WYAS Archaeological Services

Stanley Ferry Quarry

Wakefield

West Yorkshire

Geophysical Survey

Report no. 3464
September 2020

Client: Wakefield Sand and Gravel Ltd

Stanley Ferry Quarry, Wakefield, West Yorkshire

Geophysical Survey

Summary

A geophysical (magnetometer) survey was undertaken on approximately 22 hectares of land located at Birkwood and Smalley Bight, to the north-west of Stanley Ferry, Wakefield, West Yorkshire. Anomalies of a possible archaeological origin have been detected which may suggest part of a former field system and a tentative ring ditch. Possible medieval ridge and furrow cultivation have also been detected along with former field boundaries, modern ploughing and a field drain. Responses associated with a possible former route of the River Calder, and anomalies associated with flooding have been recorded in Birkwood. Based on the results of the geophysical survey the potential for significant archaeological remains within the site is deemed to be low.

WYAS
Archaeological Services

Report Information

Client:	Wakefield Sand and Gravel Ltd
Address:	Thornhill Works, Calder Road, Dewsbury, WF12 9HY
Report Type:	Geophysical Survey
Location:	Stanley Ferry, Wakefield
County:	West Yorkshire
Grid Reference:	SE 3542 2331 / SE 3521 2357
Period(s) of activity:	?Prehistoric / medieval / modern
Report Number:	3464
Project Number:	X182
Site Code:	SFQ20
OASIS ID:	archaeol1-403621
Planning application:	20/01159/FUL
Date of fieldwork:	April and August 2020
Date of report:	September 2020
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1 Introduction

Archaeological Services ASWYAS has been commissioned by Peter Cardwell on behalf of Wakefield Sand and Gravel Ltd to undertake a geophysical survey in advance of proposed mineral extraction on land located to the north-west of Stanley Ferry near Wakefield, West Yorkshire. This was undertaken in line with current best practice (CIfA 2014; Schmidt *et al.* 2015). The survey was undertaken in response to a brief for a geophysical survey (Cardwell 2020b) and a project design (Brunning 2020), both of which were approved by the West Yorkshire Archaeology Advisory Service (WYAAS). The survey was carried out between 14th and 20th April and on the 21st August 2020 to provide additional information on the archaeological resource of the Site.

Site location, topography and land-use

The survey area is split into two areas of proposed extraction; Birkwood and Smalley Bight, centred on National Grid Reference SE 3542 2331 and SE 3521 2357 respectively, and located to the east and west of the River Calder. The application boundaries are located to the north-west of Stanley Ferry approximately 3km to the north-east of Wakefield (Fig. 1).

Birkwood measures approximately 11.9ha and Smalley Bight 10.1ha. Both areas are situated within the river floodplain and are relatively level lying between approximately 17m above Ordnance Datum (aOD) and approximately 20m aOD.

Soils and geology

The underlying bedrock comprises Pennine Middle Coal Measures Formation, consisting of mudstone, siltstone and sandstone. Sedimentary bedrock formed approximately 310 to 318 million years ago in the Carboniferous Period. Superficial deposits have been recorded as alluvium made up of clay, silt, sand and gravels (BGS 2020). The soils of the survey area are characterised as loamy, freely draining floodplain soils (CSAI 2020).

2 Archaeological Background

The following information has been taken from the brief for the geophysicsl survey (Cardwell 2020b). Details on other sites within the wider vicinity are included in the archaeological and heritage assessment prepared for the client (Cardwell 2020a).

There is limited evidence for settlement or occupation sites of prehistoric date within the study area until the pre-Roman Iron Age. Activity during this period is accordingly based primarily upon a number of stray finds, mostly from the higher ground around the proposed development, and these collectively suggest that despite the probable flooding adjacent to the Calder that there may have been limited occupation that was sited to exploit the river as a source of both food and water, for communications and trade, and later to make use of the

adjacent fertile alluvial soils. While the river has probably changed course since this period there is no direct evidence either from aerial photographs, LiDAR data or from the site soil surveys for the presence of any former palaeochannels within the application boundaries.

The earliest evidence of activity recorded within the area is that of two Lower or Middle Palaeolithic handaxes (WYHER 3813) found on the higher ground of Lee Moor about 1.6km to the north-west. Three flint blades (WYHER 3812) which are now identified as Early Mesolithic in date were found at Lake Lock some 1.7km to the north.

The only direct evidence for occupation of Neolithic date was recorded during the archaeological investigations undertaken on the site of the St John's opencast site (WYHER 7866) 1.7m to the south-east. The features investigated included pits and gullies of both Neolithic and Bronze Age date together with flint, pottery and a stone axe. A number of isolated finds include both Neolithic and Bronze Age flint artefacts recovered near to Roman Station Farm (WYHER 1534) some 1.0km to the north while stone axes of Neolithic date have been found at Clarke Hall (WYHER 1996), on the site of the former Fox Pit (WYHER 2000) and from Lee Moor Road in Stanley (WYHER 3839).

A number of axes of Bronze Age date are also recorded within the study area. Principal amongst these is the hoard found in a gravel bed of the River Calder near to Smalley Bight Farm (WYHER 2784). The hoard consisted of a total of eleven bronze implements – seven 'Yorkshire' three-ribbed socketed axes, a wing-flanged axe, two palstaves and a bronze object possibly bearing the design of a bearded man's head. Although the precise location from where the hoard was found is unclear.

The proposed development is located in an area with evidence for occupation and activity during both the later Iron Age and Roman periods, mostly based upon aerial photographic evidence or individual find spots. The suggestion of a Roman road between Castleford and Wakefield that ran via Altofts, possibly crossing the River Calder at Stanley Ferry, remains unsubstantiated, although a ford at Stanley Ferry is possible given that one is recorded from the medieval period. Enclosures, associated field systems and trackways are recorded as cropmarks throughout much of the area.

Recorded finds of Roman date within the vicinity of the proposed development attest to activity within the area during this period. The principal such find is that of a hoard of 7,198 copper-alloy coins of 4th century date recovered in an earthenware vase at Smalley Bight Farm (WYHER 1923). These were found during ploughing in 1905 and the vase was recorded as being scarcely two feet (0.6m) below the surface of the ground. The precise location of the find is not recorded but Walker (1934, 23) states that the urn was recovered from a wide embankment adjacent to the River Calder, one end of which was used as a sand pit. A sand pit (S7) (See Fig. 12) is depicted towards the south-western part of the Smalley Bight area on the 1908 Ordnance Survey map and it is considered probable that the find was made either to the south or the east of the pit close to the river. Information obtained from the

landowner, subsequent to the preparation of the brief, suggests that the hoard of Roman coins (WYHER 1923) were recovered from a smaller sand pit to the south-east of Smalley Bight and therefore outside of the survey area.

There are no recorded sites of either settlements or field systems of late Iron Age or Roman date within the boundaries of the proposed development, with the nearest potential such site being the cropmarks of a co-axial field system and trackway (WYHER 15450) located some 0.5km to the south. The cropmarks of ditches towards the base of Birkwood Hill (WYHER 4203) some 0.4km to the east of the proposed development, and those to the south of Lake Lock (WYHER 6323) some 0.4km to the north, are both recorded as of uncertain date. With the exception of the latter, these sites and those cropmarks of field boundaries, trackways and a possible enclosure recorded some 0.4km or more to the north-east around Methley Lanes (WYHER 4518 and WYHER 4519) are at a similar height (some 20m aOD) to the proposed development area.

There is no archaeological evidence for occupation within the study area prior to the Norman Conquest, though both documentary sources and some stray finds attest to settlement and activity during the Anglo-Saxon and Anglo-Scandinavian periods. It has also been suggested that the field names for Great Pen Hill and Little Pen Hill (WYHER 2364), located immediately to the north of the Smalley Bight area, have a British derivation. Stanley is recorded in the Domesday Book though Altofts is not documented until about 1090. A number of fields within the Birkwood area are named Stanley Royds, the latter possibly referring to cleared land and suggesting assarting to enable arable cultivation.

With the exception of a possible early medieval lead-alloy gaming piece recorded by the Portable Antiquities Scheme south of the Birkwood area (PAS 942569), the only archaeological evidence for occupation or activity within the study area during this period is the logboat (WYHER 2173) found during the construction of the Stanley Ferry Aqueduct in 1838. It was made from a whole oak log and probably dates (on the basis of a radiocarbon determination) to the early 11th century. The recorded location of where the logboat was found is immediately to the east of the northern end of the Aqueduct. It was recovered from a layer of gravel at a depth of 5.6m below the ground surface and 1.8m below the ordinary bed of the river at that time. A number of tree trunks were found at a similar level.

