GEOPHYSICAL SURVEY REPORT

Willersey Road, Badsey, Worcestershire

Client

Martin J Cook

Survey Report

01069

Date

January 2021

Survey Report 01069: Willersey Road, Badsey, Worcestershire

Survey dates	7, 9-11 December 2020
Field co-ordinator	Simon Lobel BSc Richard Fleming
Field Team	Oliver Thomas Liam Brice-Bateman BA Stephen Weston BA
Report Date	7 January 2021
CAD Illustrations	Rebecca Fradgley BSc Magdalena Udyrysz-Krawec MSc
Report Author	Rebecca Fradgley BSc
Project Manager	Simon Haddrell BEng AMBCS PCIfA
Report approved	Dr John Gater BSc DSc(Hon) MCIfA FSA

SUMO Geophysics Ltd
Cowburn Farm
Market Street
Thornton
Bradford
BD13 3HW

T: 01274 835016

SUMO Geophysics Ltd
Vineyard House
Upper Hook Road
Upton upon Severn
Worcestershire
WR8 0SA

T: 01684 592266

www.sumoservices.com
geophysics@sumoservices.com

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2. SURVEY TECHNIQUE

Detailed magnetic survey (magnetometry) and Ground Penetrating Radar (GPR) were chosen as the most efficient and effective methods of locating the type of archaeological anomalies which might be expected at this site.

Magnetometer: Bartington Grad 601-2 Traverse Interval 1.0m Sample Interval 0.25m

GPR:	Mala Mira	Traverse Interval 0.08m	Sample Interval 0.08m

3 SUMMARY OF RESULTS

3.1 Magnetometer and Ground Penetrating Radar (GPR) surveys conducted over land off Willersey Road, Badsey, Worcestershire identified no definite archaeological anomalies. Evidence for former ridge and furrow is seen across the whole of the survey area in the magnetometer results, while linear trends and a small discrete response of uncertain origin, plus a modern pathway, are visible in the GPR data.

4 INTRODUCTION

4.1 **SUMO Geophysics Ltd** were commissioned to undertake a geophysical survey of an area outlined for the creation of a new cemetery. This survey forms part of an archaeological investigation being undertaken by **Martin J Cook**.

4.2 Site details

NGR / Postcode	SP 079 419 / WR11 7JT
Location	The survey area is located to the south-east of the village of Badsey, to the east of Evesham, Worcestershire. Willersey Road forms the northern and eastern boundaries of the site, with agricultural land to the south and farm buildings to the west.
HER	Worcestershire
District	Wychavon
Parish	Badsey CP
Topography	Mostly level
Current Land Use	Grassland / pasture
Geology (BGS 2020)	Solid: Blue Lias Formation and Charmouth Mudstone Formation (undifferentiated) - mudstone. Superficial: none recorded.
Soils (CU 2020)	Soilscape 9: lime-rich loamy and clayey soils with impeded drainage.
Archaeology (WHER 2020)	Worcestershire Historic Environment Record (HER) identifies nine heritage assets within a 500m radius of the site. The postulated Roman Road from Hinton on the Green to Ryknild Street (WSM30628) lies immediately north of the site, following the course of Willersey Road and Pear Tree Lane. Ridge and furrow earthworks (WSM70184; WSM34471; WSM70183) are recorded on land to the north-west and south-east of the area, with the remaining records associated with 19th century barns and outbuildings.
Survey Methods	Magnetometer survey (fluxgate gradiometer)
Study Area	Magnetometer: *c.*4.7 ha GPR: *c.*1.3 ha

4.3 **Aims and Objectives**

To locate and characterise any anomalies of possible archaeological interest within the study area.

5 RESULTS

5.1 *Magnetometer*

5.1.1 *Probable / Possible Archaeology*

No magnetic responses have been recorded that could be interpreted as being of archaeological interest.

5.1.2 *Agricultural – Ridge and Furrow*

Widely spaced, slightly curved, parallel linear anomalies are present across both survey areas. They are indicative of former ridge and furrow cultivation and could have medieval or post-medieval origins.

5.1.3 *Ferrous / Magnetic Disturbance*

Ferrous responses close to boundaries are due to adjacent fences and gates. Small scale ferrous anomalies ("iron spikes") are present throughout the data and are characteristic of small pieces of ferrous debris (or brick / tile) in the topsoil; they are commonly assigned a modern origin. Only the most prominent of these are highlighted on the interpretation diagram. An area of magnetic disturbance, also of modern origin, has been identified along the western edge of Area 1.

