

# Geophysical Survey Report

## Bullinghope, Hereford

for

**Worcestershire County Council**

May 2008

Job Ref: J2479

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**Document Title:**        **Geophysical Survey Report  
Bullinghope, Hereford**

**Client:**                    **Worcestershire County Council**

**Stratascan Job No:**    **J2479**

**Techniques:**            **Detailed magnetic survey (gradiometry)**

**National Grid Ref:**    **SO 513 377**



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LIST OF FIGURES.....	2
1 SUMMARY OF RESULTS.....	3
2 INTRODUCTION.....	3
2.1 Background synopsis.....	3
2.2 Site location.....	3
2.3 Description of site .....	3
2.4 Geology and soils .....	3
2.5 Site history and archaeological potential .....	3
2.6 Survey objectives .....	4
2.7 Survey methods .....	4
3 METHODOLOGY .....	4
3.1 Date of fieldwork .....	4
3.2 Grid locations .....	4
3.3 Survey equipment.....	4
3.4 Sampling interval, depth of scan, resolution and data capture.....	5
3.4.1 Sampling interval .....	5
3.4.2 Depth of scan and resolution.....	5
3.4.3 Data capture.....	5
3.5 Processing, presentation of results and interpretation.....	6
3.5.1 Processing.....	6
3.5.2 Presentation of results and interpretation.....	6
4 RESULTS.....	7
4.1 Area 1 .....	7
4.2 Area 2 .....	7
4.3 Area 3 .....	7
5 CONCLUSION .....	8
APPENDIX A – Basic principles of magnetic survey .....	9
APPENDIX B – Glossary of magnetic anomalies .....	10

## LIST OF FIGURES

- |           |          |  |
|-----------|----------|--|
| Figure 1  | 1:25 000 | General location plan                                      |
| Figure 2  | 1:2000   | Site plan showing location of grids and referencing        |
| Figure 3  | 1:1250   | Plot of raw magnetometer data- Areas 1 and 2               |
| Figure 4  | 1:1500   | Trace plot showing positive values- Areas 1 and 2          |
| Figure 5  | 1:1500   | Trace plot showing negative values- Areas 1 and 2          |
| Figure 6  | 1:1250   | Plot of processed magnetometer data- Areas 1 and 2         |
| Figure 7  | 1:1250   | Abstraction and interpretation of anomalies- Areas 1 and 2 |
| Figure 8  | 1:1000   | Plot of raw magnetometer data- Area 3                      |
| Figure 9  | 1:1000   | Trace plot showing positive values- Area 3                 |
| Figure 10 | 1:1000   | Trace plot showing negative values- Area 3                 |
| Figure 11 | 1:1000   | Plot of processed magnetometer data- Area 3                |
| Figure 12 | 1:1000   | Abstraction and interpretation of anomalies- Area 3        |

## **1 SUMMARY OF RESULTS**

The geophysical survey undertaken over 4.8ha of agricultural land at Bullinghope has identified a number of anomalies of possible archaeological origin. Positive anomalies indicate the presence of cut features such as ditches, whereas negative anomalies represent possible former earthworks or banks. Magnetic disturbance related to made ground and near-by metallic objects has affected the data in a number of areas.

## **2 INTRODUCTION**

### **2.1 Background synopsis**

Stratascan were commissioned to undertake a geophysical survey of an area outlined for development. This survey forms part of an archaeological investigation being undertaken by Worcestershire County Council.

### **2.2 Site location**

The site is located near Bullinghope, Hereford at OS ref. SO 513 377.

### **2.3 Description of site**

The survey area consists of 4.8ha of flat agricultural land separated into 3 survey areas.

### **2.4 Geology and soils**

The underlying geology is Lower Old Red Sandstone (British Geological Survey South Sheet, Fourth Edition Solid, 2001).

The overlying soils are known as Newnham which are typical brown earths. These consist of well drained reddish coarse and fine loamy soils over gravel (Soil Survey of England and Wales, Sheet 3 Midland and Western England).

### **2.5 Site history and archaeological potential**

A desk based assessment compiled by Herefordshire Archaeology states that the site has high potential for prehistoric and Roman remains. This would suggest that there is potential for anomalies of an archaeological origin within the survey data.

## 2.6 Survey objectives

The objective of the survey was to locate any features of possible archaeological significance in order that they may be assessed prior to development.

## 2.7 Survey methods

Detailed magnetic survey (gradiometry) was used as an efficient and effective method of locating archaeological anomalies. More information regarding this technique is included in the Methodology section below.

# 3 **METHODOLOGY**

## 3.1 Date of fieldwork

The fieldwork was carried out over three days from 19<sup>th</sup> May 2008. Weather conditions during the survey were dry and sunny.

## 3.2 Grid locations

The location of the survey grids is based on the Ordnance Survey National Grid, see Figure 2. The referencing and alignment of grids was achieved using a Leica DGPS System 500.

A DGPS (differential Global Positioning System) can locate a point on the ground to a far greater accuracy than a standard GPS unit. A standard GPS suffers from errors created by satellite orbit errors, clock errors and atmospheric interference, resulting in an accuracy of 5m-10m. Calculations to correct for these errors are performed at an accurately located base station. The base station then transmits the corrections which are received by DGPS consoles giving sub metre accuracy averaging around 0.5m error.

## 3.3 Survey equipment

Although the changes in the magnetic field resulting from differing features in the soil are usually weak, changes as small as 0.2 nanoTesla (nT) in an overall field strength of 48,000nT, can be accurately detected using an appropriate instrument.

The mapping of the anomaly in a systematic manner will allow an estimate of the type of material present beneath the surface. Strong magnetic anomalies will be generated by buried iron-based objects or by kilns or hearths. More subtle anomalies such as pits and ditches can be seen if they contain more humic material which is normally rich in magnetic iron oxides when compared with the subsoil.

To illustrate this point, the cutting and subsequent silting or backfilling of a ditch may result in a larger volume of weakly magnetic material being accumulated in the trench compared to the undisturbed subsoil. A weak magnetic anomaly should therefore appear in plan along the line of the ditch.

The magnetic survey was carried out using a dual sensor Grad601-2 Magnetic Gradiometer manufactured by Bartington Instruments Ltd. The instrument consists of two fluxgates very accurately aligned to nullify the effects of the Earth's magnetic field. Readings relate to the difference in localised magnetic anomalies compared with the general magnetic background. The Grad601-2 consists of two high stability fluxgate gradiometers suspended on a single frame. Each gradiometer has a 1m separation between the sensing elements so enhancing the response to weak anomalies.

### 3.4 Sampling interval, depth of scan, resolution and data capture

#### 3.4.1 Sampling interval

Readings were taken at 0.25m centres along traverses 1m apart. This equates to 3600 sampling points in a full 30m x 30m grid.

