NAA

GEOPHYSICAL SURVEY

BROUGHTON MOOR RNAD
CUMBRIA

prepared for

Atelier 2 Architects

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NORTHERN ARCHAEOLOGICAL ASSOCIATES

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Location	Broughton Moor RNAD, Broughton Moor, Great Broughton, Cumbria, CA15 7FB
Planning authority	Cumbria
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Date of Fieldwork	8th and 9th January 2020

BROUGHTON MOOR RNAD, CUMBRIA
GEOPHYSICAL SURVEY REPORT

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Disclaimer

The results of geophysical survey may not reveal all potential archaeology and do not provide a comprehensive map of the sub-surface, but only responses relative to the environment. Geological, agricultural and modern responses may mask archaeological features. Short-lived features may not give strong responses. Only clear features have been interpreted and discussed in this report.

BROUGHTON MOOR RNAD, CUMBRIA
GEOPHYSICAL SURVEY REPORT

Summary

Northern Archaeological Associates (NAA) was commissioned by Atelier 2 Architects to undertake a geophysical survey of land in the east of Broughton Moor Royal Naval Armaments Depot (RNAD) in advance of a proposed residential development (NGR: NY 06176 32181). The work was required to assess the archaeological potential of the site and to help inform subsequent archaeological mitigation.

The earliest known human activity in Broughton Moor RNAD is in the form of medieval field systems. During the post-medieval period, the area of Broughton Moor was extensively mined. Broughton Moor Royal Naval Armaments Depot was constructed in 1938 and drastically changed the appearance of Broughton Moor with the construction of more than 100 buildings with varying functions.

The geophysical survey targeted c.6.8ha of land in the east of Broughton Moor RNAD and was carried out on 8th and 9th January 2020. Anomalies detected by the survey are considered to be largely agricultural, modern or geological in nature, and caused by features associated with the RNAD, land drains, possible ridge and furrow, modern activity or geological changes in the substrata.

Two former field boundaries depicted on the 1863 Ordnance Survey map appear as broad areas of increased magnetic values. It is plausible that an earthwork in the centre of the site—first recorded on mid-19th century maps—is indicative of post-medieval mineral extraction, and that nearby bipolar anomalies are indicative of associated mining activity.

Several linear anomalies and trends have been identified that generally lack the patterning required for detailed interpretation. Although it is possible that they relate to infilled features, it is more likely that they are either caused by agricultural activity or are geological or pedological in origin.

1.0 INTRODUCTION

1.1 Northern Archaeological Associates Ltd (NAA) was commissioned by Atelier 2 Architects to undertake a geophysical survey of land in the east of Broughton Moor Royal Naval Armaments Depot (RNAD), Cumbria, in advance of a proposed residential development (NGR: NY 06176 32181). The work was required to assess the archaeological potential of the site and to help inform subsequent archaeological mitigation. The geophysical survey was carried out on 8th and 9th January 2020.

1.2 This report details the setting (location, topography, geology) and archaeological background of the scheme and sets out the methodology used for the geophysical survey. The interpretation of the geophysical survey is achieved through the analysis of identified anomalies and is aided by an examination of supporting information. The results of the geophysical survey are discussed below, and the interpretations are supported by appropriate illustrations. Where feasible, a detailed synopsis of anomalies is provided and, if possible, the features that the anomalies are likely to relate to are suggested.

2.0 LOCATION, TOPOGRAPHY AND GEOLOGY

Location

2.1 Broughton Moor RNAD is located in north-west Cumbria, between the villages of Broughton Moor and Great Broughton (Fig. 1). The RNAD is composed of a network of regularly spaced buildings linked by a rail system. The proposed development area (PDA) comprises c.6ha of mixed-use land in the east of Broughton Moor RNAD. At the time of the survey, the PDA contained two derelict Explosive Store Houses (ESH) joined by a RNAD railway and grassland that was being used as pasture for cattle.

2.2 The northern and western hinterland of the PDA appeared relatively unaltered since the closure of the military depot. Land to the south of the PDA was being developed for residential housing. The eastern edge of the site was bounded by Church Road, which runs between the villages of Broughton Moor and Great Broughton, and land to the east of the PDA was largely agricultural in nature.

