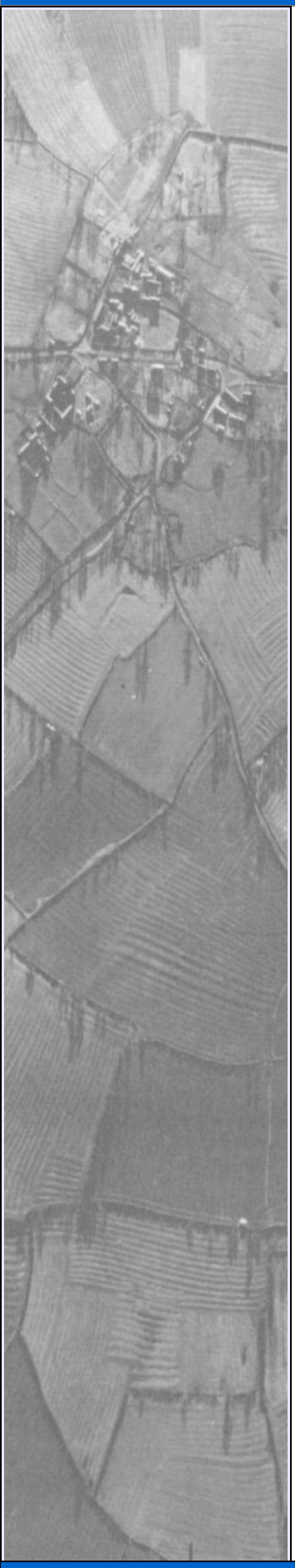

Land off Bransford Road
Rushwick
Worcestershire

MAGNETOMETER SURVEY REPORT

for

Cotswold Archaeology

Kerry Donaldson & David Sabin

May 2015

Ref. no. 611

ARCHAEOLOGICAL SURVEYS LTD

Land off Bransford Road
Rushwick
Worcestershire

Magnetometer Survey Report

for

Cotswold Archaeology

Fieldwork by David Sabin (Hons) MCIfA
Report by Kerry Donaldson BSc (Hons)
Report checked by David Sabin
Primary archive location - Archaeological Surveys Ltd, Yatesbury, Wiltshire

Survey date – 15th May 2015
Ordnance Survey Grid Reference – **SO 81665 53790**

Worcestershire HER ref: WSM66647
OASIS ID: archaeol20-212507

Archaeological Surveys Ltd
1 West Nolands, Nolands Road, Yatesbury, Calne, Wiltshire, SN11 8YD
Tel: 01249 814231 Fax: 0871 661 8804
Email: info@archaeological-surveys.co.uk
Web: www.archaeological-surveys.co.uk

CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

A detailed magnetometer survey was carried out by Archaeological Surveys Ltd on land off Bransford Road, Rushwick near Worcester at the request of Cotswold Archaeology. The results revealed two series of positive and negative responses with some linearity and similar orientations, and although a natural origin cannot be ruled out, the anomalies cannot be confidently interpreted. Several amorphous and sinuous positive and negative anomalies have also been located in the southern part of the site and these appear to relate to naturally formed features within a zone containing sands and gravels.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Cotswold Archaeology to undertake a magnetometer survey of an area of land off Bransford Road, Rushwick near Worcester. A planning application has been made to Malvern Hills District Council (15/00504/OUT) for a residential development of up to 41 homes, with associated new access, car parking, on site biodiversity and an extension to the existing village hall site. The survey forms part of an archaeological assessment of the site.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2015) and approved by Mike Glyde, Historic Environment Planning Officer for Worcestershire County Council, prior to commencing the fieldwork.

1.2 Survey objectives and techniques

1.2.1 The objective of the survey was to use magnetometry to locate geophysical anomalies that may be archaeological in origin so that they may be assessed prior to development of the site. The methodology is considered an efficient and effective approach to archaeological prospection.