5.2 *GPR*

Uncertain Origin

A number of tentative linear trends have been detected, predominantly in the northern part of the survey area. The majority of the responses are relatively shallow (c. 0.1m - 0.3m in depth) suggesting that they are most likely to have a modern explanation; however, their exact origin is unknown.

A single discrete reflection has been identified at a depth of 1.15m in the south of the site. While an archaeological explanation cannot be ruled out, especially given the known features of interest in the vicinity of the site, there are no such responses in the magnetic data; as a consequence a natural origin is perhaps more likely.

Modern path

A curving linear anomaly has been detected at a depth of 0.05m and corresponds with the location of a modern path, visible on Google Earth imagery (Fig. 11).

6 DATA APPRAISAL & CONFIDENCE ASSESSMENT

6.1 Historic England guidelines (EH 2008) Table 4 states that the typical magnetic response on the local soils / geology is variable. The results from this survey indicate the presence of former ridge and furrow and there is no *a priori* reason to suggest that the technique would not have detected archaeological features, should they be present.

6.2 The GPR data across the survey areas displays a moderate contrast between linear responses and that of the background, indicating that the underlying ground is conducive to a GPR survey. A depth penetration of up to 1.6 metres was achieved by the Mala Mira system, and a number of anomalies of uncertain origin were detected, indicating the GPR survey was effective.

7 CONCLUSION

7.1 The survey off Willersey Road, Badsey has not identified any features of definite archaeological interest, nor any obvious obstructions in the area outlined for the proposed cemetery. The magnetic data reveal evidence for ridge and furrow cultivation across the site, while the GPR data have identified numerous linear trends of uncertain origin. The latter are thought most likely to be modern, given their shallow depth, while a small discrete feature at a depth of *c.*1m is possibly natural, although an archaeological origin cannot be ruled out entirely. The line of a modern pathway has also been detected in the GPR results and it coincides with a feature in the same location on Google Earth imagery.

8 REFERENCES

BGS 2020 British Geological Survey, Geology of Britain viewer [accessed 06/01/2021] *website*: (http://www.bgs.ac.uk/opengeoscience/home.html?Accordion1=1#maps)

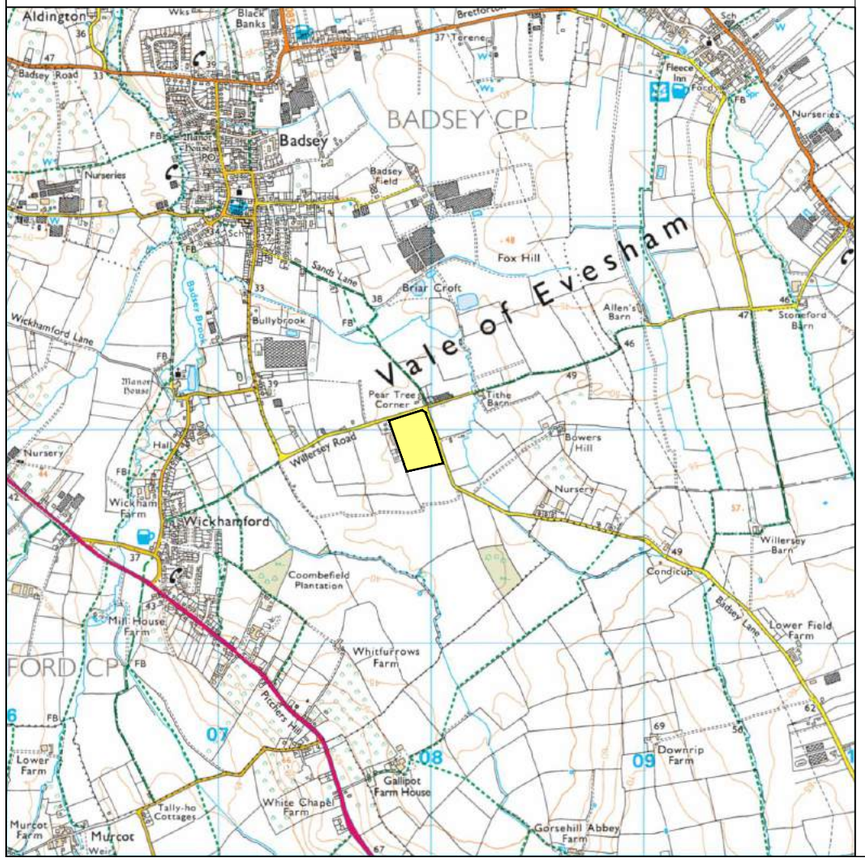
CIfA 2014 *Standard and Guidance for Archaeological Geophysical Survey.* Amended 2016. CIfA Guidance note. Chartered Institute for Archaeologists, Reading http://www.archaeologists.net/sites/default/files/CIfAS%26GGeophysics_2.pdf