Geology and soils

2.3 The solid geology of the evaluation area is of Pennine Middle Coal Measure Formation consisting of Mudstone, Siltstone and Sandstone, overlain by Devensian diamicton till (BGS 2019). The soils are mapped as being Disturbed Soils 3, consisting of

Carboniferous shale and sandstone and associated drift. This group is largely composed of restored soils following opencast mining activity, and so can vary depending on the cocktail of soils that were removed and restored (Soil Survey of England and Wales 1983; Jarvis *et al*. 1984, 159–61).

Topography

2.4 The natural topography of the PDA slopes downwards to the south, so that the north of the field lies at 91m above Ordnance Datum (aOD) and the south of the field is 81m aOD.

3.0 ARCHAEOLOGICAL AND HISTORICAL BACKGROUND

3.1 Historic maps show the evolution of the site until the erection of the RNAD in the mid-20th century. The First Edition 1867 Ordnance Survey map shows the site as part of open fields. An enclosed 'mound' is recorded on the 1867 map that survives as an earthwork in the modern landscape between Areas A, C and D (Fig. 2), and is considered likely to relate to post-medieval mineral extraction. Buckhill Colliery was located to the west of the PDA in 1873 and is shown on the 1900 Ordnance Survey map to have a substantial level of operation with direct rail links to the Cleator and Workington Junction Railway. In 1938, the site was acquired by the Ministry of Defence and converted into a Royal Naval Armaments Depot (RNAD). The RNAD was centred on the colliery and originally comprised 132 magazines, as well as a series of other buildings used for administration, inspection testing, and laboratories that were linked by a narrow-gauge railway (Thomas 1997). During the Second World War, the RNAD was extended to its current size and composition. After the war, the Royal Navy continued to use the depot until 1963, after which the tenancy was taken over by the Federal Republic of Germany (1963–1977), the United States Navy (1977–1981), and NATO (1981–1992). The site began to be 'rundown' in 1991. The last train left the depot on the 3rd June 1992 and the site was officially shut on the 31st December 1992.

3.2 In 2001, a rapid archaeological desk-based assessment of the RNAD identified that the earliest evidence of human activity in the site was medieval field systems (Conolly 2001). The desk-based assessment identified 24 sites of cultural heritage in the RNAD and its immediate hinterland. Notably, during the post-medieval period the area was mined extensively, and 10 heritage assets associated with 19th-century mining activity are recorded in the RNAD area.

3.3 In 2014, NAA undertook an archaeological building survey, walkover survey and trial trenching on land directly to the south of the current PDA in advance of the housing development that is presently under construction (Pole and Town 2014). The building survey comprised a Level 1 survey of four RNAD buildings, and the walkover survey recorded medieval field systems, evidence of post-medieval coal mining, as well as features related to the RNAD. Fourteen trial trenches were excavated and revealed evidence of shallow ridge and furrow and post-medieval coal mining, including a waggon-way.

4.0 AIMS AND OBJECTIVES

4.1 The aim of the geophysical survey was to map and record potential buried features located within the PDA. Through comprehensive analysis of the results of the geophysical survey, NAA aimed to provide a detailed interpretation that assessed the archaeological potential of the site to inform future archaeological mitigation strategies.

4.2 The objectives of the survey were to:

- undertake a geophysical survey across areas deemed suitable for data collection;
- attempt to identify and record any sub-surface remains within the survey boundary;
- characterise the nature of identified anomalies and, where possible, suggest the nature of feature to which they potentially relate;
- assess the archaeological significance of identified anomalies;
- identify possible concentrations of past activity in order to inform the requirement for any further archaeological investigation at the site; and
- produce a detailed report that includes illustrated results of the geophysical survey.

5.0 METHODOLOGY

5.1 The geophysical survey was undertaken as a gradiometer survey using the Bartington Grad601-2 dual magnetic gradiometer system with data logger. The readings were recorded at a resolution of 0.01nT and data was collected with a traverse interval of 1m and a sample interval of 0.25m. All recorded survey data were collected with reference to a site survey grid comprising individual 30m x 30m squares. The grid was established using Real Time Kinematic (RTK) differential GPS equipment and marked out using non-metallic survey markers. All grid nodes were set out with a positional accuracy of at least 0.1m as per existing guidelines (CIfA 2014; Schmidt *et al*. 2015) and could be

relocated on the ground by a third party. The base lines used to create the survey grids are shown on Figure 2 and further details are available in Appendix A.

5.2 The processing was undertaken using Geoplot 3.0 software and consisted of standard processing procedures. Details of processing steps applied to collected data are given in Appendix B.

5.3 On the greyscale plot (Fig. 3 and Fig. 4), positive readings are shown as increasingly darker areas and negative readings are shown as increasingly lighter areas.

