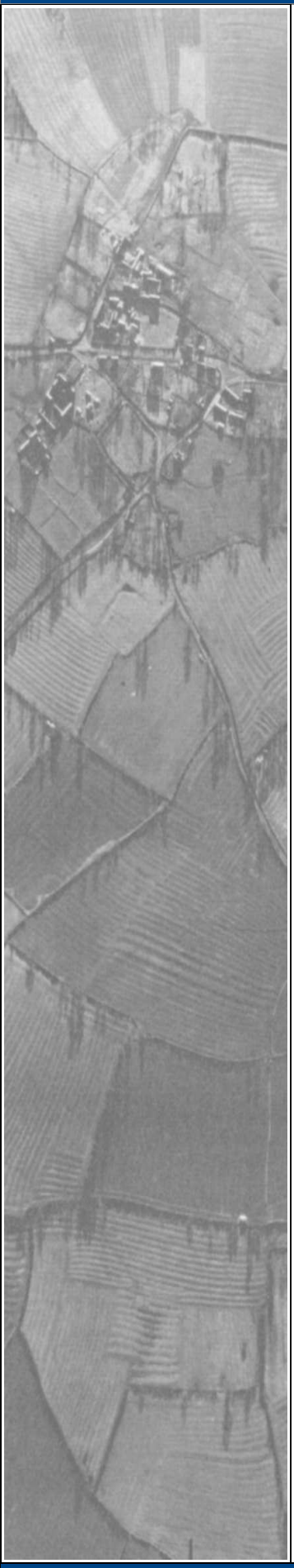

Twelve Oaks
Highworth
Swindon

MAGNETOMETER SURVEY REPORT

for

Foundations Archaeology

Kerry Donaldson & David Sabin

August 2019

Ref. no. J799

ARCHAEOLOGICAL SURVEYS LTD

Twelve Oaks

MAGNETOMETER SURVEY REPORT

for

Foundations Archaeology

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Primary archive location - Archaeological Surveys Ltd, Yatesbury, Wiltshire

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SUMMARY

Detailed magnetometry was carried out over 9.8ha within the former Twelve Oaks Golf Course, Highworth, Swindon. The results from a small field forming the southern part of the site revealed a continuation of Iron Age and early Roman settlement located by previous surveys further to the south. There are a number of ring ditches and rectilinear enclosures covering at least 1ha. Further north there are a small number of weakly positive, poorly defined, linear and curvilinear anomalies which appear to have been truncated by ridge and furrow and could relate to further cut features. Evidence for modern ground disturbance and make-up has also been located, along with former ridge and furrow.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Foundations Archaeology to undertake a magnetometer survey of an area of land at the former Twelve Oaks Golf Course, Highworth, Swindon. The site has been outlined for a proposed training facility for Swindon Town Football Club, in the area of the former golf course, with a residential development in the south. The survey forms part of an archaeological assessment.

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. Justify methodology and approach if possible.

1.2.2 Geophysical survey can provide useful information on the archaeological potential of a site; however, the outcome of any survey relies on a number of factors and as a consequence results can vary. The success in meeting the aims and objectives of a survey is, therefore, often impossible to predetermine.

1.3 Standards, guidance and recommendations for the use of this report

1.3.1 The survey and report generally follow the recommendations set out by: European Archaeological Council (2015) *Guidelines for the Use of Geophysics in Archaeology;* 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.* Note: currently Historic

England (2018) no longer support the guidelines set out in English Heritage (2008) *Geophysical survey in archaeological field evaluation* and there are currently no plans to update the document. As a consequence other sources of written guidance referring to this document may be out of date and/or contain unsupported information (e.g. Chartered Institute for Archaeologists, 2014).

1.3.2 Archaeological Surveys Ltd provide a detailed geophysical survey report and it is recommended that where possible the contents should be considered in full. The Summary provides a brief overview of the results with more detail available in the Discussion and/or Conclusion. The *List of anomalies* within the Results provides a detailed assessment of the anomalies within separate categories which can be useful in inferring a level of confidence to the interpretation. Quality and factors influencing the interpretation of anomalies is also set out within the results.

1.3.3 It is recommended that the full report should always be considered when using data and interpretation plots; where this is not possible, in the field for example, the abstraction and interpretation plots should retain their colour coding and be used with a corresponding legend.

1.3.4 Where targeting of anomalies by excavation is to be carried out, care should be taken to place trenches over solid lines or features visible on the abstraction and interpretation plots. Archaeological Surveys abstraction and interpretation avoids the use of dashed or dotted line formats, and broken or fragmented lines used in interpretive plots may well correspond closely with truncation of archaeological features.

1.4 Site location, description and survey conditions

1.4.1 The site is located at the former Twelve Oaks Golf Course, to the west of Lechlade Road on the northern edge of Highworth, Swindon. It is centred on Ordnance Survey National Grid Reference (OS NGR) SU 20125 94200, see Figs 01 and 02.

1.4.2 The geophysical survey covers approximately 9.8ha. Area 1 is a small field utilised as pasture approximately 1.7ha in area and it had previously been used as a sports field. Area 2 is immediately to the north and has been recently utilised as a car park covering 0.23ha. The ground cover consisted mainly of limestone gravel with some small areas of grass to the east and west. The eastern side of the area contained a concrete pad and steel mesh. Area 3, covering approximately 7.7ha, is the main area of the former golf course and contains several modern earthworks and areas of vegetation that prevented survey. The northern part of the area contained a gallop and several jumps. Area 4 is two fields in the western part of the site which have been previously subject to widespread ground make-up. Several traverses were surveyed within these fields (covering approximately 0.28ha) in order to determine if the material completely covered this part of the site and if it was

magnetically contaminated.

Plate 1: Area 1 looking south east

Plate 2: Area 2 looking east

Plate 3: Area 3 looking north

1.4.3 The ground conditions across the site were generally considered to be favourable for the collection of magnetometry data. Weather conditions during the survey were mainly warm and dry.

1.5 Site history and archaeological potential

1.5.1 Previous geophysical surveys carried out on land immediately to the south of the site (Beaverstock, 2018 a & b; Archaeological Surveys, 2018) located a large number of ring ditches, linear ditches and enclosures. Subsequent evaluation dated them to the mid-late Iron Age, with some early Roman settlement being abandoned by the 2nd century (Beaverstock, 2018c). These appear likely to extend into the southern part of the site, although ridge and furrow is also likely to have caused some truncation.

1.5.2 The site contains earth banks associated with the former golf course and widespread ground make-up which can be seen on LiDAR imagery (see Fig 09). Ridge and furrow earthworks are also evident.

1.6 Geology and soils

1.6.1 The underlying geology is mudstone from the Oxford Clay Formation (BGS, 2017).

1.6.2 The overlying soil is from the Denchworth association and is a pelo-stagnogley. It consists of a slowly permeable, seasonally waterlogged, clayey soil.