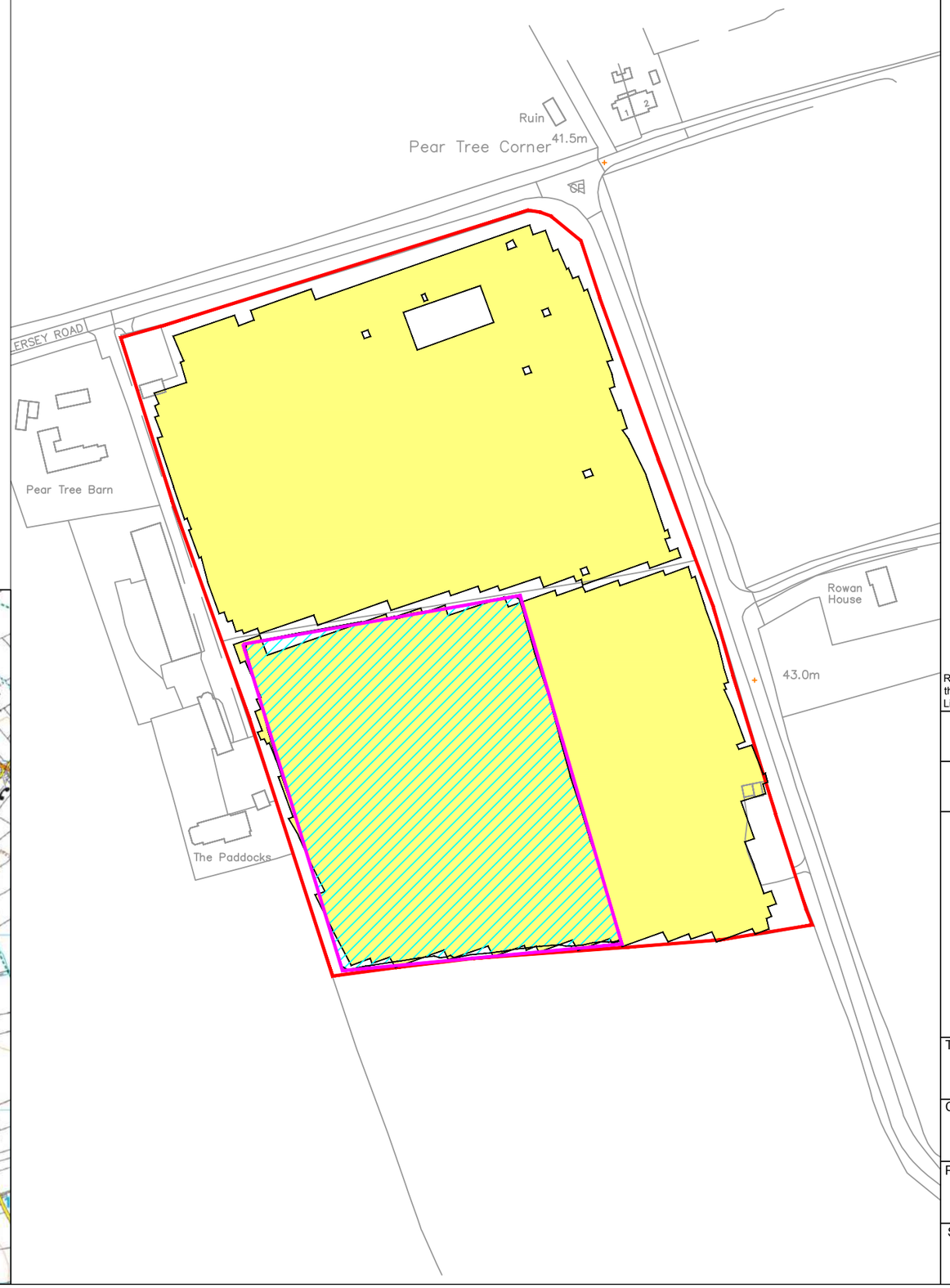
CU 2020 The Soils Guide. Available: www.landis.org.uk. Cranfield University, UK. [accessed 06/01/2021] *website: http://mapapps2.bgs.ac.uk/ukso/home.html*

EAC 2016 *EAC Guidelines for the Use of Geophysics in Archaeology,* European Archaeological Council, Guidelines 2.