5.4 Interpretation of identified anomalies is generally achieved through analysis of anomaly patterning and increases in magnetic response, and is often aided by examining supporting information (including but not limited to historic maps, LiDAR survey data, aerial photographs, as well as geophysical survey data and excavation results in the direct hinterland of the scheme). The interpreted data uses colour coding to highlight specific readings in the survey area (see Fig. 5).

Surface conditions and other mitigating factors

5.5 Field boundaries comprised hedgerows and metal fencing.

5.6 At the time of the survey, there was a large amount of standing water across the site, and there were several areas of boggy ground in the west of the site.

5.7 There were two ESH within the centre of the PDA that were joined by a narrow-gauge railway. One of the buildings was surrounded by an earth bunding (traverse), which would have been used to isolate the building and reduce any blast impact if accidental munition detonation occurred. Soil used to build the traverse was probably taken from the land directly to the south of the ESH, where there are two large depressions. It should be noted that there is a high likelihood that any potential buried archaeological features, if extant, were destroyed or truncated during the erection of the RNAD. Consequently, a tentative interpretation applies in areas where there is considered to be a high level of modern ground disturbance.

5.8 Attempts were made to avoid areas affected by above-ground features that were likely to have a high magnetic susceptibility, such as metal fencing and the RNAD buildings, to minimise the potential for their magnetic responses to impinge on the survey results and mask potential buried features.

6.0 GEOPHYSICAL SURVEY RESULTS

General anomalies across the site (Fig. 5)

6.1 There are several weak and diffuse linear trends. These fail to produce the necessary patterning or increases in magnetic response = to be interpreted fully, and consequently their origin is unknown.

6.2 There are several possible alignments of regularly spaced linear anomalies considered likely to relate to agricultural activity. Those with strong increases in magnetic value probably relate to land drains, while those with fainter increases in magnetic value are likely to denote ridge and furrow.

6.3 Dipolar anomalies are often likely to relate to ferrous or modern objects buried in the topsoil. It should also be noted that the site lies in an area that was extensively mined during the post-medieval period, and so it is possible that isolated responses (including dipolar anomalies) across the site could relate to mining or quarrying activity. As these anomalies fail to have a coherent patterning, and the vast majority are likely to be of a modern nature, they have not been depicted on interpretation plots. Areas of increased magnetic response have been used to highlight concentrations of dipolar anomalies. These are likely to be caused by magnetic debris in the topsoil or near the surface of the site.

6.4 Several isolated bipolar responses have been identified. These are considered to be modern and denote highly magnetic material, such as ferrous objects.

6.5 Strong responses caused by above-ground features external to the survey area, such as metal fencing and gates, have been characterised as external interference.

6.6 There are several broad responses in the north of the survey area that are considered likely to relate to geological or pedological changes in the substrata.

Area A

6.7 A field boundary recorded on the 1863 Ordnance Survey map runs through the centre of Area A (see Fig. 5) (**A1**).

6.8 Two perpendicular linear anomalies (**A2**) appear to the north of the two ESH. **A2** anomalies appear on a different alignment to anomalies identified as being of an agricultural nature, but their full extent is not known as they potentially relate to a

feature that continues to the south of the survey area. Consequently, it is not possible to speculate if these anomalies relate to an infilled buried feature of an archaeological nature, an alternative agricultural regime to those identified within the data or an alternative modern activity.

6.9 The regularly spaced linear anomlies are considered likely to relate to agricultural activity. The linear anomalies with strong increases in magnetic value are indicative of land drains. There are two orientations of linear anomalies with weak increases in magnetic value, although tentative it is plausible that these denote ridge and furrow.

6.10 Several trends have been identified but lack the necessary patterning for detailed interpretation. Although it is plausible that the trends with a more coherent form may be suggestive of infilled features, it is more likely that they are indicative of either agricultural activity or geological or pedological changes within the substrata.

6.11 There is a linear bipolar anomaly (**A3**) running adjacent to the southern field boundary of Area A. It was noted at the time of the survey that a manhole cover was located in the south-east of Area A. It is likely **A3** is indicative of a buried utility.

6.12 Several broad areas (**A4** and **A5)** of increased magnetic value were identified that are considered likely to relate to geological or pedological changes within the substrata.

Areas B and C

6.13 A field boundary recorded on the 1863 Ordnance Survey map occurs on a north-south orientation in the east of Area B (**B1**).

