



**PHASE**  
SITE INVESTIGATIONS

**Land off Pit Lane  
Wombwell  
South Yorkshire**

**Archaeological geophysical survey**

**Project No. ARC/3653/1374**

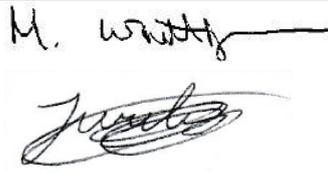
**December 2024**



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South Yorkshire**

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Date	09/12/24	Date	09/12/24



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## 1. SUMMARY

Phase Site Investigations Ltd was commissioned to carry out a magnetic gradient survey at land off Pit Lane, Wombwell, South Yorkshire. 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 MACS data was collected on profiles spaced 0.5 m apart with readings taken at between 0.1 and 0.15 m intervals.

The survey has identified a number of anomalies that are related to probable and possible archaeological features. The interpretation of some of these anomalies is not certain as the responses are fragmented, short and / or diffuse. Some of these could be related to archaeological features but it is possible that some could be a product of natural features / variations, agricultural or other modern activity. There are numerous anomalies of uncertain origin. The majority of these are probably related to agricultural, or other modern, activity or natural features / variations but it is possible that some could be associated with additional archaeological features / activity.

There are a large number of isolated responses across the site. There is known mining activity in the vicinity of the site and it is possible that some of the isolated responses could be related to mining features / activity, such as shafts or bellpits. But the majority of these responses will be related to other surface / near-surface material.

Anomalies have also been identified that are related to agricultural activity and sub-surface utility apparatus (pipe, drain or cable).

## 2. INTRODUCTION

### 2.1 Overview

Phase Site Investigations Ltd was commissioned by MAP Archaeological Practice Ltd to carry out an archaeological geophysical survey at land off Pit Lane, Wombwell, South Yorkshire, 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\_3653\_1374\_01.

### 2.2 Site description

The site is situated to the south of Pit Lane, on the western edge of Wombwell, South Yorkshire (approximate centre at NGR SE 387 028), approximately 5 km to the south-east of Barnsley and covered an area of approximately 7.4 ha.

The site encompassed three arable fields that had recently been seeded. The ground sloped upwards to the east and north and was soft underfoot. The edges of the fields were waterlogged and very soft underfoot as a result of recent heavy rainfall. The site was bounded to the north and west by hedgerows, to the east by garden fences and to the south by a metal fence and garden fences. Overhead cable posts with metal stays were present in the northern two fields.

The geology of the site consists of alternating bands of mudstone, siltstone and sandstone of the Pennine Middle Coal Measures Formation and sandstone of the Pennine Middle Coal Measures Formation with no recorded superficial deposits (British Geological Survey, 2024).

### 2.3 Archaeological background

An archaeology and heritage desk-based assessment (MAP Archaeological Practice, 2023) indicates that,

*'Late prehistoric and Romano-British activity is well documented within the vicinity of the site, including at the Scheduled site of 'Romano-British settlements in Wombwell Wood' located approximately 1.3 km from the site, and cropmarks depicting an enclosure approximately 190m to the west.'*

The desk-based assessment also gives details on a geophysical survey that was undertaken approximately 990 m to the north-west of the site, noting that,

*'Clearly defined linear features, which were interpreted as being of archaeological origin were identified in the results of the survey. The features likely relate to a field system and associated enclosures with possible pits also identified.'*

As for the site itself, the following is mentioned:

*'Given the prevalence of recognised archaeological activity within the vicinity of the site, LiDAR data was also consulted as part of this assessment [...]. With the exception of a possible north-east to south-west orientated linear feature, no obvious archaeological features were noted.'*

Additionally, the desk-based assessment notes that,



*'Wombwell Main Colliery, located to the north-west and immediate west of the site, operated between 1853 and 1969 and, at its peak operated over an area of 1300 acres [...]. Mineral extraction is well recorded in the area with bell pits also being recorded to the south of the site [...].*

*The first edition Ordnance Survey map depicts the site as agricultural land bounded to the north and east by a footpath and to the west by further farmland. [...]*

*By the late 19<sup>th</sup> century Ordnance Survey County Series mapping depicts a brick yard and kilns being present to the immediate west of the site, although no associated features are depicted within the site boundary.'*

## **2.4 Scope of work**

The survey area was specified by the client.

Due to the presence of waterlogged / soft boggy ground, overhead cable posts with metal stays and internal field boundaries, the area accessible / suitable for survey was reduced to approximately 6.3 ha, the extents of which are shown in drawing ARC\_3653\_1374\_02. For the purposes of this survey each field has been given a number.

No other problems were encountered during the survey which was carried out on 28 and 29 October 2024.



### 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 OSTN15 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 1:2500 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown at a scale of 1:1250. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.

The data is relatively 'noisy', with a disturbed / variable magnetic background in places, and so greyscale plots of the data have been shown at two ranges; a range of -2 nT to 3 nT, which is 'standard' for archaeological surveys and a relatively wide (for archaeological surveys) range of -5 to 5 nT. The latter smooths out the data and can make it easier to identify some anomalies but very weak responses may not be visible in the wider range.