1.2.2 The survey and report generally follow the recommendations set out by: English Heritage (2008) *Geophysical survey in archaeological field evaluation;* and Institute for Archaeologists (2002) *The use of Geophysical Techniques in Archaeological Evaluations*. The work has been carried out to the Chartered Institute for Archaeologists (2014) *Standard and Guidance for Archaeological Geophysical Survey.*

1.3 Site location, description and survey conditions

1.3.1 The site is located to the north of Bransford Road in Rushwick to the south west of Worcester. It is centred on Ordnance Survey National Grid Reference (OS NGR) SO 81665 53790, see Figures 01 and 02.

1.3.2 The geophysical survey covers approximately 3.4ha, predominantly within the eastern half of an irregularly shaped arable field partly divided by a pond. A strip to the west of the pond and a small area to the north of the pond are within the development boundary and have also been surveyed.

1.3.3 The ground cover consisted of an arable crop approximately 0.3m high, and the site slopes down towards the south and south west, with a shallow combe to the south of the pond in the western part of the site. Within the base of the combe there is evidence for emerging springs.

1.3.4 The ground conditions across the site were generally considered to be favourable for the collection of magnetometry data. Some localised areas of waterlogged and rutted soil were noted to the north west and south of the pond. Weather conditions during the survey were fine.

1.4 Site history and archaeological potential

1.4.1 There are currently no known designated or non-designated archaeological remains or other heritage assets within the site and no recorded remains which may extend into the site recorded on the Worcestershire County Historic Environment Record. The presence and extent of below ground archaeological remains is, however, largely unknown in the area. Previous archaeological interventions prior to the construction of the Worcester Western Bypass did recover small quantities of prehistoric worked flint, some possibly Neolithic/Early Bronze Age in date, as well as Roman and medieval pottery. A trial trench archaeological evaluation carried out 500m from the site, ahead of residential development east of Claphill Lane in 2013, found no archaeological remains. The 1841 Tithe Map shows the land divided into two fields, both called Park Field. By the First Edition Ordnance Survey mapping of the 1880s the site was depicted as a single field, which by the time of the 1928 edition has been planted as orchard, and it remained so until the late 20th century. The pond appears to have been constructed during the late 20th century.

1.4.2 Despite the lack of known archaeological sites or findspots within the site or immediate vicinity there is always the potential for the geophysical survey to locate anomalies that relate to previously unrecorded archaeological features should they be present within the site. It is also possible that there may be anomalies associated with the former use of the site as an orchard.

1.4.3 During the course of the survey no significant cultural material was observed on the field surface, although the majority of the area was obscured by crops.

1.5 Geology and soils

1.5.1 The underlying solid geology across the site is mainly Triassic mudstone from the Sidmouth Mudstone Formation, with a band of dolomitic siltstone from the Sidmouth Mudstone Formation towards the north eastern corner. Overlying the southern half of the site are Quaternary deposits from the Holt Heath Sand and Gravel Member with some sands and gravels from the Kidderminster Station Member at the most north eastern edge (BGS, 2013).

1.5.2 The overlying soil across the survey area is from the Newnham association and is a typical brown earth. It consists of a well drained, reddish, coarse and fine loamy soil over gravel. (Soil Survey of England and Wales, 1983).

1.5.3 Magnetometry survey carried out across similar soils has produced variable results. Triassic mudstones can be associated with poor magnetic contrast, and sands and gravels can contain natural pit-like features. The underlying geology and soils are considered acceptable for magnetic survey.

2 METHODOLOGY

2.1 Technical synopsis

2.1.1 Magnetometry survey records localised magnetic fields that can be associated with features formed by human activity. Magnetic susceptibility and magnetic thermoremnance are factors associated with the formation of localised fields. Additional details are set out below and within Appendix A.

2.1.2 Iron minerals within the soil may become altered by burning and the break down of biological material; effectively the magnetic susceptibility of the soil is increased, and the iron minerals become magnetic in the presence of the Earth's magnetic field. Accumulations of magnetically enhanced soils within features, such as pits and ditches, may produce magnetic anomalies that can be mapped by magnetic prospection.

