ARCHAEOLOGICAL SERVICES WYAS

Thomson's Lawn
Hagley Hall Registered Park
Worcestershire

Geophysical Survey

Report no. 2587

March 2014

Client: Hagley Hall Estates

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Hagley Hall Registered Park
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Geophysical Survey

Summary

A geophysical survey, comprising both magnetometer and resistance surveys, was carried out within the Thomson's Lawn area of Hagley Hall Registered Park in order to identify and locate drainage features shown on early 20th century plans and any other unrecorded features. Both surveys have identified some of the features recorded on the 1935 plan although the resistance survey gives a clearer and more extensive picture of the below ground features. The results indicate that the 1935 plan provides an accurate location of the features that clearly correlate with the geophysical anomalies. The surveys have not identified any features in the vicinity of a spot where water is arising from an unmapped source. On the basis of the current survey resistivity would seem to be the most suitable technique to locate below ground features of this type.

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Report Information

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Address:	c/o Mark Van Oss and Associates, The Office, Arlington Manor, Arlington, Bilbury, Gloucerstershire
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1 Introduction

Archaeological Services WYAS (ASWYAS) was commissioned by Ben Stephenson of BSA Heritage Ltd, on behalf of Hagley Hall Estates, to undertake a geophysical (magnetometer and earth resistance) survey of land in Hagley Hall Registered Park as part of an ongoing restoration of the Arcadian landscape within the park. Information on the drainage of Thomson's Lawn was sought to inform future works to repair and improve the existing drainage system which will safeguard the restored landscape for the longer term. Although a drainage map dating to the 1930s exists, this is not compatible with modern digital survey and observation of water flows within the area suggested there may be other drains or culverts that are not depicted on the 1935 map. The survey was carried out on February 18th and February 19th 2014.

Site location, topography and land-use

The two survey areas are located in the Thomson's Lawn area of Hagley Hall Registered Park. Area 1 comprised an irregular block, centred at SO 925 810, covering approximately 0.8 hectares, whilst Area 2, centred at SO 926 810, comprised a rectangular block covering approximately 0.2 hectares. Both areas are flat and under grass (see plates).

Soils and geology

The underlying bedrock comprises Alveley Member mudstone, siltstone and sandstones (British Geological Survey 2014). There are no recorded superficial deposits. The soils are classified in the Bromsgrove association being characterised as well-drained, reddish coarse loams, mainly over soft sandstone (Soil Survey of England and Wales 1983).

2 Aims, Methodology and Presentation

The main aims of the geophysical survey were to better locate previously mapped drainage routes, to gain a better understanding of any hitherto undocumented sub-surface features and determine which technique was most likely to identify and locate the sub-surface drainage features. In order to achieve this both magnetometer and resistivity surveys were undertaken within the Thomson's Lawn area of the park. The areas for survey were determined following discussions with the project hydrologist. Two areas were identified; one targeted on an area shown to contain drains on a 1935 plan and a second area to the north-east which currently has water arising from an unknown and unmapped source.

The general objectives of the geophysical survey were:

- to provide information about the nature and possible interpretation of any magnetic and resistance anomalies identified;

- to therefore determine the presence/absence and extent of any buried drainage features; and
- to prepare a report summarising the results of the survey.

Magnetometer survey

The site grid was laid out using a Trimble VRS differential Global Positioning System (Trimble 5800 model). Bartington Grad601 magnetic gradiometers were used during the survey, taking readings at 0.25m intervals on zig-zag traverses 0.5m apart within 30m by 30m grids, so that 7200 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. Geoplot 3 (Geoscan Research) software was used to process and present the data. Further details are given in Appendix 1.

Resistance survey

A Geoscan RM15 resistance meter was used, with the instrument logging each reading automatically at 1m intervals on traverses 1m apart. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth penetration of 1m for most archaeological features. Further details are given in Appendix 2.