EH 2008 *Geophysical Survey in Archaeological Field Evaluation.* English Heritage, Swindon https://content.historicengland.org.uk/images-books/publications/geophysical-survey-in-archaeological-field-evaluation/geophysics-guidelines.pdf/

WHER 2020 Worcestershire Historic Environment Record [accessed 06/01/2021] *website:* www.heritagegateway.org.uk





	Magnetometer Survey Areas
	GPR Survey Area

N

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: Site Location

Client: Martin J Cook

Project: 01069 - Willersey Road, Badsey, Worcestershire

Scale: NOT TO SCALE

Fig No: 01

N

+2nT

-1nT

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
Magnetometer Survey - Greyscale Plots

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 62.5
1:1250 @ A3

Fig No:
02

N

KEY

	Agriculture (ridge and furrow)
	Magnetic disturbance
	Ferrous

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

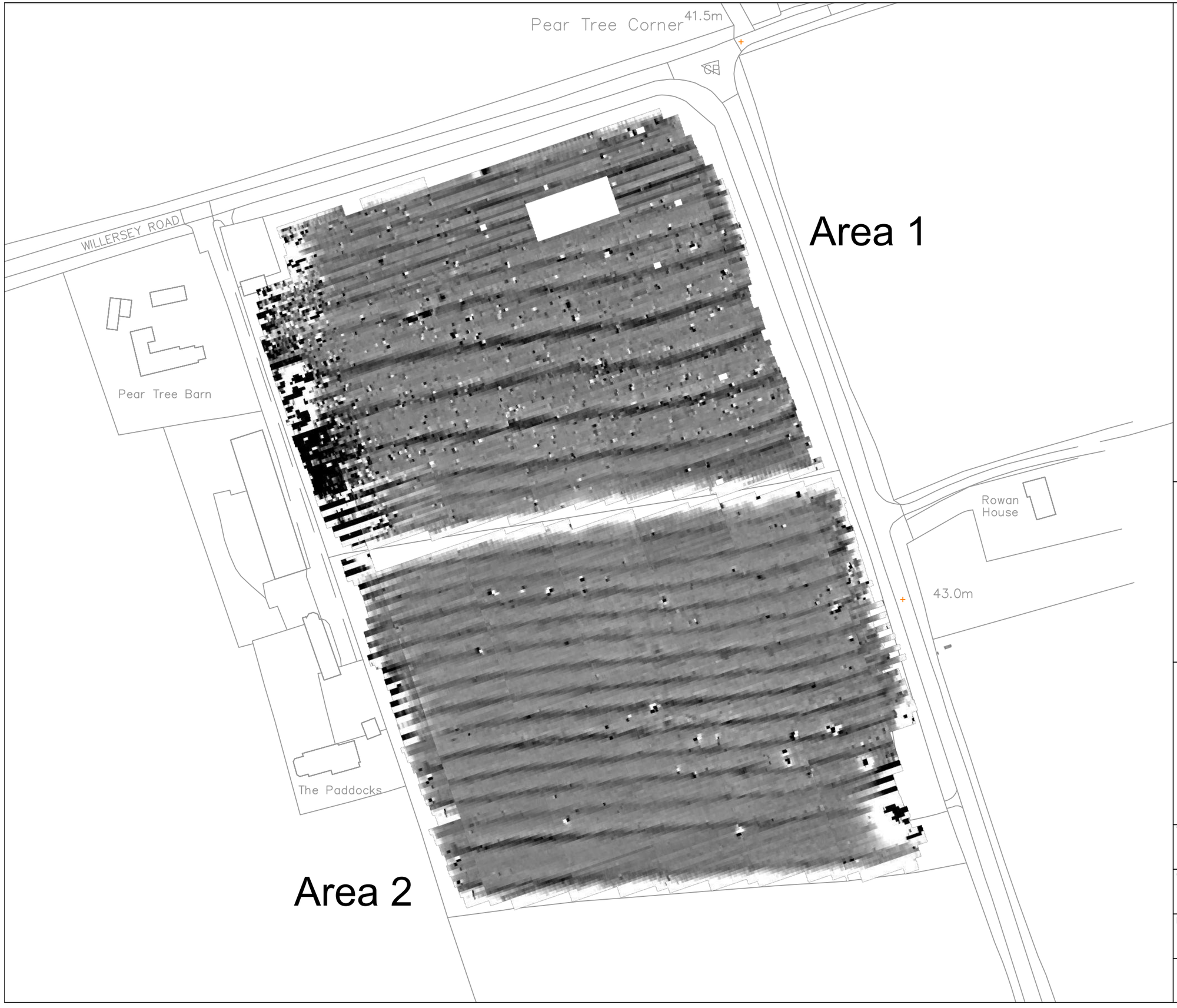
Title:
Magnetometer Survey - Interpretation

