magnitude surveys

Geophysical Survey Report of Watercrook Roman Fort, Kendal, Cumbria

For

Oxford Archaeology

On Behalf Of

United Utilities

Magnitude Surveys Ref: MSSD456

Scheduled Monument Number: 1007178

HER Event Number: Requested

OASIS Number: TBC

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Unit 17, Commerce Court

Challenge Way

Bradford

BD4 8NW

01274 926020

info@magnitudesurveys.co.uk

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Final 2.0	Client corrections	Leanne Swinbank, BA ACIfA	N/A	Leanne Swinbank, BA ACIfA	22 March 2019

Abstract

Magnitude Surveys was commissioned to assess the subsurface archaeological potential of a c. 1ha area of land immediately southeast of Watercrook Roman Fort. A fluxgate magnetometer survey was successfully completed, identifying anomalies indicative of regularly aligned wall footings, ditches, pits and industrial activity associated with the vicus of the Roman fort across the northern area of the site. Further possible archaeology which may also relate to this vicus was identified in the central survey area, though alternatively it may relate to activity associated with a 19th century orchard recorded at this location. Modern activity including a service and footpath was also identified in the southmost area of the site.

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1. Introduction

1.1. Magnitude Surveys Ltd (MS) was commissioned by Oxford Archaeology on behalf of United Utilities to undertake a geophysical survey on a c. 1ha area of predominantly pasture land to the immediate west of Watercrook Roman Fort (Scheduled Monument number: 1007178), near Watercrook Farm, Kendal, Cumbria (SD 5156 9062).

1.2. The geophysical survey comprised hand-carried GNSS-positioned fluxgate magnetometer survey.

1.3. The survey was conducted in line with the current best practice guidelines produced by Historic England (David et al., 2008), the Chartered Institute for Archaeologists (CIfA, 2014) and the European Archaeological Council (Schmidt et al., 2015).

1.4. The survey was conducted in line with the WSI and complied with the conditions of the Section 42 licence.

1.5. The survey commenced on 11th March 2019 and was completed on the same date.

2. Quality Assurance

2.1. Magnitude Surveys is a Registered Organisation of the Chartered Institute for Archaeologists (CIfA), the chartered UK body for archaeologists, and a corporate member of ISAP (International Society of Archaeological Prospection).

2.2. Director Dr. Chrys Harris is a Member of CIfA, has a PhD in archaeological geophysics from the University of Bradford and is the Vice-Chair of ISAP. Director Finnegan Pope-Carter is a Fellow of the London Geological Society, the chartered UK body for geophysicists and geologists, as well as a member of GeoSIG, the CIfA Geophysics Special Interest Group. Reporting Analyst Dr. Kayt Armstrong has a PhD in archaeological geophysics from Bournemouth University, is the Vice Conference Secretary and Editor of ISAP News for ISAP, and is the UK Management Committee representative for the COST Action SAGA.

2.3. All MS managers have relevant degree qualifications to archaeology or geophysics. All MS field and office staff have relevant archaeology or geophysics degrees and/or field experience.

3. Objectives

3.1. The objective of this geophysical survey is to assess the subsurface archaeological potential of the survey area in advance of the construction of a replacement outfall pipeline to the River Kent.

4. Geographic Background

4.1. The site is located c. 300m to the south of the town of Kendal, c. 31km north of the city of Lancaster (Figure 1). Survey was undertaken on flat agricultural pasture, lying directly south of the River Kent within the river's meanders (Figure 2).

4.2. Survey considerations:

Survey Area	Ground Conditions	Further Notes
1	Flat short grass.	Bounded by open field to the north and west, the River Kent to the east and dry-stone wall to the south. Access to the area is via a gate in the SE corner.
2	Flat short grass.	Bounded by dry-stone walls to the north, open field to the west and open field and a concrete structure to the east. The road to the farm runs along southern boundary of the survey area and consists of a drystone wall and post and wire fence.
3	Flat short grass.	Bounded by open field to the south, east and west. The road to the farm runs along the northern boundary of the survey area.

4.3. The underlying geology comprises a sedimentary bedrock of limestone for the Dalston Formation. Superficial deposits consist of alluvial deposits of clay, sand and gravel (British Geological Survey, 2019).