Reporting

A general site location plan, incorporating the 1:50000 Ordnance Survey (OS) mapping, is shown in Figure 1. Figure 2 is a large scale (1:1500) digital map over which the 1935 estate plan showing the drainage features has been geo-referenced. It is estimated that there may be an error of between 2m and 5m by the superimposition of the metric and non-metric maps/plans. The processed (greyscale) and unprocessed (X-Y trace) plots of the magnetometer data and an interpretation figure are presented in Figures 3, 4 and 5. The resistance data and interpretation are similarly presented in Figures 6, 7 and 8 at the same scale.

Technical information on the equipment used, data processing and survey methodologies are given in Appendix 1, Appendix 2 and Appendix 3. Appendix 4 describes the composition and location of the archive.

Although the survey was not carried out specifically to identify sub-surface archaeological features or deposits the report complies with guidelines outlined by English Heritage (David *et al.* 2008) and by the Institute for Archaeologists (IfA 2010). 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 'raw' and 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.

3 Results and Discussion (see Figs 3 to 8 inclusive)

For ease of discussion both data sets and areas are discussed together.

To the west of Area 1 a high magnitude linear magnetic anomaly, **A**, aligned north-east/south-west correlates broadly with a pipe shown on the 1935 plan that terminates at a rectangular feature labelled 'new tank' on the plan. This tank is clearly visible as a rectangular area of high resistance, **B**. The piping marked on the plan running north from this tank towards Jacobs Well is not clearly visible in either data set although a weak low resistance anomaly, **C**, on the same alignment, possibly locating an unmarked pipe/drain is identified in the resistance data. Linear resistance anomalies, **D** and **E**, also locate two (mapped) pipes that lead to the tank, **B**; **E** correlates with magnetic anomaly **A**. Another resistance anomaly, **F**, connecting between Tank B and a second tank, which manifests as a rectangular area of low resistance, **G**, is also depicted on the 1935 plan.

A twelve inch pipe marked on the 1935 plan has been identified by both techniques at different locations in the two survey areas. In Area 1 in the resistance data it manifests as a sinuous curvilinear anomaly, **H**, and is recorded as **I** in Area 2. It is also recorded as a magnetic anomaly, **J** in Area 1. No anomalies indicative of pipes are recorded in the magnetic data in Area 2 although a cluster of discrete anomalies, **K**, are noted. These anomalies are likely to be caused by ground disturbance associated with the recently created haul road (see Plate 1 and Plate 3). These haul roads also manifest in the resistance data as a linear band of relatively low resistance, **L**; the loosely compacted nature of the material forming the road surface (and hence waterlogged) readily conducts the current hence a low resistance reading.

Linear resistance anomaly **M**, aligned to the east of Area 1, possibly locates another pipe marked on the 1935 plan. A high resistance linear anomaly, **N**, could locate another, unrecorded, pipe in Area 1.

All other variation in the resistance data is considered to be due to geological variation or to modern activity.

4 Conclusions

The survey has clearly demonstrated that both techniques have the potential to identify sub-surface drainage features. However, it is considered possible that there are other sub-surface features which neither technique has been able to identify either due to the depth at which the features are buried, the size/width of the feature or simply that there is insufficient magnetic or resistive contrast between the target features and the surrounding soils. For example no features have been located adjacent to the spot in Area 2 where water is arising. However, the current high level of the water table could possibly indicate a natural spring or possibly an unrecorded (and undetected) pipe fractured during the construction of the haul road. Of the two techniques resistivity has proved to be the more successful and has identified most of the drains marked on the 1935 plan, at least in part. If further work were required it is suggested that this technique is more likely to gain positive results. The survey has also shown there to be a good correlation between the anomalies and the marked position of the sub-surface features and therefore the 1935 plan could be used with a reasonable degree of confidence to investigate the identified drains, if necessary.