#### 3.4.2 Depth of scan and resolution

The Grad 601 has a typical depth of penetration of 0.5m to 1.0m. This would be increased if strongly magnetic objects have been buried in the site. The collection of data at 0.5m centres provides an optimum methodology for the task balancing cost and time with resolution.

#### 3.4.3 Data capture

The readings are logged consecutively into the data logger which in turn is daily downloaded into a portable computer whilst on site. At the end of each job, data is transferred to the office for processing and presentation.

### 3.5 Processing, presentation of results and interpretation

#### 3.5.1 Processing

Processing is performed using specialist software known as *Geoplot 3*. This can emphasise various aspects contained within the data but which are often not easily seen in the raw data. Basic processing of the magnetic data involves 'flattening' the background levels with respect to adjacent traverses and adjacent grids. 'Despiking' is also performed to remove the anomalies resulting from small iron objects often found on agricultural land. Once the basic processing has flattened the background it is then possible to carry out further processing which may include low pass filtering to reduce 'noise' in the data and hence emphasise the archaeological or man-made anomalies.

The following schedule shows the basic processing carried out on all processed gradiometer data used in this report:

1. *Despike* (useful for display and allows further processing functions to be carried out more effectively by removing extreme data values)

*Geoplot parameters:*

X radius = 1, y radius = 1, threshold = 3 std. dev.  
Spike replacement = mean

2. *Zero mean grid* (sets the background mean of each grid to zero and is useful for removing grid edge discontinuities)

*Geoplot parameters:*

Threshold = 0.25 std. dev.

3. *Zero mean traverse* (sets the background mean of each traverse within a grid to zero and is useful for removing striping effects)

*Geoplot parameters:*

Least mean square fit = off

#### 3.5.2 Presentation of results and interpretation

The presentation of the data for each site involves a print-out of the raw data both as greyscale (Figures 3 and 8) and trace plots (Figures 4, 5, 9 and 10), together with a greyscale plot of the processed data (Figures 6 and 11). Magnetic anomalies have been identified and plotted onto the 'Abstraction and Interpretation of Anomalies' drawing for the site (Figures 7 and 12).



## 4 RESULTS

### 4.1 Area 1

The data collected in Area 1 is dominated by the presence of magnetic disturbance caused by made ground that is likely to be related to the railway located immediately north of this survey area.

Positive linear and area anomalies are evident within this survey area. These anomalies indicate the presence of cut features such as ditches and may be of an archaeological origin. A sub-rectangular feature made up of these anomalies can be seen in the central regions of Area 1. Parallel sets of positive linear anomalies evident in the central and eastern limits of the survey area have been interpreted as being related to agricultural activity.

A number of discrete positive anomalies can be noted in this area. These anomalies indicate the presence of pits of a possible archaeological origin.

A negative linear anomaly is evident in the central region of Area 1. This anomaly may represent a former earthwork or bank.

### 4.2 Area 2

A number of positive linear anomalies are evident in Area 2. Some of these anomalies have been attributed to agricultural activity, however many of them have been interpreted as being related to cut features such as ditches of an archaeological origin.

Discrete positive anomalies identified within this survey area have been interpreted as pits of a possible archaeological origin.

Bipolar anomalies spread across the survey area indicate the presence of buried ferrous objects.

### 4.3 Area 3

Positive linear and area anomalies representing cut features of a possible archaeological origin are evident across this survey area. A number of curvilinear and sub circular features can also be noted both in the northern and southern limits.

Discrete positive anomalies are evident within Area 3. The majority are located south of the dividing fence. These anomalies have been interpreted as pits of a possible archaeological origin.

Magnetic disturbance related to fence-lines, pipes and the railway may mask any subtle archaeological features that may be present within this survey area.

## 5 CONCLUSION

Anomalies of a possible archaeological origin have been identified in each of the three areas surveyed at Bullinghope. The most common features are positive linear anomalies which represent cut features such as ditches. The majority of these anomalies are located in Area 3 which may suggest a centre of activity in this area.

Discrete positive anomalies, representing pits of a possible archaeological origin, are also evident in each of the three survey areas with a concentration in Area 3.

Magnetic disturbance can be noted in each of the survey areas and is particularly prevalent in Area 1. This disturbance, related to metallic objects and made ground, may mask subtle features of an archaeological origin that may be present in these areas.

## 6 REFERENCES

British Geological Survey, 2001. *Geological Survey Ten Mile Map, South Sheet, Fourth Edition (Solid)*. British Geological Society.

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 3 Midland and Western England*.

### APPENDIX A – Basic principles of magnetic survey

Detailed magnetic survey can be used to effectively define areas of past human activity by mapping spatial variation and contrast in the magnetic properties of soil, subsoil and bedrock.

Weakly magnetic iron minerals are always present within the soil and areas of enhancement relate to increases in *magnetic susceptibility* and permanently magnetised *thermoremnant* material.

Magnetic susceptibility relates to the induced magnetism of a material when in the presence of a magnetic field. This magnetism can be considered as effectively permanent as it exists within the Earth's magnetic field. Magnetic susceptibility can become enhanced due to burning and complex biological or fermentation processes.

Thermoremnance is a permanent magnetism acquired by iron minerals that, after heating to a specific temperature known as the Curie Point, are effectively demagnetised followed by re-magnetisation by the Earth's magnetic field on cooling. Thermoremnant archaeological features can include hearths and kilns and material such as brick and tile may be magnetised through the same process.

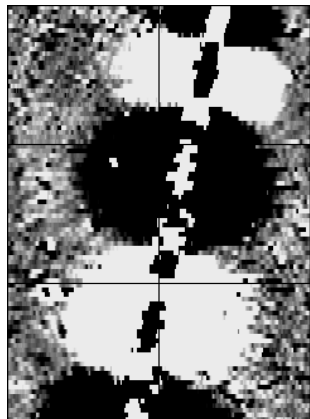
Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement allowing assessment and characterisation of subsurface features. Material such as subsoil and non-magnetic bedrock used to create former earthworks and walls may be mapped as areas of lower enhancement compared to surrounding soils.

Magnetic survey is carried out using a fluxgate gradiometer which is a passive instrument consisting of two sensors mounted vertically either 0.5 or 1m apart. The instrument is carried about 30cm above the ground surface and the top sensor measures the Earth's magnetic field whilst the lower sensor measures the same field but is also more affected by any localised buried field. The difference between the two sensors will relate to the strength of a magnetic field created by a buried feature, if no field is present the difference will be close to zero as the magnetic field measured by both sensors will be the same.

Factors affecting the magnetic survey may include soil type, local geology, previous human activity, disturbance from modern services etc.