6.14 A 'mound' recorded on 19th-century maps, which survives as an earthwork in the north-west of Area C, is considered likely to relate to post-medieval mining activity. Although it was not possible to survey the mound itself, the results identified several amorphous bipolar anomalies (**C1**) directly to the east of the earthwork. Although very speculative, it is plausible that these anomalies relate to feature(s) associated with the mound and are indicative of mining activity.

6.15 Three sides of a rectilinear anomaly span Areas B and C (**B2** and **C2**). It is unclear if these anomalies are associated with agricultural activity such as the land drains, or instead are indicative of alternative activity such as an infilled feature. Another linear anomaly (**B3** and **C3**) occurs in the south of Areas B and C on a different orientation

from **B2** and **C2**. It is unclear if these anomalies all relate to the same activity; if they do, they are suggestive of 'herring bone' land drains or infilled features.

6.16 As with Area A, there are regularly spaced linear anomalies in Areas B and C that are considered likely to denote field drains.

6.17 Two bipolar anomalies have been identified (**B4** and **C4**). Generally, bipolar anomalies relate to ferrous material and are indicative of modern activity. However, given the level of mineral extraction within the hinterland of the site, the potential that they relate to mining activity cannot be completely dismissed.

Area D

6.18 A broad linear anomaly (**D1**) has been identified that appears on a different alignment to anomalies suggested to be of an agricultural nature. It is unclear if **D1** denotes an infilled feature, relates to agricultural activity or denotes geological or natural variations in pedological formations. It should be noted that there was a high level of running water in a southerly direction corresponding with the natural topography. It is plausible that **D1** continues to the south and is part of the same feature as **A4** and denotes a former gully or small watercourse.

6.19 The series of bipolar linear anomalies **D2** corresponds with the location of the narrow-gauge railway that runs between the buildings.

6.20 Linear bipolar anomaly **D3** is likely to be the continuation of **A3** and denote a buried utility.

6.21 Much of the ground within Area D was likely to have been heavily disturbed during the erection of the ESH. In particular, the areas of magnetic disturbance to the south of the ESH in Area D correspond with edges of depressions, and are likely to have been caused during the construction of the buildings.

7.0 CONCLUSIONS

7.1 NAA was commissioned to undertake a geophysical (gradiometer survey) in the east of Broughton Moor RNAD to assess the archaeological potential of the site in advance of a proposed residential development.

7.2 The geophysical survey targeted approximately 6.8ha of land and was carried out on 8th and 9th January 2020. Generally, anomalies were considered likely to be of an agricultural, modern or geological nature.

7.3 Two weak linear anomalies correspond with the locations of former field boundaries recorded on 19th-century maps, and it is plausible that a bipolar anomaly relates to a mound also recorded on the historic maps that is considered likely to be caused by mining activity. Several linear anomalies and trends were also identified, but lacked the required characteristics for detailed interpretation. Although tentative, it is considered likely that they are either agricultural or geological in origin.

8.0 STORAGE AND CURATION

8.1 The records of the geophysical survey are currently held by NAA. All material will be appropriately packaged for long-term storage in accordance with national guidelines (CIfA 2014; Schmidt *et al*. 2015). An OASIS form will be completed within three months of the completion of the project. This will include submission of a PDF version of the final report to the Archaeology Data Service via the OASIS form.

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Ordnance Survey (1867) Six-inch Cumberland XLV (includes: Bridekirk; Broughton Moor; Dearham) (Surveyed 1864 to 1865).

Ordnance Survey (1900) Six-inch Cumberland XLV.SW (includes: Broughton; Broughton Moor; Dearham; Flimby; Maryport. (Revised 1899).

APPENDIX A
TECHNICAL INFORMATION

GRADIOMETER SURVEY

Magnetic surveys measure distortions in the earth's magnetic field caused by small magnetic fields associated with buried features (Gaffney and Gater 2003, 36) that have either remnant or induced magnetic properties (Aspinal *et al*. 2008, 21–6). Human activity and inhabitation often alter the magnetic properties of materials (Aspinal *et al*. 2008, 21) resulting in the ability for numerous archaeological features to be detected through magnetic surveys. Intensive burning or heating can result in materials attaining a thermoremanent magnetisation; examples of which include kilns, ovens, hearths and brick structures (*ibid*., 27; Gaffney and Gater 2003, 37). When topsoil that is rich with iron oxides fills a man-made depression in the subsoil, it creates an infilled feature, such as a pit or ditch, with a higher magnetic susceptibility compared to the surrounding soil (Aspinal *et al*. 2008, 37–41; Gaffney and Gater 2003, 22–6). Magnetic surveys can also detect features with a lower magnetically susceptibility than the surrounding soil, an example of which is a stone wall.