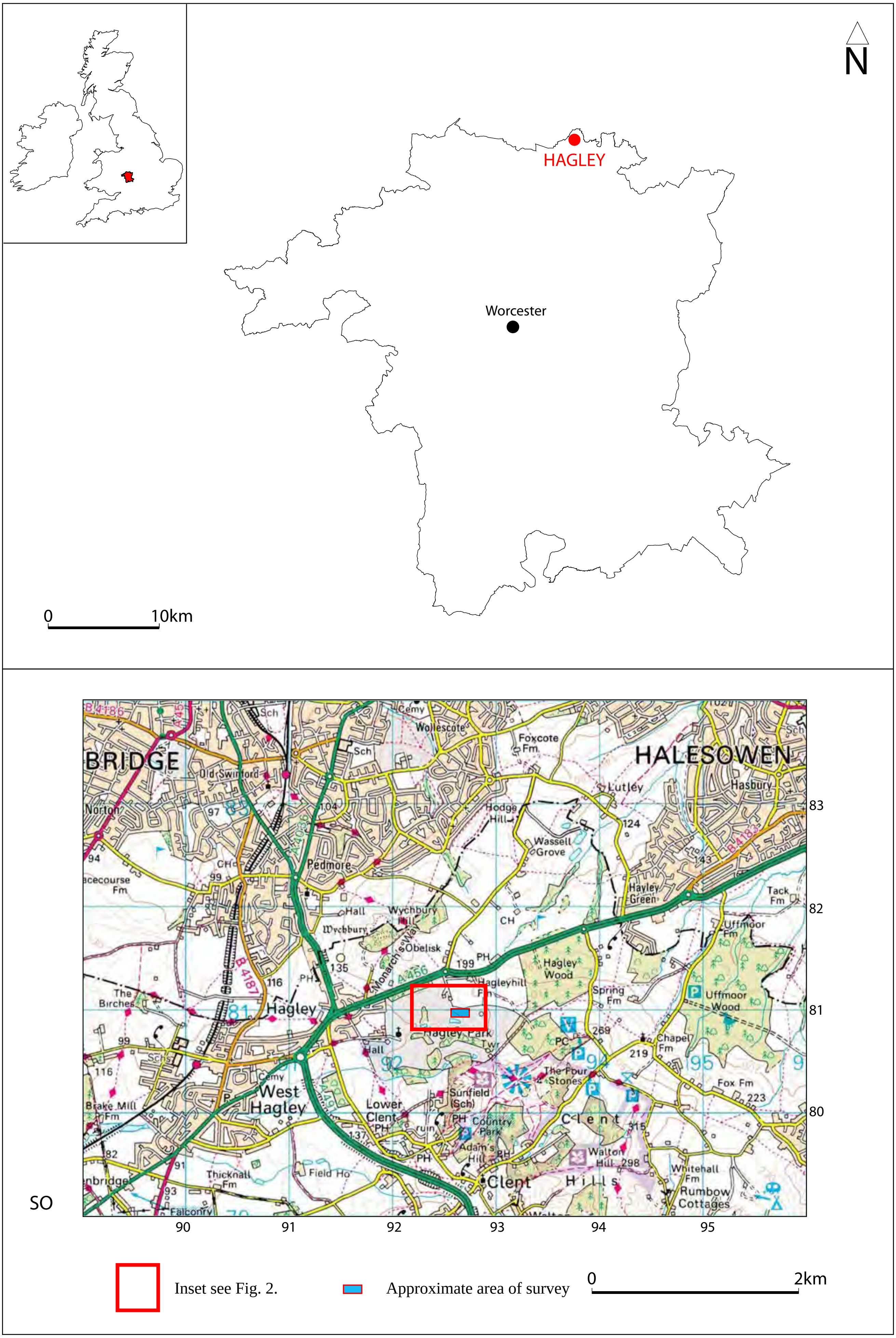

Fig. 1. Site location

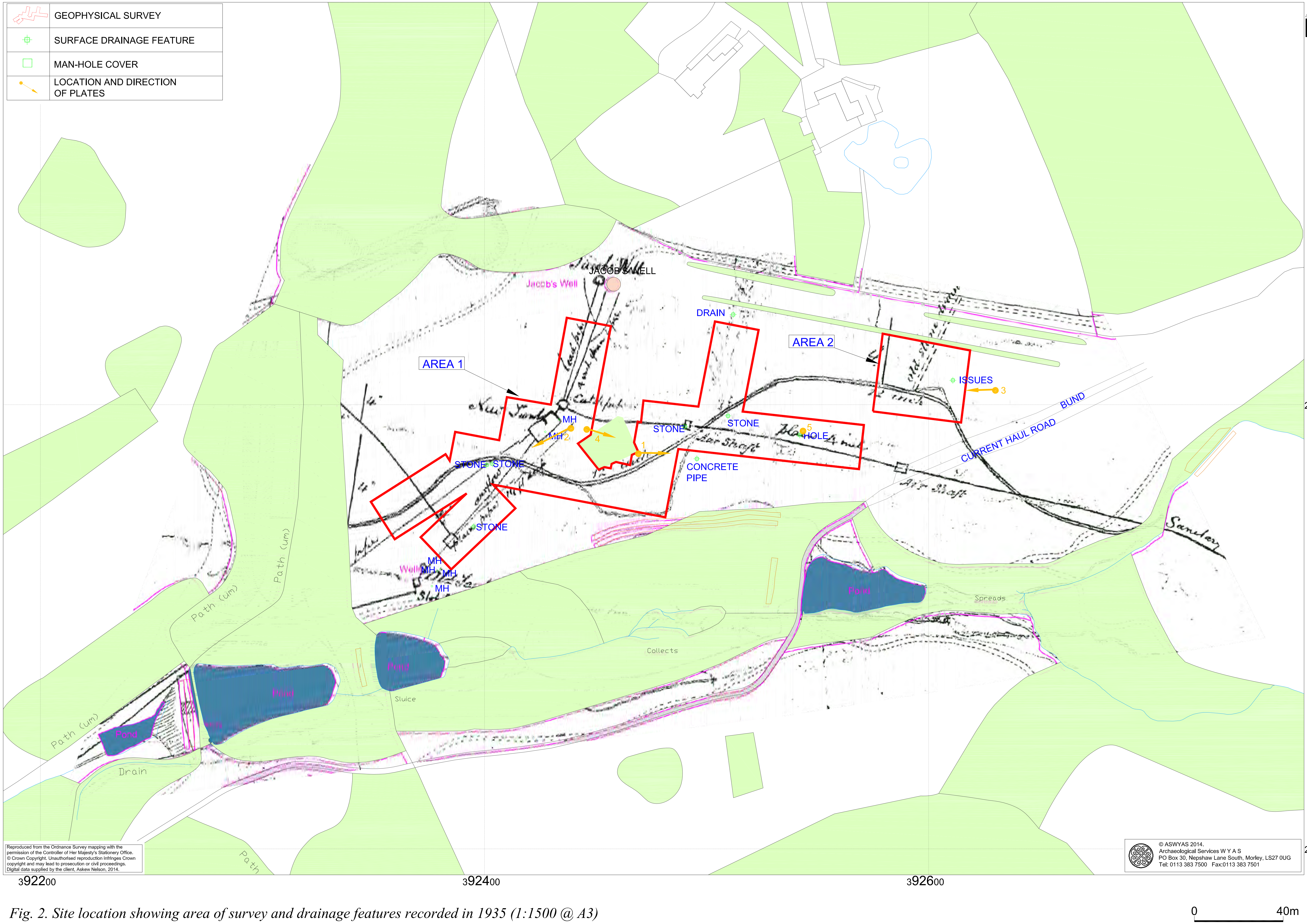

Fig. 2. Site location showing area of survey and drainage features recorded in 1935 (1:1500 @ A3)

Fig. 3. Processed greyscale magnetometer data (1:1000 @ A4)