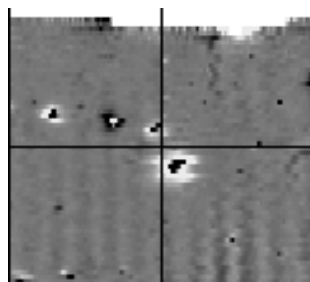
## APPENDIX B – Glossary of magnetic anomalies

### Bipolar



A bipolar anomaly is one that is composed of both a positive response and a negative response. It can be made up of any number of positive responses and negative responses. For example a pipeline consisting of alternating positive and negative anomalies is said to be bipolar. See also dipolar which has only one area of each polarity. The interpretation of the anomaly will depend on the magnitude of the magnetic field strength. A weak response may be caused by a clay field drain while a strong response will probably be caused by a metallic service.

### Dipolar

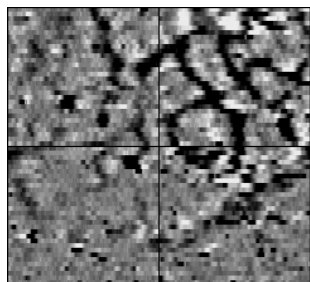


This consists of a single positive anomaly with an associated negative response. There should be no separation between the two polarities of response. These responses will be created by a single feature. The interpretation of the anomaly will depend on the magnitude of the magnetic measurements. A very strong anomaly is likely to be caused by a ferrous object.

### Positive anomaly with associated negative response

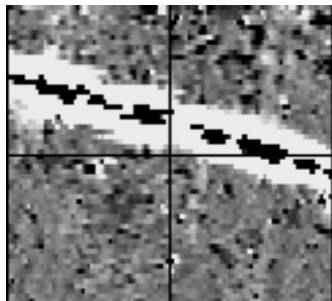
See bipolar and dipolar.

### Positive linear



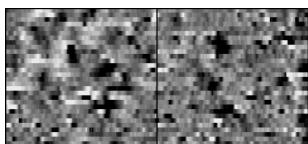
A linear response which is entirely positive in polarity. These are usually related to infilled cut features where the fill material is magnetically enhanced compared to the surrounding matrix. They can be caused by ditches of an archaeological origin, but also former field boundaries, ploughing activity and some may even have a natural origin.

### Positive linear anomaly with associated negative response



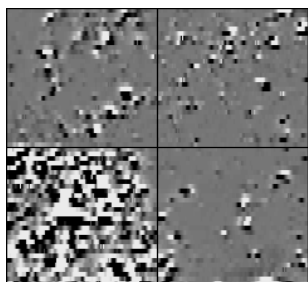
A positive linear anomaly which has a negative anomaly located adjacently. This will be caused by a single feature. In the example shown this is likely to be a single length of wire/cable probably relating to a modern service. Magnetically weaker responses may relate to earthwork style features and field boundaries.

### Positive point/area



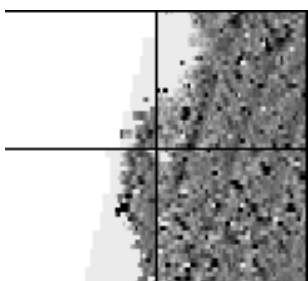
These are generally spatially small responses, perhaps covering just 3 or 4 reading nodes. They are entirely positive in polarity. Similar to positive linear anomalies they are generally caused by infilled cut features. These include pits of an archaeological origin, possible tree bowls or other naturally occurring depressions in the ground.

### Magnetic debris



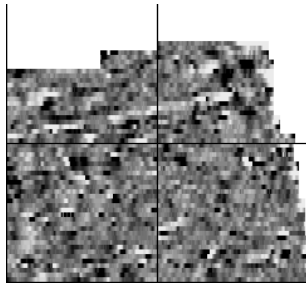
Magnetic debris consists of numerous dipolar responses spread over an area. If the amplitude of response is low ( $\pm 3\text{nT}$ ) then the origin is likely to represent general ground disturbance with no clear cause, it may be related to something as simple as an area of dug or mixed earth. A stronger anomaly ( $\pm 250\text{nT}$ ) is more indicative of a spread of ferrous debris. Moderately strong anomalies may be the result of a spread of thermoremanent material such as bricks or ash.

### Magnetic disturbance



Magnetic disturbance is high amplitude and can be composed of either a bipolar anomaly, or a single polarity response. It is essentially associated with magnetic interference from modern ferrous structures such as fencing, vehicles or buildings, and as a result is commonly found around the perimeter of a site near to boundary fences.

### Negative linear

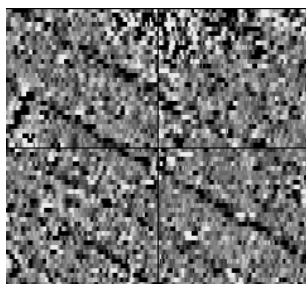


A linear response which is entirely negative in polarity. These are generally caused by earthen banks where material with a lower magnetic magnitude relative the background top soil is built up. See also ploughing activity.

### Negative point/area

Opposite to positive point anomalies these responses may be caused by raised areas or earthen banks. These could be of an archaeological origin or may have a natural origin.

### Ploughing activity



Ploughing activity can often be visualised by a series of parallel linear anomalies. These can be of either positive polarity or negative polarity depending on site specifics. It can be difficult to distinguish between ancient ploughing and more modern ploughing, clues such as the separation of each linear, straightness, strength of response and cross cutting relationships can be used to aid this, although none of these can be guaranteed to differentiate between different phases of activity.

### Polarity

Term used to describe the measurement of the magnetic response. An anomaly can have a positive polarity (values above 0nT) and/or a negative polarity (values below 0nT).

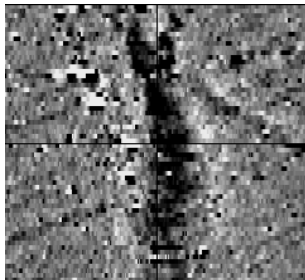
### Strength of response

The amplitude of a magnetic response is an important factor in assigning an interpretation to a particular anomaly. For example a positive anomaly covering a 10m<sup>2</sup> area may have values up to around 3000nT, in which case it is likely to be caused by modern magnetic interference. However, the same size and shaped anomaly but with values up to only 4nT may have a natural origin. Trace plots are used to show the amplitude of response.

## Thermoremnant response

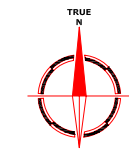
A feature which has been subject to heat may result in it acquiring a magnetic field. This can be anything up to approximately +/-100 nT in value. These features include clay fired drains, brick, bonfires, kilns, hearths and even pottery. If the heat application has occurred insitu (e.g. a kiln) then the response is likely to be bipolar compared to if the heated objects have been disturbed and moved relative to each other, in which case they are more likely to take an irregular form and may display a debris style response (e.g. ash).