The Altofts enclosure plan surveyed in 1810 covers the full extent of the Birkwood area. No structures are mapped at this time and all of the fields totally or partially within this area are ‘ancient inclosure’, although the date of this enclosure is not known. The fields to the east are largely rectilinear in form, while those to the west are less regular and two of these are called ‘Sand Beds’. A drain (S1) (see Fig. 12) into the River Calder from a new allotment to the south-east was established at the time of the enclosure and its former course cuts across the very northern extent of the Birkwood area.

By the time of the 1839 tithe award plan the New (or Calder) Cut of the Aire and Calder Navigation had been constructed and its western embankment defines the eastern side of the Birkwood area. The three fields to the west previously forming the majority of the area had been combined into a single field ('Top of Sand Beds') with the others being unaltered and all named 'Stanley Royds' or 'Top of Sand Beds'. With the exception of a single grass field all of the area is under arable cultivation. By this date two buildings (S2) (see Fig. 12) have been established in the extreme south-eastern corner of the area to the north of the river. These are probably a house and outbuildings, with an attached garden, and are likely to be a small farmstead or smallholding. This holding was probably established when these fields were severed from those further to the east from this date by the New Cut, leading to the construction of new buildings to the west.

By the date of the 1854 Ordnance Survey the entire Birkwood area forms a single large field, with the exception of the northern part of the area which is divided from the remainder by a new drain (S5) (see Fig. 12) between the New Cut and the River Calder. The buildings previously depicted are no longer mapped and presumed to have been demolished. The site of the buildings may be within an area of rough ground adjacent to the hardstanding near to the entrance into the field. Another building (S3), possibly a field barn, has been constructed further along the riverbank to the west by this date. This is depicted as probably ruinous on the 1894 Ordnance Survey map, and remains so on that of 1908 but after that date is not shown. No structural evidence for the building survives, although the recorded location is towards the western edge of a slight spread of broken bricks. By this date drain S5 has been infilled, and a well (S6) is mapped at its former eastern extent at the base of the embankment for the New Cut. If still evident then this is now capped with a concrete cover (although this may be related to a culvert beneath the canal). Further to the north two trade weights (PAS 525493 and PAS 532442) have been found, the latter just within the application boundary.

The enclosure award plan for Stanley probably dates to the early 19th century and covers the Smalley Bight area. This depicts a number of fields within the proposed development area all of which are 'Old Inclosures'. These are broadly rectilinear in form but have irregular boundaries. This field pattern remains largely unaltered at the time of the 1846 tithe award plan, other than towards the western end where a pond (S4) is depicted at the junction of a number of fields, two of which are new. With the exception of a single field of grass all of the area is under arable cultivation. Field names of potential note are 'Dent Croft' and 'Deancroft' towards the western edge of the area, but whether this indicates that these fields (the former located on marginally higher ground) were previously associated with an adjacent dwelling, and if so of what date, is uncertain.

The Ordnance Survey mapping from 1854 onwards depicts the gradual removal of the field boundaries within this area, initially from the eastern part and then, by 1894 also from the western part when most of the area consists of two larger fields (and the pond is no longer shown). On both the 1908 and 1921 Ordnance Survey maps a sand pit (S7) (see Fig. 12) is

depicted towards the south-western part of the area, progressing eastwards on the latter, together with a track to the pit and another curving track heading north to south across the centre of the area. The sand pit had been infilled by 1933, while the track across the field was removed sometime between 1953 and 1966. During the site walkover survey a considerable amount of post-medieval and modern pottery, clay tobacco pipe, ceramic building material, slate, glass, slag, cinder and plastic was noted on the ground surface within the south-western quadrant of the area, most of which is considered likely to be derived from the infilling of the pond and sand pit recorded within this part of the site in the 19th and 20th century respectively, although a proportion could be related to earlier activity such as manuring. The existing river embankments appear to date to the late 1960s or early 1970s.

3 Aims, Methodology and Presentation

The aims and objectives of the programme of geophysical survey is to gather sufficient information to establish the presence/absence, character, extent, of any archaeological remains within the specific area and to inform further strategies should they be necessary. The principal objectives of the survey was:

- to record the location and extent of any anomalies of probable archaeological or geoarchaeological origin within the survey areas
- to characterise as far as possible the nature of any anomalies identified
- to prepare a report summarising the results of the survey and an associated archive

The specific objectives of the survey were:

- to establish if there is any evidence for palaeochannels within either survey area and particularly an earlier alignment or course of the River Calder
- to establish whether there is any evidence for structural remains associated with buildings S2 and S3 within the Birkwood area;
- to establish whether there is any evidence for structures or other features in the area of either the ‘Dent Croft’ and ‘Deancroft’ field names within the Smalley Bight area;
- to establish whether there is any evidence for the former drains within the Birkwood area or former field boundaries mapped within both areas

Magnetometer survey

For the Birkwood site, the site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble R6 model). The survey was undertaken using Bartington Grad601 magnetic gradiometers. These were employed taking readings at 0.125m intervals

on zig-zag traverses 0.5m apart within 30m by 30m grids, so that 14,400 readings were recorded in each grid. These readings were stored in the memory of the instrument and later downloaded to computer for processing and interpretation. The survey was undertaken between the 14th and 20th of April 2020. This part of the site was under a sown arable crop. Bespoke in-house software was used to process and present the data. Further details are given in Appendix 1.

For the Smalley Bight an eight channel SenSYS MX V3 system containing eight FGM650 sensors was undertaken. Readings are taken every 20MHz (between 0.05 and 0.1m). Data will be recorded onto a device, using a Carlson GNSS Smart antenna, for centimetre accuracy. These readings were stored in the memory of the instrument and downloaded for processing and interpretation. This part of the survey was undertaken on the 21st of August 2020. The ground conditions of the site consisted of a harvested crop. DLMGPS and MAGNETO software, alongside bespoke in-house software was used to process and present the data. Further details are given in Appendix 1.

Reporting

A general site location plan, incorporating the 1:50000 Ordnance Survey (OS) mapping, is shown in Figure 1. Figure 2 displays processed magnetometer data at a scale of 1:4000 whilst Figure 3 shows an overview of the interpretation at the same scale. Minimally processed data, together with interpretation of the survey results are presented in Figures 4 to 11 inclusive at a scale of 1:1250. Figure 12 shows the heritage assets within the vicinity of the development area. Figure 13 shows the interpretation on the 1st edition Ordnance Survey mapping dated 1854.

Technical information on the equipment used, data processing and survey methodologies are given in Appendix 1. Technical information on locating the survey area is provided in Appendix 2. Appendix 3 describes the composition and location of the archive. A copy of the completed OASIS form is included in Appendix 4.

The survey methodology, report and any recommendations comply with guidelines outlined by the European Archaeological Council (Schmidt *et al*. 2015) and by the Chartered Institute for Archaeologists (CIfA 2014). All figures reproduced from Ordnance Survey mapping are with the permission of the controller of Her Majesty's Stationery Office (© Crown copyright).

The figures in this report have been produced following analysis of the data in processed formats and over a range of different display levels. All figures are presented to most suitably display and interpret the data from this site based on the experience and knowledge of Archaeological Services staff.

4 Results and Discussion (see Figs. 4 to 11)

Ferrous anomalies and magnetic disturbance

Ferrous anomalies, as individual 'spikes', or as large discrete areas are typically caused by ferrous (magnetic) material, either on the ground surface or in the plough-soil. Little importance is normally given to such anomalies, unless there is any supporting evidence for an archaeological interpretation, as modern ferrous debris or material is common on rural sites, often being present as a consequence of manuring or tipping/infilling. There is no obvious pattern or clustering to their distribution in this survey to suggest anything other than a random background scatter of ferrous debris in the plough-soil.

An area of magnetic disturbance (**F1**) along the southern limits of the Smalley Bight area corresponds to a sand pit (S7 on Fig. 12) and is marked on mapping dating from 1908. The high magnitude magnetic response is the product ferrous material that has been used to backfill the former sandpit. Further disturbance to the south-west of **F1** is due to the location of an electricity pylon.

Magnetic disturbance (**F2**) in the south-eastern corner of Birkwood may be associated with an early 19th century farmstead shown on the 1839 tithe award plan (S2, Fig. 12). The recorded house and outbuildings, with an attached garden, are likely to have formed a small farmstead or smallholding. Their demolition during the 19th century is likely to have left material that will cause the area of magnetic disturbance but also have been spread into the site. This part of the survey area is also located next to the Ferry Lane, Birkwood Lane and the bridge over the Aire and Calder Navigation. The construction of both the road and the embankment for the bridge could also have spread ferrous material into the corner of the survey area.