The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing '*areas sk01.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 small / relatively weak isolated dipolar and bipolar anomalies present in the data. There is little evidence to suggest that they are associated with archaeological features and so the majority of these have not been shown in the interpretation. Isolated dipolar / bipolar responses have been shown in proximity to some anomalies that are suggestive of archaeological features and some responses of uncertain origin, as well as several large / strong isolated bipolar anomalies. These responses are all highly likely to be caused by modern material but the potential for these to be associated with archaeological features is increased slightly by their proximity to other anomalies / features. It is also possible that some of these anomalies could be related to mining features such as shafts or bellpits.

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 a field by field 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

There are a relatively large number of isolated responses across the site, which have contributed to the 'noisy' magnetic background. These are indicative of a spread of modern material. The responses could be related to 'green waste', which is added to manure but which contains significant amounts of ferrous material, or it could be from a spread of other modern material / debris. Only the larger / stronger isolated responses have been shown on the interpretation.

There are anomalies suggestive of archaeological features present in several parts of the site. Many of these anomalies are fragmented or discontinuous. It is possible that some of the sub-surface features associated with these responses were originally fragmented but it is considered more likely that many of the features have been differentially truncated by agricultural activity. Some anomalies may become weaker because the magnetic susceptibility of the soils infilling them has decreased or there may be an increase in soil cover. Where the responses become weaker or more diffuse, they are often shown as trends as it is not certain if a significant sub-surface feature is still present in that area, or if the magnetic responses is from the vestigial remains of a feature. Stronger responses, which may indicate where more extensive remains are present, have been shown as positive linear / curvi-linear responses.

It is worth noting that the underlying geology across the site is coal measures and Wombwell Main Colliery was, located to the north-west of the site. It is possible therefore that there could have been historic mining activity on the site. Mining features, such as bellpits or shafts, can produce responses that are similar to those from other modern near-surface features / material, and so it can be difficult to differentiate between them or identify / confirm the presence of potential mining activity but it is possible that some of the isolated responses identified by this survey could be associated with mining activity.

### 4.2 Field 1

- Basic topography:** Upwards slope to the north and east.
- Field description:** Arable field that had been recently seeded. The field was soft underfoot and waterlogged / boggy in places, particularly around the edges. The field was bounded by garden fences to the east and by hedgerows in the other directions. An overhead cable post was present adjacent to the northern field boundary.
- 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 isolated dipolar and bipolar responses have been shown. These will be related to concentrations, or larger objects or features, of relatively modern ferrous or fired material. At this site it is likely that they are not archaeologically significant but have been shown to highlight areas where there may be more substantial / larger relatively modern material / objects.
- 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.

Several series of linear responses are present associated with modern ploughing regime(s).

Trends of uncertain origin. Some are related to parts of infilled features / remnants of features but the majority are of uncertain origin.

Numerous isolated positive responses, the majority of which are probably related to relatively modern buried ferrous / fired material or natural features / variations but some could be caused by other features / activity. There are a relatively large number of these responses and so only selected large / strong responses have been shown on the interpretation.

Positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural, drainage or natural features but it is possible that some area caused by infilled archaeological features.

Positive linear / curvi-linear responses indicative of infilled features. These could be associated with infilled archaeological features but some could be related to agricultural, drainage or natural features.

#### **Further discussion / additional information:**

**Anomaly 1A** is a broad, diffuse, but relatively strong positive linear anomaly. The diffuse nature of the response could suggest that it is related to a natural feature but it appears to be on the same alignment as more coherent, albeit weaker responses to the south-west (**Anomalies 1B**). It is likely that the anomalies are related to an infilled ditch and the diffuse response of Anomaly 1A could indicate where the material infilling the ditch has been spread by ploughing activity. It is also possible that the anomalies are related to a combination of anthropogenic and natural features. **Anomalies 1C** are nearby anomalies that are suggestive of an infilled ditch. It is not certain if these are related to / respect Anomalies 1A and 1B or if the feature terminates.

There are a number of linear / curvi-linear responses in the north of field (**Anomalies 1D**), some of which are relatively diffuse. It is possible that some of these could be related to infilled features, including archaeological ditches, but some could be natural features or be caused by agricultural activity.

There are numerous other trends across the survey area that are generally relatively weak, short and / or diffuse and so cannot be reliably interpreted. They do not form any obvious patterns or relationships that would indicate that they are associated with sub-surface features and it is likely that the majority of them are a product of agricultural, or other modern, activity or natural variations. Several of these trends stand out slightly (**Anomalies 1E**) as they are more coherent or regular in shape and these may have greater potential to be related to sub-surface features.

There is a cluster of isolated responses (**Anomalies 1F**) in the north-west of the area, some of which may form generally linear alignments (shown as trends). It is possible that some of these responses could be related to archaeological features / activity but it is also possible that



they are a product of modern activity, including potentially mining activity. There are a number of other isolated responses across the area that could, potentially, be related to mining activity (**Anomalies 1G**), although it is likely that the majority of these will be related to other modern material. Should mining activity be identified on the site then it is also possible that some of the remaining smaller / weaker isolated responses could also be related to mining activity but it is likely that a large majority of these will be related to other surface / near-surface material.

### 4.3 Field 2

**Basic topography:**

Steep upwards slope to the east.

**Field description:**

Arable field that had been recently seeded. The field was soft underfoot and waterlogged / boggy in places, particularly around the edges. The field was bounded by garden fences to the east and by hedgerows in the other directions. Overhead cable posts with metal stays were present adjacent to the northern and eastern field boundaries (the latter was in an area that could not be surveyed due to the ground conditions).

