS co-ordinates. The data is gridded using in-house software and parameters are set based on the sensor spacing and mean values. No additional processing is required. The gridded data is then displayed in Surfer 9 (Golden Software) and image files of the data are created.

1.4.2 The data was exported as greyscale raster images (PNG files). Data for the entire site is presented at a scale of 1:4000 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown at a scale of 1:1500. All greyscale plots were clipped at -2 nT to 3 nT. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.

1.4.3 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing *'013-CFP-NOW-A1 – Overlay Plan.dwg'*. The base plan was in the Ordnance Survey National Grid co-ordinate system and as the survey grids / data were referenced directly to National Grid co-ordinates the data could be simply superimposed onto the base plan in the correct position.

1.5 Interpretation

1.5.1 The anomalies have been categorised based on the type of response that they have and an interpretation as to the cause(s) or possible cause(s) of each anomaly type is also provided. The following anomaly types may be present within the data:

Dipolar, bipolar and strong responses

Dipolar and bipolar responses are those that have a sharp variation between strongly positive and negative components.

In the majority of cases these responses are usually caused by modern ferrous features / objects, although fired material (such as brick), some ferrous or industrial archaeological features and strongly magnetic gravel could also produce dipolar and bipolar responses.

Isolated dipolar responses are those that have a single positive and negative element. They are usually caused by isolated, ferrous or fired material on or near to the surface. The objects that cause dipolar responses are usually relatively small, such as spent shotgun cartridges, iron nails and horseshoes (hence they are often referred to as 'iron spikes') or pieces of modern brick or pot. Some types of archaeological artefacts can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Bipolar anomalies have strong positive and negative components but are not technically magnetic dipoles. The majority of **isolated bipolar responses** are caused by ferrous or fired material on or near to the surface. These responses tend to be produced from larger objects, compared to dipolar anomalies, or a concentration of smaller objects. Some archaeological features/ activity, including areas of burning or industrial activity can also produce this type of response but unless there is strong supporting evidence to the contrary they are assumed not to be of archaeological significance.

Smaller isolated dipolar and bipolar responses have not been shown on the interpretation as there is no evidence to suggest that they are related to archaeological activity. Several larger isolated bipolar responses have been shown as these could be associated with more significant sub-surface features or material (although in this instance they are not thought to be of archaeological interest).

Bipolar linear anomalies are usually produced by metallic buried pipes / cables, although some ceramic pipes or features containing fired material, such as brick structures or foundations, can also produce bipolar anomalies. In some instances the anomaly can extend for a significant distance beyond the feature that produces the anomaly. Bipolar anomalies are often very strong and can potentially mask responses from other sub-surface features in the vicinity of the underlying feature.

Areas containing numerous **strong dipolar / bipolar responses (magnetic disturbance)** are usually caused by greater concentrations of ferrous or fired material and are often found adjacent to field boundaries where such material tends to accumulate. Above ground metallic or strongly magnetic features, such as fences, gates, pylons and buildings can also produce very strong bipolar responses. If an area of magnetic disturbance is located away from existing field boundaries then it could indicate a former field boundary, several large isolated objects in close proximity, an area where modern material has been tipped or an infilled cut feature, such as a quarry pit. Areas of dipolar / bipolar response can occasionally be caused by features / material associated with archaeological industrial activity or natural deposits that have varying magnetic properties but they are usually caused by modern activity. Responses in areas of magnetic disturbance can sometimes be so strong that archaeological features located beneath them may not be detected.

Very strong responses, notably bipolar anomalies, from modern features can dominate the data for a significant distance beyond the feature. The extent of these areas is usually shown either as part of the bipolar anomaly or as a **limit of very strong response.** It should be noted that this effect extends beyond the feature and so the limit of the response does not correspond to the actual size or location of the feature within it. In many cases where these strong responses are present at the edge of survey area the feature causing the anomaly be actually be located beyond the survey area. It should be recognised that other sub-surface features located within these areas may not be detected.

Negative linear / curvi-linear anomalies

Negative linear / curvi-linear anomalies occur when a feature has lower magnetic readings than the surrounding material and can often be associated with ploughing regimes or plastic / concrete pipes or natural features.

They can also indicate the presence of a feature that cuts into magnetic soils or bedrock and which is infilled with less magnetic material and in certain geologies can be associated with archaeological features.

Any negative linear anomalies in this data set are thought to relate to agricultural or other relatively modern activity.

Linear / curvi-linear anomalies (probable agricultural)

In many geological / pedological conditions agricultural features / regimes can produce magnetic anomalies due to the accumulation / alignment of magnetic topsoil. In most cases these are exhibited as a series of **broadly parallel positive linear** anomalies. The majority of these responses are associated with modern ploughing regimes but in some instances, where the responses are broader and more widely spaced, they can indicate the presence of the remnants of ridge and furrow.

Field drain systems can also produce linear anomalies, usually where the drains are made from fired ceramic or infilled with magnetic gravels.

Where a series of parallel anomalies are present then the approximate orientation of the anomalies are shown on the interpretation drawing to indicate the direction of the agricultural regime but for the sake of clarity individual anomalies have not been shown.

Individual anomalies may be shown if the response is not part of a regime.

Broad area of positive / negative responses

Broad areas of positive / negative responses can have a variety of causes. If the areas are generally quite large and irregular in shape then they are usually suggestive of natural features, such as lenses of sand and gravel deposits, palaeochannels or other natural features / variations where the natural material differs from the surrounding sub-surface. In some instances anomalies of this type can be associated with anthropogenic (usually modern) activity.