Further disturbance seen along the limits of the survey areas are a magnetic response caused by metal fencing within the field boundaries.

Geological anomalies

The survey has detected a number of anomalies within Birkwood that have been interpreted as geological in origin. Due to the location, within the floodplain of the River Calder, these responses are likely to be associated with past flooding.

However, the larger of the responses, especially the westernmost (**G1**) may indicate a former course of the river, changing the meandering a little. This anomaly corresponds with a feature seen in the 1m resolution LiDAR DTM data (NLS 2020). A similar response (**G2**) to the east is not visible in the LiDAR data but it is likely to be alluvial deposits.

Agricultural anomalies

In the north-east section of Birkwood, a linear dipolar response has been recorded which corresponds to a drain marked on OS mapping dating from 1852, this correlates to S5 on Figure 12 and also seen on the 1st edition Ordnance Survey mapping. The dipolar nature of the response suggests that the drain have been replaced with a ferrous pipe that runs from beneath the canal to the river.

Remnants of former field boundaries have been detected in both areas. Two of the boundaries in Smalley Bight, near the old sand pit correspond to Ordnance Survey mapping dating from 1852 and were removed by 1894.

Field boundaries that have been detected within Birkwood correspond to boundaries marked on the Altofts enclosure plan, surveyed in 1810. By 1854 all the previous boundaries had been removed.

The geophysical survey has detected possible ridge and furrow (**A1**) on a north-west to south-east alignment within Smalley Bight. This is identified by the research for the historical background as an area called Deancroft. This was suggested as an area of possible settlement but apart from the ridge and furrow there are no anomalies that would indicate structures within the survey data. Further possible ridge and furrow cultivation has been recorded in Birkwood, to the immediate north and south of the drain. Modern ploughing trends can be seen throughout both areas.

Possible archaeological anomalies

Anomalies of a possible archaeological origin have been recorded within the dataset. The most prominent of these lie within Smalley Bight and consist of fragmented ditch lengths (**P1, P2, P3**). It is possible that these responses are contemporary and perhaps form part of an ancient field system. These anomalies are oriented at right angles with the river and as such could have been boundaries that were designed to limited access to the water source. No such boundaries are present in the historical mapping and as such could pre-date the post-medieval period. Given their orientation they could also perhaps be temporary ditches that were excavated to help drain the fields during flood events.

A faint circular response (**P4**) in the south of Smalley Bight measures approximately 20m in diameter. The anomaly is just visible above the background levels and the ploughing trends. It is possible the response represents a ring ditch, although this is tentative and other explanations such as natural striations are also plausible.

Smaller pit-like responses have been recorded within Birkwood. It is possible, that they are anthropogenic. Although as they are scattered throughout and form no patterns they may simply be associated with past flood events causing pit-like features.

5 Conclusions

The geophysical survey has been successful in detecting a number of magnetic anomalies. Possible archaeological remains include fragmented ditches which may be associated with a former field system. A possible ring ditch has also been recorded, although very weak in magnetic strength and as such could also have been produced by underlying geological deposits. A possibility always remains that earlier archaeological features may be buried at depth beneath medieval or later silt deposits.

Medieval ridge and furrow cultivation has been recorded along with former field boundaries, modern ploughing and a field drain. Magnetic disturbance, in the south of Smalley Bight is associated with a former sand pit.

Responses associated with a possible former route of the River Calder and responses associated with flooding / alluvial deposits have been recorded in Birkwood. Based on the results of the geophysical survey the potential for significant archaeological remains within the site is deemed to be low.

Appendix 1: Magnetic survey - technical information

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the Earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haemetite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms. Areas of human occupation or settlement can then be identified by measuring the magnetic susceptibility of the topsoil because of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. The magnetic susceptibility of a soil can also be enhanced by the application of heat and the fermentation and bacterial effects associated with rubbish decomposition. The area of enhancement is usually quite large, mainly due to the tendency of discard areas to extend beyond the limit of the occupation site itself, and spreading by the plough.

Types of Magnetic Anomaly

In the majority of instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being present as a consequence of manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

Methodology: Gradiometer Survey

The main method of using the fluxgate gradiometer for commercial evaluations is referred to as ***detailed survey*** and requires the surveyor to walk at an even pace carrying the instrument within a grid system. A sample trigger automatically takes readings at predetermined points, typically at 0.25m intervals, on traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation.

During this survey a Bartington Grad601 magnetic gradiometer was used at Birkwood taking readings on the 0.1nT range, at 0.125m intervals on zig-zag traverses 0.5m apart within 30m by 30m square grids. The instrument was checked for electronic and mechanical drift at a common point and calibrated as necessary. The drift from zero was not logged.

An eight channel Sensys MX V3 system containing eight FGM650 sensors was used which was towed across the Smalley Bight area using an ATV. Readings were taken every 20MHz (between 0.05 and 0.1m). Data was be recorded onto a device, using a Carlson GNSS Smart antenna, for centimetre accuracy. These readings were stored in the memory of the instrument and downloaded for processing and interpretation

The gradiometer data have been presented in this report in processed greyscale format. The data in the greyscale images have been interpolated and selectively filtered to remove the effects of drift in instrument calibration and other artificial data constructs and to maximise the clarity and interpretability of the archaeological anomalies.

Appendix 2: Survey location information

An initial survey station was established using a Trimble VRS differential Global Positioning System (Trimble R6 model). The data was geo-referenced using the geo-referenced survey station with a Trimble RTK differential Global Positioning System (Trimble R6 model). The accuracy of this equipment is better than 0.01m. The survey grids were then super-imposed onto a base map provided by the client to produce the displayed block locations. However, it should be noted that Ordnance Survey positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if co-ordinates are measured off hard copies of the mapping rather than using the digital co-ordinates.

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

Appendix 3: Geophysical archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Microsoft Word 2000), and graphics files (Adobe Illustrator CS2 and AutoCAD 2008) files; and
- a full copy of the report.

At present the archive is held by Archaeological Services WYAS although it is anticipated that it may eventually be lodged with the Archaeology Data Service (ADS). Brief details may also be forwarded for inclusion on the English Heritage Geophysical Survey Database after the contents of the report are deemed to be in the public domain (i.e. available for consultation in the West Yorkshire Environment Record).

Appendix 4: Oasis form

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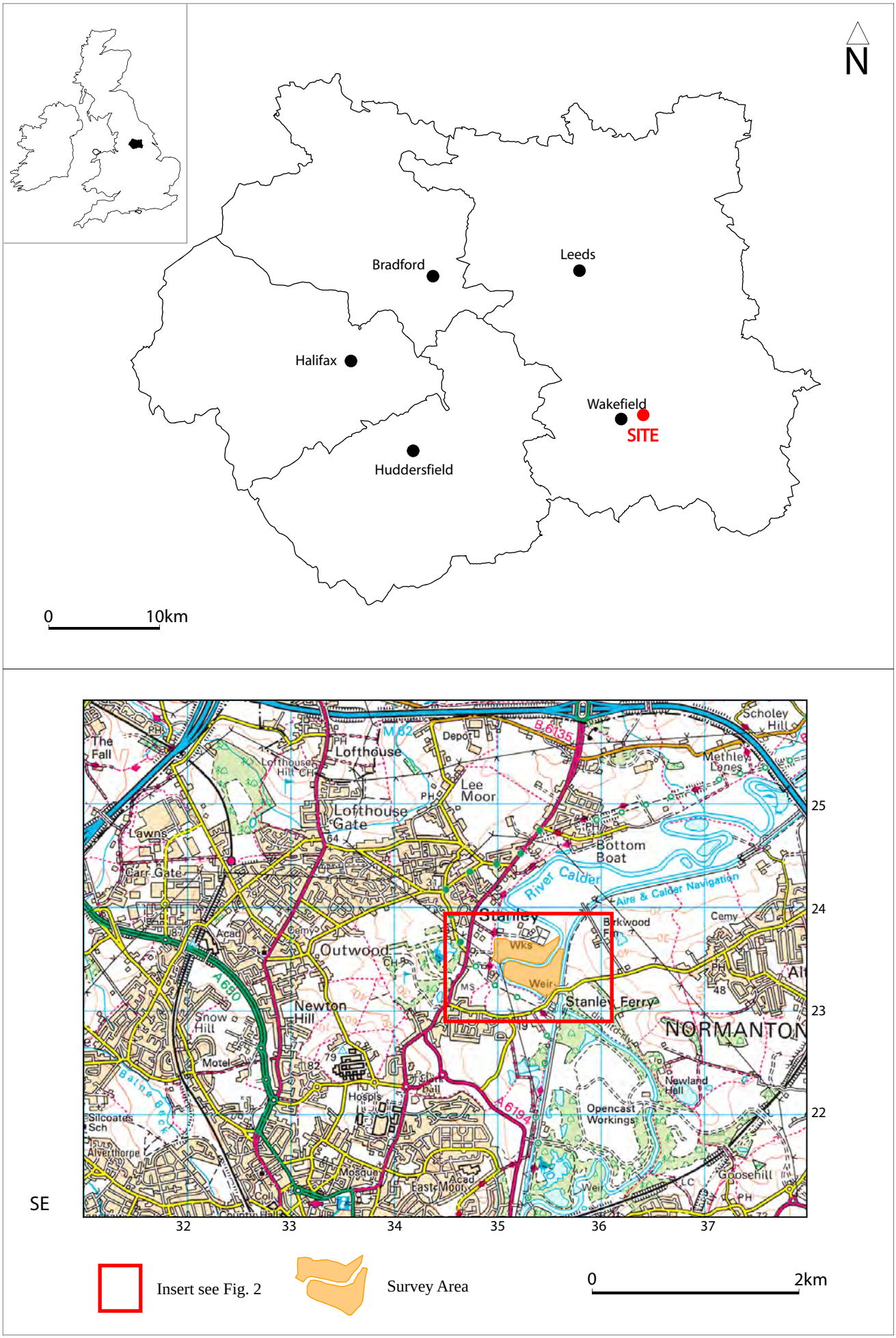