2.1.3 Magnetic thermoremnance can occur when ferrous minerals have been heated to high temperatures such as in a kiln, hearth, oven etc. On cooling, a permanent magnetisation may be acquired due to the presence of the Earth's magnetic field. Certain natural processes associated with the formation of some igneous and metamorphic rock may also result in magnetic thermoremnance.

2.1.4 The localised variations in magnetism are measured as sub-units of the Tesla, which is a SI unit of magnetic flux density. These sub-units are nano Teslas (nT), which are equivalent to 10^{-9} Tesla (T).

2.2 Equipment configuration, data collection and survey detail

2.2.1 The detailed magnetic survey was carried out using a SENSYS

MAGNETO®MXPDA 5 channel cart-based system. The instrument has 5 fluxgate gradiometers spaced 0.5m apart with readings recorded at 100 Hz. The gradiometers have a range of recording data between 0.1nT and 10,000nT. The system is linked to a Leica GS10 RTK GPS with data recorded by SENSYS MAGNETO®MXPDA software on a rugged PDA computer system.

2.2.2 Data are collected along a series of parallel survey transects wherever possible. The length of each transect is variable and relates to the size of the survey area and other factors including ground conditions. A visual display allows accurate placing of transects and helps maintain the correct separation between adjacent traverses.

2.2.3 Data are not collected within fixed grids and data points are considered to be random even though the data are collected in a systematic manner covering all accessible areas (Aspinall, Gaffney and Schmidt, 2009).

2.3 Data processing and presentation

2.3.1 Magnetic data collected by the MAGNETO®MXPDA cart-based system are initially prepared using SENSYS MAGNETO®DLMGPS software. Survey tracks are analysed and georeferenced raw data (UTM Z30N) are then exported in ASCII format for further analysis and display using TerraSurveyor.

2.3.2 The data are collected between limits of ±10000nT and clipped for display. Data are interpolated to a resolution of effectively 0.5m between tracks and 0.18m along each survey track. A zero median traverse function is required in order to remove fixed offset values present within the sensors which do not undergo a zeroing procedure in the field. The approach ensures that the gradiometer sensors are very accurately aligned and fixed to the vertical magnetic field and are not influenced by localised magnetic fields or disturbed by vibration. Although a zero median traverse algorithm can remove anomalies aligned with the survey tracks, in practice this rarely occurs due to the use of long traverses, high resolution measurement and variability within the magnetic susceptibility of long linear features.

2.3.3 Appendix C contains metadata concerning the survey and data attributes and is derived directly from TerraSurveyor. Reference should be made to Appendix B for further information on any processes, such as clipping, carried out on the data.

2.3.4 A TIF file is produced by TerraSurveyor software along with an associated world file (.TFW) that allows automatic georeferencing (OSGB36 datum) when using GIS or CAD software. The main form of data display used in the report is the minimally processed greyscale plot.

2.3.5 The raster images are combined with base mapping using ProgeCAD Professional 2014, creating DWG file formats. All images are externally

referenced to the CAD drawing in order to maintain good graphical quality. The CAD plots are effectively georeferenced facilitating relocation of features using GPS, resection method, etc.

2.3.6 An abstraction and interpretation is offered for all geophysical anomalies located by the survey. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing. A brief summary of each anomaly, with an appropriate reference number, is set out in list form within the results (Section 3) to allow a rapid and objective assessment of features within the survey area.

2.3.7 A digital archive is produced with this report, see Appendix D below. The main archive is held at the offices of Archaeological Surveys Ltd with the raw data, CAD file and greyscale image archived with the Archaeology Data Service (ADS).

3 RESULTS

3.1 General assessment of survey results

3.1.1 The detailed magnetic survey was carried out over approximately 3.4ha within a single arable field.

3.1.2 Magnetic anomalies located can be generally classified as positive and negative anomalies of an uncertain origin, linear anomalies of an agricultural origin, anomalies with a natural origin, areas of magnetic disturbance and strong discrete dipolar anomalies relating to ferrous objects.