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 62.5
1:1250 @ A3

Fig No:
03



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+5nT

-5nT

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

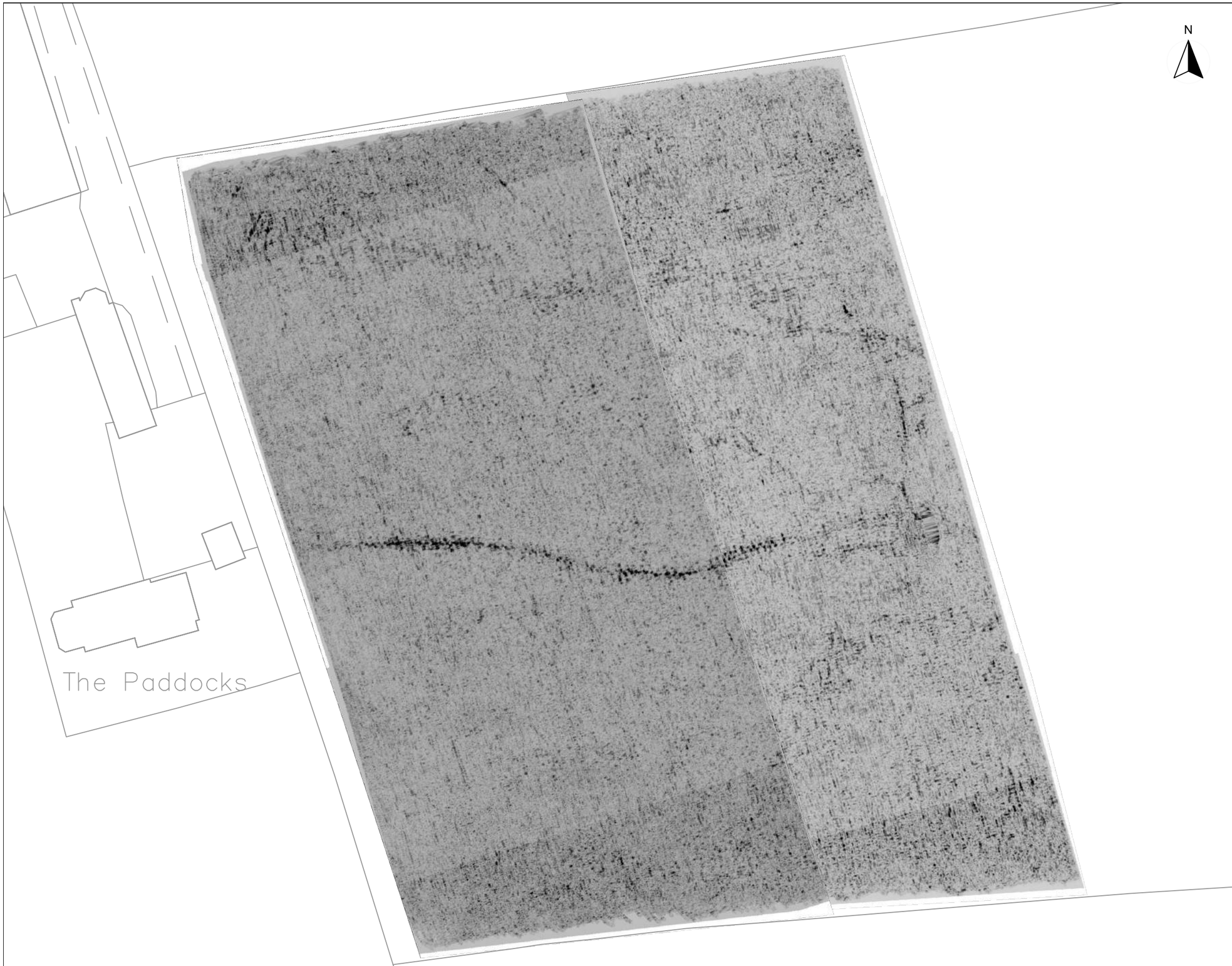
Title:
Minimally Processed Data - Greyscale Plot