Fig. 1. Site location

PROJECT ID: X182_SFQ20

SURVEY AREA

SECTOR BOUNDARY

SECTOR 1
SEE FIGS 4-5

SECTOR 2
SEE FIGS 6-7

SECTOR 3
SEE FIGS 8-9

SECTOR 4
SEE FIGS 10-11

N

4238 00

4236 00

4234 00

4232 00

2.0

-1.0

nT

4348 00

4350 00

4352 00

4354 00

4356 00

0

200m

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Nepshaw Lane South, Morley, LS27 7JQ
Tel: 0113 535 0163

Fig. 2. Survey location showing processed greyscale magnetometer data (1:4000 @ A3)

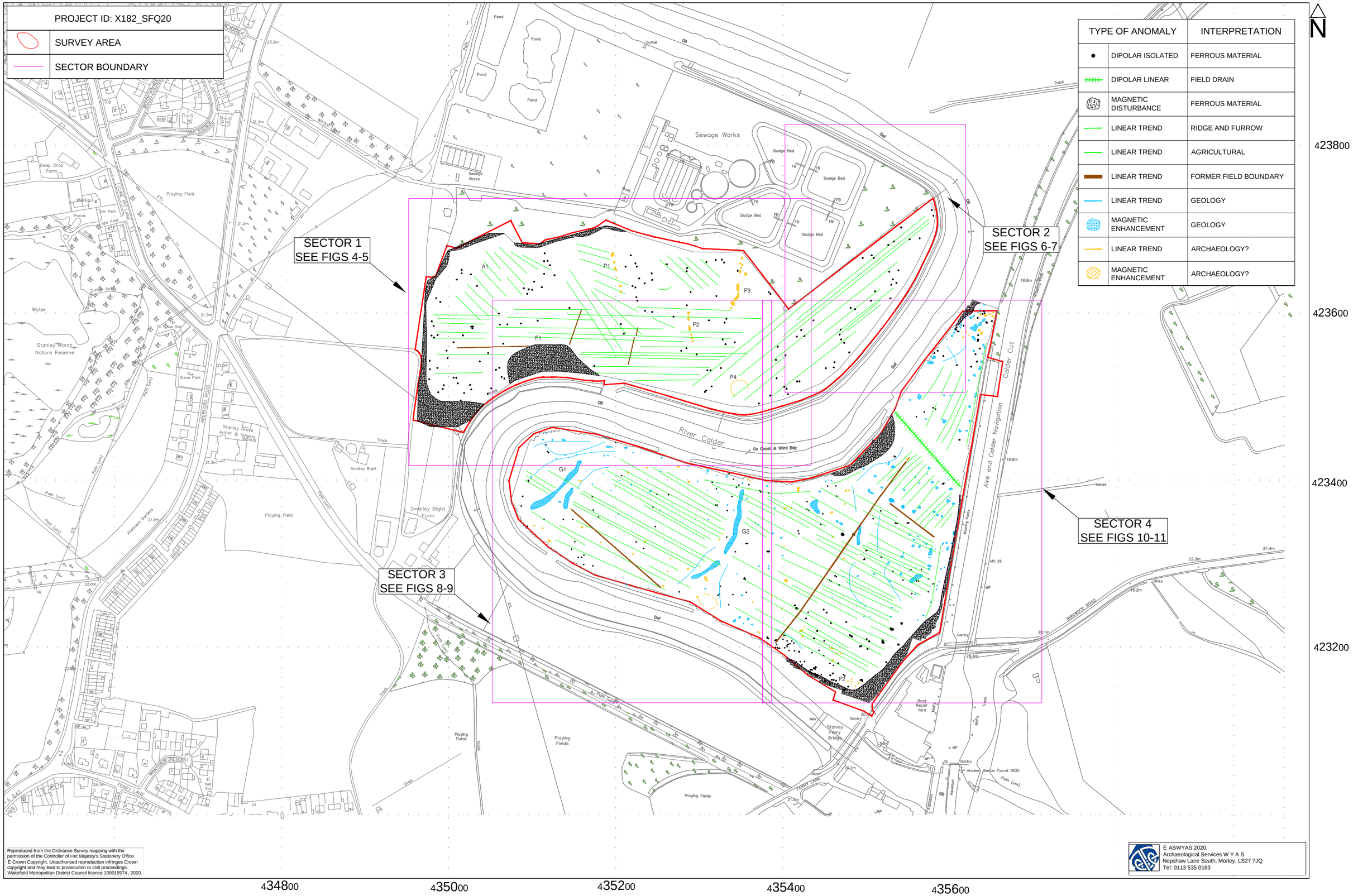

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Fig. 3. Overview interpretation of magnetometer data (1:4000 @ A3)

PROJECT ID: X182_SFQ20

SECTOR BOUNDARY

N

FB

FB

Sludge Bed

FB

FB

Sludge

2.0

-1.0

nT

CR

River Calder

Co Const & Ward Bdy

4236 00

4350 00

4352 00

4354 00

0 50m

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Fig. 4. Processed greyscale magnetometer data; Sector 1 (1:1250 @ A3)