3.2 Statement of data quality

3.2.1 Data are considered representative of the magnetic anomalies present within the site. There are no significant defects within the dataset.

3.3 Data interpretation

3.3.1 The list of sub-headings below attempts to define a number of separate categories that reflect the range and type of features located during the survey. A basic explanation of the characteristics of the magnetic anomalies is set out for each category in order to justify interpretation, a basic key is indicated to allow cross referencing to the abstraction and interpretation plot. CAD layer names are included to aid reference to associated digital files (.dwg/.dxf). Sub-headings are then used to group anomalies with similar characteristics within the survey area.

Report sub-heading CAD layer names and plot colour	Description and origin of anomalies
Anomalies with an uncertain origin AS-ABST MAG POS LINEAR UNCERTAIN AS-ABST MAG POS DISCRETE UNCERTAIN AS-ABST MAG POS UNCERTAIN AS-ABST MAG NEG UNCERTAIN	The category applies to a range of anomalies where there is not enough evidence to confidently suggest an origin. Anomalies in this category may well be related to archaeologically significant features, but equally relatively modern features, geological/pedological features and agricultural features should be considered. Positive anomalies are indicative of magnetically enhanced soils that may form the fill of 'cut' features or may be produced by accumulation within layers or 'earthwork' features; soils subject to burning may also produce positive anomalies. Negative anomalies are produced by material of comparatively low magnetic susceptibility such as stone and subsoil.
Anomalies with an agricultural origin AS-ABST MAG AGRICULTURAL	The anomalies are often linear and form a series of parallel responses or are parallel to extant land boundaries. Where the response is broad, former ridge and furrow is likely; narrow response is often related to modern ploughing.
Anomalies associated with magnetic debris AS-ABST MAG STRONG DIPOLAR	Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.
Anomalies with a modern origin AS-ABST MAG DISTURBANCE	The magnetic response is often strong and dipolar indicative of ferrous material and may be associated with extant above surface features such as wire fencing, cables, pylons etc.. Often a significant area around such features has a strong magnetic flux which may create magnetic disturbance; such disturbance can effectively obscure low magnitude anomalies if they are present. Fluxgate sensors may respond erratically and with hysteresis adjacent to strong magnetic sources.
Anomalies with a natural origin AS-ABST MAG NATURAL FEATURES	Naturally formed magnetic anomalies are are caused by localised variability in the magnetic susceptibility of soils, subsoils and other drift or solid geologies. Anomalies may be amorphous, linear or curvilinear and may appear 'fluvial' or discrete; the latter are almost impossible to distinguished from pit-like anomalies with an anthropogenic origin. Fluvial, glacial and periglacial processes may be responsible for their formation within drift material and subsoil.

Table 1: List and description of interpretation categories

3.4 List of anomalies

Area centred on OS NGR 381665 253790, see Figures 03 & 04.

Anomalies with an uncertain origin

(1) - Positive and negative broad linear anomalies are oriented west-north-west to east-south-east and north-north-east to south-south-west. It is not possible to determine if they relate to natural or anthropogenic features.

(2) - Weakly positive linear and broad weakly positive responses with a west-south-west to east-north-east and others north-north-west to south-south-east orientation. These are generally parallel with the current field boundaries and it is possible that they may be associated with agricultural activity.

(3) - A weakly positive broad linear anomaly is located in the south western part of the survey area. Although it is parallel/orthogonal to anomalies (1), its position lies in the base of a narrow combe between a recently constructed pond to the north and the corner of the field. An association with anomalies (1) is possible, but a modern feature, such as a buried pipe, should also be considered.

(4) - The survey area contains a small number of discrete positive responses. While these may relate to pit-like features, it is not possible to determine if they are natural or anthropogenic in origin.

Anomalies with an agricultural origin

(5) - Evident within much of the site are a series of linear anomalies parallel with the eastern field boundary. The site has been used as an orchard in the 20th century but until recently the field was used for growing potatoes. It would appear that these are a response to the alternate ridges and furrows associated with the cultivation of potatoes.