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres xx
1:XXXX @ A3

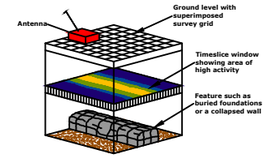
Fig No:
04



Timeslice at 0.20m depth

TIMESLICE PLOTS

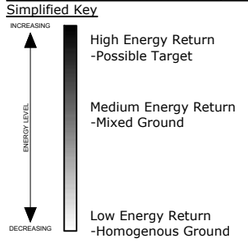
In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Calculations, based on an average velocity, have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

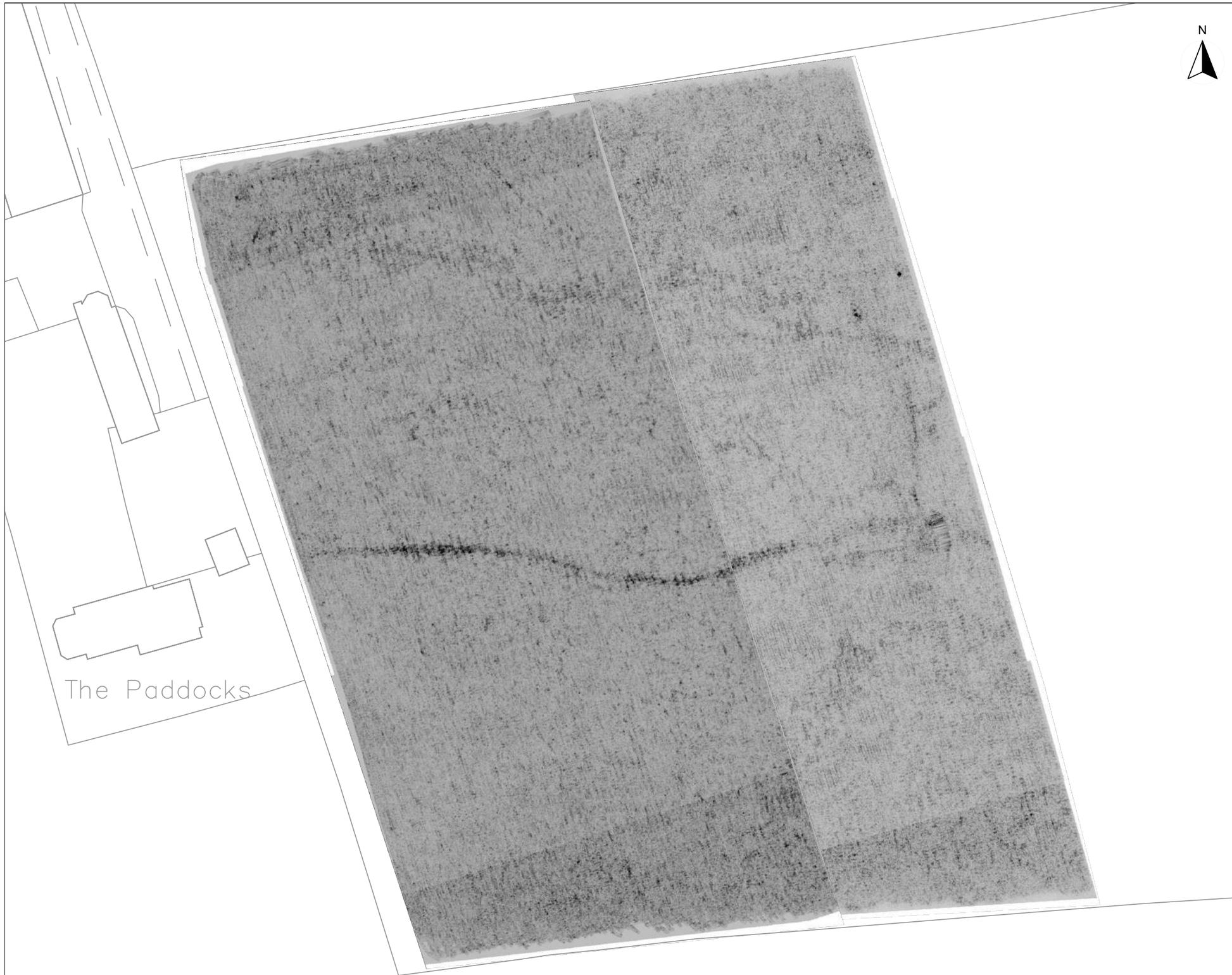
Title:
GPR Survey - Timeslice at 0.20m depth

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
05



Timeslice at 0.40m depth

TIMESLICE PLOTS

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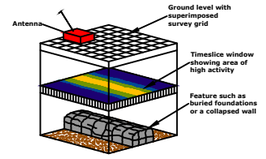

