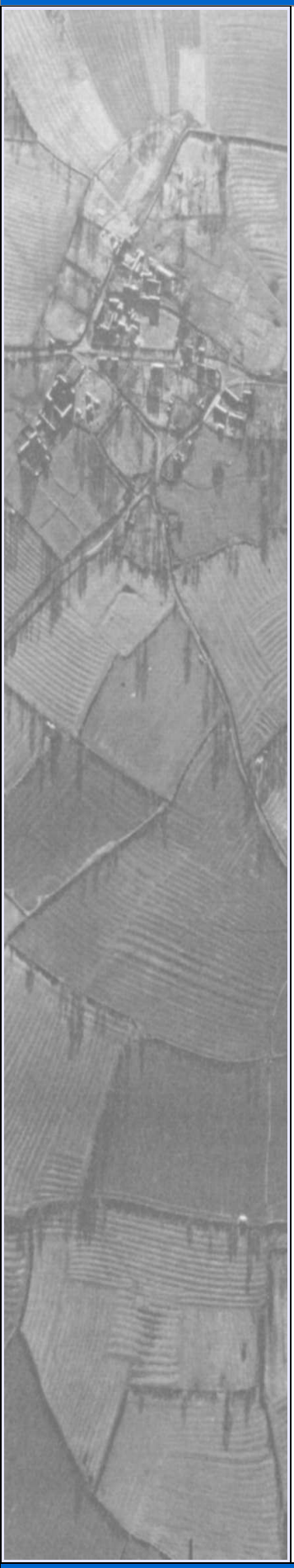

Wenmouth Manor
St Neot
Cornwall

MAGNETOMETER SURVEY REPORT

for

CgMs Consulting

David Sabin and Kerry Donaldson

March 2015

Ref. no. 592

ARCHAEOLOGICAL SURVEYS LTD

Wenmouth Manor
St Neot
Cornwall

Magnetometer Survey Report

for

CgMs Consulting

Fieldwork by David Sabin
Report by David Sabin BSc (Hons) MIFA and Kerry Donaldson BSc (Hons)

Survey date – 25th February 2015
Ordnance Survey Grid Reference – **SX 19768 67065**

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SUMMARY

A detailed magnetometer survey was undertaken by Archaeological Surveys Ltd over the proposed location of a single wind turbine, access track and cable route at Wenmouth Manor, St Neot, Cornwall. The survey located a number of rectangular enclosures and linear ditches of archaeological potential. At least one possible ring ditch was also revealed by the survey. A large number of positive and negative linear and discrete responses were also located, although many lack clarity and definition. Although some may relate to archaeological features, a natural origin should also be considered. A number of discrete negative responses may indicate buried stones, although whether these are natural or deliberately buried is not known.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by CgMs Consulting to undertake a magnetometer survey of an area of land at Wenmouth Manor, St Neot, Cornwall. The site has been outlined for a proposed development of a single wind turbine by Capture Energy, and the survey forms part of an archaeological assessment of the site.

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 Institute for Archaeologists (2011) *Standard and Guidance for Archaeological Geophysical Survey.*

1.3 Site location, description and survey conditions

1.3.1 The site is located at Wenmouth Manor, 1km south east of St Neot in Cornwall. The proposes turbine is centred on Ordnance Survey National Grid Reference (OS NGR) SX 19768 67065, see Figures 01 and 02.

1.3.2 The geophysical survey covers approximately 2.1ha within a single pasture field. The survey area is based on a 1ha block centred on the proposed

turbine location, together with an approximately 30m wide access corridor extending towards it from the north west and another corridor extending along the eastern field boundary covering the proposed cable route.

1.3.3 The ground conditions across the site were generally considered to be favourable for the collection of magnetometry data, although some small patches of boggy ground were unsurveyable. Weather conditions during the survey were damp and occasionally foggy.

1.4 Site history and archaeological potential

1.4.1 Within the field to the north west of the site, there is cropmark evidence for an Iron Age/Romano-British round with dimensions of 84m by 74m (MCO43436). There is also evidence for the medieval settlements of Trevegoe 500m to the west (MCO24622) and at East Killatown, 500m to the south east (MCO53321) (Cornwall Council, 2015).