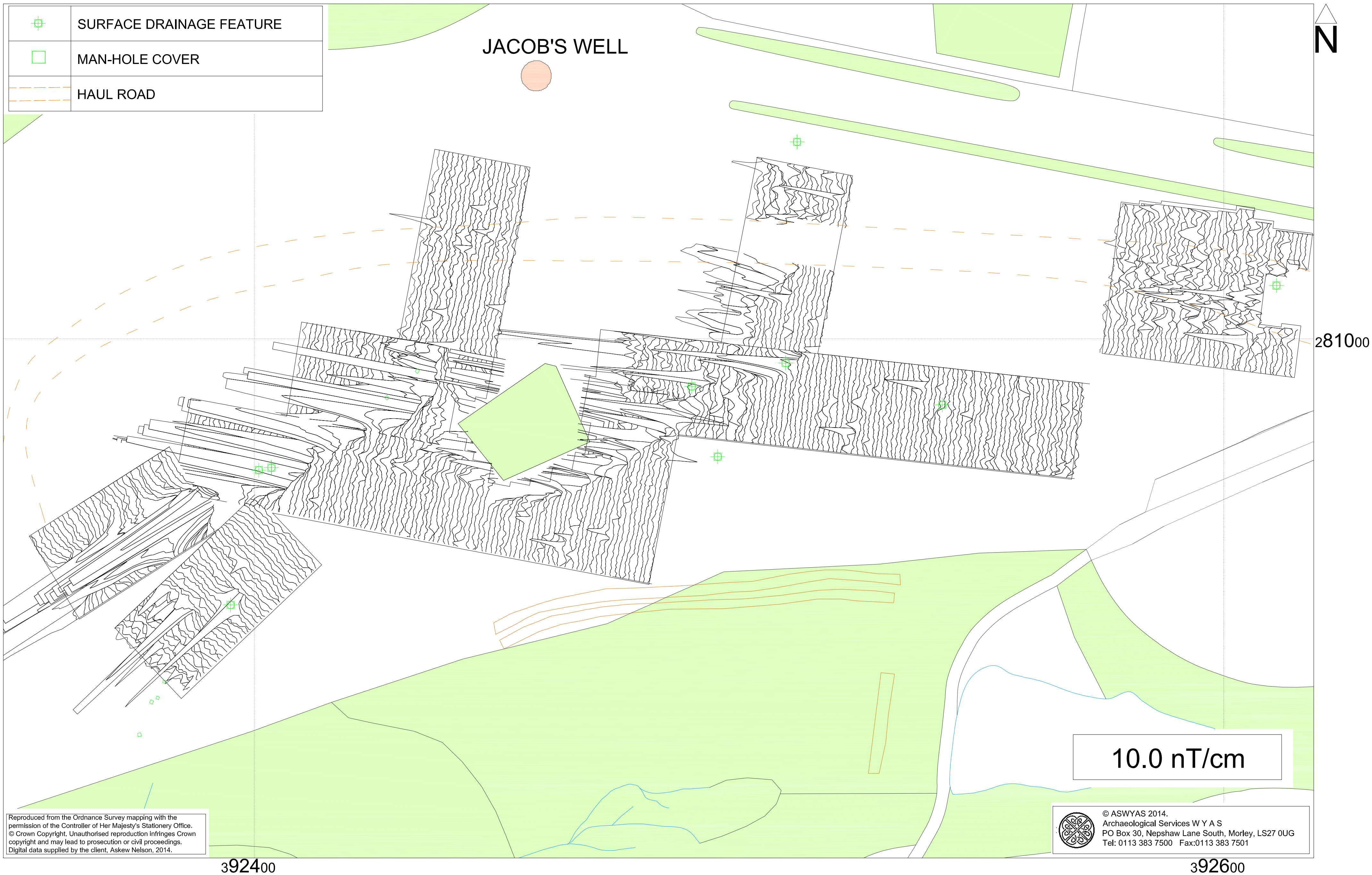

Fig. 4. XY trace plot of minimally processed magnetometer data (1:1000 @ A4)