**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 isolated dipolar and bipolar responses have been shown. These will be related to concentrations, or larger objects or features, of relatively modern ferrous or fired material. At this site it is likely that they are not archaeologically significant but have been shown to highlight areas where there may be more substantial / larger relatively modern material / objects.

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

Linear bipolar anomalies associated with sub-surface utility apparatus (pipe, drain or cable).

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.

Series of linear responses are present associated with modern ploughing regime(s).

Trends of uncertain origin. Some are related to parts of possible infilled features / remnants of features but the majority are of uncertain origin.

Numerous isolated positive responses, the majority of which are probably related to relatively modern buried ferrous / fired material or natural features / variations but some could be caused by other features / activity. There are a relatively large number of these responses and so only selected large / strong responses have been shown on the interpretation.

Positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural, drainage or natural features but it is possible that some area caused by infilled archaeological features.

Positive linear / curvi-linear responses indicative of infilled features. These could be associated with infilled archaeological features but some could be related to agricultural, drainage or natural features.

#### **Further discussion / additional information:**

**Anomalies 2A** are broad, diffuse positive linear / curvi-linear anomalies. Diffuse responses are often related to natural features / variations and whilst this could be the case here it is thought more likely that these anomalies are related to infilled ditches. The diffuse responses could indicate where the material infilling the ditch has been spread by ploughing activity. **Anomalies 2B** are shorter / weaker and so the interpretation of these is less certain and it is not clear if they relate to natural or anthropogenic features / activity.

There are numerous trends across the survey area that are generally relatively weak, short and / or diffuse and so cannot be reliably interpreted. They do not form any obvious patterns or relationships that would indicate that they are associated with sub-surface features and it is likely that the majority of them are a product of agricultural, or other modern, activity or natural variations. Several of these trends stand out slightly (**Anomalies 2C**) as they are more coherent or regular in shape and these may have greater potential to be related to sub-surface features.

There are a large number of isolated responses and several areas of magnetic disturbance across the area and some of these could, potentially, be related to mining activity, although it is likely that the majority of these will be related to other modern material. **Anomalies 2D** stand out as they are large strong responses and **Anomalies 2E** are relatively large / strong. These could all have potential to be related to sub-surface features, with Anomalies 2D possibly being related to larger / more substantial features but they could all also be related to other sub-surface material. If mining activity is identified on the site, then it is also possible that some of the remaining smaller / weaker isolated responses could also be related to mining activity but it is likely that a large majority of these will be related to other surface / near-surface material.

#### **4.4 Field 3**

<b>Basic topography:</b>	Steep upwards slope to the east.
<b>Field description:</b>	Arable field that had been recently seeded. The field was soft underfoot and waterlogged / boggy in places, particularly around the edges. The field was bounded by garden fences to the east, a metal fence and garden fences to the south and by hedgerows in the other directions.
<b>Summary of anomalies:</b>	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 isolated dipolar and bipolar responses have been shown. These will be related to concentrations, or larger objects or features, of relatively modern ferrous or fired material. At this site it is

likely that they are not archaeologically significant but have been shown to highlight areas where there may be more substantial / larger relatively modern material / objects.

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

A linear bipolar anomaly associated with sub-surface utility apparatus (pipe 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.

Series of linear responses are present associated with modern ploughing regime(s).

Trends of uncertain origin. Some are related to parts of possible infilled features / remnants of features but the majority are of uncertain origin.

Numerous isolated positive responses, the majority of which are probably related to relatively modern buried ferrous / fired material or natural features / variations but some could be caused by other features / activity. There are a relatively large number of these responses and so only selected large / strong responses have been shown on the interpretation.

Positive linear / curvi-linear responses of uncertain origin. Some responses may be related to agricultural, drainage or natural features but it is possible that some area caused by infilled archaeological features.

Positive linear / curvi-linear responses indicative of infilled features. These could be associated with infilled archaeological features but some could be related to agricultural, drainage or natural features.

#### **Further discussion / additional information:**

**Anomalies 3A** are linear / curvi-linear anomalies that, although they are diffuse and fragmented, are suggestive of infilled ditches. **Anomalies 3B** could be continuations of one of these features but it is possible that these are related to agricultural activity (they are broadly aligned with the current field boundary). **Anomalies 3C** are in the vicinity of Anomalies 3A and could be related to sub-surface features but these are too weak to reliably interpret and it is possible that they are related to natural variations or agricultural activity.

There are numerous trends across the survey area that are generally relatively weak, short and / or diffuse and so cannot be reliably interpreted. They do not form any obvious patterns or relationships that would indicate that they are associated with sub-surface features and it is likely that the majority of them are a product of agricultural, or other modern, activity or natural variations. Several of these trends stand out slightly (**Anomalies 3D**) as they are



more coherent or regular in shape and these may have greater potential to be related to sub-surface features.

There are a large number of isolated responses and several areas of magnetic disturbance across the area and some of these could, potentially, be related to mining activity, although it is likely that the majority of these will be related to other modern material. **Anomalies 3E** stand out as they are large strong responses and **Anomalies 3F** are relatively large / strong. These could all have potential to be related to sub-surface features, with Anomalies 3E possibly being related to larger / more substantial features but they could all also be related to other sub-surface material. If mining activity is identified on the site, then it is also possible that some of the remaining smaller / weaker isolated responses could also be related to mining activity but it is likely that a large majority of these will relate to other surface / near-surface material.