## Weak background variations



Weakly magnetic wide scale variations within the data can sometimes be seen within sites. These usually have no specific structure but can often appear curvy and sinuous in form. They are likely to be the result of natural features, such as soil creep, dried up (or seasonal) streams. They can also be caused by changes in the underlying geology or soil type which may contain unpredictable distributions of magnetic minerals, and are usually apparent in several locations across a site.

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 OS 100km square = SO



39  
38  
37  
36  
35



49 50 51 52 53

Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

Survey area

Site centred on NGR **SO 513 377**

Client **WORCESTERSHIRE COUNTY COUNCIL**

Project Title **GEOPHYSICAL SURVEY - BULLINGHOPE, HEREFORD** Job No. 2479

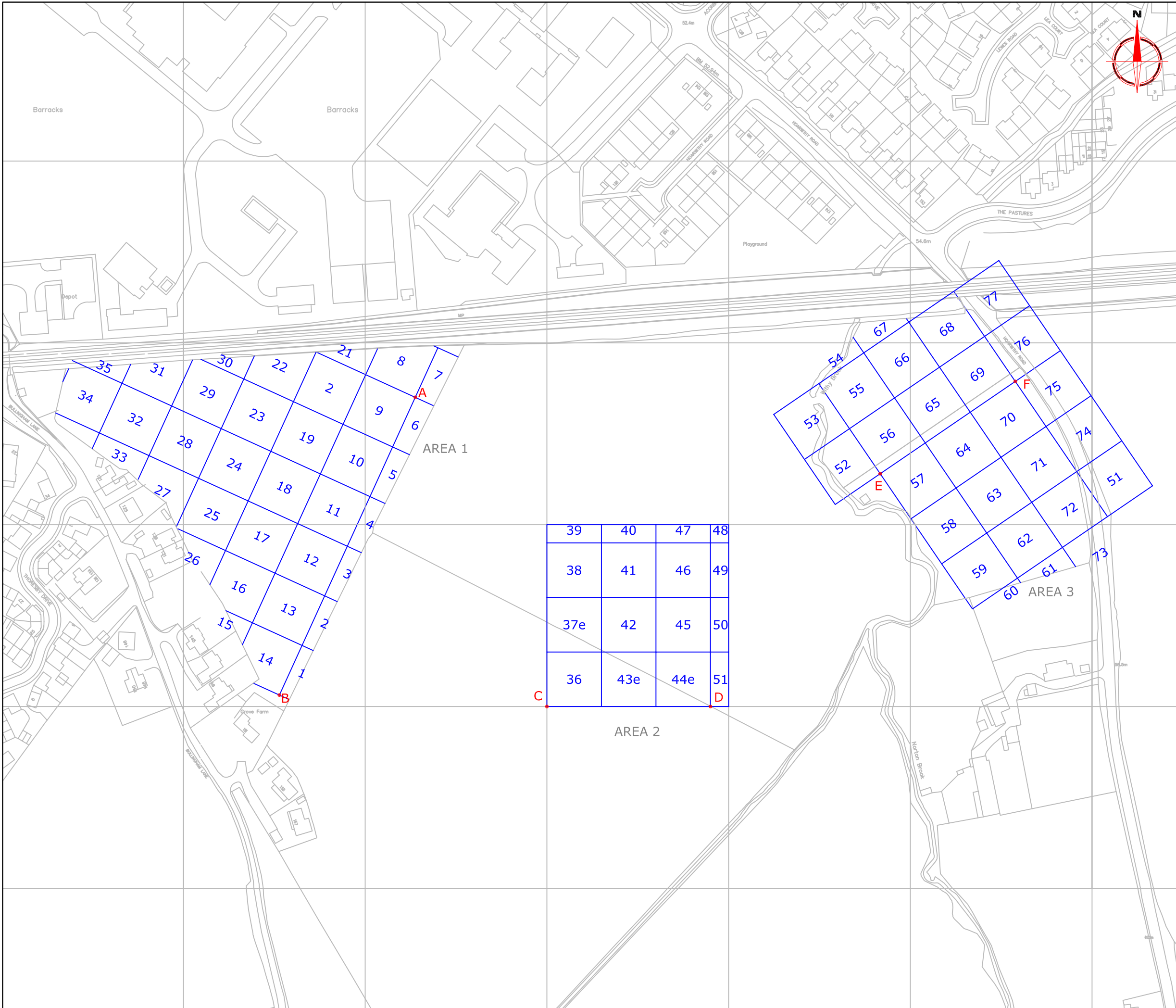
Subject **LOCATION PLAN OF SURVEY AREA**

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 F: +44 (0)1684 594142  
 E: info@stratascan.co.uk  
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Scale **1:25 000** 0m 500 1000m

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>01</b>





Amendments		
Issue No.	Date	Description
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-	-	-

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<b>B</b>	351127.55 , 237769.89
<b>C</b>	351200.00 , 237600.00
<b>D</b>	351290.00 , 237600.00
<b>E</b>	351383.41 , 237728.03
<b>F</b>	351457.74 , 237778.78