1.6.3 Magnetometry carried out over similar geology and soil has produced good

results. The site is, therefore, considered suitable 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 (also known as thermoremanence) are factors associated with the formation of localised fields.

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). Additional details are set out in 2.2 below and within Appendix A.

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 (FGM650) spaced 0.5m apart with readings recorded at 20Hz. The cart is pushed at walking speed and not towed. Each sensor is not zeroed in the field as the vertical axis alignment is precisely fixed leaving sensor offsets that are removed during data processing. The fixing of the vertical alignment ensures the sensors are not unduly influenced by localised magnetic fields and that the vertical component of a magnetic anomaly is measured. The gradiometers have a range of recording data between ±0.1nT and ±8000nT. They are linked to a Leica GS10 RTK GNSS with data recorded by SENSYS MAGNETO®MXPDA software on a rugged PDA computer system.

2.2.2 Due to the fixed offsets within the fluxgate sensors, as a result of the manufacturing and tensioning process, the survey data do not provide a visually useful dataset until a zero median traverse algorithm is applied. It is recognised that this has the

potential to affect some anomalies detrimentally by removing linear features orientated parallel to survey transects. However, this has not been noted as a particular problem with the system due to the high resolution data collection, generally long length of traverses and variability within the magnetic characteristics of a linear anomaly.

2.2.3 Data are collected along a series of parallel survey transects to achieve 100% coverage of the surveyable land. 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. 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).

2.2.4 Fluxgate sensors are highly sensitive to temperature change and this manifests as drift during the course of a survey. This can be particularly noticeable during the morning as temperatures rise and the equipment warms or cools. Sensor drift within the course of a traverse will appear as a line trending from negative to positive after processing with a zero median traverse algorithm. To remove the potential for temperature drift, data were collected after a 20 minute stabilisation period and traverses were limited to a time of generally <100s.

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. The software effectively allocates a geographic position for each data point and can compensate for fixed offsets present within the FGM650 sensors. The offsets are positive or negative values present on all fluxgate gradiometer sensors. Some systems use manual or electronic balancing to effectively zero the sensors; however, this is a short term measure that is prone to drift through temperature changes and vibration and can easily be incorrectly set due to localised magnetic fields. The FGM650 sensors are very accurately aligned to the vertical magnetic gradient and are highly stable showing negligible drift on long traverses. The offset values are removed using TerraSurveyor software.

2.3.2 Survey tracks are analysed and georeferenced raw data (UTM Z30N) are then exported in ASCII format for further analysis and display within TerraSurveyor. The removal of the offset values (compensation) of the sensors is also carried out in TerraSurveyor using a zero median traverse function. Data are then considered to be minimally processed. Note: without the zero median traverse function it is not possible to create a meaningful data plot as all sensors have a different offset value. 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 The minimally processed data are collected between limits of ±8000nT and clipped for display at ±3nT. Data are interpolated to a resolution of effectively 0.5m between tracks and 0.15m along each survey track.

2.3.4 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 processing.

2.3.5 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. With regard to the Sensys MXPDA, minimally processed data are considered by the manufacturer to be data that are compensated by SENSYS MAGNETO DLMGPS software, see 2.3.1 and 2.3.2. Note: traceplots are not considered to be appropriate as they do not provide an accurate or useful assessment of the magnetic anomalies due to the very high density of data collection. In addition, traceplots cannot be meaningfully plotted against base mapping and in areas of complexity traces may be lost or highly confused. Traceplots may be used to demonstrate characteristic magnetic profiles across discrete features where it is considered beneficial.

2.3.6 The raster images are combined with base mapping using ProgeCAD Professional 2016, creating DWG (2010) 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 GNSS, resection method, etc.

2.3.7 An abstraction and interpretation is drawn and plotted 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. Appendix E sets out CAD layer names with colour and graphic content for each interpretation category, see 3.3.

2.3.8 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 each survey area.

2.3.9 The abstraction and interpretation procedure has been supported by analysis of a digital terrain model and/or contour plot derived from the Environment Agency's LiDAR data (Fig 09).

2.3.10 A digital archive is produced with this report, see Appendix D below. The main archive is held at the offices of Archaeological Surveys Ltd.

3 RESULTS

3.1 General assessment of survey results

3.1.1 The detailed magnetic survey was carried out over approximately 9.8ha. Areas 1 and 2 lie in the southern part of the site, Area 1 is a grass field and Area 2 is a small car park. These will be considered as a single area. Area 3 is the main former golf course and Area 4 is two fields subject to limited survey in order to confirm the extent of ground make-up visible on LiDAR data plots.

3.1.2 Magnetic anomalies located can be generally classified as positive linear and discrete positive responses of archaeological potential, positive and negative anomalies of an uncertain origin, anomalies associated with land management, linear anomalies of an agricultural origin, areas of magnetic debris and disturbance, strong discrete dipolar anomalies relating to ferrous objects and strong multiple dipolar linear anomalies relating to buried services or pipelines.

3.1.3 Anomalies located within each survey area have been numbered and are described in 3.4 below.

3.2 Statement of data quality and factors influencing the interpretation of anomalies

3.2.1 Data are considered representative of the magnetic anomalies present within the site. There are no significant defects within the dataset. Former cut features, such as ditches and pits, appear to demonstrate useful magnetic contrast similar to the results obtained from a previous survey on land to the south.

3.2.2 The archaeological potential of the majority of Area 2 and some zones within Area 3 could not be determined due to magnetic debris, magnetic disturbance and unsurveyed zones due to the presence of tall or dense vegetation and modern ground make-up. The limited survey in Area 4 proved widespread ground make-up with magnetic material, site observations suggest this material may be 1 - 2m deep.

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 general explanation of the characteristics of the magnetic anomalies is set out for each category in order to justify interpretation, see Table 1.

Interpretation category	Description and origin of anomalies
Anomalies with archaeological potential	Anomalies have the characteristics (mainly morphological) of a range of archaeological features such as pits, ring ditches, enclosures, etc. The category is used where there is a high level of confidence which may be due to additional supporting information where morphology is unclear or uncharacteristic.

