Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Environmental Statement

Volume 4

Appendix 10.3: Geophysical Survey Report of Bonstone Compound

June 2021

Water for the North West

Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section

Project No:	B27070CT
Document Title:	Proposed Marl Hill Section Environmental Statement Volume 4 Appendix 10.3: Geophysical Survey Report of Bonstone Compound
Document Ref.:	RVBC-MH-TA-010-003
Revision:	0
Date:	June 2021
Client Name:	United Utilities Water Ltd

Jacobs U.K. Limited

5 First Street
Manchester M15 4GU
United Kingdom
T +44 (0)161 235 6000
F +44 (0)161 235 6001
www.jacobs.com

Geophysical Survey Report

of

Proposed Bonstone Compound

Haweswater Aqueduct Resilience Programme – Proposed Marl Hill Section

For

ADAS

On Behalf Of

United Utilities

Magnitude Surveys Ref: MSSD898

April 2021

Unit 17, Commerce Court

Challenge Way

Bradford

BD4 8NW

01274 926020

info@magnitudesurveys.co.uk

Report By:

Anna Chmielowska BA MA PhD

Report Approved By:

Dr Kayt Armstrong MCIfA

Issue Date:

09 April 2021

Abstract

Magnitude Surveys were commissioned to assess the subsurface archaeological potential of a c.9.42ha area of land at the Proposed Bonstone Compound, Lancashire. A fluxgate gradiometer survey was successfully completed across the majority of the survey area. c. 1.3ha was left unsurveyed due to ecological constraints. Agricultural activity including ridge and furrow cultivation, a mapped former field boundary, and land drains have been identified. Anomalies classified as 'Undetermined' were identified within the survey area and while archaeological interpretations for these cannot be excluded, no anomalies suggestive of significant archaeological activity have been identified. The impact of modern activity on the site is limited to magnetic interference around field perimeters and that caused by overhead cable poles and farming equipment.

Contents

List of Figures

1. Introduction

1.1. Magnitude Surveys Ltd (MS) was commissioned by ADAS on behalf of United Utilities, to undertake a geophysical survey over a c. 9.42ha area of land at the Proposed Bonstone Compound, Lancashire (SD 69785 48869).

1.2. The geophysical survey comprised hand-carried GNSS-positioned fluxgate gradiometer survey. Magnetic survey is the standard primary geophysical method for archaeological applications in the UK due to its ability to detect a range of different features. The technique is particularly suited for detecting fired or magnetically enhanced features, such as ditches, pits, kilns, sunken featured buildings and industrial activity (David *et al*., 2008).

1.3. The survey was conducted in line with the current best practice guidelines produced by the Chartered Institute for Archaeologists (CIfA, 2020) and the European Archaeological Council (Schmidt *et al.,* 2015).

1.4. It was conducted in line with a WSI produced by MS (Adams, 2021) .

1.5. The survey commenced on 31.03.2021 and took two days to complete.

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 for Archaeological Prospection).

2.2. The directors of MS are involved in cutting edge research and the development of guidance/policy. Specifically, Dr Chrys Harris has a PhD in archaeological geophysics from the University of Bradford, is a Member of CIfA and is the Vice-Chair of the International Society for Archaeological Prospection (ISAP); Finnegan Pope-Carter has an MSc in archaeological geophysics and is a Fellow of the London Geological Society, as well as a member of GeoSIG (CIfA Geophysics Special Interest Group); Dr Kayt Armstrong has a PhD in archaeological geophysics from Bournemouth University, is a Member of CIfA, the Editor of ISAP News, and is the UK Management Committee representative for the COST Action SAGA; Dr Paul Johnson has a PhD in archaeology from the University of Southampton, is a Fellow of the Society of Antiquaries of London, has been a member of the ISAP Management Committee since 2015, and is currently the nominated representative for the EAA Archaeological Prospection Community to the board of the European Archaeological Association.

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

3. Objectives

3.1. The objective of this geophysical survey was to assess the subsurface archaeological potential of the survey area.

4. Geographic Background

4.1. The survey area was located c. 1.5km south of Newton (Figure 1). Gradiometer survey was undertaken across multiple pasture fields. The survey area was bounded by fields to the north and west, and roads to the east and south (Figure 2). An area of c.1.3ha was not surveyed due to ecological constraints, notably the presence of nesting birds.

4.2. Survey considerations:

Survey Area	Ground Conditions	Further Notes
1	The area consisted of a pasture field which sloped down towards the west and north.	The survey area was bounded by wood and wire fencing in all directions.
2	The area consisted of a pasture field which sloped down towards the north.	The survey area was bounded by wood and wire fencing to the west, south and east. The field continued to the north.
3	The area consisted of a pasture field. The area was predominantly flat, slightly sloping down towards the north.	The survey area was bounded by wood and wire fencing to the west. The field continued to the north, east and south.
4	The area consisted of a pasture field. The area was predominantly flat, slightly sloping down towards the north.	The survey area was unbounded in all directions except the east, where it was bounded by a ditch and hedges.
5	The area consisted of a pasture field which sloped down towards the north.	The survey area was unbounded in all directions except the west, where it was bounded by a ditch and hedges.
6	The area consisted of a flat, pasture field.	The survey area was bounded to the west and east by wood and wire fencing. The field continued to the north and south.

4.3. The underlying geology comprises Chadian mudstone. Superficial deposits consist of Devensian diamicton (British Geological Survey, 2021).