1.4.2 The location of the round less than 100m away may indicate that there is potential for the geophysical survey to locate archaeological features within the site.

1.4.3 A large granite boulder, of unknown date, which could be a previously unrecorded standing stone or more recent rubbing stone, was noted in the valley base located just to the west of the survey and within the same field. It was not clear whether this was an ancient or relatively modern feature.

1.5 Geology and soils

1.5.1 The underlying geology within the site is slate and siltstone from the Saltash Formation.

1.5.2 The overlying soil across the site is from the Denbigh 1 association and is a typical brown earth. It consists of a well drained, fine loamy and fine silty soils over rock (Soil Survey of England and Wales, 1983).

1.5.3 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 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 20 Hz. The gradiometers have a range of recording data between 0.1nT and 10,000nT. They are 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.

2.3 Data processing and presentation

2.3.1 Magnetic data collected by the MAGNETO®MXPDA cart-based system are initially prepared and automatically compensated using SENSYS MAGNETO®DLMGPS software. Georeferenced raw data are then exported in ASCII format for further analysis and display using TerraSurveyor.

2.3.2 The data are collected at ±10000nT and clipped for display at ±20nT. Data are resampled to a resolution of effectively 0.5m between tracks and 0.15m along each survey track. Appendix C contains specific information 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.

2.3.3 A TIFF 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.

2.3.4 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.

2.3.5 An abstraction and interpretation is offered for all geophysical anomalies located by the survey. 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. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.3.6 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 2.1ha within a single pasture field. An area of 1ha was centred on the turbine location, with a 30m wide corridor to cover the access track to the west and cable route to the south east.

3.1.2 Magnetic anomalies located can be generally classified as positive responses of archaeological potential, positive and negative anomalies of an uncertain origin, linear anomalies of an agricultural origin 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.

Report sub-heading CAD layer names and plot colour	Description and origin of anomalies
Anomalies with archaeological potential AS-ABST MAG POS LINEAR ARCHAEOLOGY AS-ABST MAG POS DISCRETE ARCHAEOLOGY AS-ABST MAG POS CURVILINEAR RING DITCH AS-ABST MAG ENCLOSURE DITCH	Anomalies have the characteristics (mainly morphological) of a range of archaeological features such as pits, ring ditches, enclosures, etc..
Anomalies with an uncertain origin AS-ABST MAG POS LINEAR UNCERTAIN AS-ABST MAG NEG LINEAR UNCERTAIN AS-ABST MAG POS DISCRETE UNCERTAIN AS-ABST MAG NEG DISCRETE 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 RIDGE AND FURROW	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.

Table 1: List and description of interpretation categories

3.4 List of anomalies

Turbine centred on OS NGR SX 19768 67065, see Figures 03 & 04.

Anomalies of archaeological potential

(1) – A positive rectilinear anomaly forms at least three sides of sub-rectangular or square enclosure. The response along the northern edge is strong at 30-45nT. It appears to have truncated another rectilinear enclosure (2). A number of positive linear anomalies are located at the south western corner, with one extending further to the north west. A large pit can be seen immediately to the west with several positive responses within the confines of the enclosure; however, these lack clarity and cannot be confidently interpreted as associated cut features.

(2) – A rectilinear anomaly forms an enclosure feature that appears to have been truncated by anomaly (1). It also generally has a weaker response (5-15nT) than anomaly (1).

(3) – A number of positive linear anomalies are located to the east of anomaly (2). they appear to relate to linear ditches and may be associated with anomaly (2).

(4 & 5) – A positive curvilinear anomaly appears to relate to a ring ditch (4) with a similar smaller feature located immediately to the west. It also appears to join a larger curvilinear enclosure ditch (5), although this is not well defined.

(6) – A positive linear anomaly extends across the access track route in the north western part of the survey area. This appears to relate to a linear, ditch-like feature and an archaeological origin should be considered.

(7) – Located towards the southern edge of the cable route are a number of rectilinear enclosure ditches that are likely to extend beyond the survey area to the south east. The majority of these are strongly enhanced, generally with a response of around 45nT; however, the north easternmost anomaly is weaker at 8-16nT.