LIMITATIONS

Poor results can be due to several factors including short-lived archaeological occupation/use or sites with minimal cut or built features. Results can also be limited in areas with soils that are naturally deficient in iron compounds or in areas with soils overlying naturally magnetic geology, which will produce strong responses masking archaeological features.

Overlying layers, such as demolition rubble or layers of made ground, can hide any earlier archaeological features. The presence of above-ground structures and underground services containing ferrous material can distort or mask nearby features.

Particularly uneven or steep ground can increase the processing required, or distort results beyond the capabilities of processing. It is also possible in areas containing dramatic topographical changes that natural weathering, such as hillwash, often in combination with intensive modern ploughing, will reduced the topsoil on slopes and towards the peaks of hills, and possibly destroy or truncate potential archaeological features. Conversely, features at the bottom of slopes may be covered by a greater layer of topsoil and if buried features are present, they appear faint within the results, if at all.

Over processing of data can also obscure or remove features, especially if they are on the same orientation as the direction of data collection. Consequently, where possible, attempts are made to ensure data is not collected on the same orientation as known potential features and that data quality is sufficient to minimise the required data processing.

INSTRUMENTATION

The data was collected using handheld Bartington Grad 601-2 fluxgate gradiometers. The Bartington 601-2 is a single-axis, vertical component fluxgate gradiometer comprising a data logger battery cassette and two sensors. The sensors are Grad-01-1000L cylindrical gradiometer sensors mounted on a rigid carrying frame; each sensor contains two fluxgate magnetometers with 1m vertical separation.

The difference in the magnetic field between the two fluxgates in each sensor is measured in nanoTesla (nT). NAA gradiometer data is recorded with a range of ±100nT, which equates to a resolution of 0.01nT. It should be noted that the actual resolution is limited to 0.03nT as a consequence of internal instrumental noise (Bartington Instruments Ltd, 23).

The gradiometer records two lines of data on each traverse, the grids are walked in a zig-zag pattern amounting to 15 traverses. The gradiometers are calibrated at the start of every day and recalibrated whenever necessary.

SURVEY DETAILS

Table A1: survey summary

Item	Survey
Grid size	30m x 30m
Traverse interval	1m
Reading interval	0.25m
Direction of 1st traverse	N
Number of grids	107
Area covered	6.8ha

Table A2: baseline coordinates

Item	Survey
gpA	306263.6625 532326.2462
gpB	306352.0766 532245.1108

Table A3: site information and conditions

Item	Detail
Geology	Pennine Middle Coal Measure Formation
Superficial deposits	Devensian Till
Soils	Disturbed soils 3
Topography	Highest: 91m aOD Lowest: 81m aOD
Land use	Mixed use – decommissioned military base, presently used as pasture
Weather conditions prior to and during survey	Overcast with periods of rain

APPENDIX B

DATA PROCESSING INFORMATION

Gradiometer survey data is downloaded using the Bartington Grad 601 software and the processing was undertaken using Geoplot 3.0 software.

Table B1: commonly applied techniques

Process	Effect
Zero mean traverse	Removes stripping that can occur as a consequence of using multi-sensor arrays or a zig-zag data-collection method by setting the mean reading for each traverse to zero.
Destagger	Removes stagger in the data introduced through inconsistent data collection pace and often exacerbated through the zig-zag methodology.
Clip	Clips data above or below a set value to enhance potential weaker anomalies.
Despike	Removes random spikes or high readings to reduce the appearance of dominant readings, often created by modern ferrous objects that can distort the results.
Low pass filter	Removes low-frequency waves or broad anomalies such as those caused by strong or large gradual variations in the soil's magnetic susceptibility often caused by geological or natural changes in the substrata.
Interpolation	Used to smooth or reduce the blocky appearance of data by improving the spatial density and increase the quantity of data points in the Y direction.