Client  
**WORCESTERSHIRE COUNTY COUNCIL**

Project Title Job No. 2479  
**GEOPHYSICAL SURVEY - BULLINGHOPE, HEREFORD**

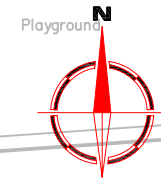
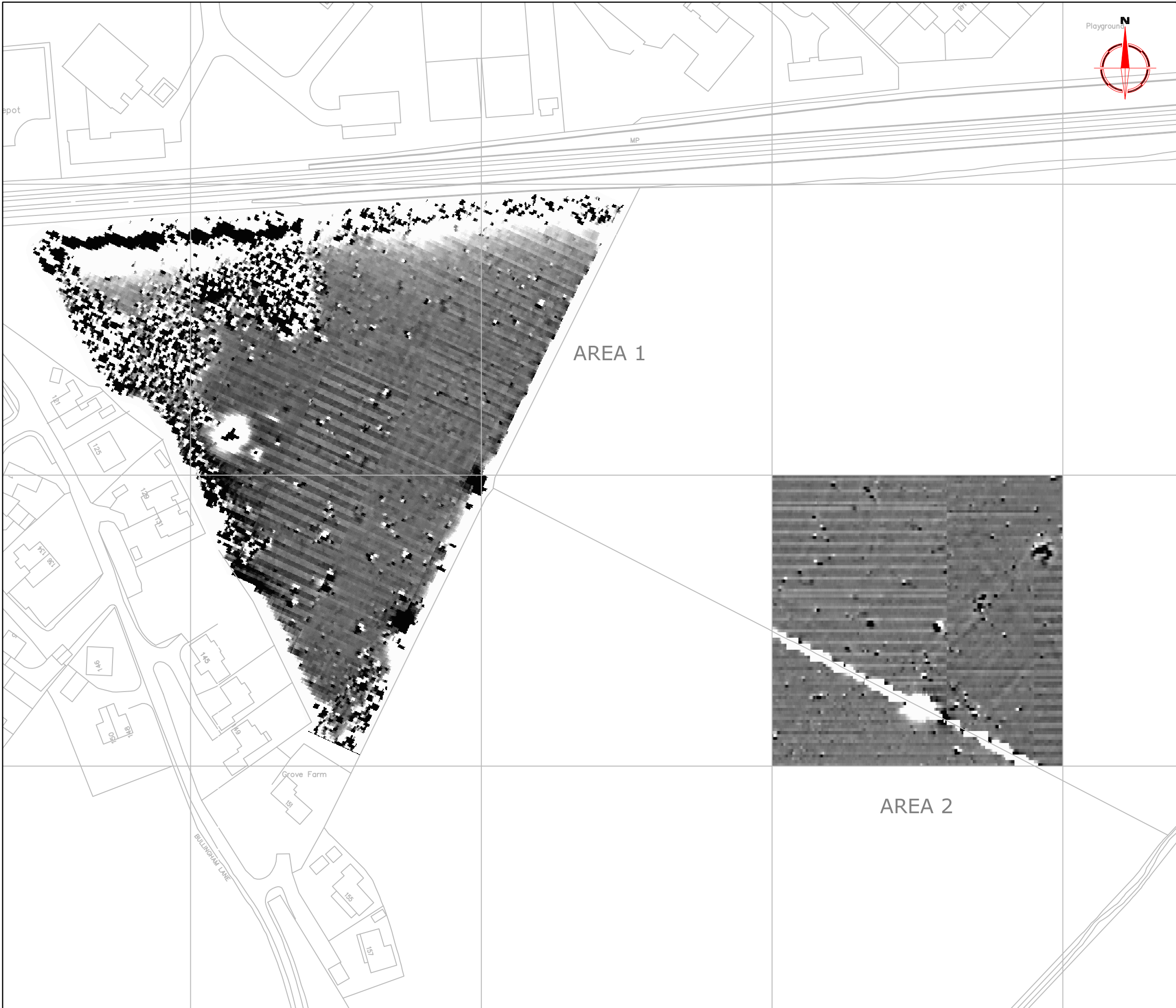
Subject  
**LOCATION AND REFERENCING OF SURVEY GRIDS**

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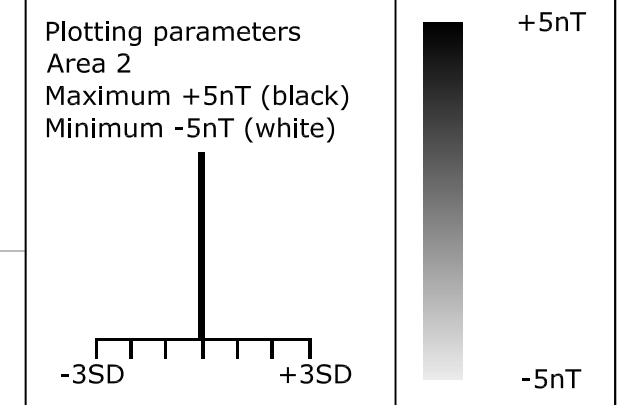
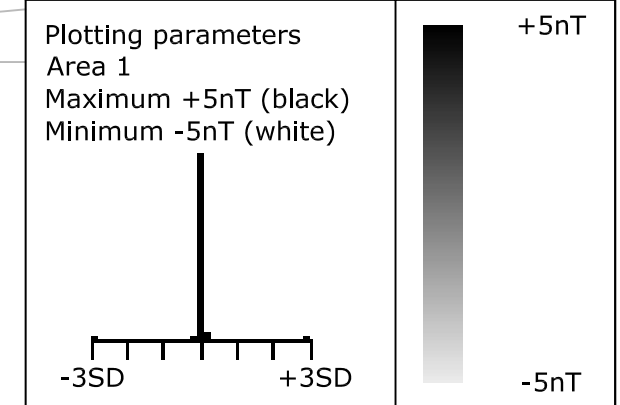


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Amendments		
Issue No.	Date	Description
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Client  
**WORCESTERSHIRE COUNTY COUNCIL**

Project Title      Job No. 2479  
**GEOPHYSICAL SURVEY  
-BULLINGHOPE, HEREFORD**

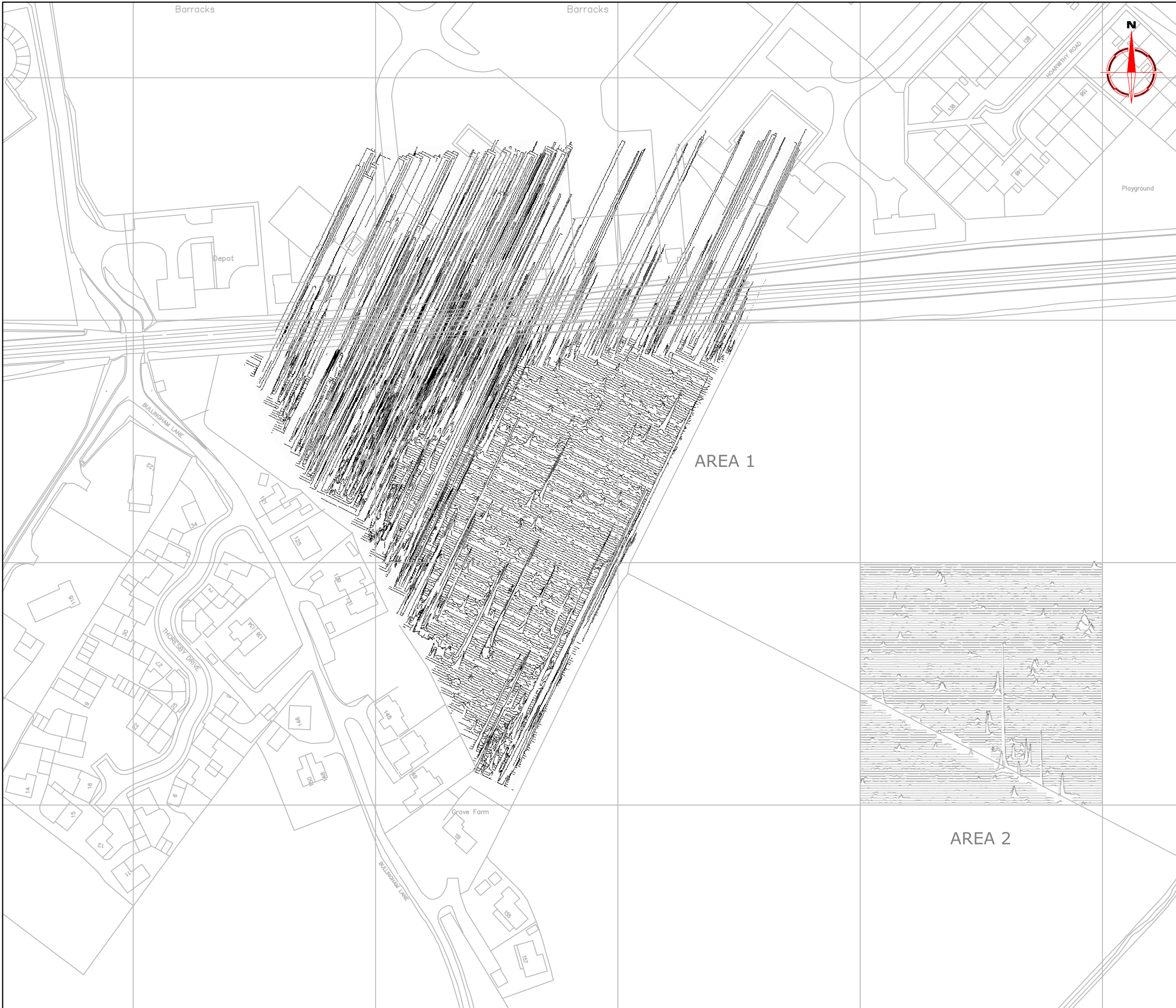
Subject  
**PLOT OF RAW GRADIOMETER DATA-  
AREAS 1 AND 2**