4.4. Slowly permeable seasonally wet acid loamy and clayey soils were present throughout the survey area (Soilscapes, 2021).

5. Archaeological Background

5.1. The following is a summary of Historic Environment Record data provided by ADAS and an environmental statement produced by Jacobs (2020) and provided by ADAS.

5.2. There are no known archaeological remains within the survey area. However, evidence of mining activity has been recorded within the vicinity of the survey area. This includes upstanding earthworks of Ashnott Lead Mine, c. 800m south of the survey area, which possibly has an origin in the 13th century. Several limekilns are also recorded within the vicinity of the survey area located c. 30m east (PRN10015) and c. 240m north (PRN10014) of the survey area.

5.3. The survey area is categorised as being within an area typical of Post-Medieval and Ancient enclosures. These patterns of enclosures will reflect regional agricultural practices and land divisions, with Post-Medieval enclosures typically dating from the 17th century onwards. Ancient enclosures, consisting of irregular enclosure pattern with curvilinear field boundaries date from before the 17th century.

5.4. A map regression has been conducted which shows that there appears to have been limited changes to the survey area since Ordnance Survey Mapping from 1885-1900.

6. Methodology

6.1. Data Collection

6.1.1. Magnetometer surveys are generally the most cost effective and suitable geophysical technique for the detection of archaeology in England. Therefore, a magnetometer survey should be the preferred geophysical technique unless its use is precluded by any specific survey objectives or the site environment. For this site, no factors precluded the recommendation of a standard magnetometer survey. Geophysical survey therefore comprised the magnetic method as described in the following section.

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

6.1.3. Table of survey strategies:

Method	Instrument	Traverse Interval	Sample Interval
Magnetic	Bartington Instruments Grad-13 Digital Three-Axis Gradiometer	1m	200Hz reprojected to 0.125m

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

6.1.4.1. 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.

6.1.4.2. 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.

6.1.4.3. 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 the EAC and Historic England guidelines for 'minimally enhanced data' (see Section 3.8 in Schmidt *et al.*, 2015: 33 and Section IV.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 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 of the gradient and total field at different plotting ranges have been used for data interpretation. Greyscale images should be viewed alongside the XY trace plot (Figures 7 and 10). XY trace plots visualise the magnitude and form of the geophysical response, aiding 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, historical maps, LiDAR data, and soil and geology maps. Google Earth (2021) was also consulted, to compare the results with recent land use.

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 are 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 from further work, in order to constantly improve our knowledge and service.

7.2. Discussion

7.2.1. A fluxgate gradiometer survey was successfully completed across the majority of the survey area. However, c.1.3ha of the survey area could not be surveyed due to the presence of nesting birds. The geophysical results are presented in combination with satellite imagery and historical maps (Figure 4).

7.2.2. The geophysical survey has primarily detected historical and modern agricultural activity. The impact of modern activity on the results is limited to magnetic interference from overhead cable poles and farming equipment, as well as fencing and metal objects at the edges of survey areas. No anomalies suggestive of significant archaeological activity were identified, although several anomalies classified as 'Undetermined' have been identified, for which an archaeological origin cannot be ruled out.

7.2.3. Evidence of agricultural activity has been identified throughout the survey area in the form of ridge and furrow cultivation and a mapped former field boundary in the central part of the survey area (Figures 5 and 6). The presence of ridge and furrow ploughing regimes indicate that the area has been under cultivation since at least the medieval/post-medieval period. Drainage features have also been detected across the majority of the survey area.

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

7.3.1.3. **Magnetic Disturbance** – The strong anomalies produced by extant metallic structures, typically including fencing, pylons, vehicles and service pipes, have been classified as 'Magnetic Disturbance'. These magnetic 'haloes' will obscure weaker anomalies relating to nearby features, should they be present, often over a greater footprint than the structure causing them.

7.3.1.4. **Undetermined** – Anomalies are classified as Undetermined when the origin of the geophysical anomaly is ambiguous and there is no supporting contextual evidence to justify 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 distinct from those caused by ferrous sources.

7.3.2. Magnetic Results - Specific Anomalies

7.3.2.1. **Ridge and Furrow (Trend)** – Arrangements of regularly-spaced weak linear and curvilinear anomalies have been identified, located in Areas 1 and 5 (Figures 5 and 6). These anomalies are indicative of ridge-and-furrow regimes and align with extant remains which are still visible within the modern landscape and can also be observed on satellite images (Figure 4).

7.3.2.2. **Agricultural (Weak**) – A weak linear anomaly has been identified crossing the centre of Area 2. This anomaly collocates with a field boundary recorded on 2nd Edition OS mapping (Figure 4). The magnetic signal of this anomaly is similar to that of many of the land drains identified within the survey area. As such, it is possible that the route of this former boundary has been repurposed as a drain. (Figure 6).

7.3.2.3. **Drainage Features** – Several linear anomalies, characterised as alignments of dipolar anomalies, have been identified across the survey area (Figures 5, 6 ,8 and 9). These anomalies are indicative of land drains, their magnetic signal being typical of fired clay drains.

7.3.2.4. **Undetermined (Weak**) – Across the survey area several anomalies have been classified as 'Undetermined' (Figures 6 & 9), including weakly positive, linear anomalies of varying length. These have no distinctive signal or shape which would allow for a confident interpretation of their cause. As such, these anomalies likely relate to natural, agricultural or modern features or objects, but an archaeological origin cannot be completely ruled out.