Table B2: processing steps

Minimal Processing	Increased Processing
• Zero mean traverse +5/-5 • Destagger: *Area A* - Grid 13: -2 - Grid 5: -1 - Grids 2, 3, 4, 16, 17, 18, 19, 21, 22, 23, 24, 26, 27, 34, 37, 38, 45, 47, 56, 60, 67, 69, 70, 78 and 79; 1 - Grids 6, 14, 35, 36, 39, 40, 49, 50, 55, 59 and 66: 2 - Grid 33; 3 - Grid 57: 5 - Grid 46: 6 - Grids 48 and 68; 10 - Grid 58: 12 *Area B* - Grids 2, 3, 6 and 19; 1 - Grids 7, 8, 9, 11, 12 and 13: 2 - Grids 14 and 15: 3 *Area C* - Grid 12; -3 - Grids 8 and 9: -1 - Grids 4, 5, 6, 10 and 11: 1	• Low Pass Filter • Interpolate Y, Expand – Linear, x2

- Grids 2 and 3: 2 *Area C* - Grid 34; -2 - Grids 1, 2, 11, 20, 21, 24, 27 and 40: 1 - Grids 7, 16, 22, 25, 29, 30, 35 and 39: 2 - Grids 17, 18 and 19: 3 - Grid 6; 4 - Grid 33: 8 - Grid 29: 9 - Grid 23: 10	

APPENDIX C

DATA VISUALISATION INFORMATION

FIGURES

The data were used to produce a series of images to demonstrate the results of surveys, which are detailed below:

- Greyscale/Colourscale Plot – This visualised the results as a shaded drawing with highest readings showing as black, running through different shades to lowest showing as white.
- XY-trace Plot – This creates a line drawing showing the peaks and troughs of the readings as vertical offset from a centreline.
- Interpreted Plot – Through detailed analysis, anomalies have been interpreted and possible features identified. Interpretation drawings are used to show potential features and in particular to reinforce and clarify the written interpretation of the data. Anomalies have been characterised using the terminology detailed in the following section, and have been assigned colour coding, outlined in keys found on the relevant figures associated with this report.

MAGNETIC ANOMALIES AND TERMINOLOGY

Table C1: lexicon of terminology

Terminology	Detail
Anomaly	Any outstanding high or low readings forming a particular shape or covering a specific area within the survey results.
Feature	A man-made or naturally created object or material that has been detected through investigation works and has sufficient characteristics or supporting evidence for positive identification.
Magnetic susceptibility	The ability of a buried feature to be magnetically induced when a magnetic field is applied.
Magnetic response	The strength of the changes in magnetic values caused by a buried feature with either a greater or lesser ability to be magnetised compared with the soil around it. Anomalies are considered to have either strong/weak or positive/negative responses. The strength of magnetic response (along with patterning) can be essential in determining the nature of an anomaly, but it should be noted that the size or strength of the magnetic response does not correlate with the size of the buried feature.
Patterning of an anomaly	The shape or form of an individual anomaly.
Thermoremanence	The affect caused when a material has been magnetically altered through a process of heating. Thermoremanent magnetisation occurs when an object or material is heated passed the Curie Point and acquires a permanent magnetisation that is associated with the magnetic field that they cooled within (Gaffney and Gater 2003, 37)

Different anomalies can represent different features created by human, agricultural or modern activity, or natural pedological or geological changes in the substrata.

Anomalies interpreted with a 'greater' categorisation are considered more likely to be of the interpreted characterisation; whereas a more tentative interpretation is applied to those with a 'lesser' categorisation as a consequence of weaker increases in magnetic response or the anomaly's incomplete patterning or irregular form.

The strength and size of anomalies can vary depending on the magnetic properties of the feature, the magnetic susceptibility of the soil, the depth to which the feature is buried, and the state of preservation.