Anomalies with an uncertain origin	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. Morphology may be unclear or uncharacteristic and there may be a lack of additional supporting information. 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 relating to land management	Anomalies are mainly linear and may be indicative of the magnetically enhanced fill of cut features (i.e. ditches). The anomalies may be long and/or form rectilinear elements and they may relate to topographic features or be visible on early mapping. Associated agricultural anomalies (e.g. headlands, plough marks and former ridge and furrow) may support the interpretation.
Anomalies with an agricultural origin	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. This category does not include agricultural features of early date or considered to be of archaeological potential (e.g. animal stockades, enclosures, farmsteads, etc).
Anomalies associated with magnetic debris	Magnetic debris often appears as areas containing many small dipolar anomalies that may range from weak to very strong in magnitude. They often occur where there has been dumping or ground make-up and are related to magnetically thermoremnant materials such as brick or tile or other small fragments of ferrous material. This type of response is occasionally associated with kilns, furnace structures, hearths and nail spreads from former wooden structures or rooves and may, therefore, be archaeologically significant. It is also possible that the response may be caused by natural material such as certain gravels and fragments of igneous or metamorphic rock. Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.
Anomalies with a modern origin	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 these 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 adjacent to strong magnetic sources. Buried services may produce characteristic multiple dipolar anomalies dependant upon their construction.

Table 1: List and description of interpretation categories

3.4 List of anomalies - Area 1 & 2

Area centred on OS NGR 420170 193970, see Figs 05 & 06.

Anomalies of archaeological potential

(1) - Positive curvilinear anomalies represent at least three ring ditches located in the south western corner of the survey area. These are a continuation of similar located by previous surveys between 20m and 175m to the south west. They

appear to be contained within a group of rectilinear enclosures (2).

(2) - Positive rectilinear anomalies relate to a group of enclosures in the south western part of the site. They are oriented north east to south west and north west to south east and they appear to contain ring ditches (1). Other linear, curvilinear and discrete anomalies are contained within the enclosures and relate to further cut features. At the eastern side of the enclosures there are a pair of parallel ditches which could indicate a trackway.

(3) - Located between 50m and 130m north east of anomalies (1) are at least 6 further ring ditch features, with fragmented positive responses likely to relate to earlier, truncated ones.

(4) - Linear and rectilinear anomalies form a north eastward extension of enclosures (2) and these enclose ring ditches (3).

(5) - A positive linear anomaly extends from the south in a north north westwards direction to join enclosures (2). It is linear further south but as it joins (2) it appears to curve around a ring ditch feature. On its western edge are a number of further curvilinear, rectilinear and linear responses, which although are not clearly defined, are likely to relate to further archaeological features.

Anomalies with an uncertain origin

(6) - Weak, short or fragmented positive linear, curvilinear and discrete anomalies in the eastern part of the survey area could relate to further cut features, such as ring ditches, but they are very weak and poorly defined.

(7) - A weakly positive linear anomaly could relate to a cut ditch-like feature; however, an agricultural origin is also possible.

(8) - Located in the north eastern part of the survey area (Area 2) are further very weakly positive linear and possible curvilinear anomalies. They are very poorly defined, but it is possible that they relate to further cut features with archaeological potential.

Anomalies with an agricultural origin

(9) - A series of parallel linear anomalies relate to former ridge and furrow cultivation.

Anomalies associated with magnetic debris

(10) - The northern part of the site (Area 2) contains a gravel covered car park and widespread magnetic debris probably relates to a ferrous base material. The response would completely obscure weaker anomalies of archaeological potential if they are present in this part of the site.

(11) - Strong, discrete, dipolar anomalies relate to ferrous objects within the site.

While the majority may be modern in origin, some could be directly associated with archaeological ferrous objects.

Anomalies with a modern origin

(12) - A rectilinear formation of discrete anomalies relates to fence posts associated with a former sports pitch.

(13) - Magnetic disturbance has been caused by ferrous fencing material (steel tubing) around the survey area and a concrete pad with steel mesh in the north east.

3.5 List of anomalies - Area 3

Area centred on OS NGR 420115 194290 see Figs 03, 04, 07 & 08.

Anomalies with an uncertain origin

(14) - Located in the south eastern corner of Area 3 are a small number of weakly positive linear and possibly curvilinear anomalies. They appear to have been truncated by, and therefore pre-date, ridge and furrow and they are situated as a possible north easterly continuation of anomalies (3) and (4), 90m to the south.

(15) - In the far north western corner of the survey area are two positive curvilinear anomalies that appear to have been truncated by ridge and furrow. If complete, they could relate to a ring ditch feature with an 11m diameter and an archaeological origin is, therefore, possible.

(16) - A positive linear anomaly appears to have been truncated by ridge and furrow. However, it is parallel with a series of ridge and furrow situated just to the east and could indicate an earlier phase of cultivation.

(17) - Located in the northern part of the survey area are a number of positive linear, curvilinear and discrete responses. The area immediately to the north has been subject to ground make-up, and it is possible that these anomalies have been caused by vehicles during construction of the mound.

(18) - Two negative linear anomalies can be seen in the results. This type of response usually indicates a plastic pipe and it is possible that these are associated with the former golf course.

Anomalies associated with land management

(19) - The survey area contains at least five former fields containing ridge and furrow and separated by double linear anomalies relating to field boundaries and/or headlands.

Anomalies with an agricultural origin

(20) - Five separate series of parallel linear anomalies relate to former ridge and furrow cultivation. The majority of these are evident on LiDAR imagery and were visible during the course of the survey.

(21) - Broadly spaced, parallel linear anomalies appear to relate to more modern agricultural activity or land drainage.

Anomalies associated with magnetic debris

(22) - Zones of magnetic debris relate to highly magnetic material used for modern ground make-up and trackways between mounds.

Anomalies with a modern origin

(23) - A modern pipe extends across the south western corner of the survey area.

3.6 List of anomalies - Area 4

Area centred on OS NGR 419840 194140 & 419858 194332 see Figs 03, 04, 07 & 08.

Anomalies associated with magnetic debris

(24) - Strongly magnetic debris relates to ferrous material within made ground.

4 CONCLUSION

4.1.1 The geophysical survey located a number of anomalies with archaeological potential within the southern part of the site. These include at least eight ring ditches appearing to be contained within a number of rectilinear enclosures. They are a continuation of similar features seen immediately to the south and south west which relate to mid/late Iron Age and early Roman settlement.

4.1.2 A number of weak and fragmented positive linear and curvilinear responses can also be seen just to the north of the archaeology and also within the south eastern and north western corners of the former golf course. The weak response and poor definition hinder interpretation; however, they do appear to have been truncated by later ridge and furrow and an archaeological origin is possible. Further weakly positive anomalies towards the northern part of the site could relate to vehicular activity during construction of the golf course.

4.1.3 Magnetic debris with a high ferrous content is evident within the ground make-up of a car park in the southern part of the site, within tracks used during construction of the golf course and across the entire ground make-up within two fields in the western part of the site.

5 REFERENCES

Archaeological Surveys, 2018. *Faringdon to Blunsdon Phase 1, Water Main Replacement, Highworth, Swindon. Report ref J748.* Unpublished typescript document.

Aspinall, A., Gaffney, C. and Schmidt, A. 2009. *Magnetometry for Archaeologists*. Lanham (US), AltaMira Press.