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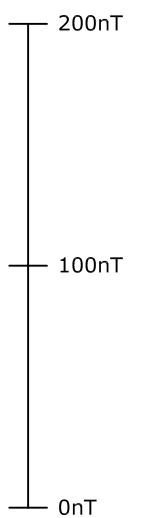
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Amendments		
Issue No.	Date	Description
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Plotting parameters  
 +40nT  
 (Positive values displace above the trace line.  
 Hidden values have not been plotted)



Client  
**WORCESTERSHIRE COUNTY COUNCIL**

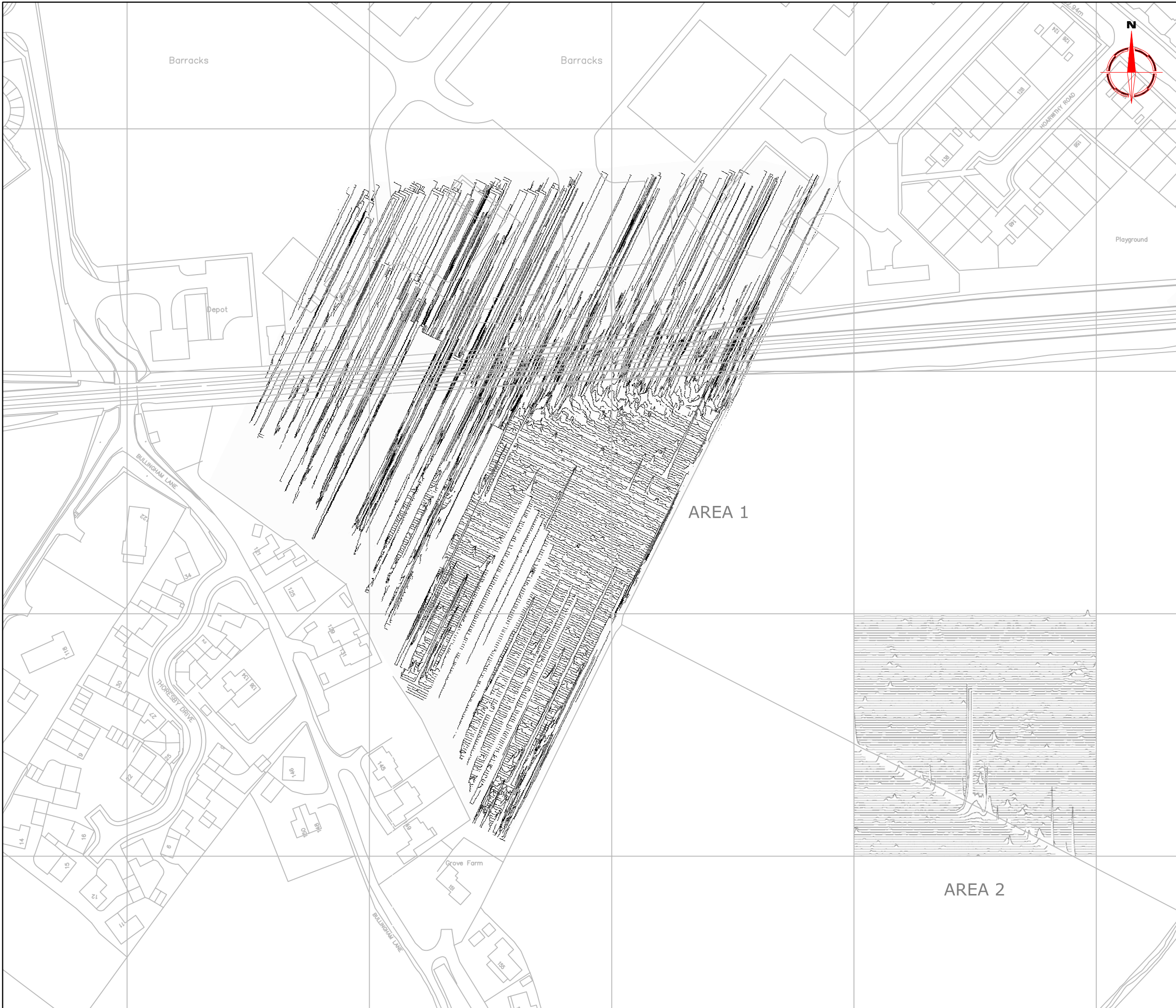
Project Title Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE, HEREFORD**

Subject  
**TRACE PLOT OF GRADIOMETER DATA**  
**SHOWING POSITIVE VALUES-**  
**AREAS 1 AND 2**

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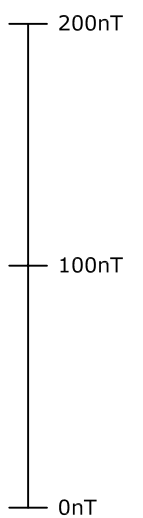


Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

Plotting parameters

-40nT

(Negative values displace above the trace line. Hidden values have not been plotted)



Client  
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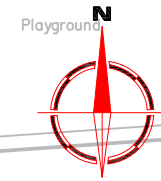
Project Title Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE, HEREFORD**