## 5. DISCUSSION AND CONCLUSIONS

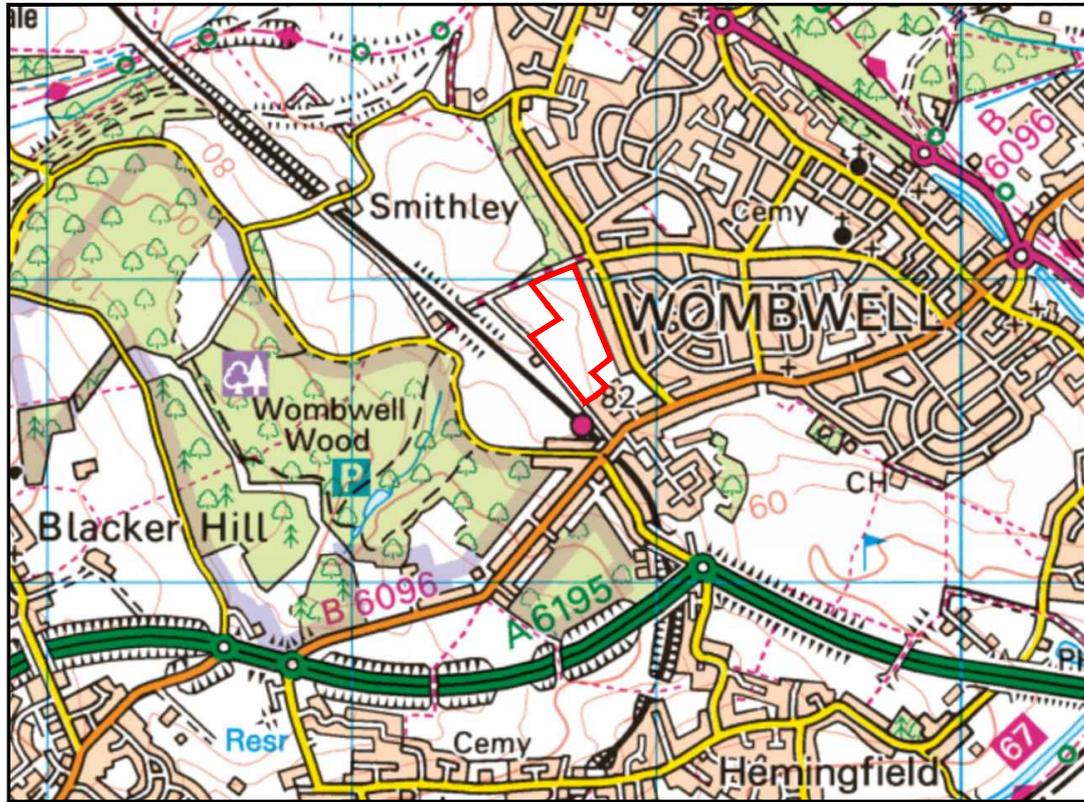
The survey has identified a number of anomalies that are related to probable and possible archaeological features. The interpretation of some of these anomalies is not certain as the responses are fragmented, short and / or diffuse. Some of these could be related to archaeological features but it is possible that some could be a product of natural features / variations, agricultural or other modern activity. There are numerous anomalies of uncertain origin. The majority of these are probably related to agricultural, or other modern, activity or natural features / variations but it is possible that some could be associated with additional archaeological features / activity.

There are a large number of isolated responses across the site. There is known mining activity in the vicinity of the site and it is possible that some of the isolated responses could be related to mining features / activity, such as shafts or bellpits. But the majority of these responses will be related to other surface / near-surface material.

Anomalies have also been identified that are related to agricultural activity and sub-surface utility apparatus (pipe, drain or cable).



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SE 37

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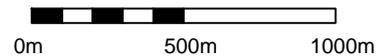
03

02



SITE LOCATION

SCALE



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Scale [A4 Sheet]	Drawing	Status
AS SHOWN	ARC_3653_1374_01	FINAL