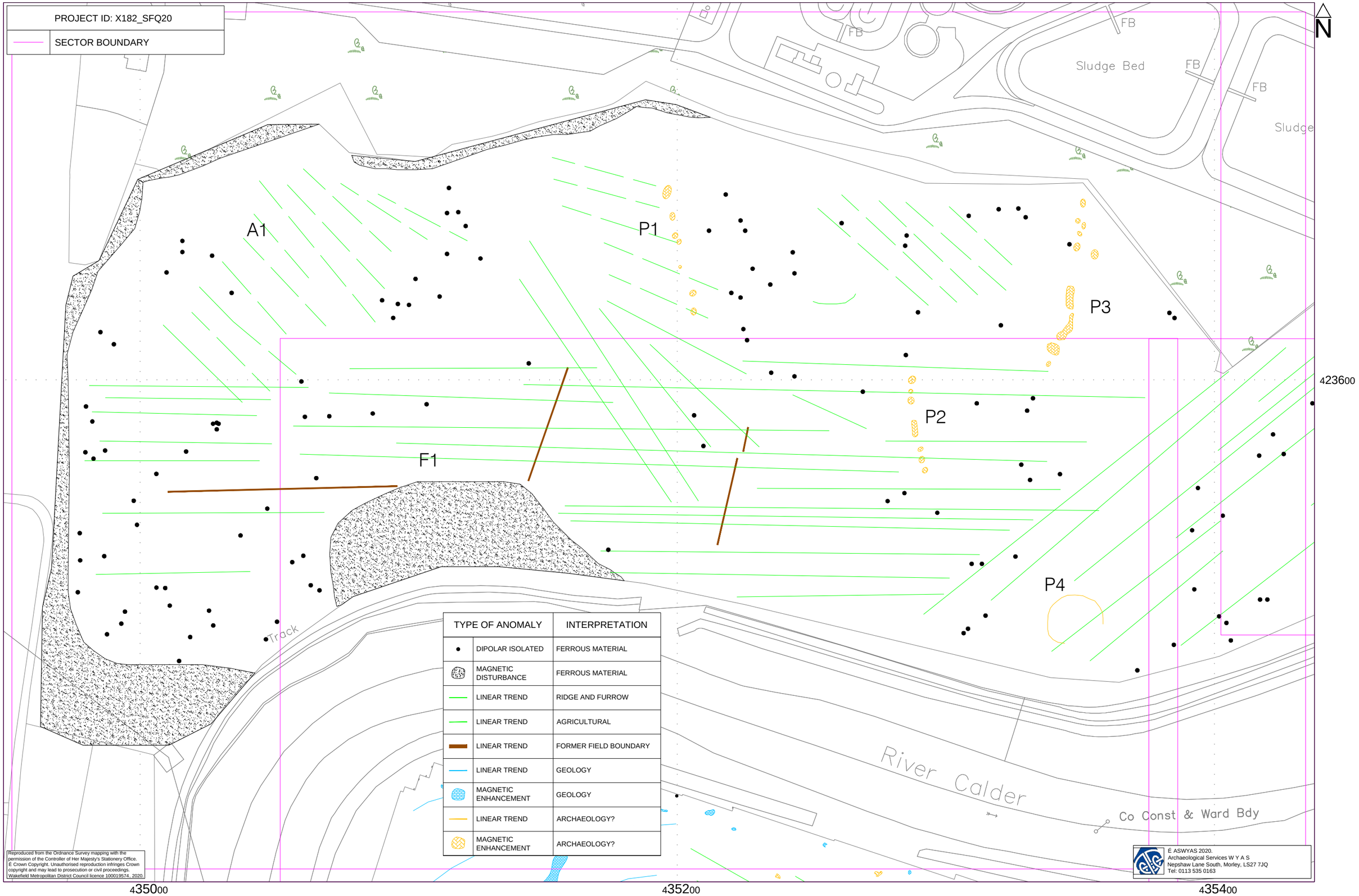


Fig. 5. Interpretation of magnetometer data; Sector 1 (1:1250 @ A3)

Fig. 6. Processed greyscale magnetometer data: Sector 2 (1:1250 @ A4)

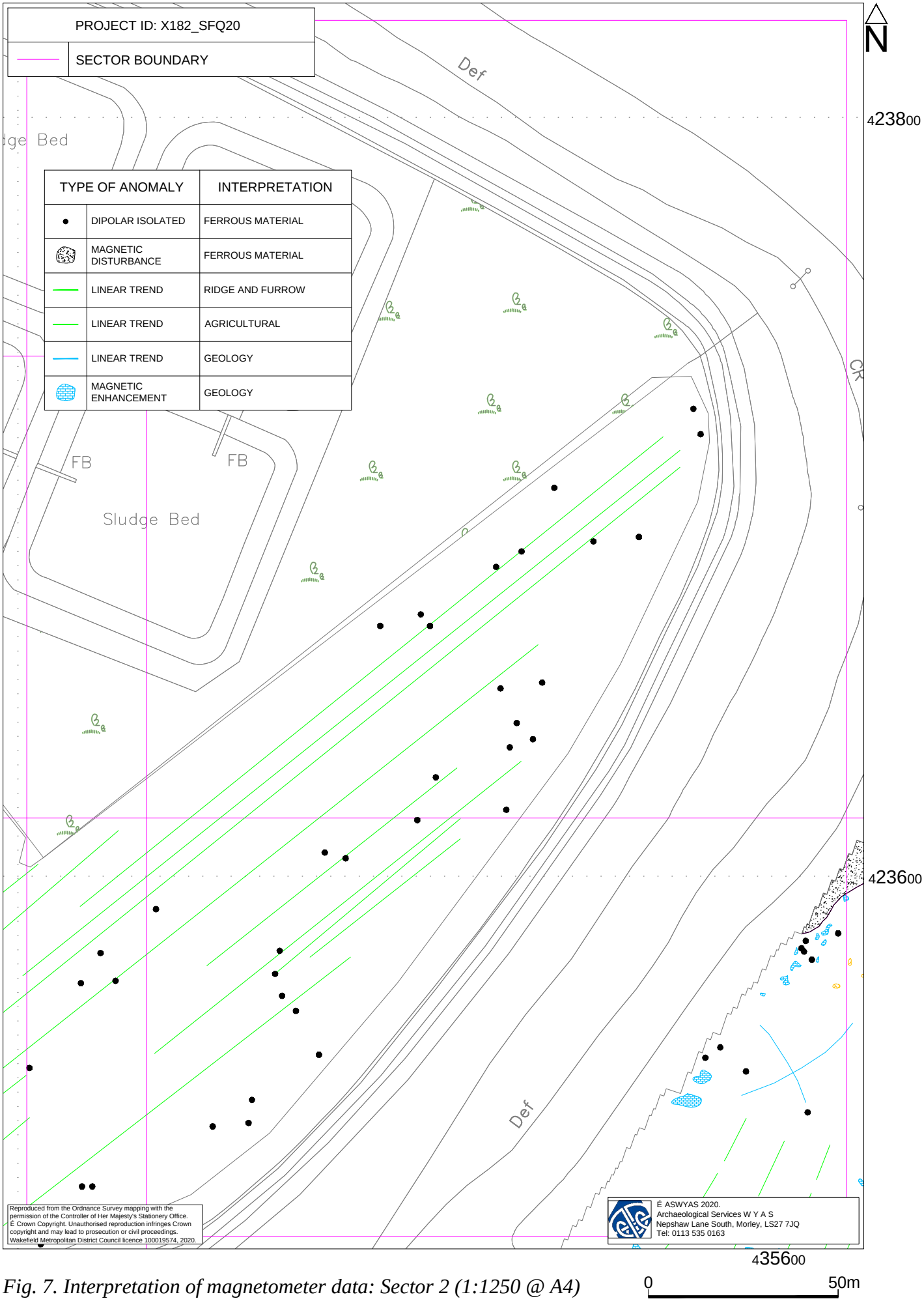


Fig. 7. Interpretation of magnetometer data: Sector 2 (1:1250 @ A4)