Subject  
**TRACE PLOT OF GRADIOMETER DATA**  
**SHOWING NEGATIVE VALUES-**  
**AREAS 1 AND 2**

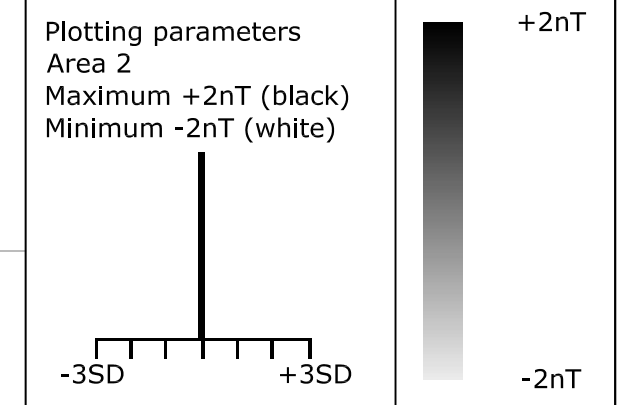
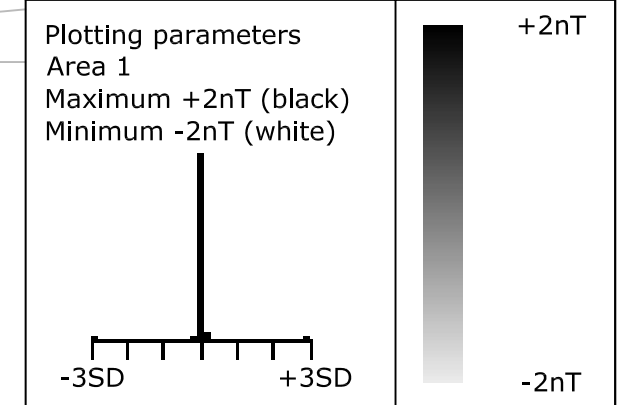
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Scale **1:1500**  
 0m 10 20 30 40 50m

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>05</b>



Amendments		
Issue No.	Date	Description
-	-	-
-	-	-



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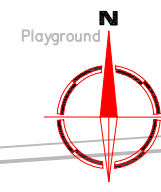
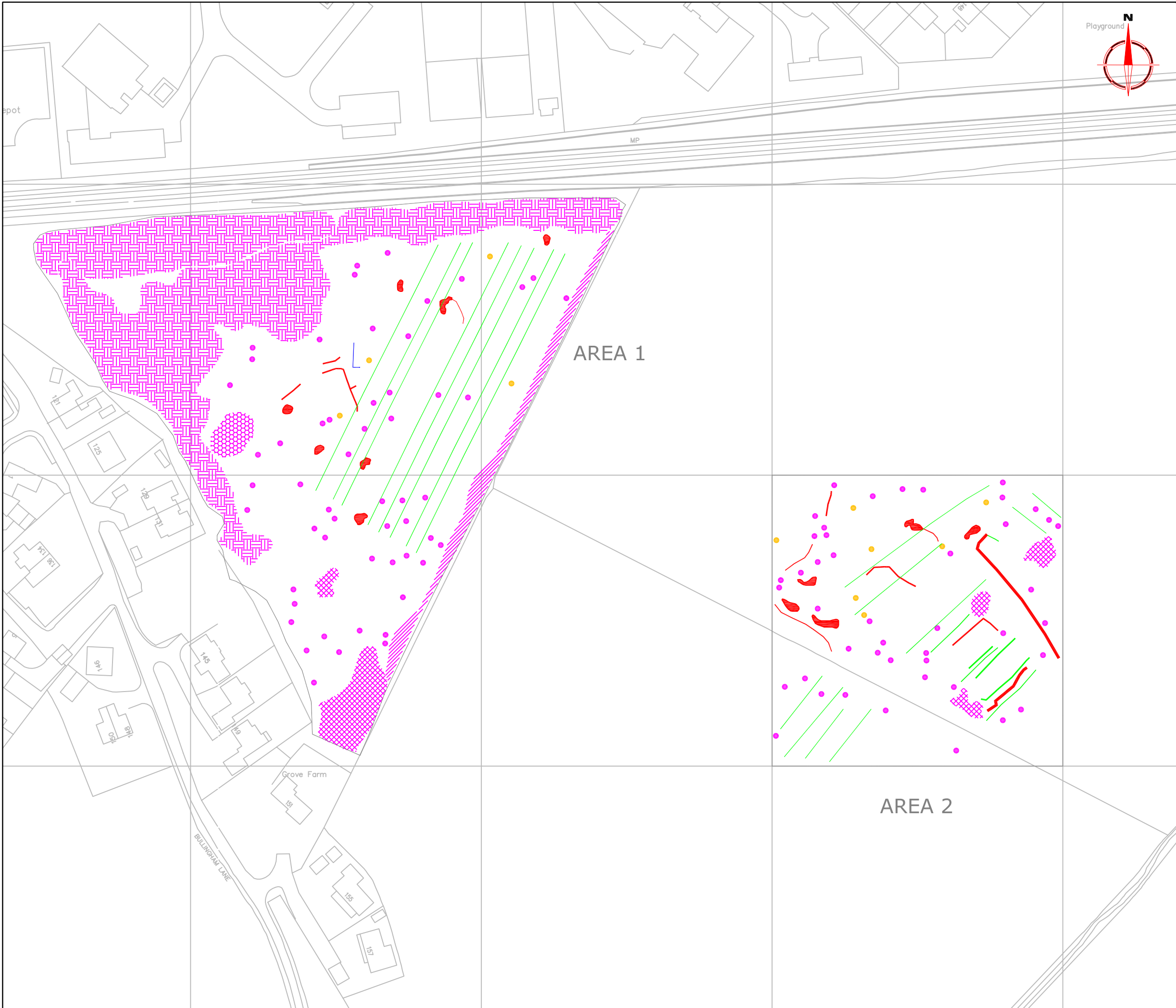
Project Title      Job No. 2479  
**GEOPHYSICAL SURVEY  
-BULLINGHOPE, HEREFORD**

Subject  
**PLOT OF PROCESSED  
GRADIOMETER DATA-  
AREAS 1 AND 2**

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Scale      0m 10 20 30 40 50m  
**1:1250**

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>06</b>



Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

KEY	
	Discrete positive anomaly - possible pit
	Positive anomaly with associated negative response - ferrous object
	Positive linear anomaly - agricultural mark
	Positive linear anomaly - cut feature of possible archaeological origin
	Negative linear anomaly- possible former earthwork/bank
	Positive area anomaly - cut feature of possible archaeological origin
	Area of magnetic disturbance related to metallic object such as fence or pipe
	Area of magnetic debris - evidence of ground disturbance
	Large bipolar area anomaly
	Area of magnetic disturbance- made ground

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Project Title Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE HEREFORD**