8. Conclusions

8.1. A fluxgate gradiometer survey was successfully completed across all but c. 1.3ha of the c. 9.42ha survey area. Modern magnetic disturbance was limited to haloes caused by fencing, poles, and farming equipment.

8.2. The geophysical results primarily reflect the agricultural usage of the survey area in the form of ridge and furrow regimes and a former field boundary. Several land drains were also identified across the survey area.

8.3. No anomalies suggestive of significant archaeological activity were identified within the survey area, though archaeological origins cannot be ruled out for the anomalies which have been classified as 'Undetermined'.

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 any dictated time embargoes.

10. Copyright

10.1. Copyright and intellectual property (IP) 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

Adams, C., 2021. Written Scheme of Investigation For a Geophysical Survey of Lullington, South Derbyshire. Magnitude Surveys Ltd.

British Geological Survey, 2021. Geology of Britain. Newton, Lancashire. [http://mapapps.bgs.ac.uk/geologyofbritain3d/]. Accessed 07/04/2021.

Chartered Institute for Archaeologists, 2020. Standards and guidance for archaeological geophysical survey. CIfA.

David, A., Linford, N., Linford, P. and Martin, L., 2008. Geophysical survey in archaeological field evaluation: research and professional services guidelines (2nd edition). Historic England.

Google Earth, 2021. Google Earth Pro V 7.1.7.2606.

Jacobs, 2020. Haweswater Aqueduct Resilience Programme - Proposed Marl Hill Section, Chapter 10 - Appendix 1, Desk Based Survey

Olsen, N., Toffner-Clausen, L., Sabaka, T.J., Brauer, P., Merayo, J.M.G., Jorgensen, J.L., Leger, J.M., Nielsen, O.V., Primdahl, F., and Risbo, T., 2003. Calibration of the Orsted vector magnetometer. Earth Planets Space 55: 11-18.

Schmidt, A. and Ernenwein, E., 2013. Guide to good practice: geophysical data in archaeology (2nd edition). Oxbow Books: Oxford.

Schmidt, A., Linford, P., Linford, N., David, A., Gaffney, C., Sarris, A. and Fassbinder, J., 2015. Guidelines for the use of geophysics in archaeology: questions to ask and points to consider. EAC Guidelines 2. European Archaeological Council: Belgium.

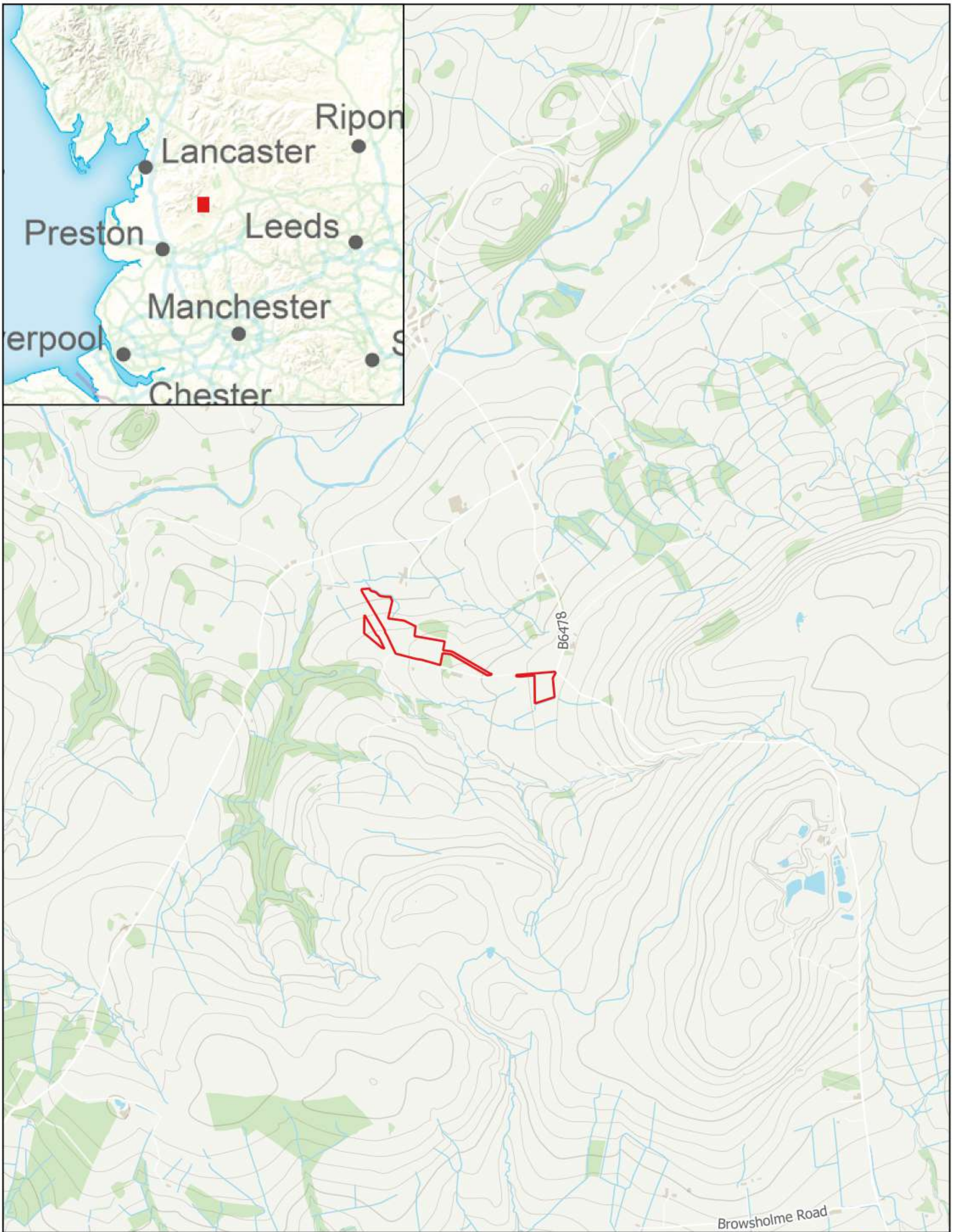
Soilscapes, 2021. Newton, Lancashire. Cranfield University, National Soil Resources Institute. [http://landis.org.uk]. Accessed 07/04/2021.