0 30m

Fig. 5. Interpretation of magnetometer data (1:1000 @ A4)

0 30m

Fig. 6. Unprocessed earth resistance data (1:1000 @ A4)

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Fig. 7. Processed earth resistance data (1:1000 @ A4)

0 30m

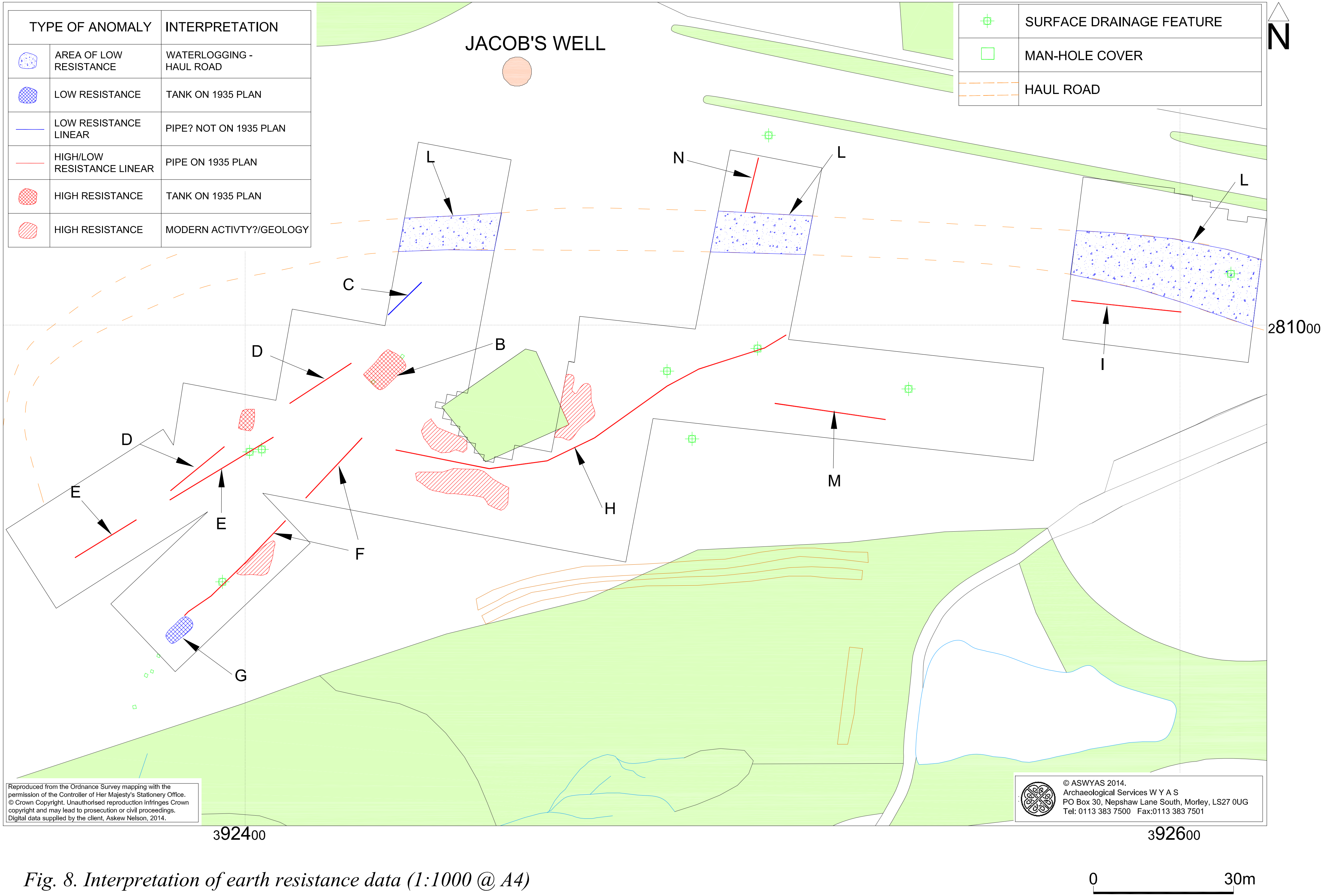

Fig. 8. Interpretation of earth resistance data (1:1000 @ A4)