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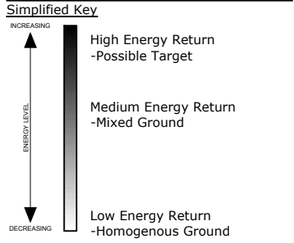


sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

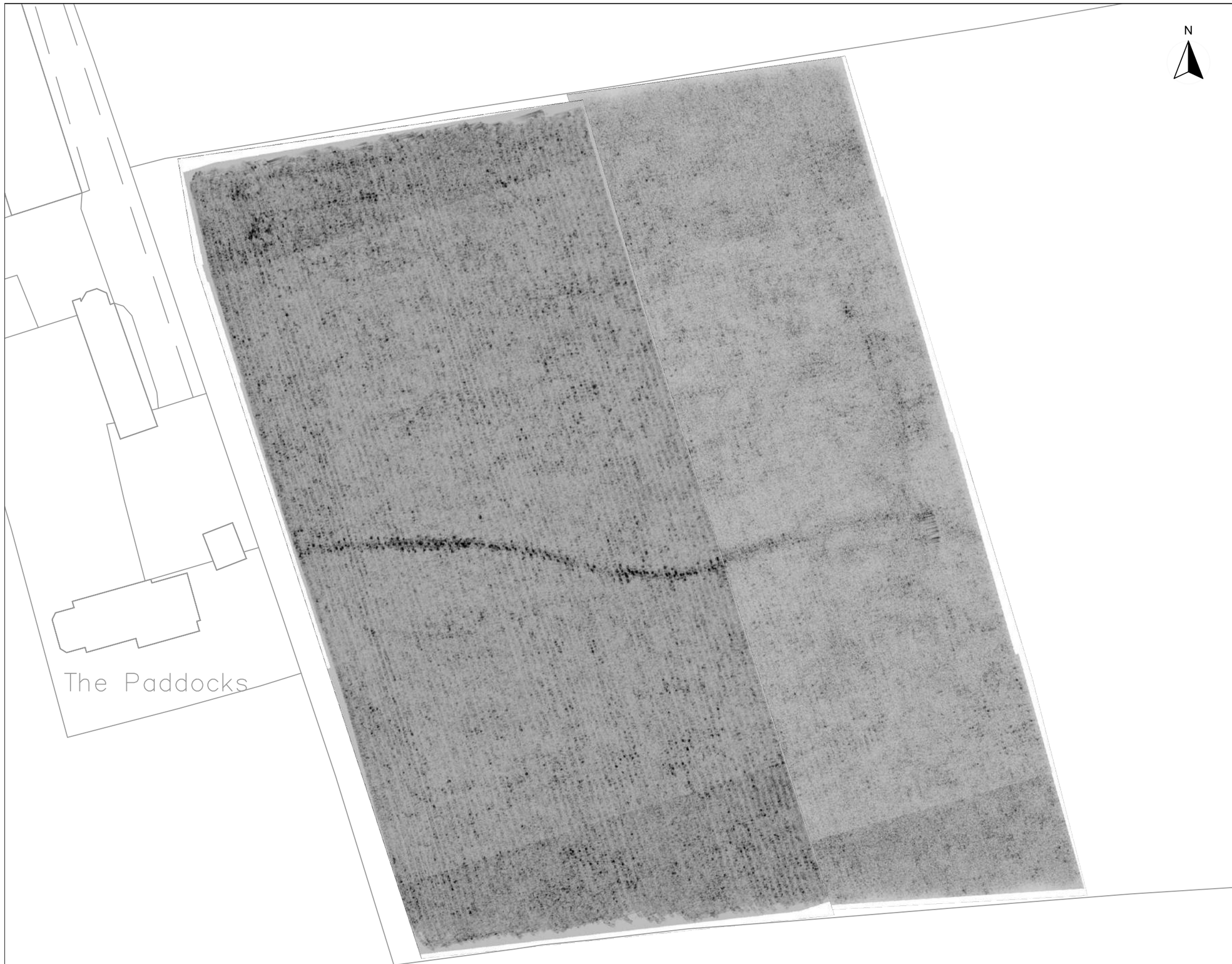
Title:
GPR Survey - Timeslice at 0.40m depth

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
06



Timeslice at 0.60m depth

TIMESLICE PLOTS

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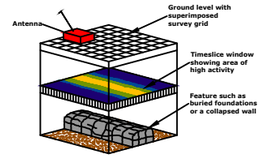

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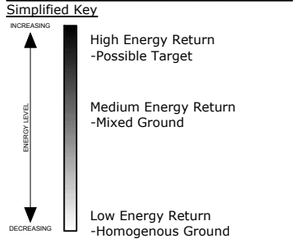
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