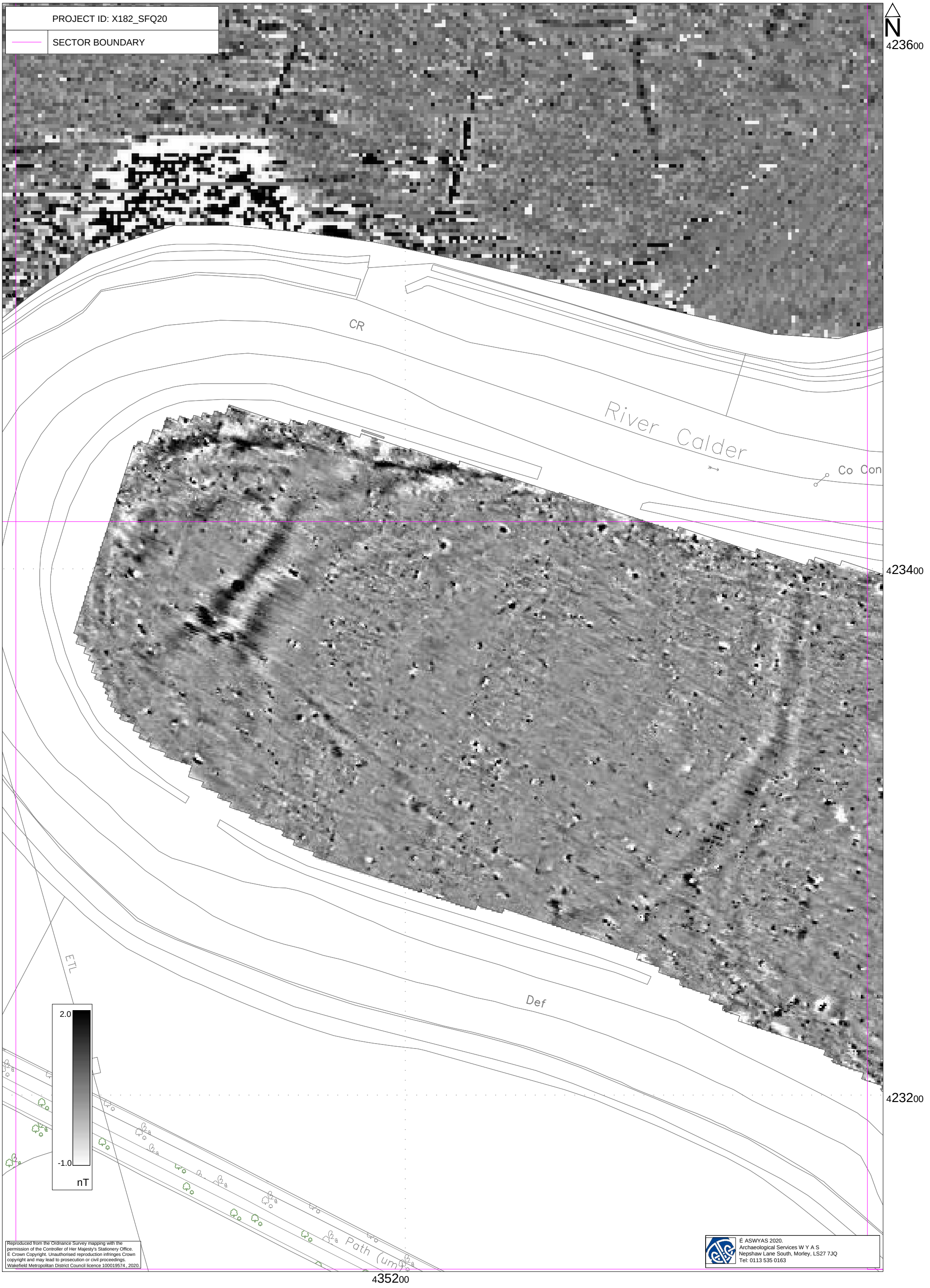


Fig. 8. Processed greyscale magnetometer data; Sector 3 (1:1250 @ A3)

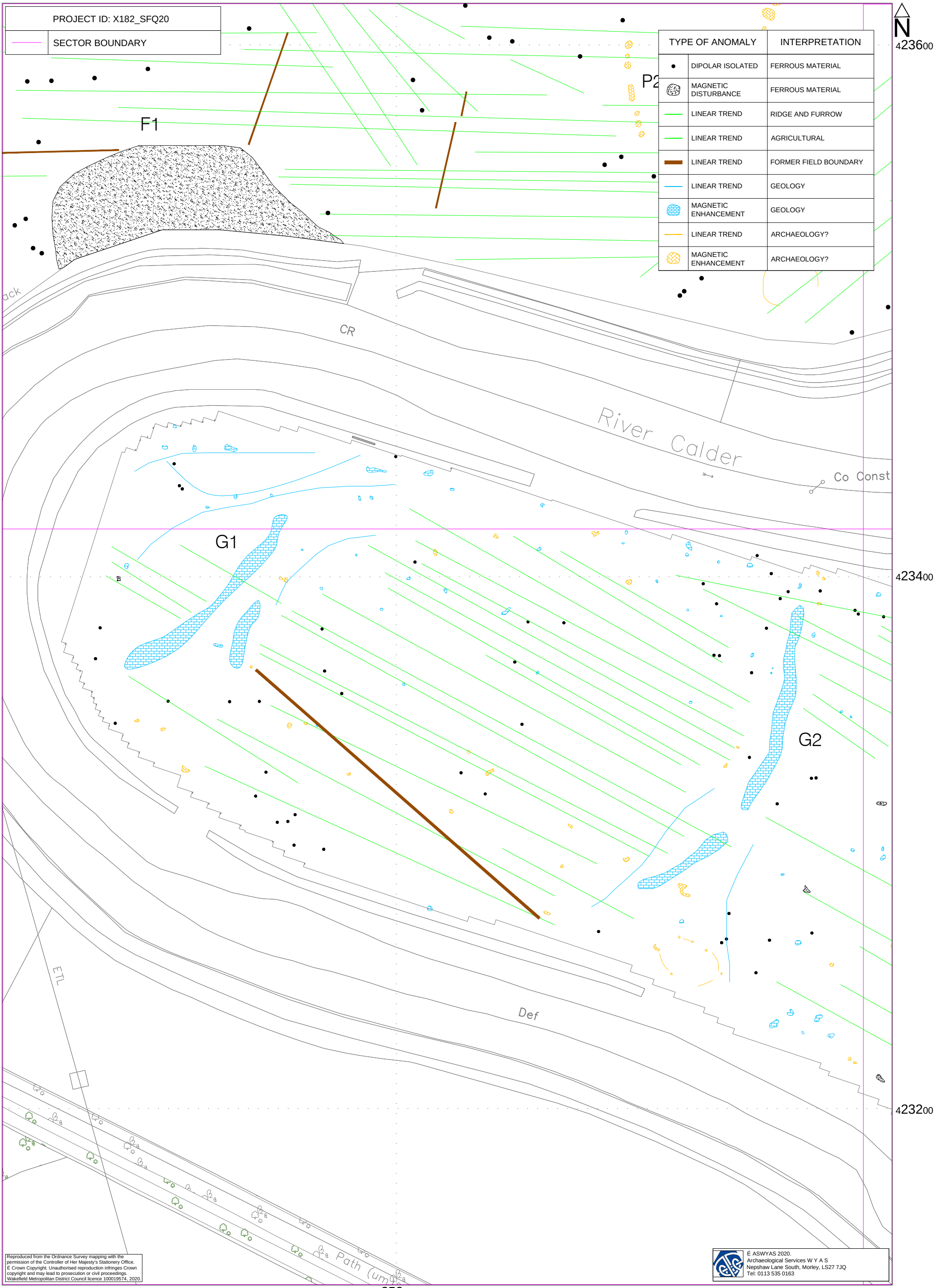


Fig. 9. Interpretation of magnetometer data; Sector 3 (1:1250 @ A3)

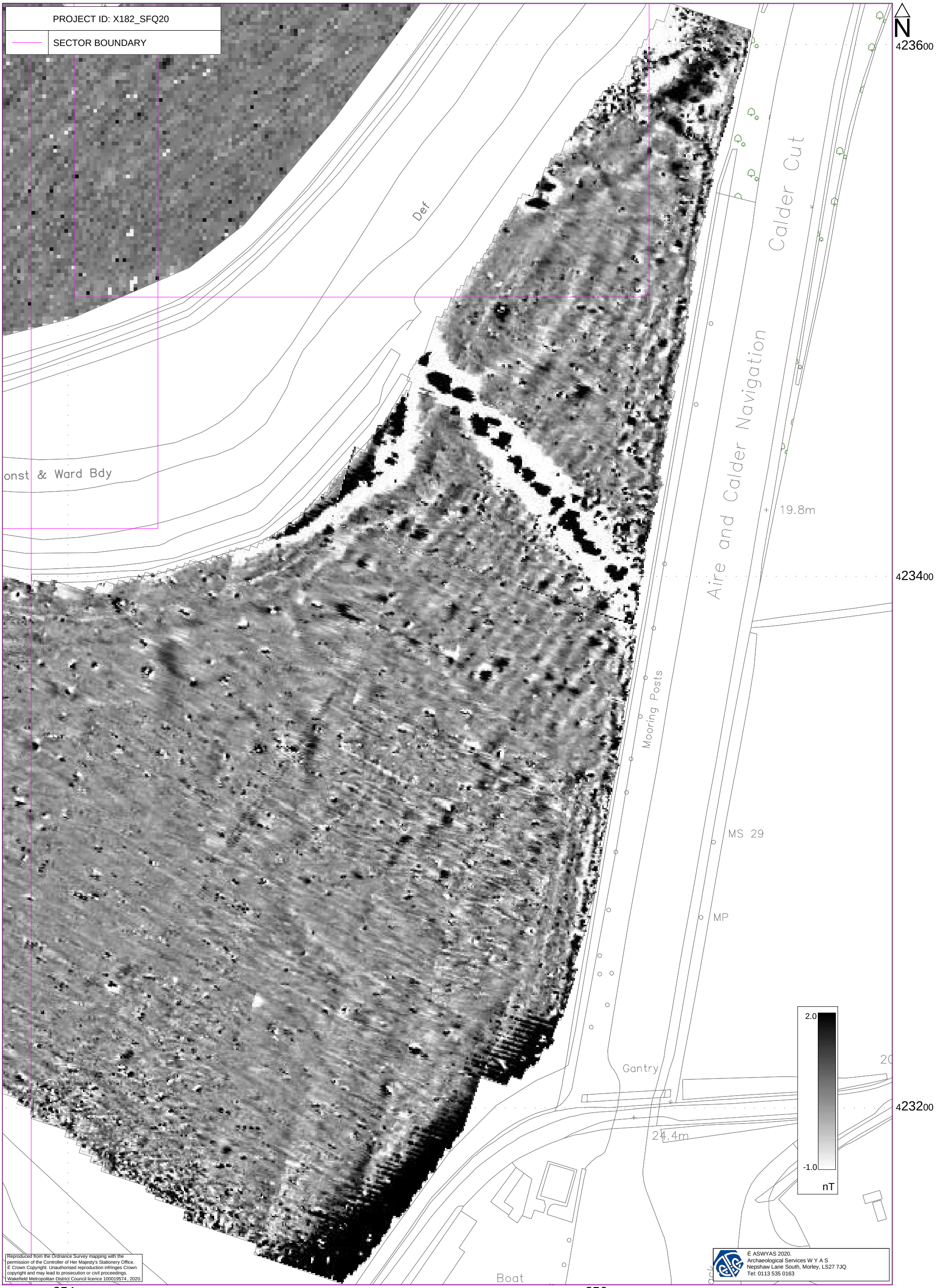


Fig. 10. Processed greyscale magnetometer data; Sector 4 (1:1250 @ A3)