Anomalies with an uncertain origin

(8) – A positive linear anomaly is located parallel with and 6m west of anomaly (16). The orientation may indicate that it is associated with anomaly (16); however, it is possible that it is a cut linear extension from the north west corner of anomaly (2).

(9) – A number of positive linear anomalies can be seen in the northern part of the survey area and are oriented north east to south west. Many are short or fragmented, but they are oriented parallel with anomaly (16) and it is possible that they may be associated with land drainage.

(10) – A negative anomaly, flanked by two positive responses can be seen at the junction between the access route and the north western corner of the turbine area. The response is indicative of a removed Cornish Hedge, and the position may indicate a former continuation for the existing land boundary to the north.

(11) – The northern part of the site contains a number of negative responses, flanked by positive responses. Generally they are short and poorly defined, and it is not possible to determine if they are associated with natural features or if they relate to former boundary features and may, therefore, have some archaeological potential.

(12) – In the northern part of the survey area is a possible positive rectilinear anomaly, it may relate to a cut, ditch-like feature.

(13) – The survey area contains a large number of positive linear, curvilinear and discrete anomalies; however, their morphology is unclear. While it is possible that some or all of these anomalies relate to natural features, an association with cut features cannot be ruled out.

(14) – A number of discrete negative responses can be seen in the western part of the turbine survey area. This type of response indicates material with a lower magnetic susceptibility than the surrounding soils, such as stone.

(15) – A cluster of negative discrete anomalies are located in the northern part of the cable route. They appear in the vicinity of a broad bank-like feature within the field. It is possible that the negative anomalies and this bank-like feature are geological, although this is not certain.

(16) – A negative linear anomaly extends across the turbine survey area from the north eastern corner in a south westerly direction. It truncates a number of archaeological features (1, 2 & 4) and corresponds to a linear depression within the field. This is likely to be a relatively modern feature such as a drain or pipe.

(17) – Extending along the northern part of the turbine area are a pair of parallel negative linear anomalies. This type of response may indicate ruts formed by vehicles.

Anomalies with an agricultural origin

(18) – A number of parallel broad linear anomalies can be seen primarily within the north eastern part of the survey area. This type of response may indicate ridge and furrow or medieval strip farming.

Anomalies associated with magnetic debris

(19) – The survey area contains very few strong, discrete, dipolar anomalies relating to ferrous objects within the topsoil.

4 CONCLUSION

4.1.1 The detailed magnetometer survey located a number of rectangular enclosures and linear ditches as well as a possible ring ditch and curvilinear enclosure. The response to many of the features was very strong, with well defined positive rectilinear anomalies; however, other responses were more defuse, less enhanced and less well defined. The enclosures and linear ditches within the turbine survey area are located away from the centre, towards the north eastern corner, and southern edge. The southern extent of the cable route is likely to pass through the location of a cluster of rectilinear enclosures and the access route to the north west appears that it may extend through a linear ditch.

4.1.2 Many of the responses lacked clarity and definition and although it is possible that they relate to pit-like and ditch-like features, a natural origin cannot be ruled out. A number of discrete negative responses were also located, and although these may relate to buried stones, it is uncertain as to whether they are natural in origin or associated with anthropogenic activity.

4.1.3 A negative linear anomaly extends through the northern part of the survey area, truncating a number of archaeological features. This anomaly appears

to relate to a drain or pipe.

5 REFERENCES

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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 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.

Appendix C – survey and data information

Magnetometer data

COMPOSITE
Filename: J592-mag-proc.xcp
Description: Imported as Composite from: J592-mag.asc
Instrument Type: Sensys DLMGPS
Units: nT
UTM Zone: 30U
Survey corner coordinates (X/Y):
Northwest corner: 219574.241748475, 67171.1616182299 m
Southeast corner: 219827.591748475, 66803.3616182299 m
Direction of 1st Traverse: 90 deg
Collection Method: Parallel
Sensors: 1
Dummy Value: 32702