4.4. The soils consist of freely draining slightly acid loamy soils (Soilscapes, 2019).

5. Archaeological Background

5.1. This section summarises a search of records on Heritage Gateway (2019) within a 1km of SD 5156 9062.

5.2. The survey area lies within the scheduled area for Watercrook Roman Fort and Civil settlement (Scheduled Monument number: 1007178), which has been recorded as earthworks, with excavations in the 1970s providing evidence of Roman occupation between the 1st to 4th centuries AD. A site of a possible bath house is also recorded to the south-east of the fort.

5.3. Evidence for prehistoric activity includes a flint scatter recrorded c. 60m east of the survey area.

6. Methodology

6.1.Data Collection

6.1.1. Geophysical prospection comprised the magnetic method as described in the following table.

6.1.2. Table of survey strategies:

Method	Instrument	Traverse Interval	Sample Interval
Magnetic	Bartington Instruments Grad-13 Digital Three-Axis Gradiometer	0.5m	200Hz reprojected to 0.125m

6.1.3. The magnetic data were collected using MS' bespoke hand-carried GNSS-positioned system.

6.1.3.1. MS' hand-carried system was comprised of Bartington Instruments Grad 13 Digital Three-Axis Gradiometers. Positional referencing was through a multi-channel, multi-constellation GNSS Smart Antenna RTK GPS outputting in NMEA mode to ensure high positional accuracy of collected measurements. The RTK GPS is accurate to 0.008m + 1ppm in the horizontal and 0.015m + 1ppm in the vertical.

6.1.3.2. Magnetic and GPS data were stored on an SD card within MS' bespoke datalogger. The datalogger was continuously synced, via an in-field Wi-Fi unit, to servers within MS' offices. This allowed for data collection, processing and visualisation to be monitored in real-time as fieldwork was ongoing.

6.1.3.3. A navigation system was integrated with the RTK GPS, which was used to guide the surveyor. Data were collected by traversing the survey area along the longest possible lines, ensuring efficient collection and processing.

6.2.Data Processing

6.2.1. Magnetic data were processed in bespoke in-house software produced by MS. Processing steps conform to Historic England's standards for "raw or minimally processed data" (see sect 4.2 in David et al., 2008: 11).

Sensor Calibration – The sensors were calibrated using a bespoke in-house algorithm, which conforms to Olsen et al. (2003).

Zero Median Traverse – The median of each sensor traverse is calculated within a specified range and subtracted from the collected data. This removes striping effects caused by small variations in sensor electronics.

Projection to a Regular Grid – Data collected using RTK GPS positioning requires a uniform grid projection to visualise data. Data are rotated to best fit an orthogonal grid projection and are resampled onto the grid using an inverse distance-weighting algorithm.

Interpolation to Square Pixels – Data are interpolated using a bicubic algorithm to increase the pixel density between sensor traverses. This produces images with square pixels for ease of visualisation.

6.3.Data Visualisation and Interpretation

6.3.1. This report presents the gradient of the sensors' total field data as greyscale images, as well as the total field data from the upper and/or lower sensors. The gradient of the sensors minimises external interferences and reduces the blown-out responses from ferrous and other high contrast material. However, the contrast of weak or ephemeral anomalies can be reduced through the process of calculating the gradient. Consequently, some features can be clearer in the respective gradient or total field datasets. Multiple greyscale images at different plotting ranges have been used for data interpretation. Greyscale images should be viewed alongside the XY trace plot (Figure 9)**.** XY trace plots visualise the magnitude and form of the geophysical response, aiding in anomaly interpretation.

6.3.2. Geophysical results have been interpreted using greyscale images and XY traces in a layered environment, overlaid against open street maps, satellite imagery, historic maps, LiDAR data, and soil and geology maps. Google Earth (2019) was consulted as well, to compare the results with recent land usages.

6.3.3. Geodetic position of results - All vector and raster data have been projected into OSGB36 (ESPG27700) and can be provided upon request in ESRI Shapefile (.SHP) and Geotiff (.TIF) respectively. Figures will be provided with raster and vector data projected against OS Open Data.