Beaverstock, K., 2018a. *Proposed Aldi, Land west of Lechlade Road, Highworth, Swindon*. TVAS report LRH17/95A. Thames Valley Archaeological Services.

Beaverstock, K., 2018b. *Land west of Lechlade Road, Highworth, Swindon*. TVAS report LRH17/95B. Thames Valley Archaeological Services.

Beaverstock, K., 2018c. *Proposed Aldi, Land west of Lechlade Road, Highworth, Swindon*. An Archaeological Evaluation. TVAS report LRH17/95. Thames Valley Archaeological Services.

Beaverstock, K., 2018b. *Land west of Lechlade Road, Highworth, Swindon*. TVAS report LRH17/95B. Thames Valley Archaeological Services.

British Geological Survey, 2017. *Geology of Britain 3D (Beta version), 1:50 000 scale [online]* available from http://mapapps.bgs.ac.uk/geologyofbritain3d/index.html? [accessed 14/8/2019].

Chartered Institute for Archaeologists, 2014. *Standard and Guidance for archaeological geophysical survey*. CIfA, University of Reading.

European Archaeological Council, 2015. *EAC Guidelines for the Use of Geophysics in Archaeology: Questions to Ask and Points to Consider.* Europae Archaeologia Consilium and Association Internationale sans But Lucratif, Belgium.

Historic England, 2018. Geophysical Survey Advice [online] available from https://historicengland.org.uk/advice/technical-advice/archaeological-science/geophysics/ [accessed July 2018].

Institute for Archaeologists, 2002. *The use of Geophysical Techniques in Archaeological Evaluations*. IfA Paper No. 6. IfA, University of Reading.

Schmidt, A., 2013. *Geophysical Data in Archaeology: A Guide to Good Practice.* Oxbow Books.

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 5 South West England.*

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 magnetic field. The difference between the two sensors will relate to the strength of 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. Different ranges are applied to data in order to determine the most suitable for anomaly abstraction and display.

Despike

Removal of data points that exceed the mean/median/threshold by selecting a window size of data points and replace by mean/median/threshold. Magnetic spikes can be caused iron objects on the surface or within the topsoil. Despike can improve the appearance of data and remove extreme readings that may affect further processing.

High Pass Filter

Removes low frequency anomalies within the data that are not considered to be archaeologically significant and may be natural in origin. A window passes over the data, the mean of all the data within the window is subtracted from the centre value. The size of the window is adjusted as is the weighting which may be uniform or Gaussian. The process is used to improve the visibility of anomalies of interest.

Low Pass Filter

Removes high frequency anomalies or 'noise' within datasets and provides a smoother output. A window passes over the data, the mean of all the data within the window is used to replace the centre value. The size of the window is adjusted as is the weighting. The process is used to improve the visibility of anomalies of interest.

Zero Median/Mean Traverse

The median (or mean) of data from 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 offset values of the gradiometer sensors. The process can remove archaeological features that run along a traverse but with the high resolution datasets created by the Sensys FGM650 sensors and the method of data collection this has not been a notable problem. In fact, the removal of offsets using software avoids carrying out a balancing procedure on site, which inevitably can never be done in magnetically clean conditions and results in improperly aligned fluxgate sensors and/or electronic adjustment values.

Appendix C – survey and data information

Area 1

Filename: J799-mag-Area1-proc.xcp
Description: Imported as Composite from: J799-mag-Area1.asc
Instrument Type: Sensys DLMGPS
Units: nT
UTM Zone: 30U
Survey corner coordinates (X/Y):OSGB36
Northwest corner: 420094.12, 194037.80 m
Southeast corner: 420271.12, 193876.85 m
Collection Method: Randomised
Sensors: 5
Dummy Value: 32702
Source GPS Points: 582100
Dimensions
Composite Size (readings): 1180 x 1073
Survey Size (meters): 177 m x 161 m
Grid Size: 177 m x 161 m
X Interval: 0.15 m
Y Interval: 0.15 m
Stats
Max: 3.32
Min: -3.30
Std Dev: 1.24
Mean: 0.04
Median: 0.00
Composite Area: 2.8488 ha
Surveyed Area: 1.7054 ha
PROGRAM
Name: TerraSurveyor
Version: 3.0.23.0
GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse:
4 Clip from -3.00 to 3.00 nT

Area 2

Filename: J799-mag-Area2-proc.xcp
Description: Imported as Composite from: J799-mag-Area2.asc
Survey corner coordinates (X/Y):OSGB36
Northwest corner: 420083.89, 194067.02 m
Southeast corner: 420200.14, 194007.02 m
Source GPS Points: 82300
Dimensions
Composite Size (readings): 775 x 400
Survey Size (meters): 116 m x 60 m
Grid Size: 116 m x 60 m
X Interval: 0.15 m
Y Interval: 0.15 m

Stats
Max: 3.32
Min: -3.30
Std Dev: 2.35
Mean: 0.00
Median: 0.08
Composite Area: 0.6975 ha
Surveyed Area: 0.26019 ha
GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse:
4 Clip from -3.00 to 3.00 nT

Area 3

Filename: J799-mag-Area3-proc.xcp
Description: Imported as Composite from: J799-mag-Area3.asc
Survey corner coordinates (X/Y):OSGB36
Northwest corner: 419951.83, 194482.60 m
Southeast corner: 420270.28, 194069.80 m
Source GPS Points: 2418400
Dimensions
Composite Size (readings): 2123 x 2752
Survey Size (meters): 318 m x 413 m
Grid Size: 318 m x 413 m
X Interval: 0.15 m
Y Interval: 0.15 m
Stats
Max: 3.32
Min: -3.30
Std Dev: 1.32
Mean: 0.08
Median: 0.01
Composite Area: 13.146 ha
Surveyed Area: 7.7062 ha
GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse:
4 Clip from -3.00 to 3.00 nT

Area 4

Filename: J799-mag-Area4-proc.xcp
Description: Imported as Composite from: J799-mag-Area4.asc
Survey corner coordinates (X/Y):OSGB36
Northwest corner: 419755.01, 194412.66 m
Southeast corner: 419917.91, 194066.01 m
Source GPS Points: 77400
Dimensions
Composite Size (readings): 1086 x 2311
Survey Size (meters): 163 m x 347 m
Grid Size: 163 m x 347 m
X Interval: 0.15 m
Y Interval: 0.15 m
Stats
Max: 3.32
Min: -3.30
Std Dev: 2.70
Mean: -0.01
Median: -0.04
Composite Area: 5.6469 ha
Surveyed Area: 0.2879 ha
GPS based Proce4
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 DeStripe Median Traverse:
4 Clip from -3.00 to 3.00 nT

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 PDF copy will be supplied to the Wiltshire Historic Environment Record with printed copies on request. The abstraction layers can also be made available as a dwg and the greyscale images as tifs with tfws for use in a GIS. The report will also be uploaded to the Online AccesS to the Index of archaeological investigationS (OASIS).