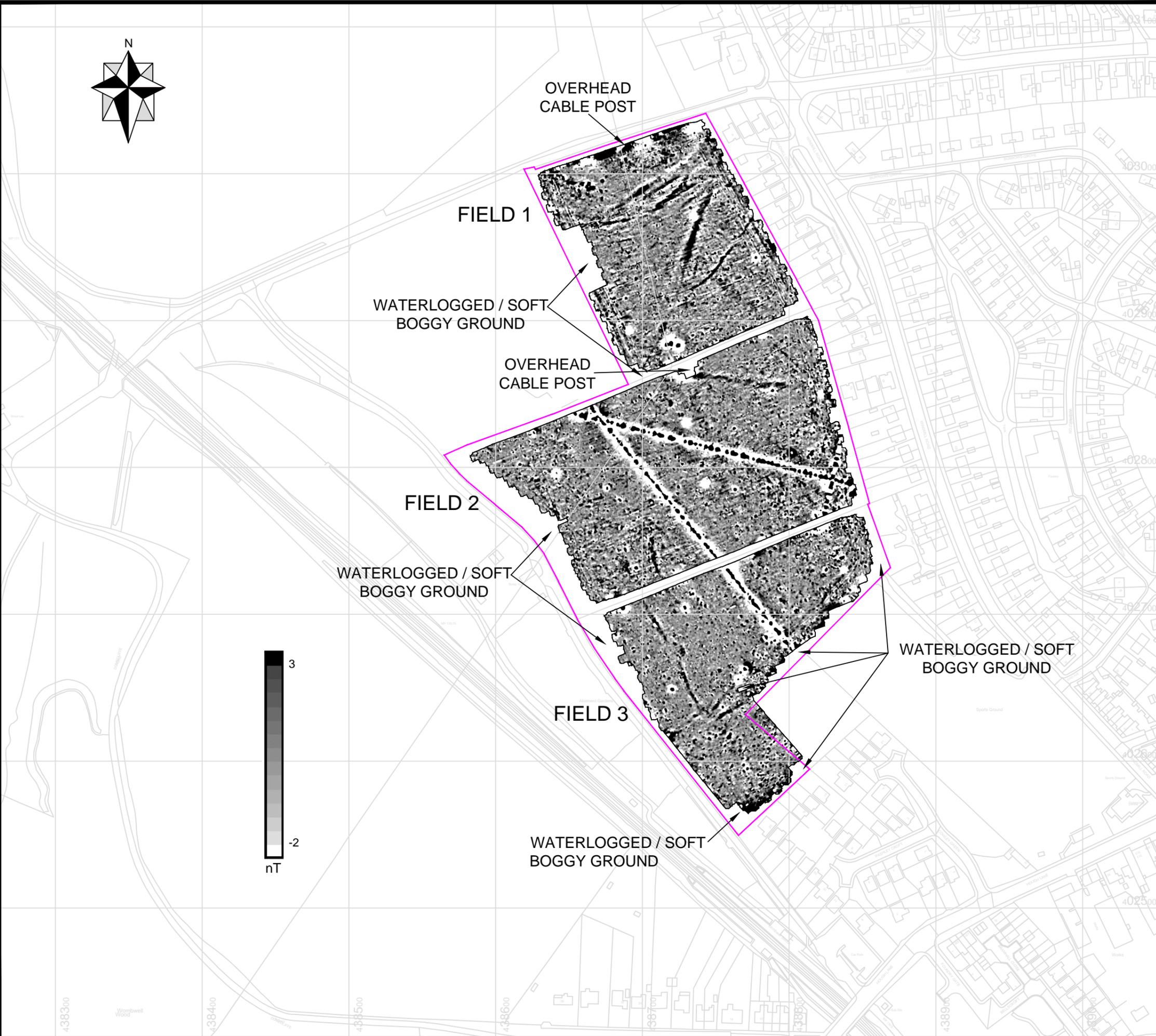
Client	MAP ARCHAEOLOGICAL PRACTICE LTD MALTON
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Site	LAND OFF PIT LANE WOMBWELL SOUTH YORKSHIRE
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Title	SITE LOCATION MAP
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Job No	ARC_3653_1374
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Chk.	MW	Drawn	JG
		Date	30/10/2024