PROJECT ID: X182_SFQ20	
	SECTOR BOUNDARY

TYPE OF ANOMALY		INTERPRETATION
	DIPOLAR ISOLATED	FERROUS MATERIAL
	DIPOLAR LINEAR	FIELD DRAIN
	MAGNETIC DISTURBANCE	FERROUS MATERIAL
	LINEAR TREND	RIDGE AND FURROW
	LINEAR TREND	AGRICULTURAL
	LINEAR TREND	FORMER FIELD BOUNDARY
	LINEAR TREND	GEOLOGY
	MAGNETIC ENHANCEMENT	GEOLOGY
	LINEAR TREND	ARCHAEOLOGY?
	MAGNETIC ENHANCEMENT	ARCHAEOLOGY?

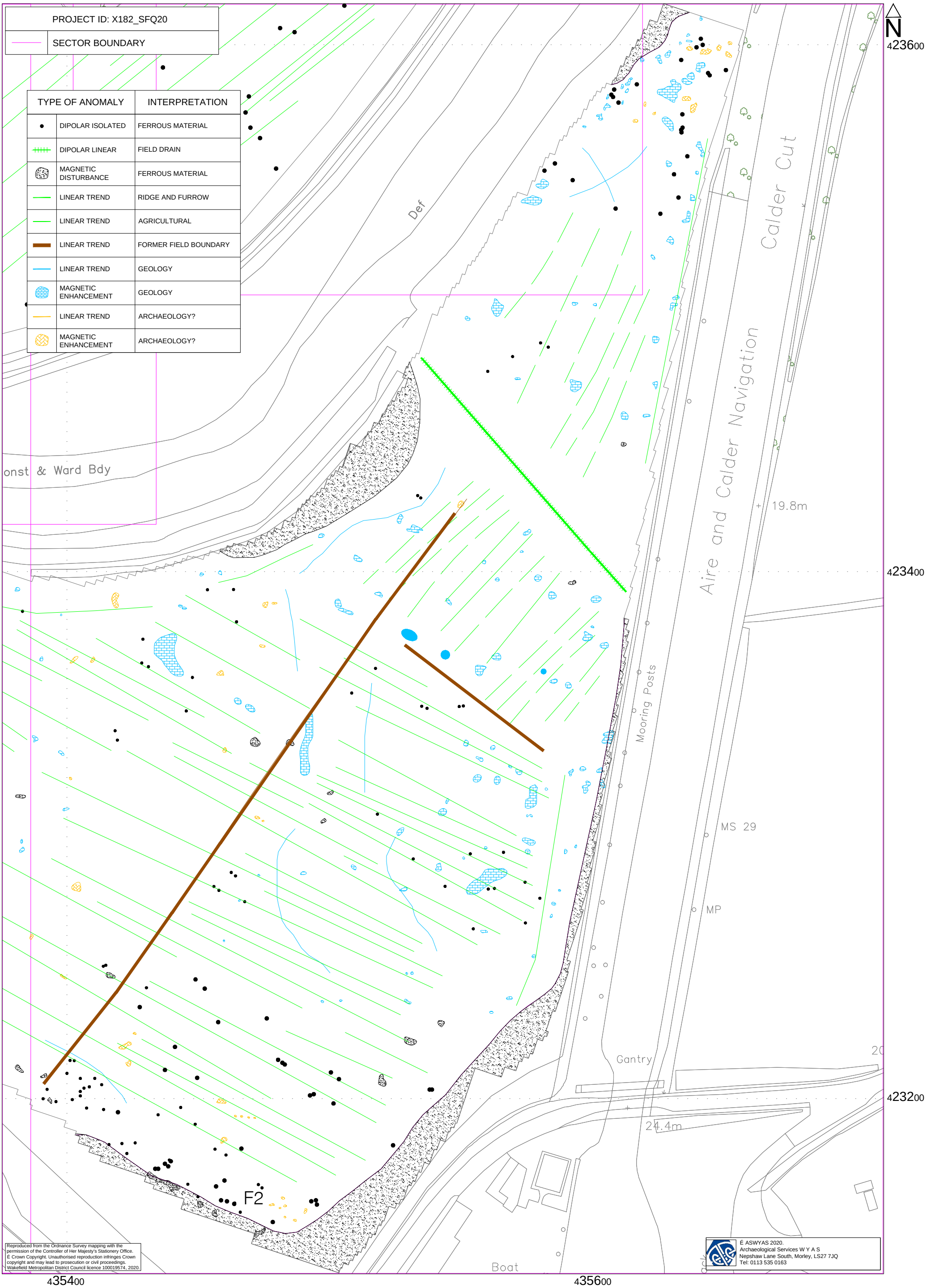
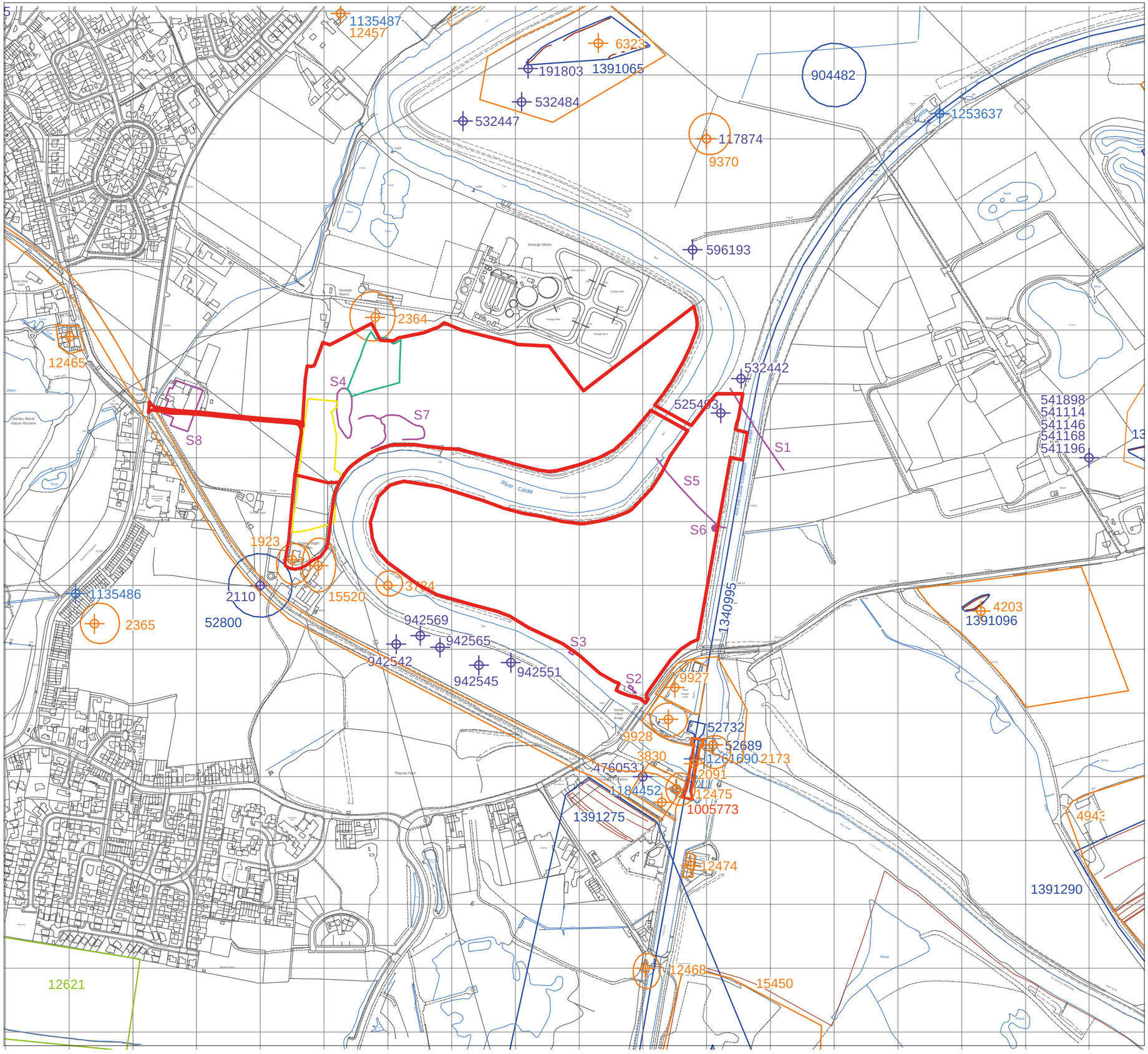