Archive contents:

File type	Naming scheme	Description
Data	J799-mag-**[area number/name]**.asc J799-mag-**[area number/name]**.xcp J799-mag-**[area number/name]**-proc.xcp	Raw data as ASCII CSV TerraSurveyor raw data TerraSurveyor minimally processed data
Graphics	J799-mag-**[area number/name]**-proc.tif	Image in TIF format
Drawing	J799-**[version number]**.dwg	CAD file in 2010 dwg format
Report	J799 report.odt	Report text in Open Office odt format

Table 2: Archive metadata

Appendix E – CAD layers for abstraction and interpretation plots

The table below sets out Archaeological Surveys Ltd CAD layer names with associated colours and graphical content. Where CAD files are available layers may be extracted for further CAD/GIS use. Note: hatched polygon boundaries are contained within layers with the RGB colour code 254, 255, 255 (near white) in order to prevent their visibility.

Report sub-heading and associated CAD layer names	Colour with RGB index		Layer content
Anomalies with archaeological potential			
AS-ABST MAG POS DISCRETE ARCHAEOLOGY		Red 255,0,0	Solid donut, point or polygon (solid)
AS-ABST MAG POS ARCHAEOLOGY		Red 255,0,0	Polygon (cross hatched ANSI37)
AS-ABST MAG POS LINEAR ARCHAEOLOGY		Red 255,0,0	Polyline or polygon (solid)
AS-ABST MAG POS CURVILINEAR RING DITCH		Magenta 255,0,255	Polyline or polygon (solid)
AS-ABST MAG POS ENCLOSURE DITCH		127,0,255	Line, polyline or polygon (solid)
Anomalies with an uncertain origin			
AS-ABST MAG POS LINEAR UNCERTAIN		255,127,0	Line, polyline or polygon (solid)
AS-ABST MAG NEG LINEAR UNCERTAIN		Blue 0,0,255	Line, polyline or polygon (solid)
AS-ABST MAG POS DISCRETE UNCERTAIN		255,127,0	Solid donut, point or polygon (solid)
Anomalies relating to land management			
AS-ABST MAG BOUNDARY		127,0,0	Line, polyline or polygon (solid or cross hatched ANSI37)
Anomalies with an agricultural origin			
AS-ABST MAG AGRICULTURAL		Green 0,255,0	Line or polyline
AS-ABST MAG RIDGE AND FURROW		0,127,63	Line, polyline or polygon (cross hatched ANSI37)
Anomalies associated with magnetic debris			
AS-ABST MAG DEBRIS		132, 132, 132	Polygon (cross hatched ANSI37)
AS-ABST MAG STRONG DIPOLAR		132, 132, 132	Solid donut, point or polygon (solid)

Anomalies with a modern origin			
AS-ABST MAG DISTURBANCE		132, 132, 132	Polygon (hatched ANSI31)
AS-ABST MAG SERVICE		132, 132, 132	Line or polyline

Table 3: CAD layering

Appendix F – copyright and intellectual property

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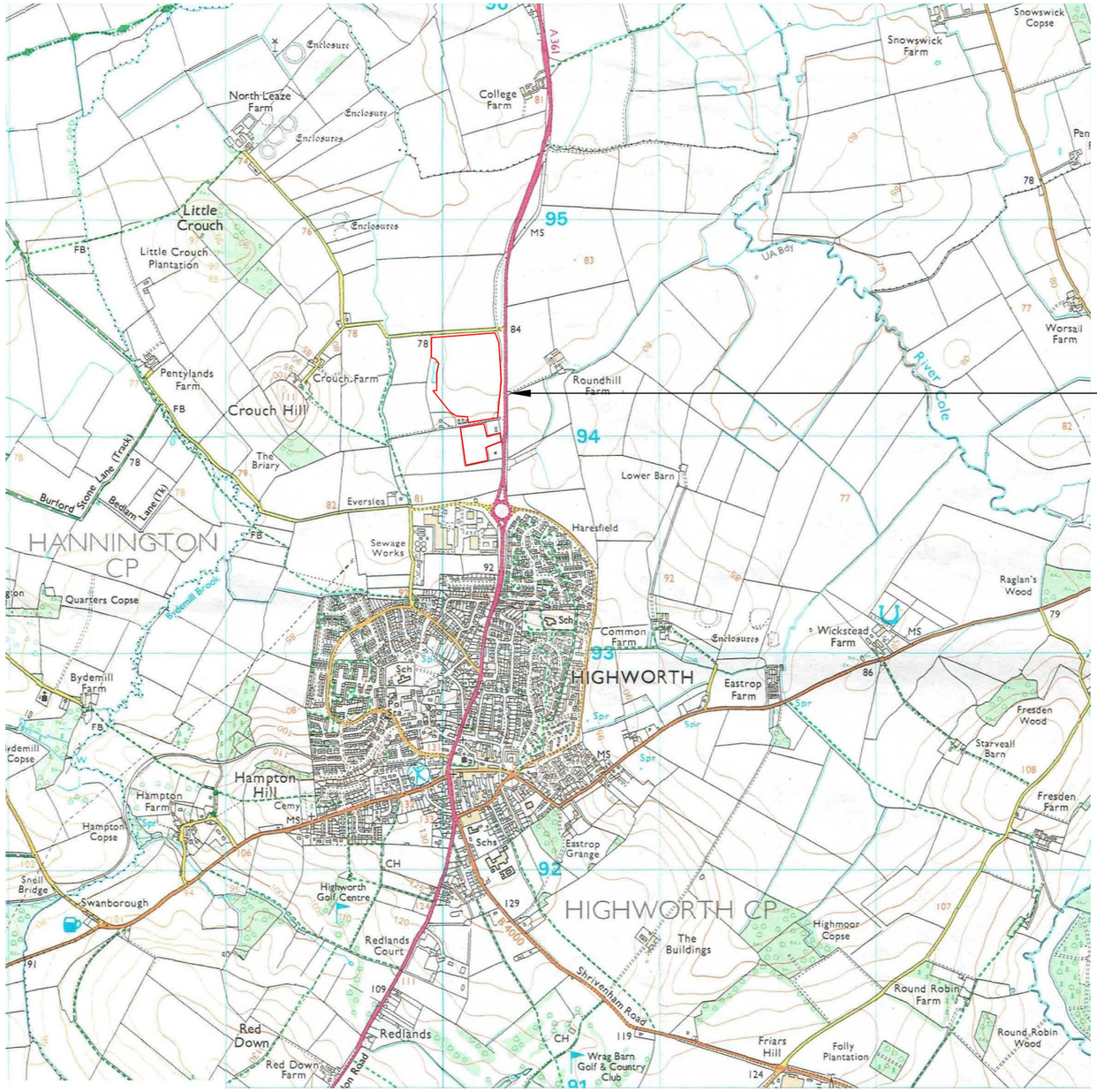
Tel: 01249 814 231