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**KEY**

— SITE BOUNDARY

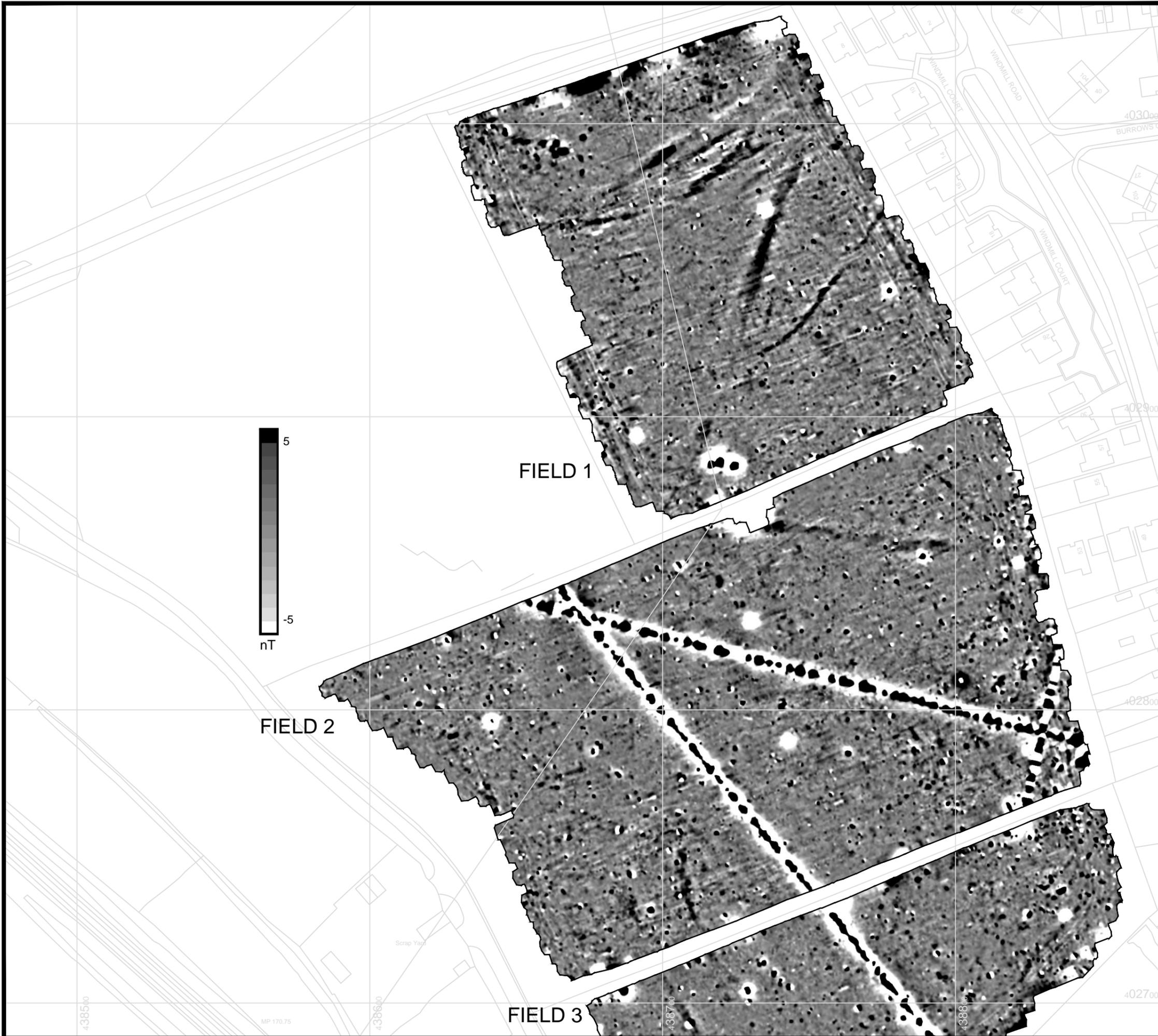


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Scale	[A3 Sheet]	Drawing	Status
1:2500		ARC_3653_1374_02	FINAL
Client	MAP ARCHAEOLOGICAL PRACTICE LTD MALTON		
Site	LAND OFF PIT LANE WOMBWELL SOUTH YORKSHIRE		
Title	LOCATION OF SITE SHOWING MAGNETIC GRADIENT DATA (‘STANDARD’ RANGE)		
ARC_3653_1374			
Surveyed	JW, JG, MP	Drawn	JW
Chk.	MW	Date	29/10/2024



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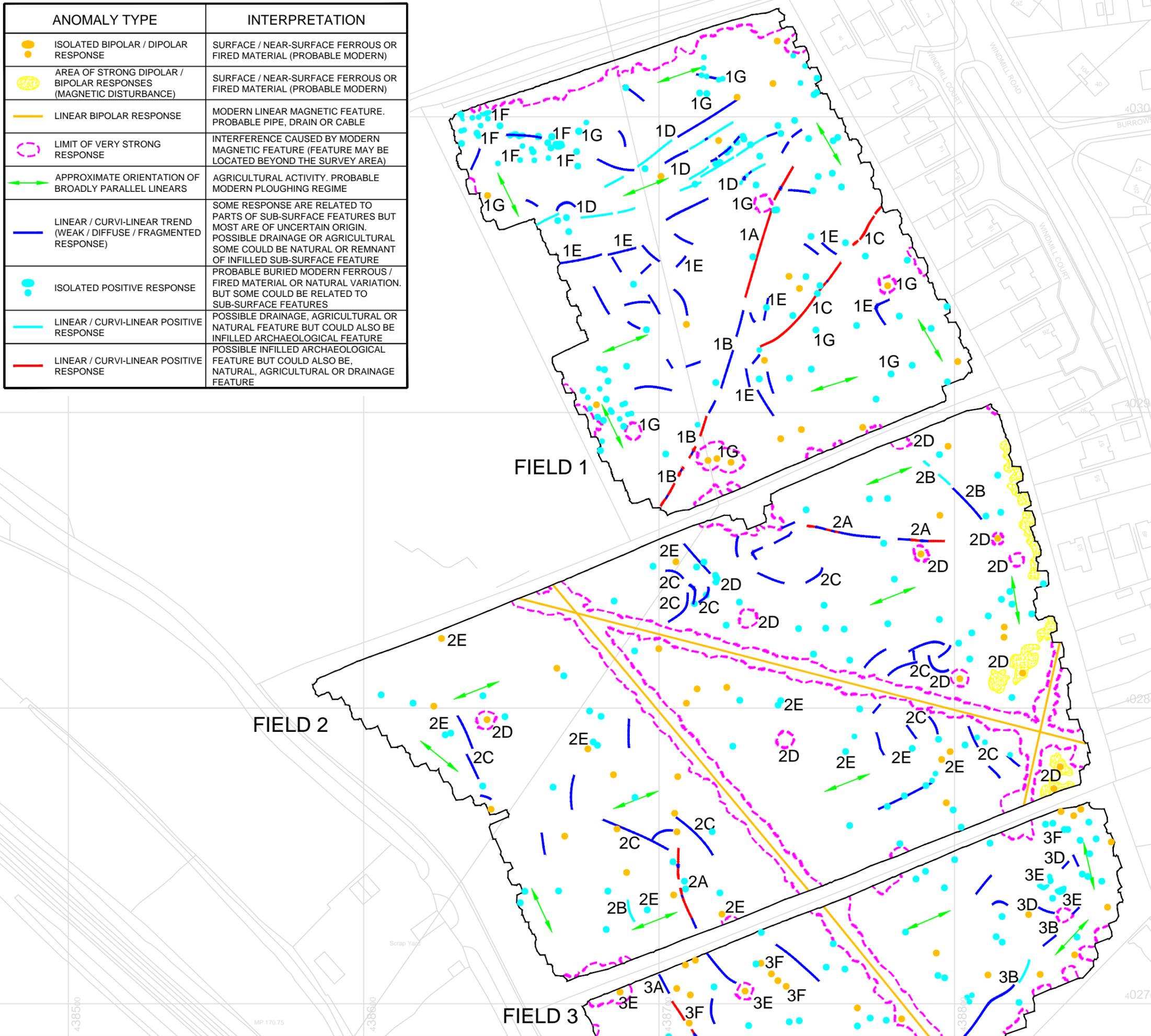