Fig. 11. Interpretation of magnetometer data; Sector 4 (1:1250 @ A3)



Key

- planning application boundary
- Scheduled Monument
- Listed Building (1200216)
- WYHER site
- WYHER event
- NRHE site
- Portable Antiquities Scheme (PAS) (525593)
- Lower Wharfdale Mapping Programme (LWMP)
- other sites
- Dent croft field name
- Deancroft field name

Note:
Data obtained from the West Yorkshire Historic Environment Record (WYHER) and the Historic England National Record of the Historic Environment (NRHE)

0 300m
scale 1:6000 @ A3

Fig. 12 Heritage assets within vicinity of proposed development (Cardwell, 2020)

PROJECT ID: X182_SFQ20

TYPE OF ANOMALY		INTERPRETATION
●	DIPOLAR ISOLATED	FERROUS MATERIAL
	DIPOLAR LINEAR	FIELD DRAIN
	MAGNETIC DISTURBANCE	FERROUS MATERIAL
	LINEAR TREND	RIDGE AND FURROW
	LINEAR TREND	AGRICULTURAL
	LINEAR TREND	FORMER FIELD BOUNDARY
	LINEAR TREND	GEOLOGY
	MAGNETIC ENHANCEMENT	GEOLOGY
	LINEAR TREND	ARCHAEOLOGY?
	MAGNETIC ENHANCEMENT	ARCHAEOLOGY?

N

423800

423600

423400

423200

348000 350000 352000 354000 356000

0 200m

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Fig. 13. Interpretation of magnetometer data on the 1st edition OS mapping dated 1854 (1:4000 @ A3)

Appendix 1: Magnetic survey - technical information

Magnetic Susceptibility and Soil Magnetism

Iron makes up about 6% of the Earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haemetite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms. Areas of human occupation or settlement can then be identified by measuring the magnetic susceptibility of the topsoil because of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of topsoils, subsoils and rocks into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected. The magnetic susceptibility of a soil can also be enhanced by the application of heat and the fermentation and bacterial effects associated with rubbish decomposition. The area of enhancement is usually quite large, mainly due to the tendency of discard areas to extend beyond the limit of the occupation site itself, and spreading by the plough.

Types of Magnetic Anomaly

In the majority of instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes)

These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being present as a consequence of manuring.

Areas of magnetic disturbance

These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire fencing and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Linear trend

This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies

Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies

Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

Methodology: Gradiometer Survey

The main method of using the fluxgate gradiometer for commercial evaluations is referred to as ***detailed survey*** and requires the surveyor to walk at an even pace carrying the instrument within a grid system. A sample trigger automatically takes readings at predetermined points, typically at 0.25m intervals, on traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation.

During this survey a Bartington Grad601 magnetic gradiometer was used at Birkwood taking readings on the 0.1nT range, at 0.125m intervals on zig-zag traverses 0.5m apart within 30m by 30m square grids. The instrument was checked for electronic and mechanical drift at a common point and calibrated as necessary. The drift from zero was not logged.

An eight channel Sensys MX V3 system containing eight FGM650 sensors was used which was towed across the Smalley Bight area using an ATV. Readings were taken every 20MHz (between 0.05 and 0.1m). Data was be recorded onto a device, using a Carlson GNSS Smart antenna, for centimetre accuracy. These readings were stored in the memory of the instrument and downloaded for processing and interpretation

The gradiometer data have been presented in this report in processed greyscale format. The data in the greyscale images have been interpolated and selectively filtered to remove the effects of drift in instrument calibration and other artificial data constructs and to maximise the clarity and interpretability of the archaeological anomalies.

Appendix 2: Survey location information

An initial survey station was established using a Trimble VRS differential Global Positioning System (Trimble R6 model). The data was geo-referenced using the geo-referenced survey station with a Trimble RTK differential Global Positioning System (Trimble R6 model). The accuracy of this equipment is better than 0.01m. The survey grids were then super-imposed onto a base map provided by the client to produce the displayed block locations. However, it should be noted that Ordnance Survey positional accuracy for digital map data has an error of 0.5m for urban and floodplain areas, 1.0m for rural areas and 2.5m for mountain and moorland areas. This potential error must be considered if co-ordinates are measured off hard copies of the mapping rather than using the digital co-ordinates.

Archaeological Services WYAS cannot accept responsibility for errors of fact or opinion resulting from data supplied by a third party.

Appendix 3: Geophysical archive

The geophysical archive comprises:-

- an archive disk containing compressed (WinZip 8) files of the raw data, report text (Microsoft Word 2000), and graphics files (Adobe Illustrator CS2 and AutoCAD 2008) files; and
- a full copy of the report.

At present the archive is held by Archaeological Services WYAS although it is anticipated that it may eventually be lodged with the Archaeology Data Service (ADS). Brief details may also be forwarded for inclusion on the English Heritage Geophysical Survey Database after the contents of the report are deemed to be in the public domain (i.e. available for consultation in the West Yorkshire Environment Record).

Appendix 4: Oasis form

OASIS DATA COLLECTION FORM: England

OASIS ID: archaeol11-403621

Project details

Project name	Stanley Ferry Quarry, Wakefield
Short description of the project	A geophysical (magnetometer) survey was undertaken on approximately 22 hectares of land located at Birkwood and Smalley Bight, to the northwest of Stanley Ferry, Wakefield, West Yorkshire. Anomalies of a possible archaeological origin have been detected which may suggest part of a former field system and a tentative ring ditch. Possible medieval ridge and furrow cultivation have also been detected along with former field boundaries, modern ploughing and a field drain. Responses associated with a possible former route of the River Calder, and responses associated with flooding have been recorded in Birkwood.
Project dates	Start: 14-04-2020 End: 21-08-2020
Previous/future work	No / Not known
Any associated project reference codes	X182 - Sitecode
Type of project	Field evaluation
Monument type	NONE None
Significant Finds	NONE None
Methods & techniques	"Geophysical Survey"
Development type	Mineral extraction (e.g. sand, gravel, stone, coal, ore, etc.)
Prompt	National Planning Policy Framework - NPPF
Position in the planning process	20/01159/FUL
Solid geology (other)	Pennine Middle Coal Measures
Drift geology	ALLUVIUM
Techniques	Magnetometry
Techniques	Magnetometry

Project location

Country	England

Site location	WEST YORKSHIRE WAKEFIELD NORMANTON Stanley Ferry Quarry
Study area	22 Hectares
Site coordinates	SE 3542 2331 53.704790928436 -1.463380324058 53 42 17 N 001 27 48 W Point
Site coordinates	SE 3521 2357 53.707142216039 -1.466532152004 53 42 25 N 001 27 59 W Point
Height OD / Depth	Min: 17m Max: 20m

Project creators

Name of Organisation	Archaeological Services WYAS
Project brief originator	Peter Cardwell
Project design originator	Peter Cardwell
Project director/manager	E Brunning
Project supervisor	C. Sykes

Project archives

Physical Archive Exists?	No
Digital Archive recipient	ASWYAS
Digital Contents	"Survey"
Digital Media available	"Geophysics","Text"
Paper Archive Exists?	No

Project bibliography 1

Publication type	Grey literature (unpublished document/manuscript)
Title	Stanley Ferry Quarry, Wakefield
Author(s)/Editor(s)	Brunning, E
Date	2020
Issuer or publisher	ASWYAS
Place of issue or publication	Leeds
Description	A4 report with A3 and A4 figures

Entered by	Emma Brunning (emma.brunning@aswyas.com)
Entered on	14 September 2020

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