12. Project Metadata

MS Job Code	MSSD898
Project Name	Geophysical Survey Report of Proposed Bonstone Compound Haweswater Aqueduct Resilience Programme – Proposed Marl Hill Section
Client	ADAS
Grid Reference	(SD 69785 48869)
Survey Techniques	Magnetometry
Survey Size (ha)	9.42ha (Magnetometry)
Survey Dates	2021-03-31 to 2021-04-01
Project Lead	Christian Adams BA MSc
Project Officer	Christian Adams BA MSc
HER Event No	N/A
OASIS No	N/A
S42 Licence No	N/A
Report Version	1.0

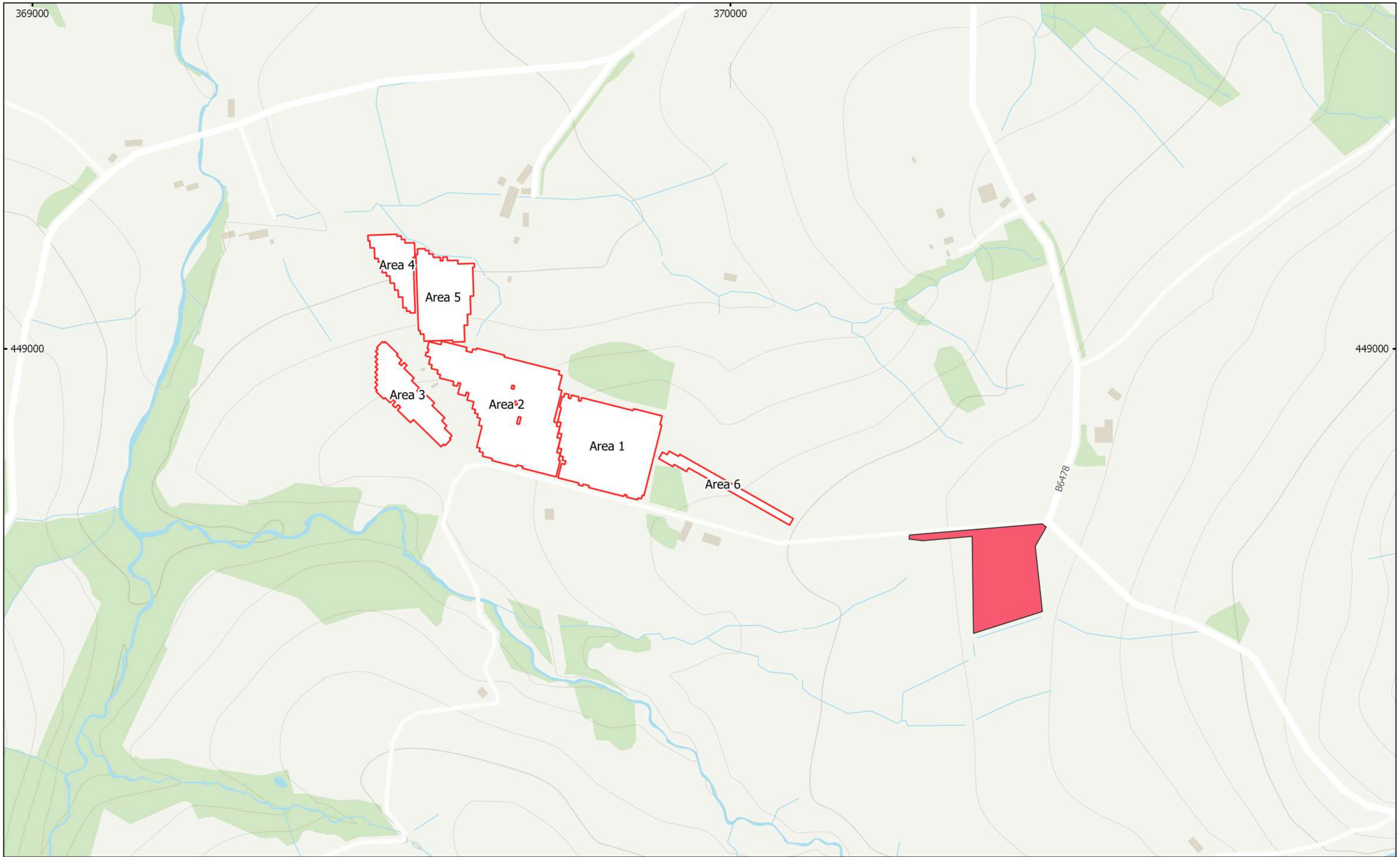
13. Document History

Version	Comments	Author	Checked By	Date
0.1	Initial draft for Project Lead to Review	AC	CA	08 April 2021
0.2	Draft for Director Approval	AC	KA	09 April 2021
1.0	Corrections from client and issued as final	CA	HB	18 April 2021