Source GPS Points: 627600

Dimensions
Composite Size (readings): 1689 x 2452
Survey Size (meters): 253 m x 368 m
Grid Size: 253 m x 368 m
X Interval: 0.15 m
Y Interval: 0.15 m

Stats
Max: 66.30
Min: -66.00
Std Dev: 28.97
Mean: 0.75
Median: 0.18
Composite Area: 9.3182 ha
Surveyed Area: 2.1021 ha

PROGRAM
Name: TerraSurveyor
Version: 3.0.23.0

Processes: 1
1 Base Layer

GPS based Proce3
1 Base Layer.
2 Unit Conversion Layer (Lat/Long to OSGB36).
3 Clip from -60.00 to 60.00 nT

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at their offices in Wiltshire (see inside cover for address). 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.

Surveys are reported on in hardcopy (recycled paper) using A4 for text and A3 for plots (all plots are scaled for A3).

This report has been prepared using the following software on a Windows XP platform:

- TerraSurveyor version 3.0.23.0 (geophysical data analysis),
- SENSYS MAGNETO®ARCH version 1.00-04(geophysical data analysis),
- ProgeCAD Professional 2014 (report graphics),
- OpenOffice.org 3.0.1 Writer (document text),
- PDF Creator version 0.9 (PDF).

Digital data produced by the survey and report include the following files:

- TerraSurveyor grid and composite files for all geophysical data,
- CSV files for raw and processed composites,
- geophysical composite file graphics as TIF images,
- CAD DWG files in 2007 version,
- report text as OpenOffice.org ODT file,
- report text as PDF / PDF/A,
- PDFs of all figures.

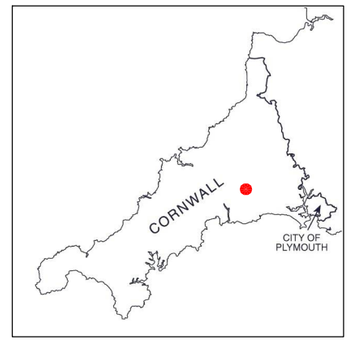
Survey location

N

Archaeological Surveys Ltd

Geophysical Survey
Wenmouth Manor
St Neot
Cornwall

Map of survey area



Survey location

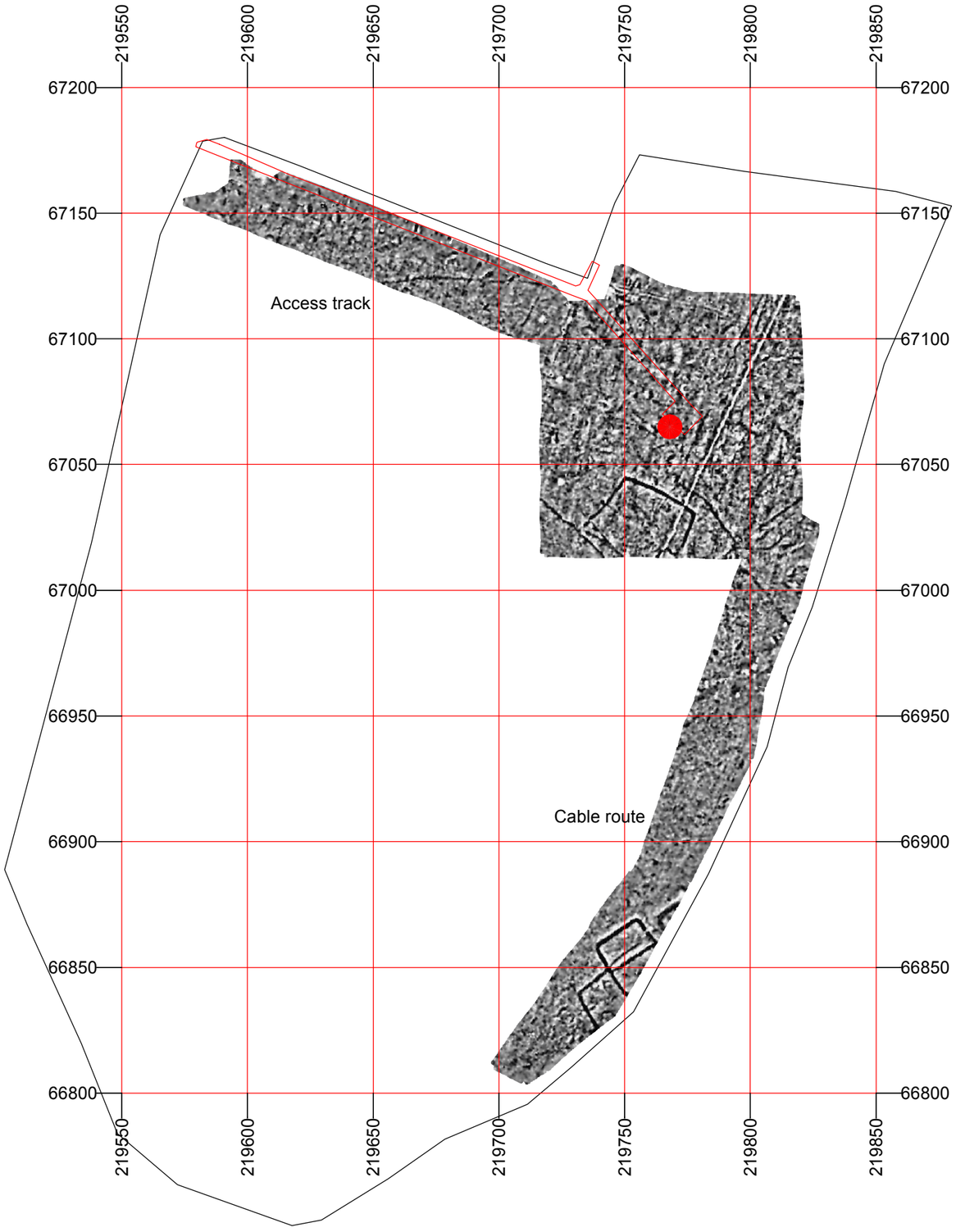
Turbine centred on OS NGR
SX 19768 67065