Anomalies with a natural origin

(6) - In the southern part of the survey area are a number of amorphous and sinuous positive and negative responses. This part of the site is mapped as containing river terrace sand and gravel deposits and the responses are mainly located on the slopes of the narrow valley that lies to the south of the recently constructed pond. They appear to relate to naturally formed features, either associated with the sands and gravels or colluviation.

Anomalies associated with magnetic debris

(7) - The survey area contains widespread strong, discrete, dipolar anomalies and some are quite large. This indicates that there are ferrous and other magnetically thermoremnant objects within the site.

Anomalies with a modern origin

(8) - Magnetic disturbance is a response to ferrous material within and adjacent to the field boundaries.

4 CONCLUSION

4.1.1 The results of the detailed magnetometer survey indicate that the site contains a number of weakly positive and negative anomalies. While they have a similar response to naturally formed features in the southern part of the site, there appear to be two orientations for several of the features and an anthropogenic origin should be considered.

5 REFERENCES

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Appendix A – basic principles of magnetic survey

Iron minerals are always present to some degree within the topsoil and enhancement associated with human activity is related to increases in the level of magnetic susceptibility and thermoremnant material.

Magnetic susceptibility is an induced magnetism within a material when it is in the presence of a magnetic field. This can be thought of as effectively permanent due to the presence of the Earth's magnetic field.

Thermoremnant magnetism occurs when ferrous material is heated beyond a specific temperature known as the Curie Point. Demagnetisation occurs at this temperature with re-magnetisation by the Earth's magnetic field upon cooling.

Enhancement of magnetic susceptibility can occur in areas subject to burning and complex fermentation processes on biological material; these are frequently associated with human settlement. Thermoremnant features include ovens, hearths, and kilns. In addition thermoremnant material such as tile and brick may also be associated with human activity and settlement.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil can create an area of enhancement compared with surrounding soils and subsoils into which the feature is cut. Mapping enhanced areas will produce linear and discrete anomalies allowing an assessment and characterisation of hidden subsurface features.

It should be noted that areas of negative enhancement can be produced from material having lower magnetic properties compared to the topsoil. This is common for many sedimentary bedrocks and subsoils which were often used in the construction of banks and walls etc. Mapping these 'negative' anomalies may also reveal archaeological features.

Magnetic survey or magnetometry can be carried out using a fluxgate gradiometer and may be referred to as gradiometry. The SENSYS gradiometer is a passive instrument consisting of two fluxgate sensors mounted vertically 65cm apart. The instrument is carried about 10-20cm above the ground surface and the upper sensor measures the Earth's magnetic field as does the lower sensor but this is influenced to a greater degree by any localised buried field. The difference between the two sensors will relate to the strength the magnetic field created by the buried feature.

There are a number of factors that may affect the magnetic survey and these include soil type, local geology and previous human activity. Situations arise where magnetic disturbance associated with modern services, metal fencing, dumped waste material etc., obscures low magnitude fields associated with archaeological features.

Appendix B – data processing notes

Clipping

Minimum and maximum values are set and replace data outside of the range with those values. Extreme values are removed improving colour or greyscale contrast associated with data values that may be archaeologically significant. It has been found that clipping data to ranges between ±20nT and ±10nT often improves the appearance of features associated with archaeology. Different ranges are applied to data in order to determine the most suitable for anomaly abstraction and display.

Zero (destripe) Median/Mean Traverse

The median (or mean) of each traverse is calculated ignoring data outside a threshold value, the median (or mean) is then subtracted from the traverse. The process is used to equalise differences between the baseline value of gradiometer sensors.

High Pass Filtering

A mathematical process used to remove low frequency anomalies relating to survey tracks and modern agricultural features.