MSSD898 - Bonstone Compound
Figure 1 - Site Location
1:25,000 @ A4

magnitude surveys

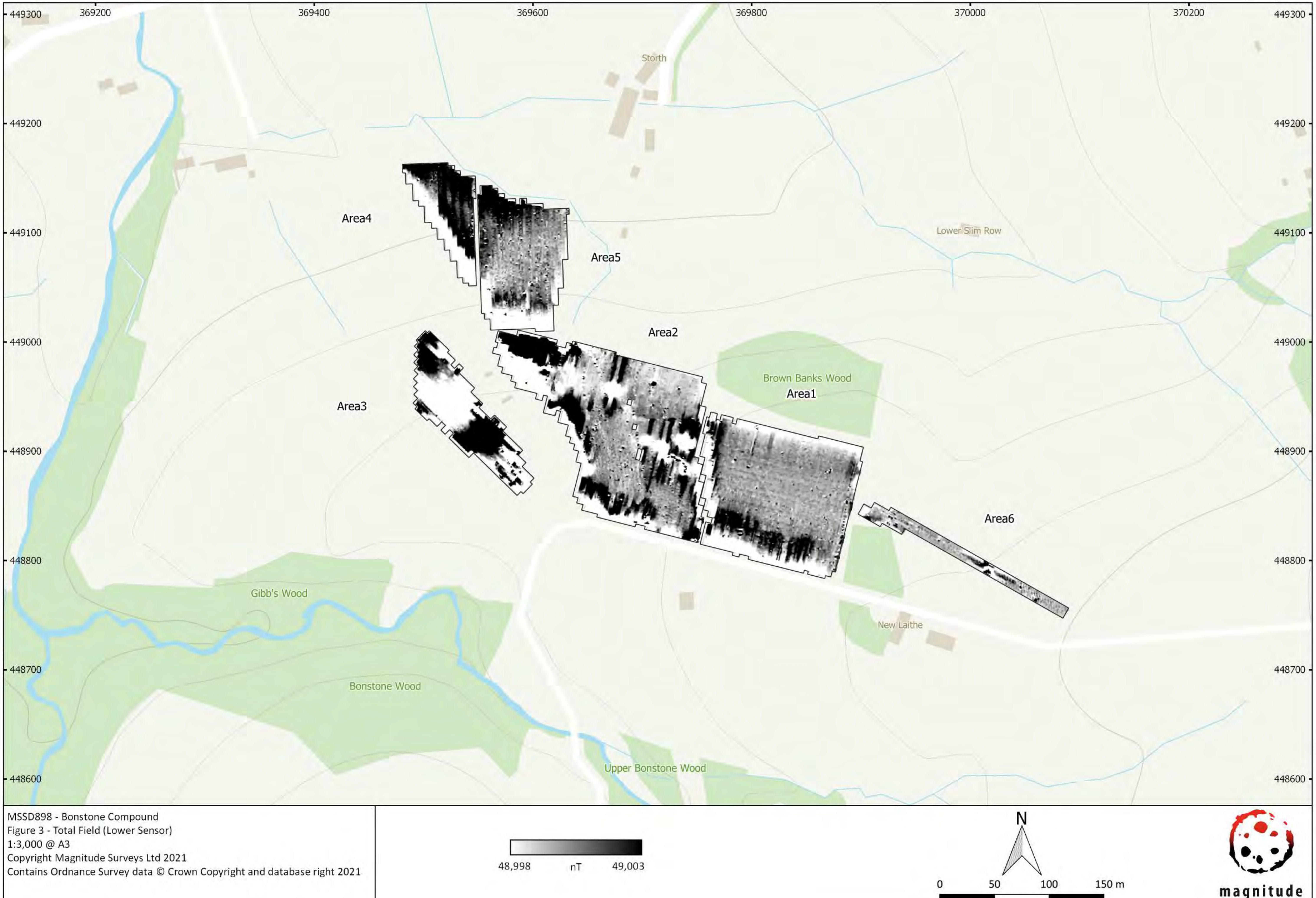


MSSD898 - Bonstone Compound
Figure 2 - Location of Survey Areas
1:5,000 @ A3

Survey Extent
Unsurveyable

N
0 100 200 300 m

magnitude surveys



MSSD898 - Bonstone Compound
Figure 3 - Total Field (Lower Sensor)
1:3,000 @ A3

magnitude surveys

MSSD898 - Bonstone Compound
Figure 4 - Magnetic Interpretation Over Historical Maps and Satellite Imagery
1:3,000 @ A3