Archaeological Surveys
Specialist Geophysical Surveyors

Geophysical Survey
Twelve Oaks
Highworth
Swindon

Map of survey area



Survey location

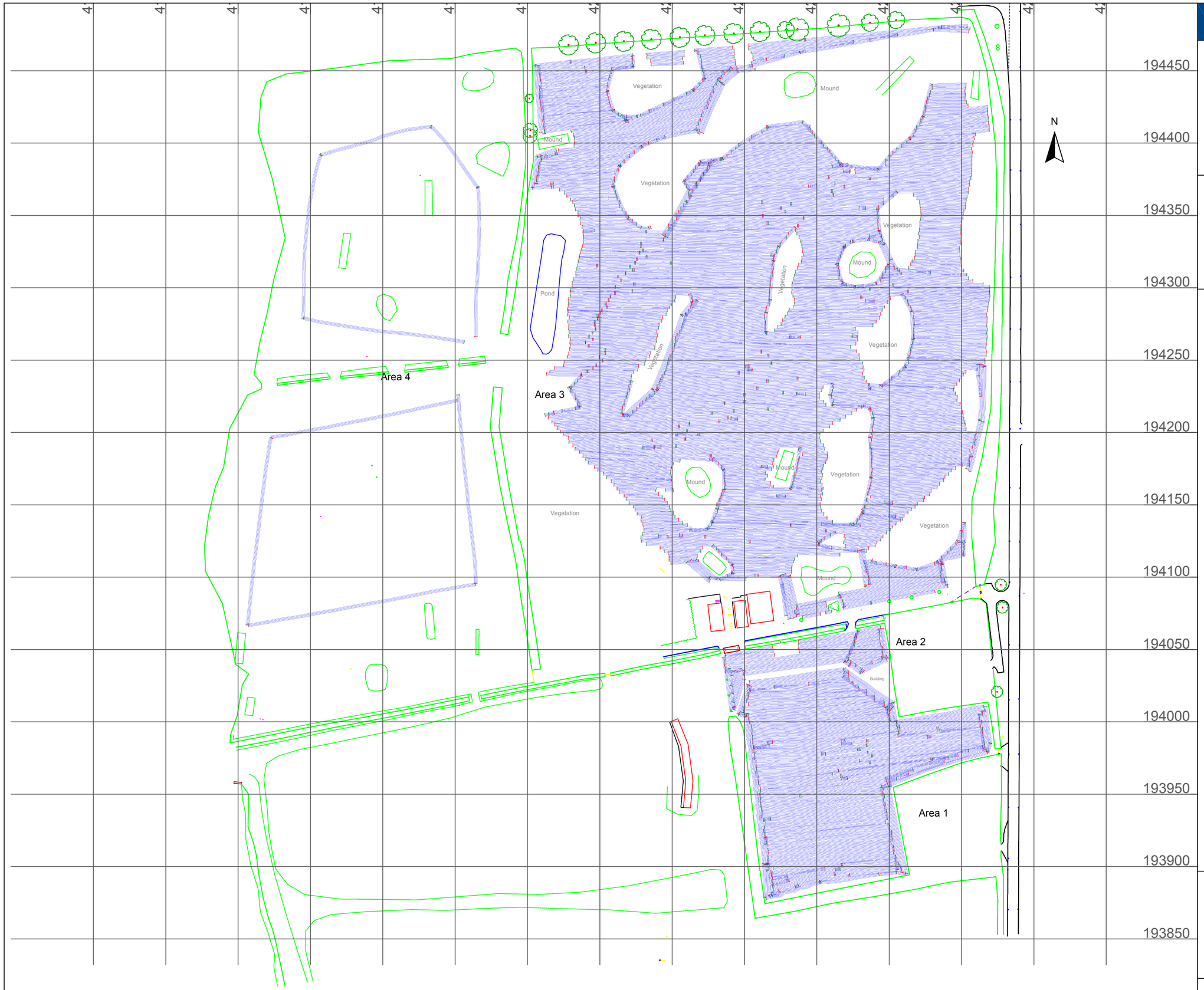
Site centred on OS NGR
SU 20125 94200

SCALE 1:25 000

0m 500m 1000m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 01



2018 water pipeline survey

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Highworth
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Referencing information

Referencing grid to OSGB36 datum at 50m intervals

Survey tracks

Survey track start

Survey track stop

SCALE 1:2500

0m 50 100m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 02

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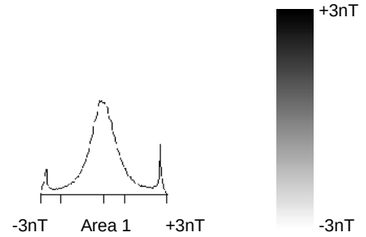
Greyscale plot of minimally processed magnetometer data