SCALE 1:25 000

0m 500m 1000m

SCALE TRUE AT A3

FIG 01



Archaeological Surveys Ltd

Geophysical Survey
Wenmouth Manor
St Neot
Cornwall

Referencing information

Referencing grid to OSGB36 datum at 50m intervals

Data collected at 20Hz and georeferenced to ETRS89 zone 30 with conversion to OSGB36 using OSTN02

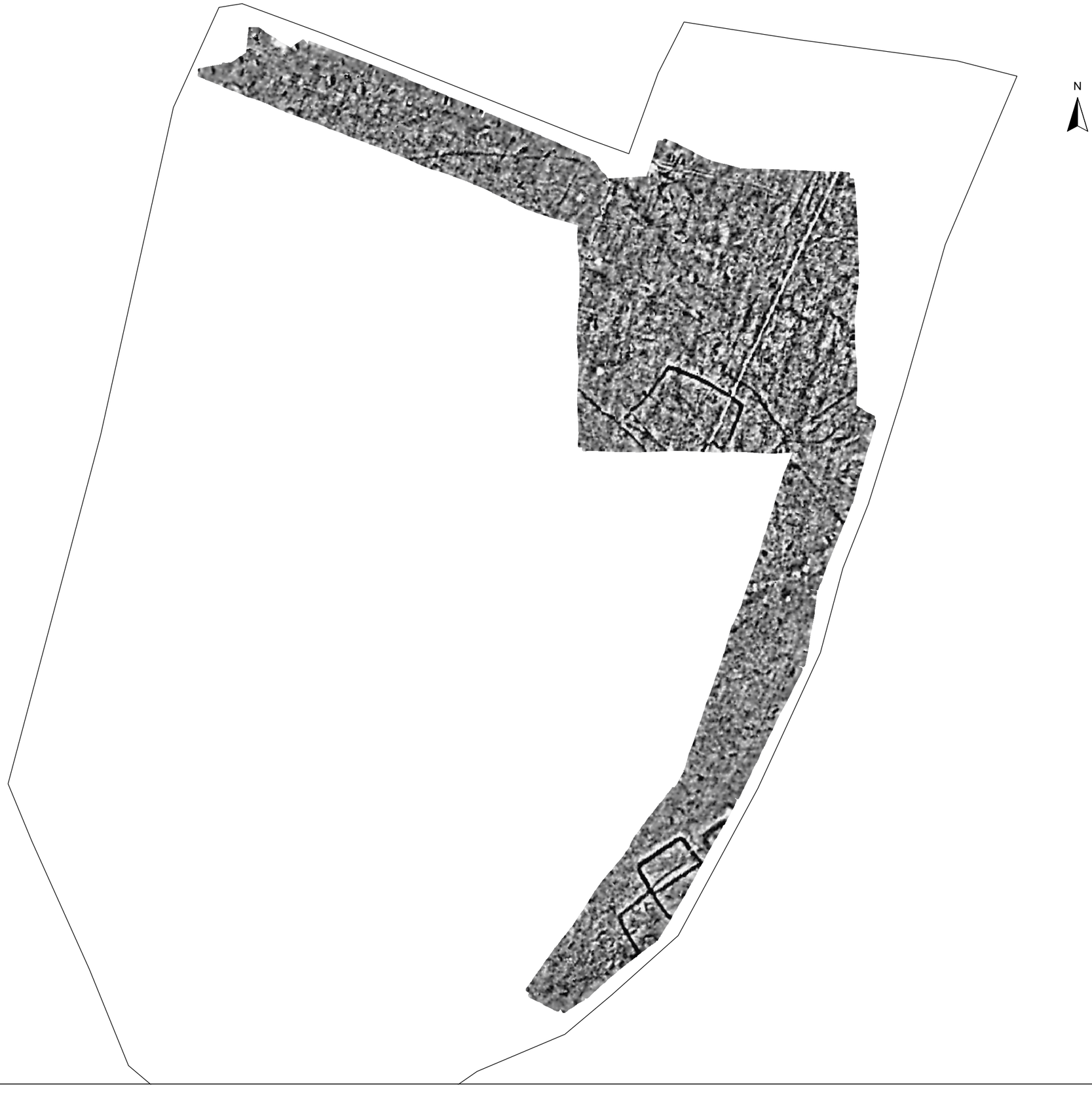
- Turbine centred on 219768 67065
- Proposed access track

SCALE 1:2000

0m 20 40 60 80 100m

SCALE TRUE AT A3

FIG 02



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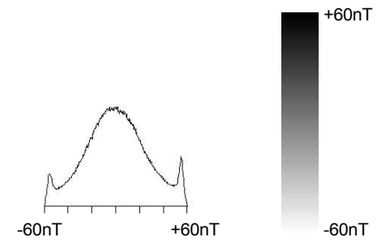
Geophysical Survey
Wenmouth Manor
St Neot
Cornwall