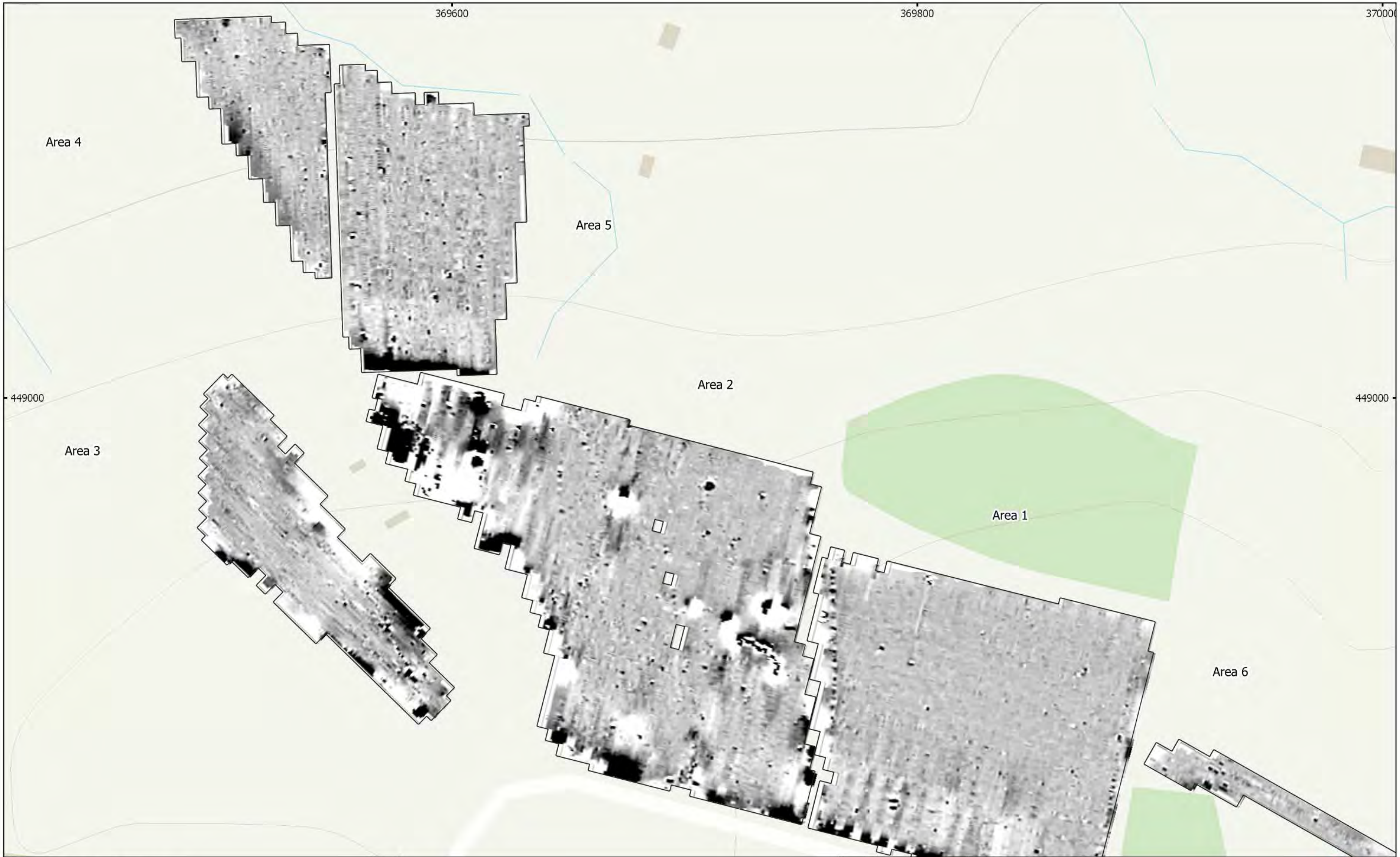
Contains historical maps: Ordnance Survey, 6" 2nd edition c. 1882-1913.
Reproduced with the permission of the National Library of Scotland.
Contains satellite imagery © 2021 Bing Satellite

Agricultural (Weak)
Magnetic Disturbance
Ferrous/Debris (Spread)
Undetermined (Weak)
Ridge and Furrow (Trend)
Drainage Feature
Ferrous (Spike)