SCALE 1:2500

0m 50 100m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 03

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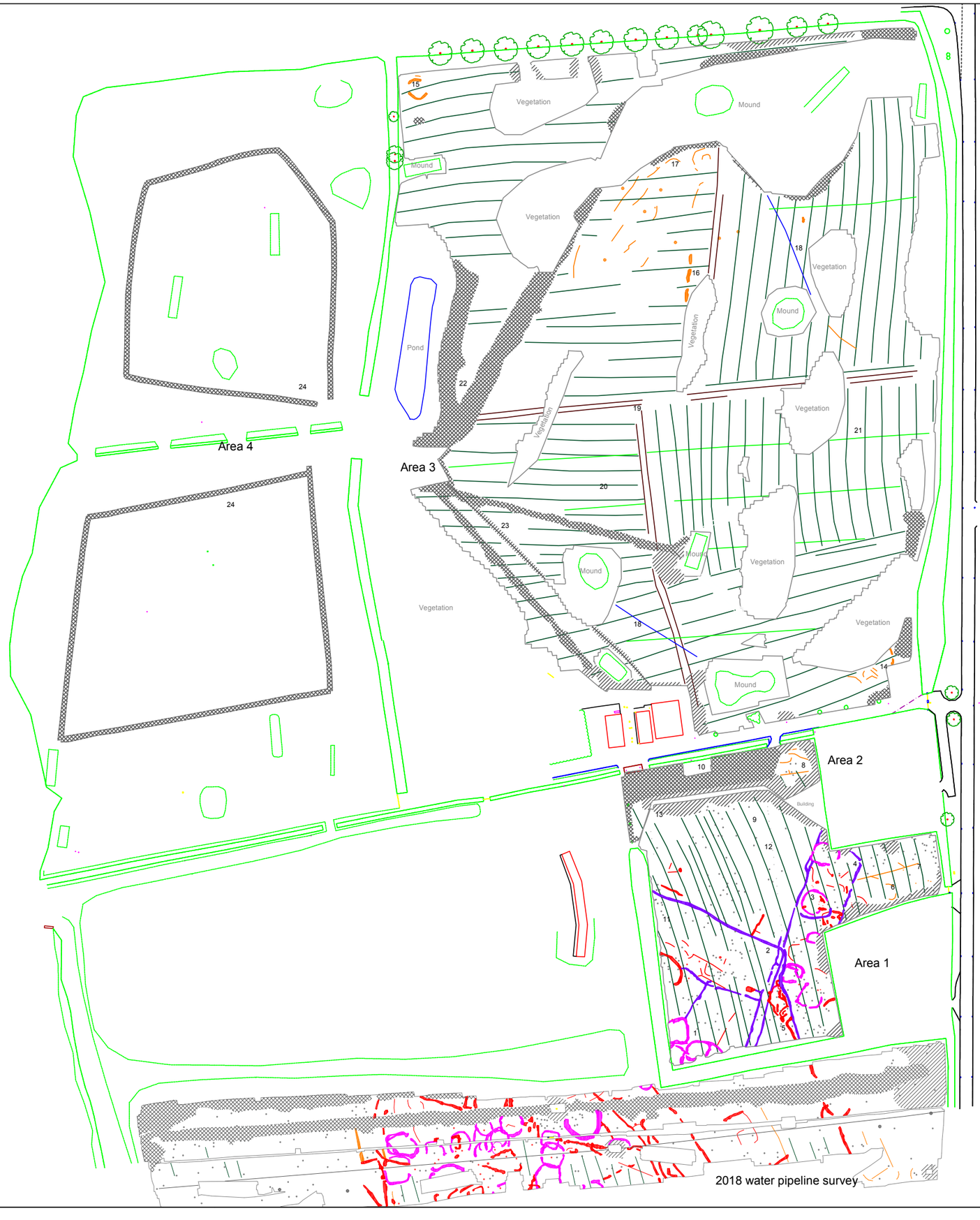
Abstraction and interpretation of magnetic anomalies



- Positive linear anomaly - cut feature of archaeological potential
- Positive curvilinear anomaly - ring ditch
- Positive rectilinear anomaly - enclosure ditch
- Positive linear anomaly - possible ditch-like feature
- Linear anomaly - of agricultural origin
- Linear anomaly - ridge and furrow
- Positive linear anomaly - former field boundary/headland
- Negative linear anomaly - material of low magnetic susceptibility
- Discrete positive response - cut feature of archaeological potential
- Discrete positive response - possible pit-like feature
- Magnetic debris - spread of magnetically thermoremnant/ferrous material
- Magnetic disturbance from ferrous material
- Strong multiple dipolar linear anomaly - pipeline / cable / service
- Strong dipolar anomaly - ferrous object

SCALE 1:2500

0m 50 100m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 04

ation

Vegetation

Mound

Area 2

Building

Area 1

N

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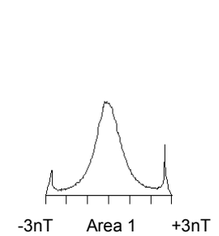
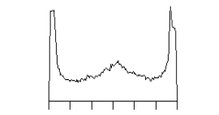
Greyscale plot of minimally processed magnetometer data - Areas 1 & 2





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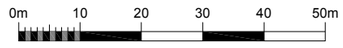

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 05

ation

18

Vegetation

Mound

14

N

Area 2

10

8

Building

13

9

12

4

7

6

3

11

2

5

1

Area 1

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Abstraction and interpretation of magnetic anomalies - Areas 1 & 2

- Positive linear anomaly - cut feature of archaeological potential
- Positive curvilinear anomaly - ring ditch
- Positive rectilinear anomaly - enclosure ditch
- Positive linear anomaly - possible ditch-like feature
- Linear anomaly - ridge and furrow
- Discrete positive response - cut feature of archaeological potential
- Discrete positive response - possible pit-like feature
- 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

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 06

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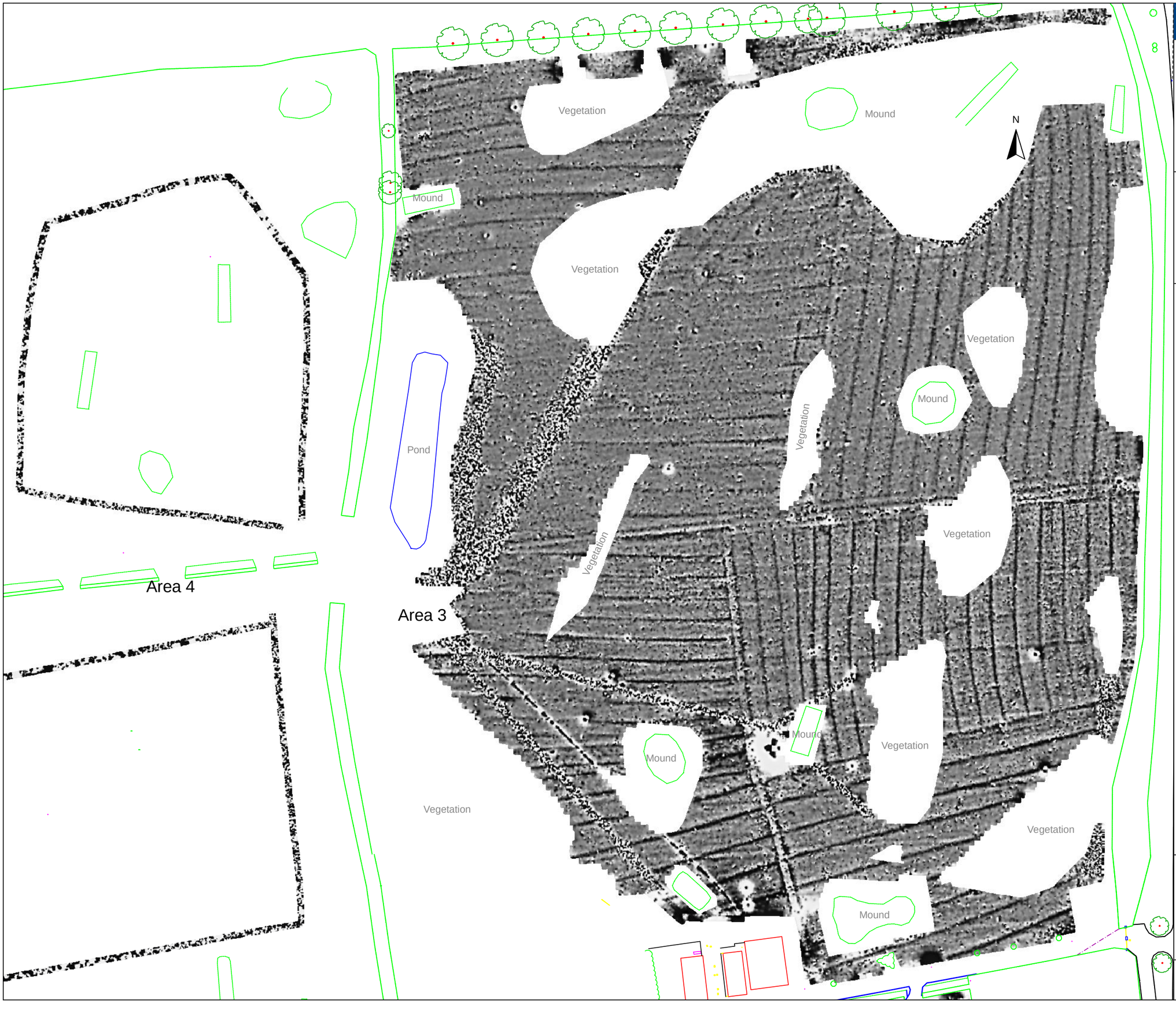
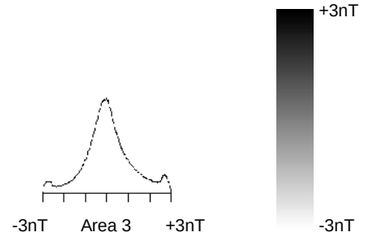
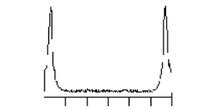
Greyscale plot of minimally processed magnetometer data - Areas 3 & 4