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Scale	[A3 Sheet]	Drawing	Status
1:1250		ARC_3653_1374_03	FINAL
Client			
MAP ARCHAEOLOGICAL PRACTICE LTD MALTON			
Site			
LAND OFF PIT LANE WOMBWELL SOUTH YORKSHIRE			
Title			
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA (RELATIVELY WIDE RANGE): FIELDS 1, 2 AND PART OF FIELD 3			
ARC_3653_1374			
Surveyed	JW, JG, MP	Drawn	JW
Chk.	MW	Date	29/10/2024

ANOMALY TYPE	INTERPRETATION
	ISOLATED BIPOLAR / DIPOLAR 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)
	LINEAR BIPOLAR RESPONSE 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 LINEARS AGRICULTURAL ACTIVITY. PROBABLE MODERN PLOUGHING REGIME
	LINEAR / CURVI-LINEAR TREND (WEAK / DIFFUSE / FRAGMENTED RESPONSE) SOME RESPONSE ARE RELATED TO PARTS OF SUB-SURFACE FEATURES BUT MOST ARE OF UNCERTAIN ORIGIN. POSSIBLE DRAINAGE OR AGRICULTURAL SOME COULD BE NATURAL OR REMNANT OF INFILLED SUB-SURFACE FEATURE
	ISOLATED POSITIVE RESPONSE PROBABLE BURIED MODERN FERROUS / FIRED MATERIAL OR NATURAL VARIATION. BUT SOME COULD BE RELATED TO SUB-SURFACE FEATURES
	LINEAR / CURVI-LINEAR POSITIVE RESPONSE POSSIBLE DRAINAGE, AGRICULTURAL OR NATURAL FEATURE BUT COULD ALSO BE INFILLED ARCHAEOLOGICAL FEATURE
	LINEAR / CURVI-LINEAR POSITIVE RESPONSE POSSIBLE INFILLED ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE, NATURAL, AGRICULTURAL OR DRAINAGE FEATURE



### NOTES

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Scale	[A3 Sheet] 1:1250	Drawing	ARC_3653_1374_04	Status	FINAL
Client	MAP ARCHAEOLOGICAL PRACTICE LTD MALTON				
Site	LAND OFF PIT LANE WOMBWELL SOUTH YORKSHIRE				
Title	INTERPRETATION OF MAGNETIC GRADIENT DATA: FIELDS 1, 2 AND PART OF FIELD 3				
ARC_3653_1374					
Surveyed	JW, JG, MP	Drawn	JW		
Chk.	MW	Date	29/10/2024		



**NOTES**

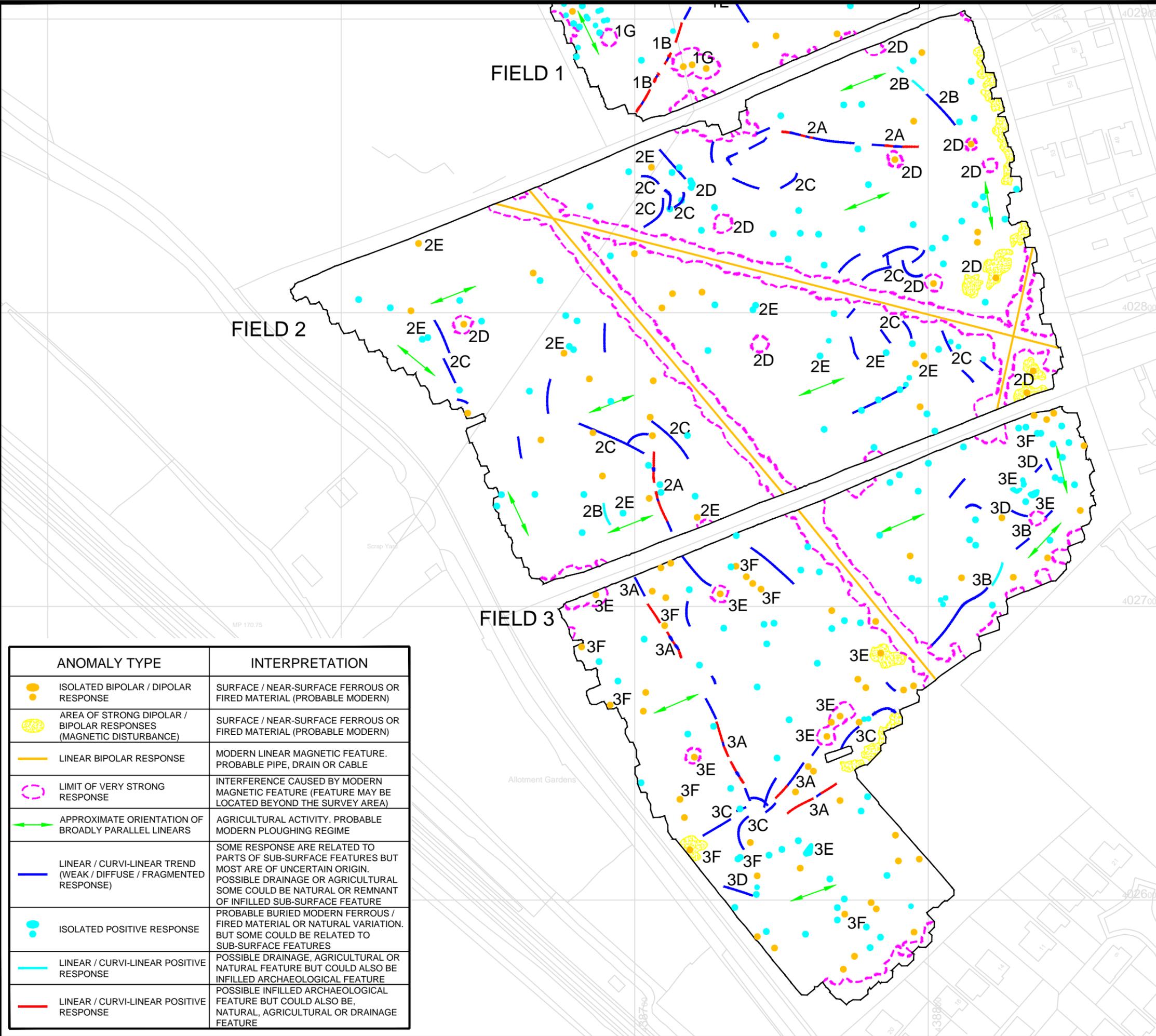
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Scale	[A3 Sheet]	Drawing	Status
1:1250		ARC_3653_1374_05	FINAL
Client			
MAP ARCHAEOLOGICAL PRACTICE LTD MALTON			
Site			
LAND OFF PIT LANE WOMBWELL SOUTH YORKSHIRE			
Title			
GREYSCALE PLOTS OF MAGNETIC GRADIENT DATA (RELATIVELY WIDE RANGE): FIELDS 2, 3 AND PART OF FIELD 1			
ARC_3653_1374			
Surveyed	JW, JG, MP	Drawn	JW
Chk.	MW	Date	29/10/2024