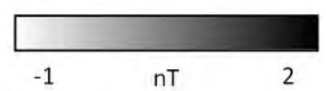
N

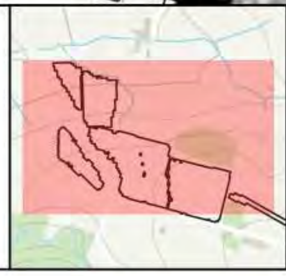
0 50 100 150 m

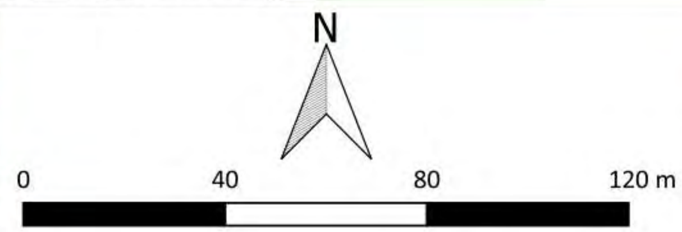
magnitude surveys



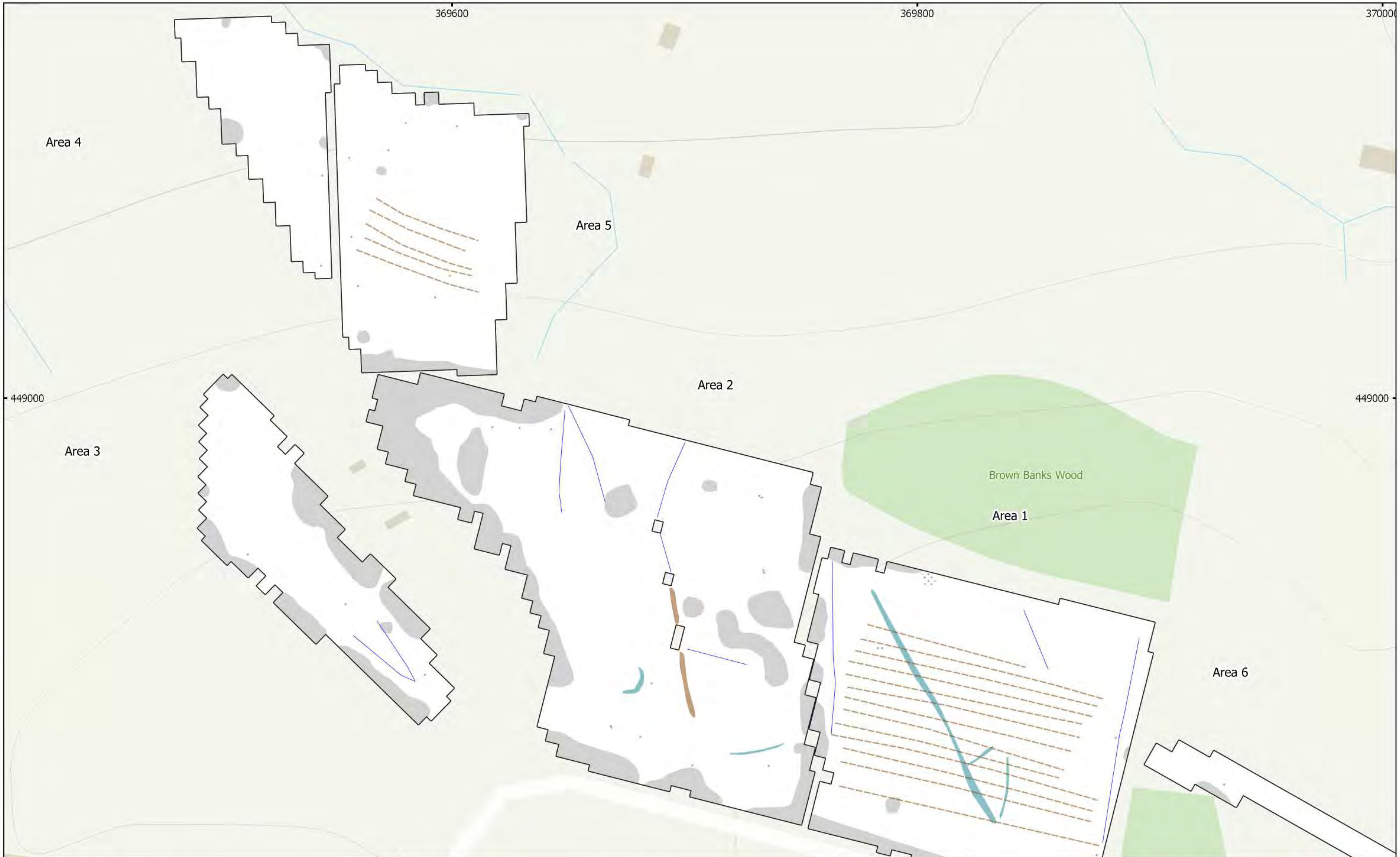
MSSD898 - Bonstone Compound
Figure 5 - Magnetic Gradient (North)
1:1,500 @ A3