Greyscale plot of minimally processed magnetometer data



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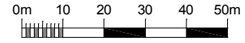
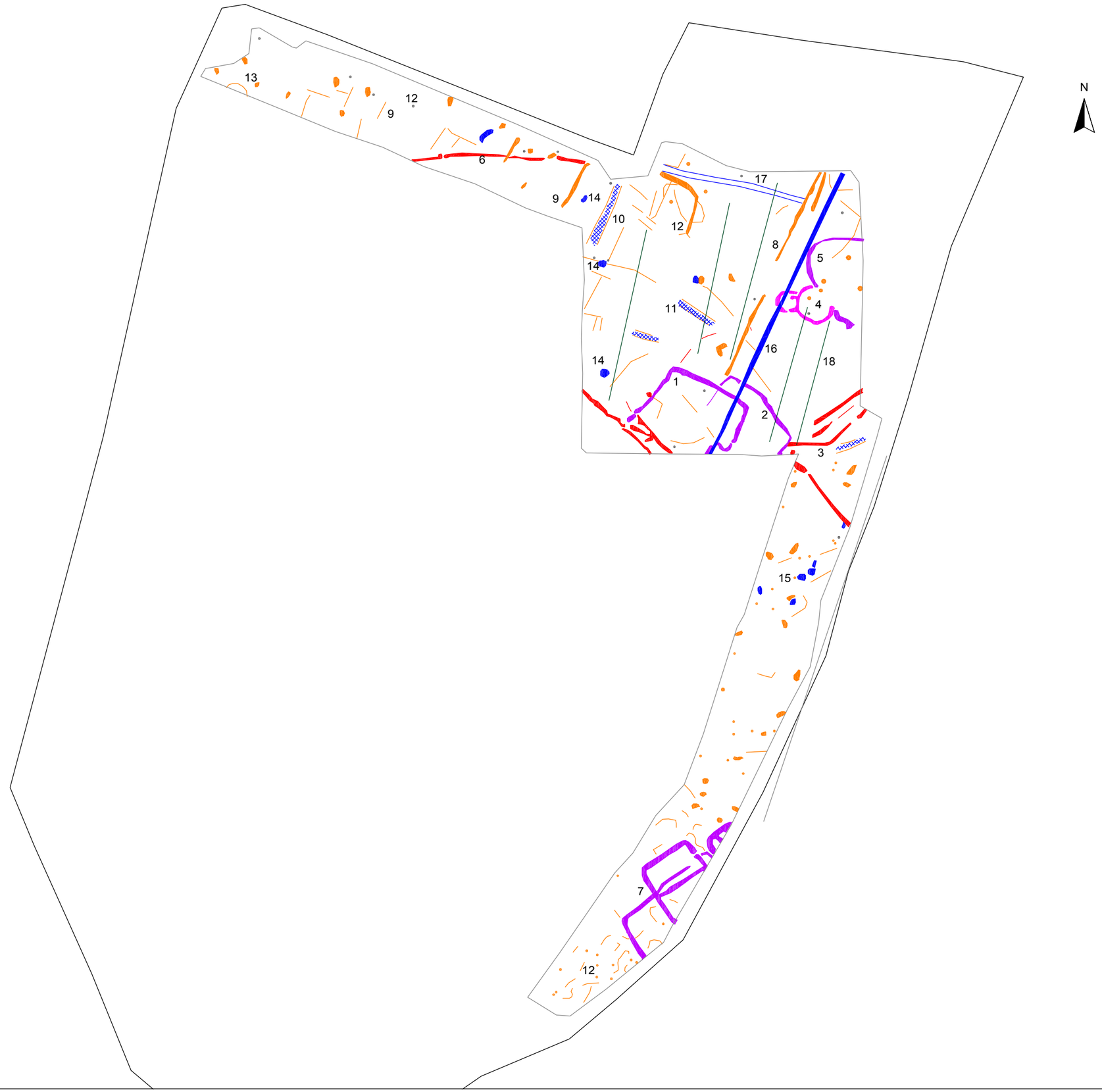