Appendix C – survey and data information

Minimally processed data

COMPOSITE
Filename: J611-mag-proc.xcp
Description: Imported as Composite from: J611-mag.asc
Instrument Type: Sensys DLMGPS
Units: nT
UTM Zone: 30U
Survey corner coordinates (X/Y): OSGB36
Northwest corner: 381535.156480009, 253902.834168137 m
Southeast corner: 381766.096480009, 253682.874168137 m
Collection Method: Randomised
Sensors: 5
Dummy Value: 32702

Source GPS Points: 5410000

Dimensions
Composite Size (readings): 1283 x 1222
Survey Size (meters): 231 m x 220 m
Grid Size: 231 m x 220 m
X Interval: 0.18 m
Y Interval: 0.18 m

Stats
Max: 5.00
Min: -5.00
Std Dev: 1.97
Mean: -0.03
Median: -0.08
Composite Area: 5.0798 ha
Surveyed Area: 3.3612 ha

PROGRAM
Name: TerraSurveyor
Version: 3.0.23.0

Processes: 2
1 Base Layer
2 Clip from -5.00 to 5.00 nT

GPS based Proce2
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at their offices in Wiltshire. Data are backed-up onto an on-site data storage drive and at the earliest opportunity data are copied to CD ROM for storage on-site and off-site.

A printed copy of the report and a PDF copy will be supplied to the Worcestershire Historic Environment Record. The report will also be uploaded to the Online AccesS to the Index of archaeological investigationS (OASIS).

The raw data as a zipped CSV file, together with a CAD file and the raster greyscale images will also be deposited with the Archaeology Data Service (ADS) for archiving.

ADS Archive contents:

Geophysical data - path: J611_Rushwick_geophysics				
Path and Filename	**Software**	**Description**	**Date**	**Creator**
J611_Rushwick_geophysics_mag_raw.csv zip file	Sensys DLMGPS	ASCII CSV (tab) file representing survey area in eastings, northings (UTM Z30N), magnetic measurement, traverse file and sensor number.	21/05/15	K.T.Donaldson
Graphic data (GIS) - path: J611_Rushwick_GIS				
J611_Rushwick_mag_proc.tif	TerraSurveyor 3.0.23.0	TIF file showing a minimally processed greyscale plot clipped to ±5nT.	21/05/15	K.T.Donaldson
J611_Rushwick_mag_proc.tfw	TerraSurveyor 3.0.23.0	World file for georeferencing TIF to OSGB36.	21/05/15	K.T.Donaldson
CAD data - path: J611_Rushwick_CAD				
J611_Rushwick_CAD.dwg	ProgeCAD 2014	CAD file for creating plots of greyscales, abstraction, interpretation and mapping. Grid coordinates as OSGB. AutoCAD 2010 format.	06/05/15	K.T.Donaldson