7. Results

7.1.Qualification

7.1.1. Geophysical results are not a map of the ground and are instead a direct measurement of subsurface properties. Detecting and mapping features requires that said features have properties that can be measured by the chosen technique(s) and that these properties have sufficient contrast with the background to be identifiable. The interpretation of any identified anomalies is inherently subjective. While the scrutiny of the results is undertaken by qualified, experienced individuals and rigorously checked for quality and consistency, it is often not possible to classify all anomaly sources. Where possible an anomaly source will be identified along with the certainty of the interpretation. The only way to improve the interpretation of results is through a process of comparing excavated results with the geophysical reports. MS actively seek feedback on their reports as well as reports of further work in order to constantly improve our knowledge and service.

7.2.Discussion

7.2.1. The geophysical results are presented in consideration with satellite imagery (Figure 7) and historic maps (Figure 8).

7.2.2. The fluxgate magnetometer survey has responded well, identifying archaeological remains and modern interference despite a relatively noisy magnetic background which may have been enhanced by alluvial deposits comprising the geographic background of the site (see Section 4).

7.2.3. Archaeological remains comprising probable walls, pits, ditches and industrial activity have been identified across Area 1, associated with the vicus of the Roman fort to the northwest. These share the same northeast-southwest alignment as the earthworks of the defences of the fort, and are within the vicinity of the bathhouse discussed in the archaeological background of the site (see Section 5). However, the survey area is too small to confidently classify these anomalies as being associated with this bathhouse. Further possible archaeological remains have been identified in Area 2 that may also be associated with the vicus, though these do not appear to share an alignment with the archaeology in Area 1 and cannot be classified with as much certainty.

7.2.4. In Area 3, magnetic disturbance associated with modern features has been detected, corresponding with a service running through the survey area and the road running across its northern boundary. A footpath is also visible in the geophysical data of this area, in addition to linear anomaly of unknown origin.

7.3.Interpretation

7.3.1. General Statements

7.3.1.1. Geophysical anomalies will be discussed broadly as classification types across the survey area. Only anomalies that are distinctive or unusual will be discussed individually.

7.3.1.2. **Magnetic Disturbance** – The strong anomalies produced by extant metallic structures along the edges of the field and by services that cross the survey area have been classified as 'Magnetic Disturbance'. These magnetic 'haloes will obscure the response of any weaker underlying features, should they be present, often over a greater footprint that the structure they are being caused by.

7.3.1.3. **Ferrous (Spike)** – Discrete ferrous-like, dipolar anomalies are likely to be the result of isolated modern metallic debris on or near the ground surface.

7.3.1.4. **Undetermined** – Anomalies are classified as Undetermined when the anomaly origin is ambiguous through the geophysical results and there is no supporting or correlative evidence to warrant a more certain classification. These anomalies are likely to be the result of geological, pedological or agricultural processes, although an archaeological origin cannot be entirely ruled out. Undetermined anomalies are generally not ferrous in nature.

7.3.2. Magnetic Results - Specific Anomalies

7.3.2.1. **Archaeology (Probable) –** Anomalies of probable archaeological origin have been detected across Area 1, and have been interpreted as relating to the vicus of the Roman fort immediately northwest of the site, based upon their location, form and alignment with the fort. These comprise parallel and perpendicular linear anomalies and alignments of anomalies including probable footings of walls such as **[1a]** and **[1b]**, characterised by enhanced negatives with little or no positive. These are most evident in the inverted magnetic gradient grayscale (Figure 4). These anomalies likely represent fragments of buildings forming a street system from the vicus, and associated pits. **[1a]** comprises rectilinear probable wall footings that are indicative of a building of at least c. 10m by 13m, and may comprise the same structure as **[1b]**; if so, this building would have a footprint of at least 20m by 20m. **[1c]** comprises a spread of archaeological material, probably consisting of ferrous and fired ceramic debris. This spread appears to be rectilinear in form and shares an alignment with other archaeological anomalies of the vicus. It could represent the remains of a possible collapsed building or a worksurface associated with industrial activity taking place on the periphery of the settlement.