**NOTES**

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ANOMALY TYPE	INTERPRETATION
ISOLATED BIPOLAR / DIPOLAR 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)
LINEAR BIPOLAR RESPONSE	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 LINEARS	AGRICULTURAL ACTIVITY. PROBABLE MODERN PLOUGHING REGIME
LINEAR / CURVI-LINEAR TREND (WEAK / DIFFUSE / FRAGMENTED RESPONSE)	SOME RESPONSE ARE RELATED TO PARTS OF SUB-SURFACE FEATURES BUT MOST ARE OF UNCERTAIN ORIGIN. POSSIBLE DRAINAGE OR AGRICULTURAL SOME COULD BE NATURAL OR REMNANT OF INFILLED SUB-SURFACE FEATURE
ISOLATED POSITIVE RESPONSE	PROBABLE BURIED MODERN FERROUS / FIRED MATERIAL OR NATURAL VARIATION. BUT SOME COULD BE RELATED TO SUB-SURFACE FEATURES
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE DRAINAGE, AGRICULTURAL OR NATURAL FEATURE BUT COULD ALSO BE INFILLED ARCHAEOLOGICAL FEATURE
LINEAR / CURVI-LINEAR POSITIVE RESPONSE	POSSIBLE INFILLED ARCHAEOLOGICAL FEATURE BUT COULD ALSO BE, NATURAL, AGRICULTURAL OR DRAINAGE FEATURE

Scale	[A3 Sheet]	Drawing	Status
1:1250		ARC_3653_1374_06	FINAL
Client	MAP ARCHAEOLOGICAL PRACTICE LTD MALTON		
Site	LAND OFF PIT LANE WOMBWELL SOUTH YORKSHIRE		
Title	INTERPRETATION OF MAGNETIC GRADIENT DATA: FIELDS 2, 3 AND PART OF FIELD 1		
ARC_3653_1374			
Surveyed	JW, JG, MP	Drawn	JW
Chk.	MW	Date	29/10/2024



## **BIBLIOGRAPHY AND REFERENCES**

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Archaeology and Heritage Desk Based Assessment

## 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 thermoremanent 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 Thermoremanent 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.

## **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 OSTN15 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  $\pm 10,000$ nT 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 1:2500 and plots for individual fields / areas (or parts of fields / areas) with accompanying interpretations are shown at a scale of 1:1250. Greyscale plots have been 'smoothed' using a visual interpolation but the data itself has not been interpolated.
- 1.4.3 The data is relatively 'noisy', with a disturbed / variable magnetic background in places, and so greyscale plots of the data have been shown at two ranges; a range of -2 nT to 3 nT, which is 'standard' for archaeological surveys and a relatively wide (for archaeological surveys) range of -5 to 5 nT. The latter smooths out the data and can make it easier to identify some anomalies but very weak responses may not be visible in the wider range.
- 1.4.4 The data has been displayed relative to a digital Ordnance Survey base plan provided by the client as drawing '*areas sk01.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.

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

### **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.

There are no anomalies of this type in this data set.

### **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 the majority of 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 linear / curvi-linear** anomalies can be associated with agricultural / drainage activity, or sometimes infilled natural 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.

The positive linear / curvi-linear anomalies at this site are believed to be caused by probable / possible archaeological features and / or agricultural activity / drainage features.

- 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.