Table C2: characterisation of anomalies

Characterisation	Detail
Archaeology	
Bipolar anomaly (mining?)	Anomalies often composed of a bipolar response that is possibly indicative of mining activity.
Positive linear anomaly	Linear anomalies with a good increase in magnetic value, but fail to be composed of the necessary patterning or shape required for detailed interpretation.
Trends	Weak and diffuse anomalies with an uncertain origin are denoted by trends. It is possible that these belong to archaeological features but, given their weak signatures or incomplete patterning, it is equally plausible that they relate to agricultural features or natural soil formations.
Agriculture	
Field boundary	Isolated linear anomalies that are likely to be indicative of former land divisions. A more conclusive interpretation is given to linear anomalies that correspond with the location of field boundaries recorded on historic maps, aerial photos or LiDAR coverage of the site.
Agriculture?	Weak, irregularly spaced or isolated linear anomalies that relate to agricultural activity, but the agricultural process they are caused by is unknown. Given the modern land uses it is plausible these anomalies relate to ridge and furrow.
Modern	
Bipolar response (modern)	Positive anomalies with associated negative 'halo' (bipolar) denote features with a strong magnetic response that are likely to be of a modern origin. Isolated bipolar responses of a modern nature are likely to relate to buried ferrous material or objects, such as metallic agricultural debris. If a trend is noted in the alignment or spacing of isolated bipolar responses, it is possible that they are indicative of ferrous fittings or connectors used on non-magnetic buried utilities. Linear bipolar anomalies are likely to be indicative of modern services.
Dipolar response	Dipolar anomalies relate to individual spikes within the data and tend to be caused by ferrous objects. These responses have been shown only when located near to archaeological features. When the site is located in a mining landscape it is possible that identified dipolar anomalies relate to mining activity and are indicative of further pits or mine shafts.
Area of increased magnetic response	Areas of increased magnetic response denote areas of disturbance containing a high concentration of dipolar and/or bipolar responses. These are generally considered to be caused by modern debris in the topsoil,

Characterisation	Detail
	although it is possible that the disturbance is in part also caused by isolated archaeological material or geological or pedological changes in the substrata.
External interference	Areas of magnetic disturbance, often along the edges of survey areas, are caused by standing metal structures such as fencing and buildings.
Natural	
Area of disturbance (geology)	Areas of variable magnetic responses can demonstrate natural features or changes in geology or soil type, and these often correspond with topographical variations.

APPENDIX D

OASIS FORM

OASIS DATA COLLECTION FORM: England

OASIS ID: northern1-382882

Project details

Project name	Broughton Moor RNAD, Cumbria
Short description of the project	Geophysical Survey Report
Project dates	Start: 08-01-2020 End: 09-01-2020
Previous/future work	Yes / Yes
Type of project	Field evaluation
Site status	None
Current Land use	Grassland Heathland 3 - Disturbed
Monument type	NONE None
Significant Finds	NONE None
Methods & techniques	"Geophysical Survey"
Development type	Rural residential
Prompt	Planning condition
Position in the planning process	Pre-application
Solid geology (other)	Pennine Middle Coal Measure Formation
Drift geology (other)	Devensian Till
Techniques	Magnetometry

Project location

Country	England
Site location	CUMBRIA ALLERDALE BROUGHTON Broughton Moor RNAD, Cumbria
Postcode	CA15 7FB
Study area	6.8 Hectares
Site coordinates	NY 06176 32181 54.675827306655 -3.455206650758 54 40 32 N 003 27 18 W Point
Height OD / Depth	Min: 81m Max: 91m

Project creators

Name of Organisation	Northern Archaeological Associates
Project brief originator	Atelier 2 Architects
Project design originator	Northern Archaeological Associates
Project director/manager	Alice James
Project supervisor	Oskar Sveinbjarnarson
Type of sponsor/funding body	Developer

Project archives

Physical Archive Exists?	No
Digital Contents	"none"
Digital Media available	"Geophysics"
Paper Archive Exists?	No

Project bibliography 1

Publication type	Grey literature (unpublished document/manuscript)
Title	Broughton Moor RNAD, Cumbria: Geophysical Survey
Author(s)/Editor(s)	James, A
Other bibliographic details	20-09
Date	2020
Issuer or publisher	NAA
Place of issue or publication	Barnard Castle
Description	blue spine