Plate 1. General view of Area 1, looking east

Plate 2. General view of Area 1, looking south-west

Plate 3. General view of Area 2, looking west

Plate 4. General view of central wooded area

Plate 5. Exposed stonework

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 so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue 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. An advantage of magnetic susceptibility over magnetometry is that a certain amount of occupational activity will cause the same proportional change in susceptibility, however weakly magnetic is the soil, and so does not depend on the magnetic contrast between the topsoil and deeper layers. Susceptibility survey is therefore able to detect areas of occupation even in the absence of cut features. On the other hand susceptibility survey is more vulnerable to the masking effects of layers of colluvium and alluvium as the technique, using the Bartington system, can generally only measure variation in the first 0.15m of ploughsoil.

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 (sometimes only visible on an XY trace plot) 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: Magnetic Susceptibility Survey

There are two methods of measuring the magnetic susceptibility of a soil sample. The first involves the measurement of a given volume of soil, which will include any air and moisture that lies within the sample, and is termed volume specific susceptibility. This method results in a bulk value that it not necessarily fully representative of the constituent components of the sample. For field surveys a Bartington MS2 meter with MS2D field loop is used due to its speed and simplicity. The second technique overcomes this potential problem by taking into account both the volume and mass of a sample and is termed mass specific susceptibility. However, mass specific readings cannot be taken in the field where the bulk properties of a soil are usually unknown and so volume specific readings must be taken. Whilst these values are not fully representative they do allow general comparisons across a site and give a broad indication of susceptibility changes. This is usually enough to assess the susceptibility of a site and evaluate whether enhancement has occurred.

Methodology: Gradiometer Survey

There are two main methods of using the fluxgate gradiometer for commercial evaluations. The first of these is referred to as ***magnetic scanning*** and requires the operator to visually identify anomalous responses on the instrument display panel whilst covering the site in widely spaced traverses, typically 10m apart. The instrument logger is not used and there is therefore no data collection. Once anomalous responses are identified they are marked in the field with bamboo canes and approximately located on a base plan. This method is usually employed as a means of selecting areas for detailed survey when only a percentage sample of the whole site is to be subject to detailed survey.

The disadvantages of magnetic scanning are that features that produce weak anomalies (less than 2nT) are unlikely to stand out from the magnetic background and so will be difficult to detect. The coarse sampling interval means that discrete features or linear features that are parallel or broadly oblique to the direction of traverse may not be detected. If linear features are suspected in a site then the traverse direction should be perpendicular (or as close as is possible within the physical constraints of the site) to the orientation of the suspected features. The possible drawbacks mentioned above mean that a ‘negative’ scanning result should be validated by sample detailed magnetic survey (see below).

The second method is referred to as ***detailed survey*** and employs the use of a sample trigger to automatically take readings at predetermined points, typically at 0.25m intervals, on zig-zag traverses 1m apart. These readings are stored in the memory of the instrument and are later dumped to computer for processing and interpretation. Detailed survey allows the visualisation of weaker anomalies that may not have been detected by magnetic scanning.

During this survey a Bartington Grad601 magnetic gradiometer was used taking readings on the 0.1nT range, at 0.25m 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.

Data Processing and Presentation

The detailed gradiometer data has been presented in this report in XY trace and greyscale formats. In the former format the data shown is 'raw' with no processing other than grid biasing having been done. The data in the greyscale images has 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.

An XY plot presents the data logged on each traverse as a single line with each successive traverse incremented on the Y-axis to produce a 'stacked' plot. A hidden line algorithm has been employed to block out lines behind major 'spikes' and the data has been clipped. The main advantage of this display option is that the full range of data can be viewed, dependent on the clip, so that the 'shape' of individual anomalies can be discerned and potentially archaeological anomalies differentiated from 'iron spikes'. Geoplot 3 software was used to create the XY trace plots.