Appendix E – copyright and intellectual property

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N

Archaeological Surveys Ltd

Geophysical Survey
Land off Bransford Road
Rushwick
Worcestershire

Map of survey area

Survey location

Site centred on OS NGR
SO 81665 53790

SCALE 1:25 000

0m 500m 1000m

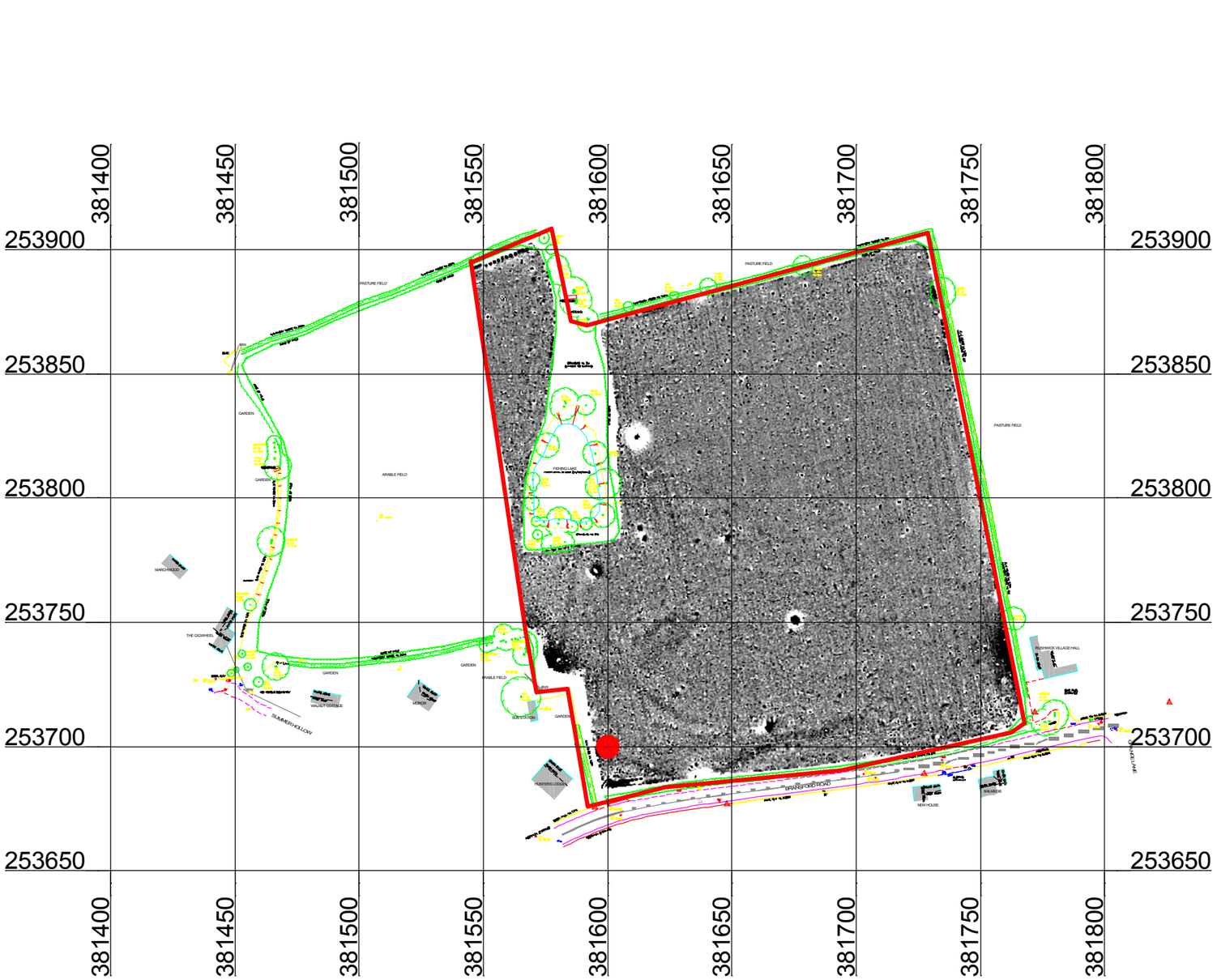
SCALE TRUE AT A3

FIG 01

Archaeological Surveys Ltd

Geophysical Survey
Land off Bransford Road
Rushwick
Worcestershire

Referencing information



Referencing grid to OSGB36 datum at 50m intervals

Data collected at 100Hz and georeferenced to ETRS89 zone 30 with conversion to OSGB36 using OSTN02

- 381600 253700
- Development boundary

SCALE 1:2000

0m 20 40 60 80 100m

SCALE TRUE AT A3

FIG 02

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Geophysical Survey
Land off Bransford Road
Rushwick
Worcestershire

Greyscale plot of minimally processed magnetometer data

+5nT

-5nT +5nT -5nT

N

SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 04

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Geophysical Survey
Land off Bransford Road
Rushwick
Worcestershire

Abstraction and interpretation of magnetometer anomalies

- Positive linear anomaly - possible ditch-like feature
- Linear anomaly - agricultural origin
- Discrete positive response - possible pit-like feature
- Positive anomaly - magnetically enhanced material
- Negative anomaly - material of low magnetic susceptibility
- Positive/negative anomaly - of natural origin
- Magnetic debris - spread of magnetically thermoremnant/ferrous material
- Magnetic disturbance from ferrous material
- Strong dipolar anomaly - ferrous object

SCALE 1:1000

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 04