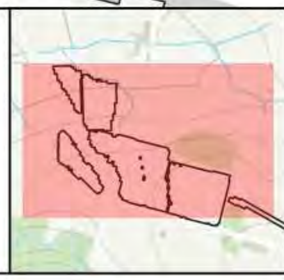


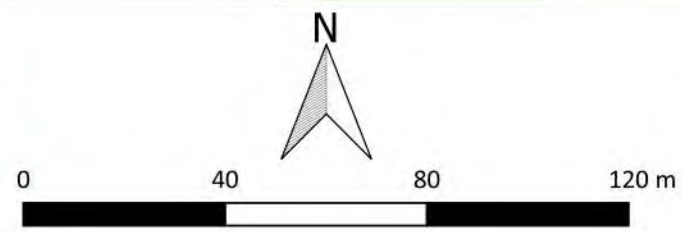
magnitude surveys



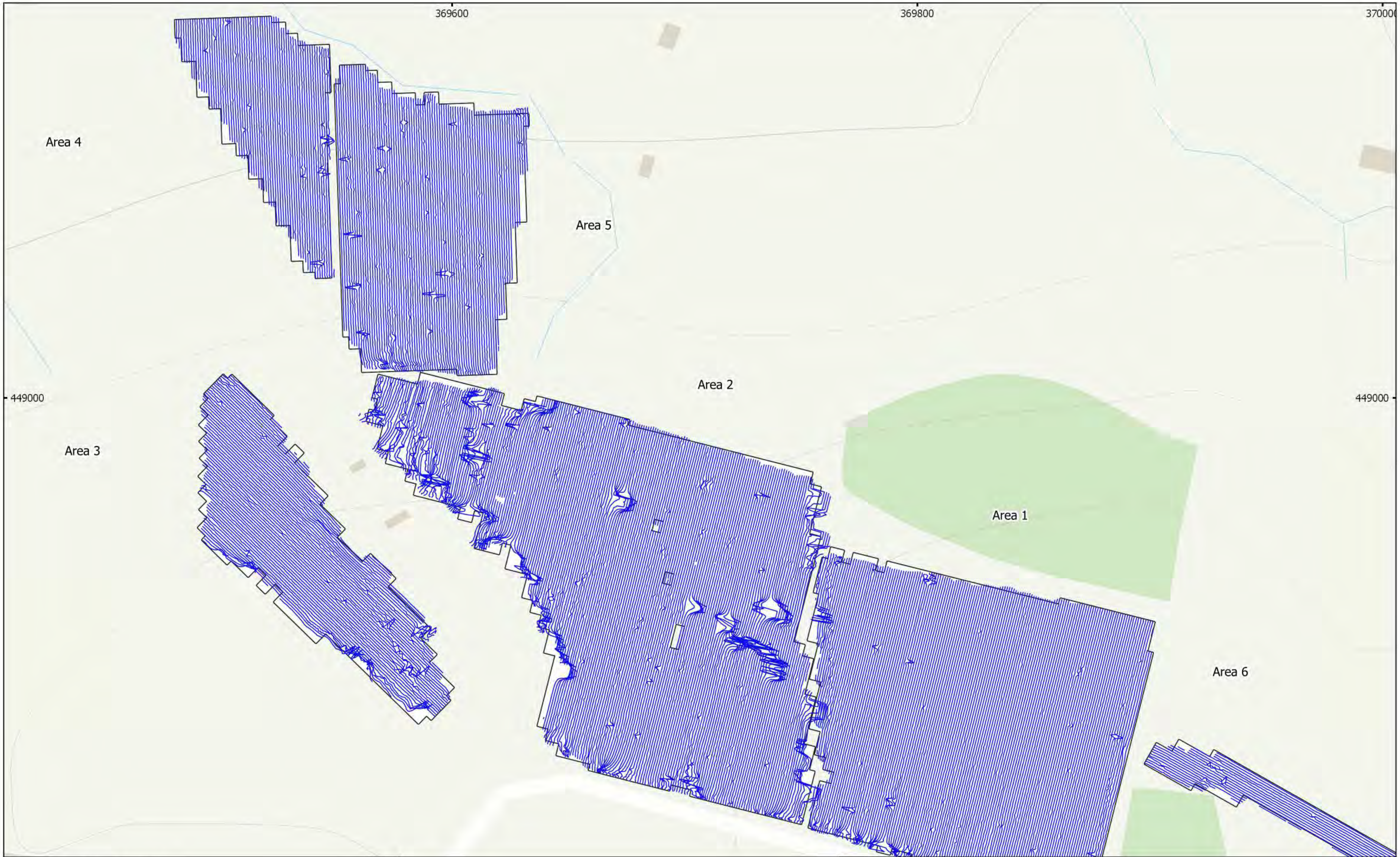
MSSD898 - Bonstone Compound
Figure 6 - Magnetic Interpretation (North)
1:1,500 @ A3

Agricultural (Weak)
Magnetic Disturbance
Ferrous/Debris (Spread)
Undetermined (Weak)
Ridge and Furrow (Trend)
Drainage Feature
Ferrous (Spike)

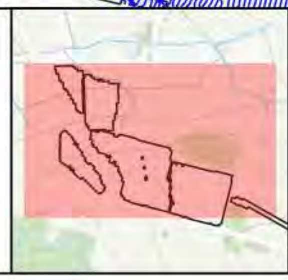


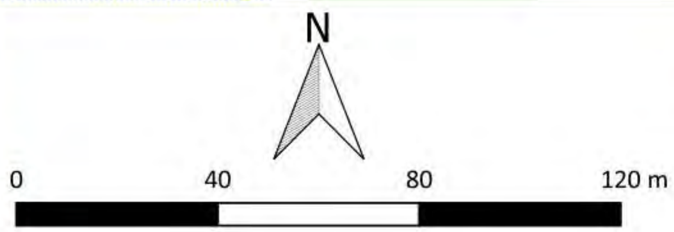


magnitude surveys



MSSD898 - Bonstone Compound
Figure 7 - XY Trace Plot (North)
30nT/cm at 1:1,500 @ A3





magnitude surveys

MSSD898 - Bonstone Compound
Figure 8 - Magnetic Gradient (South)
1:1,500 @ A3

-1 nT 2

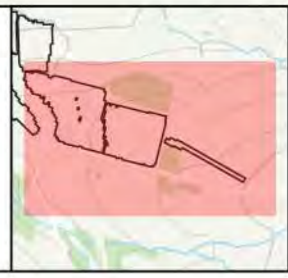
N

0 40 80 120 m

magnitude surveys

MSSD898 - Bonstone Compound
Figure 9 - Magnetic Interpretation (South)
1:1,500 @ A3

Agricultural (Weak)
Magnetic Disturbance
Ferrous/Debris (Spread)
Undetermined (Weak)
Ridge and Furrow (Trend)
Drainage Feature
Ferrous (Spike)

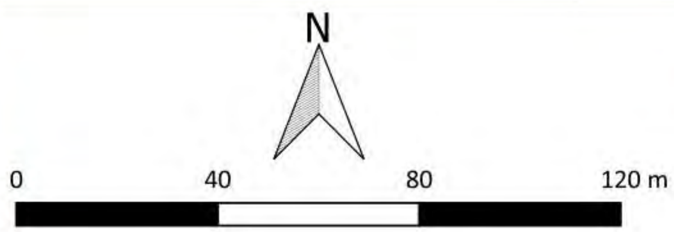


N

0 40 80 120 m

magnitude surveys

MSSD898 - Bonstone Compound
Figure 10 - XY Trace Plot (South)
30nT/cm at 1:1,500 @ A3



magnitude surveys