Geoplot 3 software was used to interpolate the data so that 3600 readings were obtained for each 30m by 30m grid. The same program was used to produce the greyscale images. All greyscale plots are displayed using a linear incremental scale.

The results and subsequent interpretation of data from geophysical surveys should not be treated as an absolute representation of the underlying archaeological and non-archaeological remains. Confirmation of the presence or absence of archaeological remains can only be achieved by direct investigation of sub-surface deposits.

Appendix 2: Earth Resistance Survey - technical information

Soil Resistance

The electrical resistance of the upper soil horizons is predominantly dependant on the amount and distribution of water within the soil matrix. Buried archaeological features, such as walls or infilled ditches, by their differing capacity to retain moisture, will impact on the distribution of sub-surface moisture and hence affect electrical resistance. In this way there may be a measurable contrast between the resistance of archaeological features and that of the surrounding deposits. This contrast is needed in order for sub-surface features to be detected by a resistance survey.

The most striking contrast will usually occur between a solid structure, such as a wall, and water-retentive subsoil. This shows as a resistive high. A weak contrast can often be measured between the infill of a ditch feature and the subsoil. If the infill material is soil it is likely to be less compact and hence more water retentive than the subsoil and so the feature will show as a resistive low. If the infill is stone the feature may retain less water than the subsoil and so will show as a resistive high.

The method of measuring variations in ground resistance involves passing a small electric current (1mA) into the ground via a pair of electrodes (current electrodes) and then measuring changes in current flow (the potential gradient) using a second pair of electrodes (potential electrodes). In this way, if a structural feature, such as a wall, lies buried in a soil of uniform resistance much of the current will flow around the feature following the path of least resistance. This reduces the current density in the vicinity of the feature, which in turn increases the potential gradient. It is this potential gradient that is measured to determine the resistance. In this case, the gradient would be increased around the wall giving a positive or high resistance anomaly.

In contrast a feature such as an infilled ditch may have a moisture retentive fill that is comparatively less resistive to current flow. This will increase the current density and decrease the potential gradient over the feature giving a negative or low resistance anomaly.

Survey Methodology

The most widely used archaeological technique for earth resistance surveys uses a twin probe configuration. One current and one potential electrode (the remote or static probes) are fixed firmly in the ground a set distance away from the area being surveyed. The other current and potential electrodes (the mobile probes) are mounted on a frame and are moved from one survey point to the next. Each time the mobile probes make contact with the ground an electrical circuit is formed between the current electrodes and the potential gradient between the mobile and remote probes is measured and stored in the memory of the instrument.

A Geoscan RM15 resistance meter was used during this survey, with the instrument logging each reading automatically at 1m intervals on traverses 1m apart. The mobile probe spacing was 0.5m with the remote probes 15m apart and at least 15m away from the grid under survey. This mobile probe spacing of 0.5m gives an approximate depth of penetration of 1m for most archaeological features. Consequently a soil cover in excess of 1m may mask, or significantly attenuate, a geophysical response.

Data Processing and Presentation

All of the illustrations incorporating a digital map base were produced in AutoCAD 2008 (© Autodesk).

The resistance data is presented in this report in greyscale format with a linear gradation of values and was obtained by exporting a bitmap from the processing software (Geoplot v3.0; Geoscan Research) into AutoCAD 2008. The data has been processed and has also been interpolated by a value of 0.5 in both the X and Y axes using a sine wave (x)/x function to give a smoother, better defined plot.

Appendix 3: Survey location information

The site grid was laid out using a Trimble dual frequency Global Positioning System (GPS) with two Rovers (Trimble 5800 models) working in real-time kinetic mode. The accuracy of such equipment was better than 0.02m. 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 for relocation purposes.

Appendix 4: 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 will also be forwarded to the client on CD at the conclusion of the project.

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