7.3.2.2. **Archaeology (Possible) –** Possible archaeological anomalies have been identified across Area 2 and the southern edge of Area 1, primarily comprising weakly enhanced linear and curvilinear anomalies in addition to more strongly enhanced pit-like anomalies. Some of these possible archaeological anomalies share a common alignment with each other, and may also be associated with

the vicus of the Roman fort, though they do not appear to share a common alignment with archaeological anomalies in Area 1. Alternatively, these anomalies may be associated with the removal of trees from an orchard which is recorded across Area 2 on historic mapping (Figure 8). As such, they have been classified as having possible rather than probable archaeological origins.

8. Conclusions

8.1. A fluxgate magnetometer survey was successfully completed across the survey area, identifying probable and possible archaeological activity in Areas 1 and 2, and modern disturbance primarily contained to the edges of the fields and Area 3. Anomalies are clearly visible despite the noisy magnetic background of the site, likely enhanced by alluvial deposits from the river bounding it to the northwest.

8.2. Archaeological activity relating to the vicus of the Roman fort directly to the northwest of the site has been identified across Area 1, including evidence of wall footings and possible industrial activity. Fragments of a street system comprising regularly laid out structures share a common alignment with the Roman fort to the northwest, and a spread of archaeological debris possibly containing fired ceramic and ferrous material indicates industrial activity occurred at the edge of the vicus. Towards the southern edge of Area 1 and in Area 2, further possible archaeological evidence has been identified which may also be associated with the vicus, though if so it is not aligned with the identified street system and contains less evidence of stone structures; it may instead related to later activity such as early 20th century tree removal.

8.3. A modern service has been detected in Area 3, in addition to a footpath.

9. Archiving

9.1. MS maintains an in-house digital archive, which is based on Schmidt and Ernenwein (2013). This stores the collected measurements, minimally processed data, georeferenced and un-georeferenced images, XY traces and a copy of the final report.

9.2. MS contributes reports to the ADS Grey Literature Library upon permission from the client, subject to the any dictated time embargoes.

10. Copyright

10.1. Copyright and the intellectual property pertaining to all reports, figures, and datasets produced by Magnitude Services Ltd. is retained by MS. The client is given full licence to use such material for their own purposes. Permission must be sought by any third party wishing to use or reproduce any IP owned by MS.

11. References

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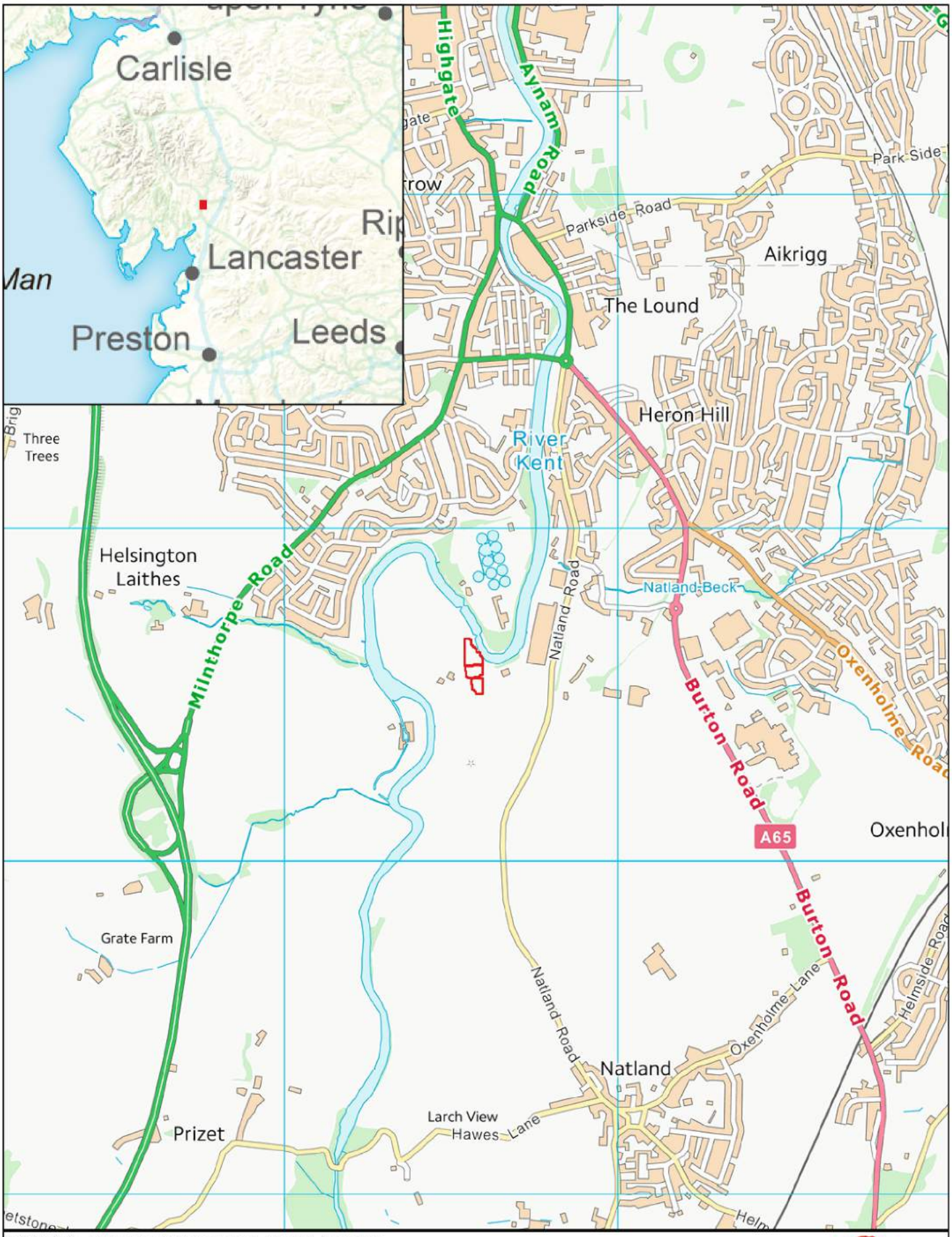

MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 1 - Site Location
1:15,000 @ A4

Site Boundary

N

0 0.25 0.5 km

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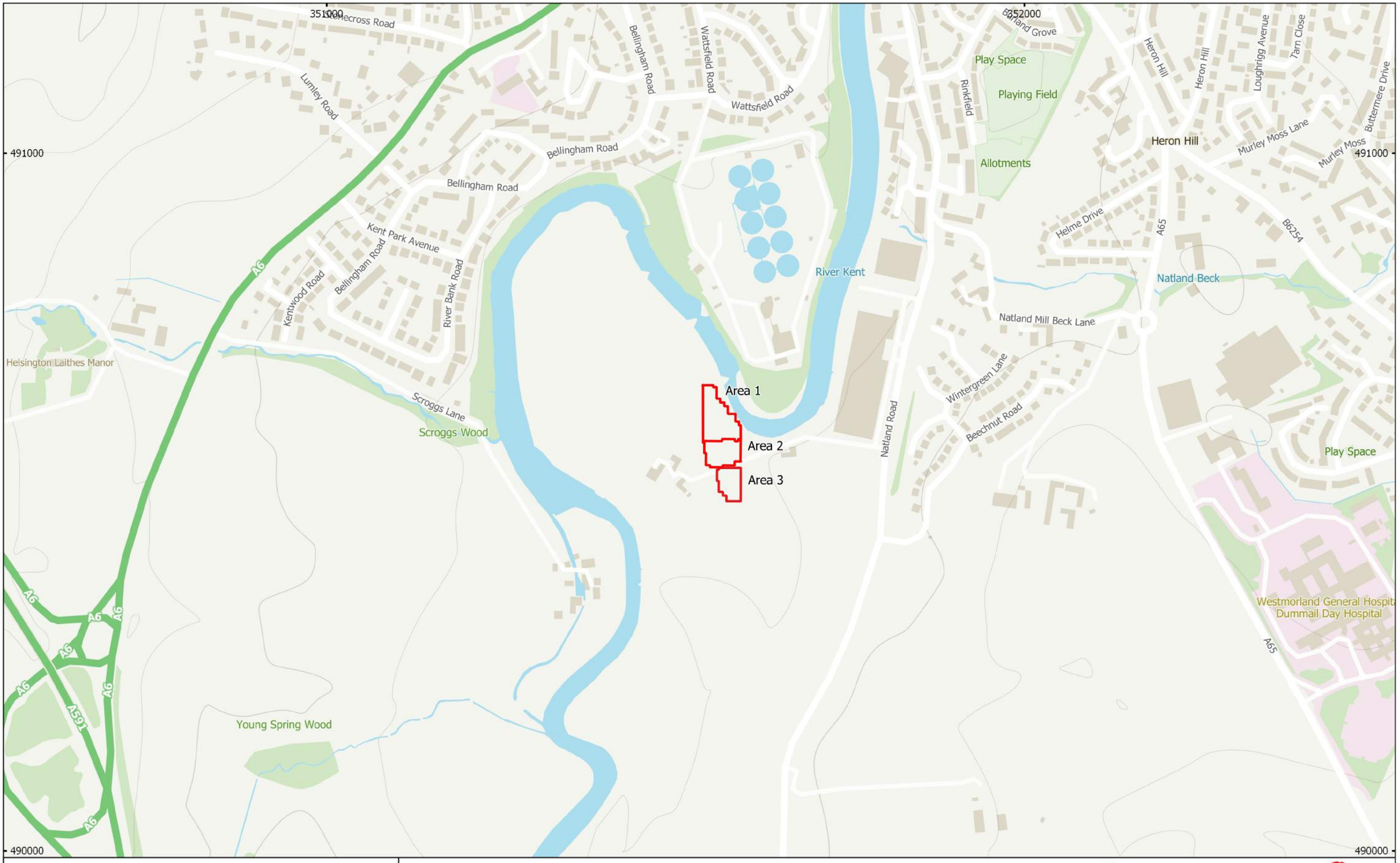


MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 2 - Location of Survey Areas
1:5,000 @ A3

Survey Extent

N

0 150 300 450 m

magnitude surveys

351500

351600

351700

490600

490600

Area 1

Area 2

Area 3

490500

490500

MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 3 - Magnetic Gradient
1:750 @ A3

-2 nT 3

N

0 20 40 60 m

magnitude surveys

351500

351600

351700

490600

490600

Area 1

Area 2

Area 3

490500

490500

MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 4 - Magnetic Gradient (Inverted)
1:750 @ A3

3 nT -2

N

0 20 40 60 m

magnitude surveys

351500

351600

351700

490600

490600

Area 1

Area 2

Area 3

490500

490500

MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 5 - Magnetic Total Field (Lower Sensor)
1:750 @ A3

48,997 nT 49,005

N

0 20 40 60 m

magnitude surveys

351500

351600

351700

490600

490600

Area 1

1b

1a

1c

Area 2

Area 3

490500

490500

MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 6 - Magnetic Interpretation
1:750 @ A3

- Archaeology Probable (Strong)
- Archaeology Probable (Weak)
- Archaeology Probable (Spread)
- Archaeology Probable (Wall Footing)
- Archaeology Probable (Possible Industrial)
- Archaeology Possible (Strong)
- Archaeology Possible (Weak)
- Archaeology Possible (Wall Footing)
- Footpath
- Undetermined (Weak)
- Magnetic Disturbance
- Service
- Ferrous (Spike)