SCALE 1:1500

0m 10 20 30 40 50m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 07

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Abstraction and interpretation of magnetic anomalies - Areas 3 & 4

Area 3

Area 4

Vegetation

Mound

Pond

N

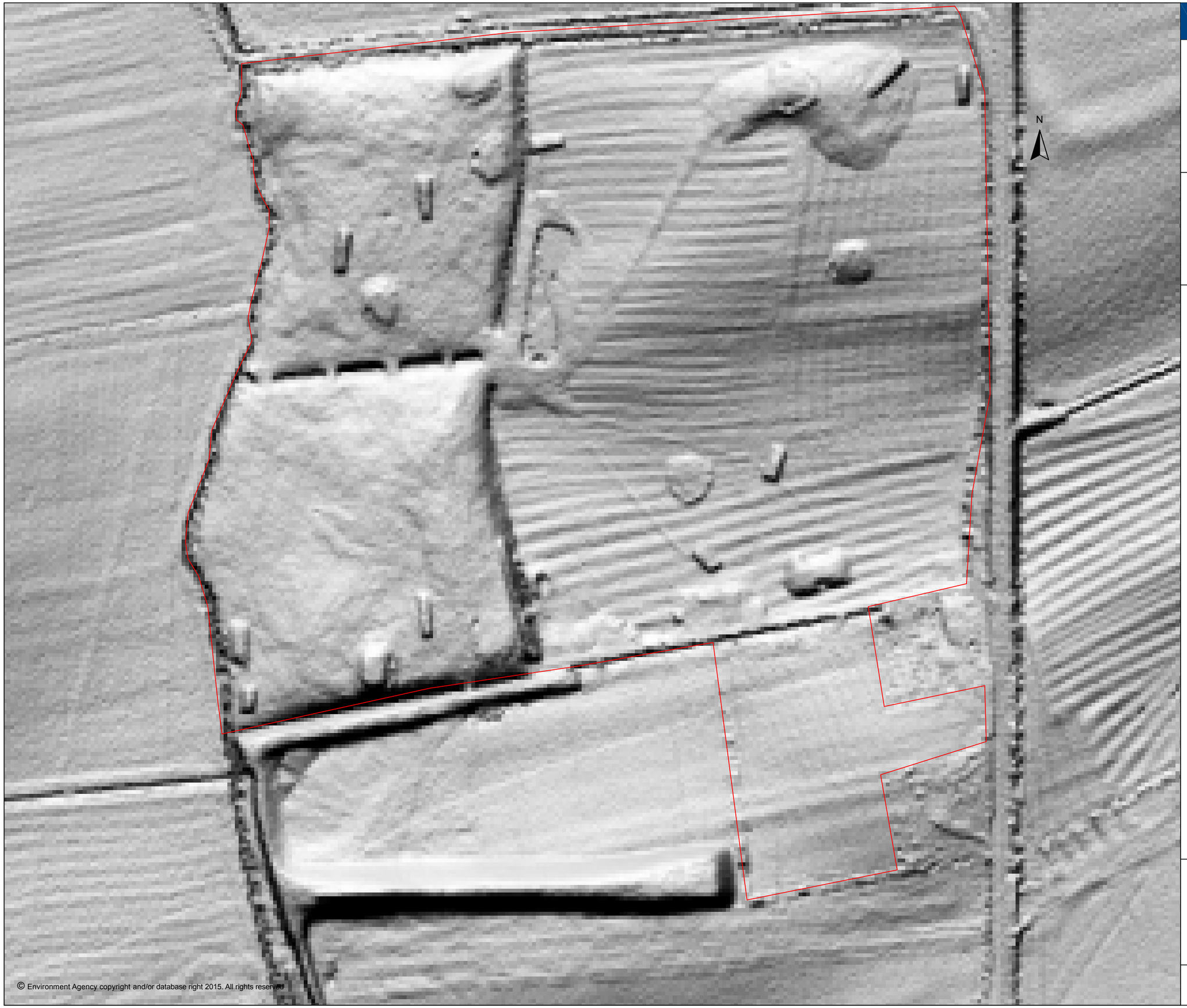
- Positive linear anomaly - possible ditch-like feature
- Linear anomaly - of agricultural origin
- Linear anomaly - ridge and furrow
- Positive linear anomaly - former field boundary/headland
- Negative linear anomaly - material of low magnetic susceptibility
- Discrete positive response - possible pit-like feature
- Magnetic debris - spread of magnetically thermoremnant/ferrous material
- Magnetic disturbance from ferrous material
- Strong multiple dipolar linear anomaly - pipeline / cable / service
- Strong dipolar anomaly - ferrous object

SCALE 1:1500

0m 10 20 30 40 50m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 08



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Digital Terrain Model

Shaded relief plot derived from Environment Agency's LiDAR data 1m resolution

SCALE 1:2500

0m 50 100m

SCALE TRUE AT A3

DRAWN BY	CHECKED BY	
KTD	DJS	FIG 09