SCALE TRUE AT A3

FIG 03

Archaeological Surveys Ltd

Geophysical Survey
Wenmouth Manor
St Neot
Cornwall



Abstraction and interpretation of magnetometer anomalies

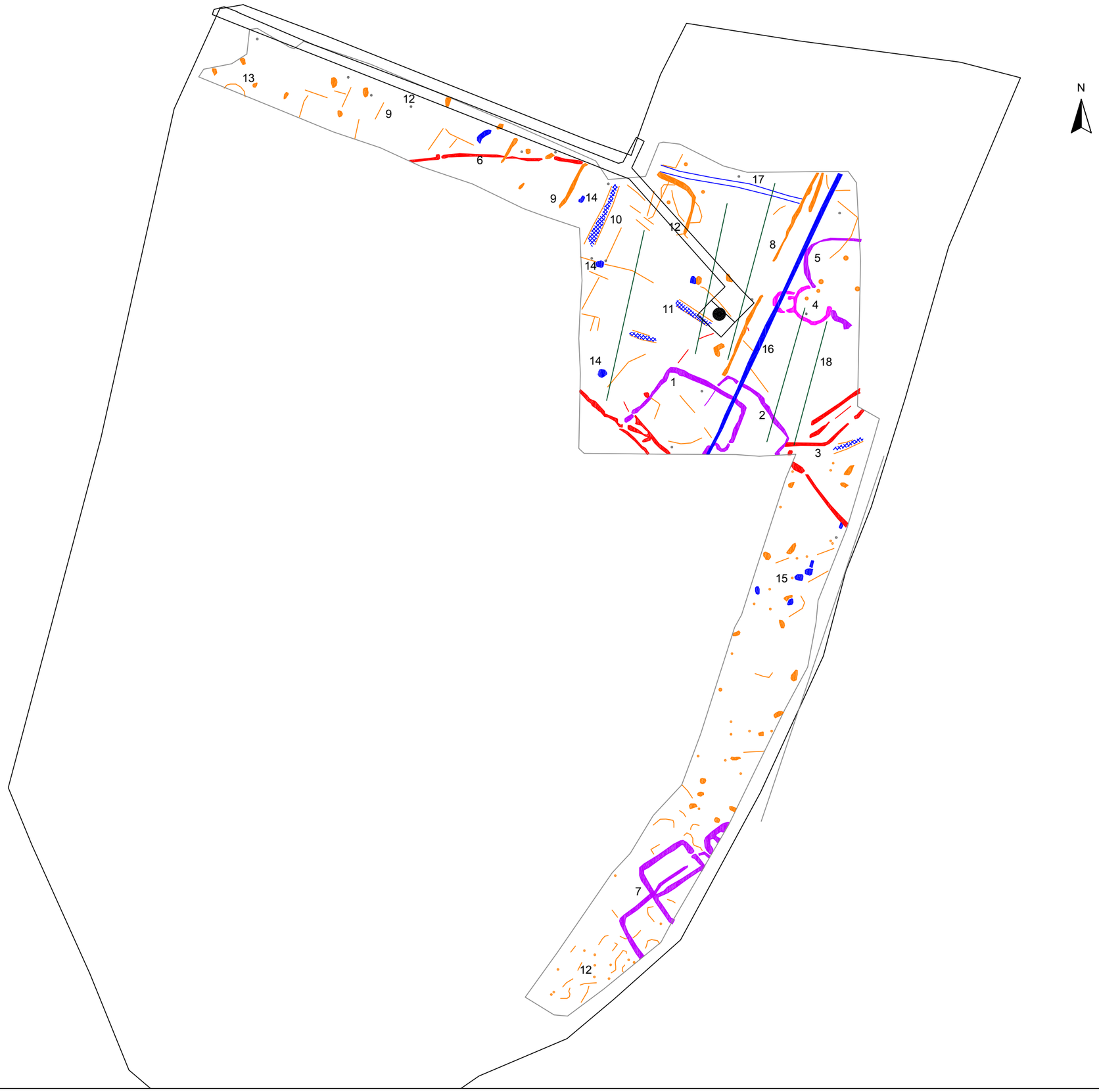
- Positive linear anomaly - cut feature of archaeological potential
- Positive linear anomaly - enclosure ditch
- Positive curvilinear anomaly - ring ditch
- Linear anomaly - ridge and furrow
- Positive linear anomaly - possible ditch-like feature
- Negative linear anomaly - material of low magnetic susceptibility
- Discrete positive response - cut feature of archaeological potential
- Discrete positive response - possible pit-like feature
- Discrete negative response - possible buried stone
- Negative anomaly - material of low magnetic susceptibility
- Strong dipolar anomaly - ferrous object

SCALE 1:1500

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 04



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Geophysical Survey
Wenmouth Manor
St Neot
Cornwall

Abstraction and interpretation of magnetometer anomalies with access track and turbine location

- Positive linear anomaly - cut feature of archaeological potential
- Positive linear anomaly - enclosure ditch
- Positive curvilinear anomaly - ring ditch
- Linear anomaly - ridge and furrow
- Positive linear anomaly - possible ditch-like feature
- Negative linear anomaly - material of low magnetic susceptibility
- Discrete positive response - cut feature of archaeological potential
- Discrete positive response - possible pit-like feature
- Discrete negative response - possible buried stone
- Negative anomaly - material of low magnetic susceptibility
- Strong dipolar anomaly - ferrous object

SCALE 1:1500

0m 10 20 30 40 50m

SCALE TRUE AT A3

FIG 05