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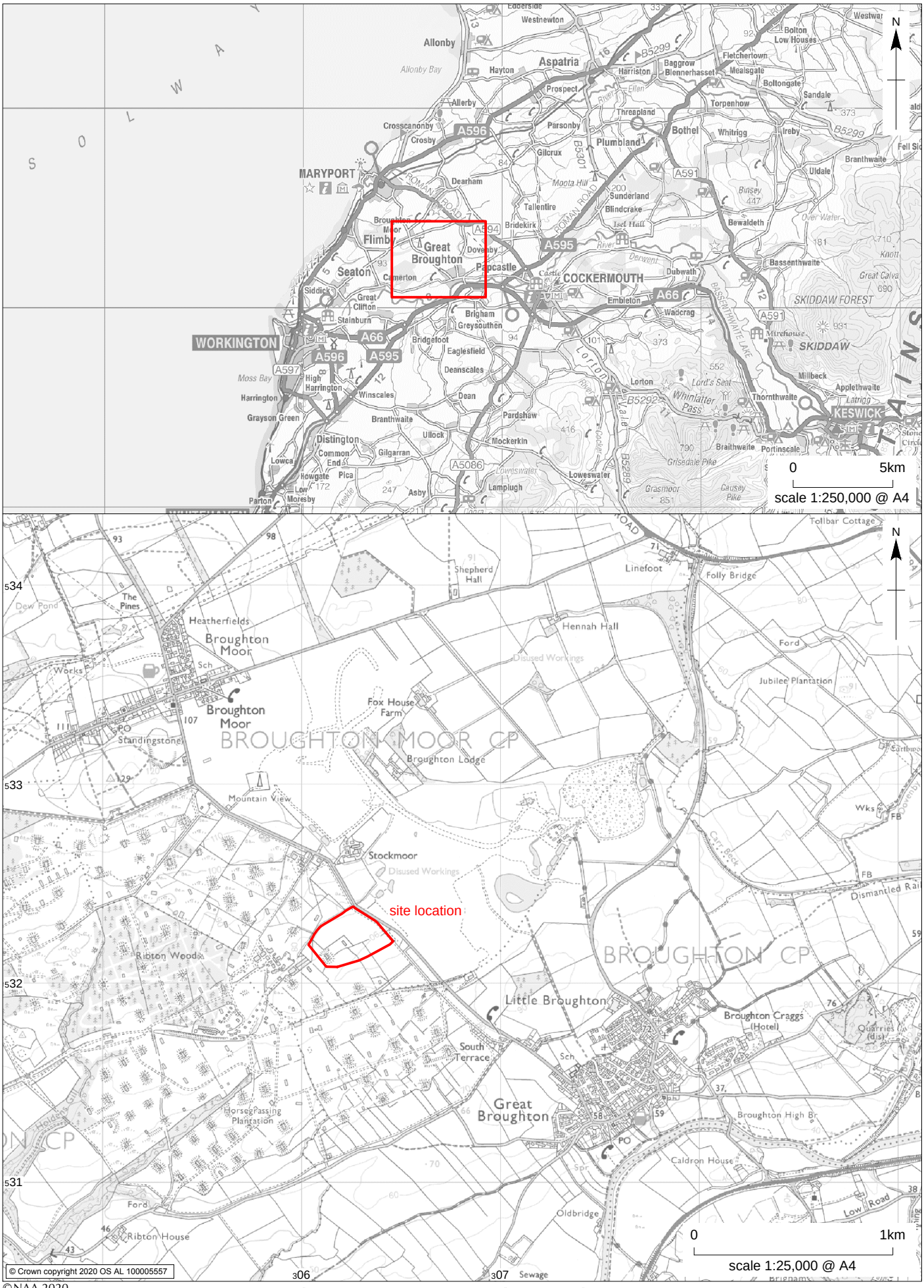

Broughton Moor RNAD, Cumbria: site location *Figure 1*

NAA
HERITAGE & ARCHAEOLOGY

KEY
geophysical survey baseline
geophysical survey grid
geophysical survey area
proposed development area

N

0 50 m
scale 1:1250 @ A3

gpA
gpB
Area A
Area B
Area C
Area D

Broughton Moor RNAD, Cumbria: location of geophysical survey

Figure 2

NAA
HERITAGE & ARCHAEOLOGY

0 50 m
scale 1:1250 @ A3

N

5nT
-4nT
Pallette:grey55.ptt

Area A
Area B
Area C
Area D

Broughton Moor RNAD, Cumbria: unprocessed greyscale plot of geophysical survey results

Figure 3

NAA
HERITAGE & ARCHAEOLOGY

0 50 m
scale 1:1250 @ A3

N

3nT
-2nT
Pallette:grey55.ptt

Area A
Area B
Area C
Area D

Broughton Moor RNAD, Cumbria: processed greyscale plot of geophysical survey results

Figure 4

NAA
HERITAGE & ARCHAEOLOGY

KEY

- bipolar response (mining?)
- positive linear response
- field boundary
- trends
- land drains
- agriculture?
- bipolar response (modern)
- area of increased magnetic response
- external interference (e.g. fencing)
- geology
- edge of geophysical survey
- proposed development area

N

0 50 m

scale 1:1250 @ A3

A1
A2
A3
A4
Area A
B1
B2
B3
B4
Area B
C1
C2
C3
C4
Area C
D1
D2
D3
D3
Area D

Broughton Moor RNAD, Cumbria: interpretation of gradiometer survey results

Figure 5