Subject  
**ABSTRACTION AND INTERPRETATION OF GRADIOMETER ANOMALIES- AREAS 1 AND 2**

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Scale 0m 10 20 30 40 50m  
**1:1250**

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>07</b>



Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

Plotting parameters  
 Area 3  
 Maximum +5nT (black)  
 Minimum -5nT (white)

-3SD      +3SD      -5nT      +5nT

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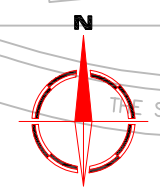
Project Title      Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE, HEREFORD**

Subject  
**PLOT OF RAW GRADIOMETER DATA-**  
**AREA 3**

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Scale 1:1000

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>08</b>



Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

Plotting parameters

-40nT

(Negative values displace above the trace line. Hidden values have not been plotted)

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Project Title Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE, HEREFORD**

Subject  
**TRACE PLOT OF GRADIOMETER DATA**  
**SHOWING POSITIVE VALUES-**  
**AREA 3**

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Scale  
**1:1000**

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>09</b>





Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

Plotting parameters  
 -40nT  
 (Negative values displace above the trace line. Hidden values have not been plotted)

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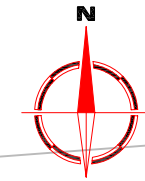
Project Title Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE, HEREFORD**

Subject  
**TRACE PLOT OF GRADIOMETER DATA**  
**SHOWING NEGATIVE VALUES-**  
**AREA 3**

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Scale  
**1:1000**

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>10</b>



Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

Plotting parameters  
 Area 3  
 Maximum +2nT (black)  
 Minimum -2nT (white)

-3SD      +3SD

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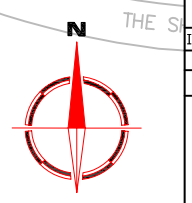
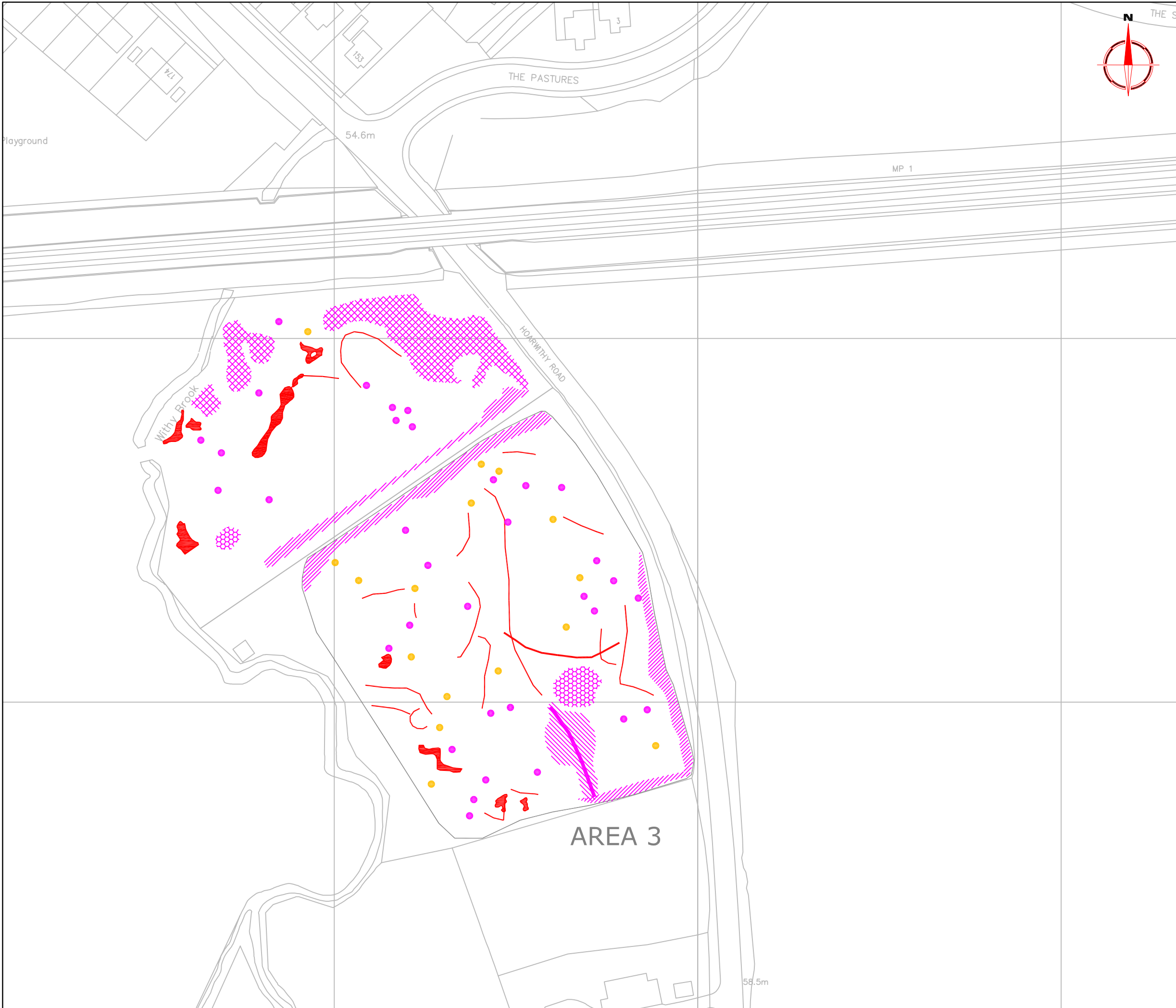
Project Title      Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE, HEREFORD**

Subject  
**PLOT OF PROCESSED GRADIOMETER DATA- AREA 3**

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Scale  
**1:1000**      0m    10    20    30    40    50

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>11</b>



Amendments		
Issue No.	Date	Description
-	-	-
-	-	-

KEY	
	Discrete positive anomaly - possible pit
	Positive anomaly with associated negative response - ferrous object
	Positive linear anomaly - cut feature of possible archaeological origin
	Positive area anomaly - cut feature of possible archaeological origin
	Area of magnetic disturbance related to metallic object such as fence or pipe
	Area of magnetic debris - evidence of ground disturbance
	Large bipolar area anomaly

Client  
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Project Title Job No. 2479  
**GEOPHYSICAL SURVEY**  
**-BULLINGHOPE HEREFORD**

Subject  
**ABSTRACTION AND INTERPRETATION OF GRADIOMETER ANOMALIES- AREA 3**

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Scale **1:1000**  
 0m 10 20 30 40 50

Plot <b>A3</b>	Checked by <b>PPB</b>	Issue No. <b>01</b>
Survey date <b>MAY 08</b>	Drawn by <b>RAJS</b>	Figure No. <b>12</b>