N

0 20 40 60 m

magnitude surveys

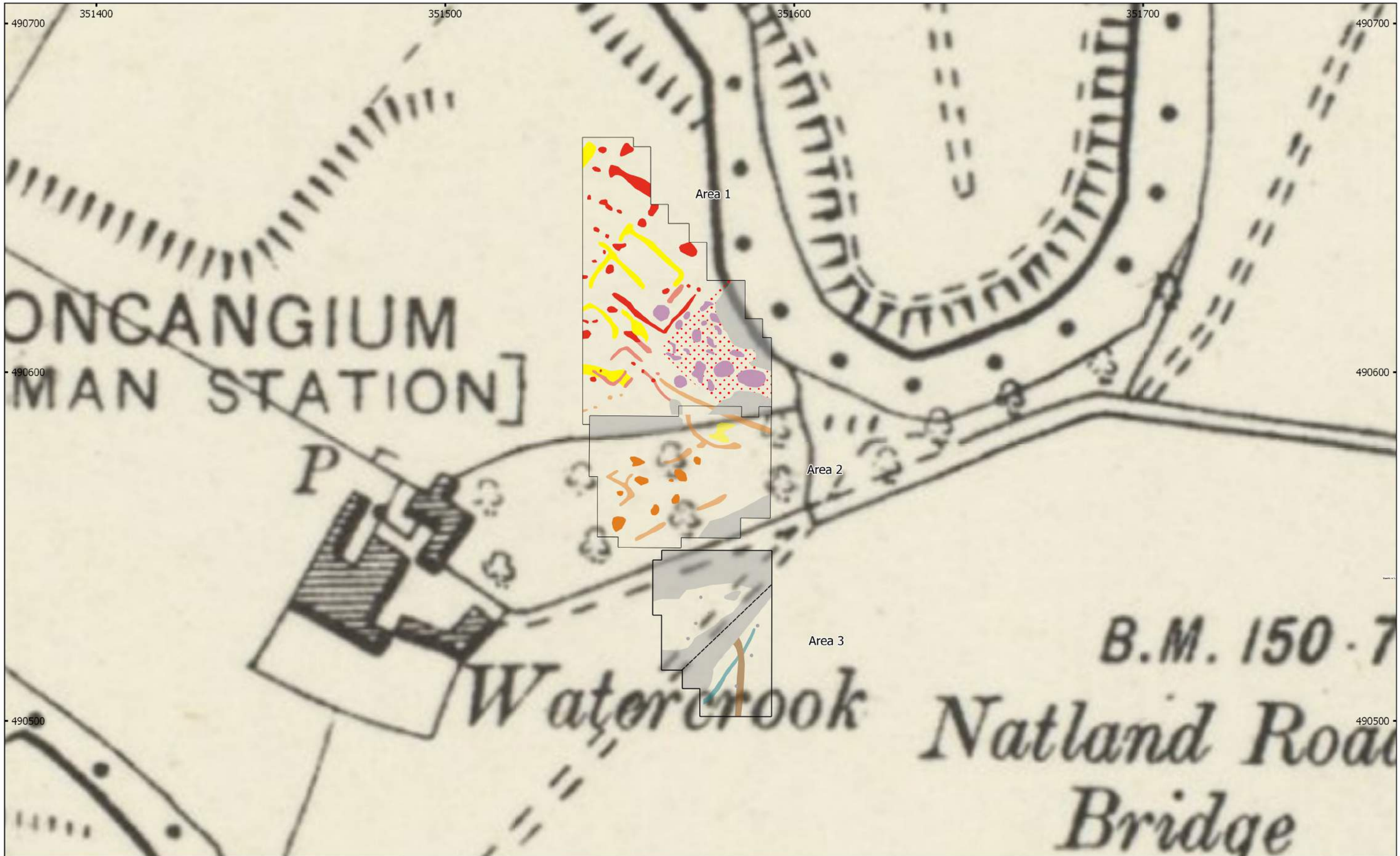
MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 7 - Magnetic Interpretation Over Satellite Imagery
1:1,000 @ A3

- Archaeology Probable (Strong)
- Archaeology Probable (Weak)
- Archaeology Probable (Spread)
- Archaeology Probable (Wall Footing)
- Archaeology Probable (Possible Industrial)
- Archaeology Possible (Strong)
- Archaeology Possible (Weak)
- Archaeology Possible (Wall Footing)
- Footpath
- Undetermined (Weak)
- Magnetic Disturbance
- Service
- Ferrous (Spike)

N

0 25 50 75 m

magnitude surveys



MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 8 - Magnetic Interpretation Over Historic Maps
1:1,000 @ A3

Contains historic maps: Ordnance Survey, 6" 2nd edition c. 1882-1913 © National Library of Scotland

- Archaeology Probable (Strong)
- Archaeology Probable (Weak)
- Archaeology Probable (Spread)
- Archaeology Probable (Wall Footing)
- Archaeology Probable (Possible Industrial)
- Archaeology Possible (Strong)
- Archaeology Possible (Weak)
- Archaeology Possible (Wall Footing)
- Footpath
- Undetermined (Weak)
- Magnetic Disturbance
- Service
- Ferrous (Spike)

N

0 25 50 75 m

magnitude surveys

351500

351600

351700

490600

490600

Area 1

Area 2

Area 3

490500

490500

MSSD456 - Watercrook Roman Fort, Kendal, Cumbria
Figure 9 - XY Trace Plot
15nT/cm at 1:750 @ A3

N

0 20 40 60 m

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