Linear / curvi-linear trends

An anomaly is categorised as a **trend** if it is not certain that the response is associated with an extant sub-surface feature. Trends are usually weak, irregular, diffuse or discontinuous and it is usually not certain what their cause is, if they represent significant sub-surface features or even if they are associated with definite features.

It is possible that some of the trends are associated with geological / pedological variations. Others may be produced by artificial constructs within the data, either caused by processing or in some instances by intersecting anomalies (usually different agricultural regimes) that give the appearance of curving or regular shapes. Many trends are a product of weak, naturally occurring responses that happen to form a regular pattern but which are not associated with a sub-surface feature.

In some instances former features that have been severely truncated can still produce broad, diffuse or weak responses even if the underlying feature has been removed. This is due to the presence of magnetic soils associated with the former feature still being present along its route. In other instances the magnetic properties of the soils filling a feature may vary and so the magnetic signature of the feature can change, even if the sub-surface feature itself remains uniform. If a response from a feature becomes significantly weak or diffuse then part of the anomaly may be shown as a trend as it is uncertain if the feature is still present or has been severely truncated or removed.

Isolated positive responses

Isolated positive responses can occur if the magnetism of a feature, area or material has been enhanced or if a feature is naturally more magnetic than the surrounding material. It is often difficult to determine which of these factors causes any given responses and so the origin of this type of anomaly can be difficult to determine. They can have a variety of causes including geological variations, infilled archaeological features, areas of burning (including hearths), industrial archaeological features, such as kilns, or deeper buried ferrous material and modern fired material.

The large number of isolated responses and lack of an obvious pattern to their distribution suggests that these anomalies are probably associated with geological / pedological variations or deeper buried ferrous or fired material. Only the larger or stronger areas of positive response have been shown on the interpretation. The majority, if not all of these responses, will be related to natural variations or relatively modern material but have been shown as their exact cause cannot be determined with certainty.

Positive linear / curvi-linear anomalies

Positive magnetic anomalies indicate an increase in magnetism and if the resulting anomaly is linear or curvi-linear then this can indicate the presence of a man-made feature. **Positive or enhanced linear / curvi-linear** anomalies can be associated with agricultural activity, drainage features but they can also be caused by ditches that are infilled with

magnetically enhanced material and as such can indicate the presence of archaeological features. Some natural infilled features can also produce positive anomalies.

There are no significant positive linear anomalies in this data set.

1.5.2 Several different ranges of data were used in the interpretation to ensure that the maximum information possible is obtained from the data.

1.5.3 X-Y trace plots were examined for all of the data and overlain onto the greyscale plot to assist in the interpretation, primarily to help identify dipolar / bipolar responses that will probably be associated with surface / near-surface iron objects. X-Y trace plots have not been used in the report as they do not show any additional anomalies that are not visible in the greyscale data. A digital drawing showing the X-Y trace plot overlain on the greyscale plot has been provided in the digital archive.

1.5.4 All isolated responses have been assessed using a combination of greyscale and X-Y trace plots.

1.5.5 Anomalies associated with agricultural regimes are present in the data. The general orientation of these regimes has been shown on the interpretation but, for the sake of clarity, each individual anomaly has not been shown.

1.5.6 The greyscale plots and the accompanying interpretations of the anomalies identified in the magnetic data are presented as 2D AutoCAD drawings. The interpretation is made based on the type, size, strength and morphology of the anomalies, coupled with the available information on the site conditions. Each type of anomaly is displayed in separate, easily identifiable layers annotated as appropriate.

1.6 Limitations of magnetic surveys

1.6.1 The magnetic survey method requires the operator to walk over the site at a constant walking pace whilst holding the instrument. 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 at which features can be detected will vary depending on their composition, size, the surrounding material and the type of magnetometer used for the survey. In good conditions large, magnetic targets, such as buried drums or tanks can be located at depths of more than 4 m. Smaller targets, such as buried foundations or archaeological features can be located at depths of between 1 m and 2 m.

1.6.3 A magnetic survey is highly sensitive to interference from surface and near-surface magnetic ‘contaminants’. Surface features such as metallic fencing, reinforced concrete, buildings or walls all have very strong magnetic signatures that can dominate readings collected adjacent to them. Identification of anomalies caused by sub-surface features is therefore more difficult or even not possible in the vicinity of surface and near-surface magnetic features.

1.6.4 The presence of made ground also has a detrimental effect on the magnetic data quality as this usually contains magnetic material in the form of metallic scrap and brick. Identification of features beneath made ground is still possible if the target feature is reasonably large and has a strong magnetic response but smaller features or magnetically weak features are unlikely to be identified.

1.6.5 It should be noted that anomalies that are interpreted as modern in origin may 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.

1.6.6 A magnetic survey does not directly locate sub-surface features - it identifies variations or anomalies in the local magnetic field caused by features. It can be possible to interpret the cause of anomalies based on the size, shape and strength of response but it should be recognised that a magnetic survey produces a plan of magnetic variations and not a plan of all sub-surface features. Interpretation of the anomalies is often subjective and it is rarely possible to identify the cause of all magnetic anomalies. Geological or pedological (soil) variations or features can produce responses similar to those caused by man-made (anthropogenic) features.

1.6.7 Anomalies identified by a magnetic survey are located in plan. It is not usually possible to obtain reliable depth information on the features that cause the anomalies.

1.6.8 Not all features will produce a measurable magnetic response and the effectiveness of a magnetic survey is also dependant on the site-specific conditions. It is not possible to guarantee that a magnetic survey will identify all sub-surface features. A magnetic survey is often most-effective at identifying sub-surface features when used in conjunction with other complementary geophysical techniques.

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 geophysical 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 geophysical 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 geophysical 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.