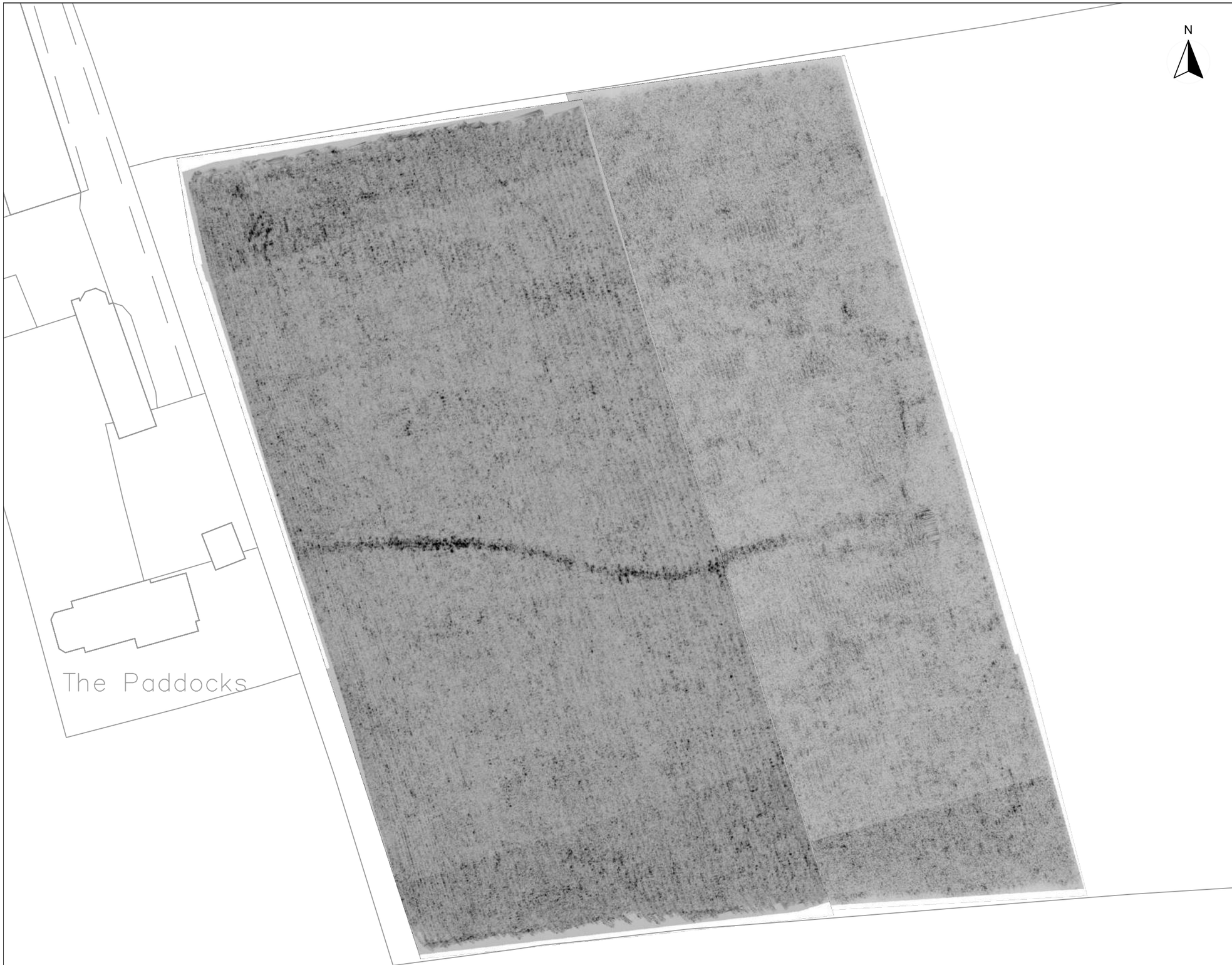
Title:
GPR Survey - Timeslice at 0.60m depth

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
07



Timeslice at 0.80m depth

TIMESLICE PLOTS

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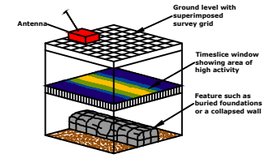

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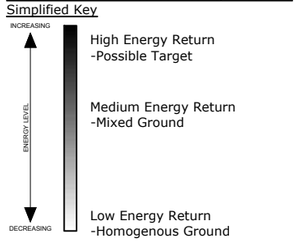
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

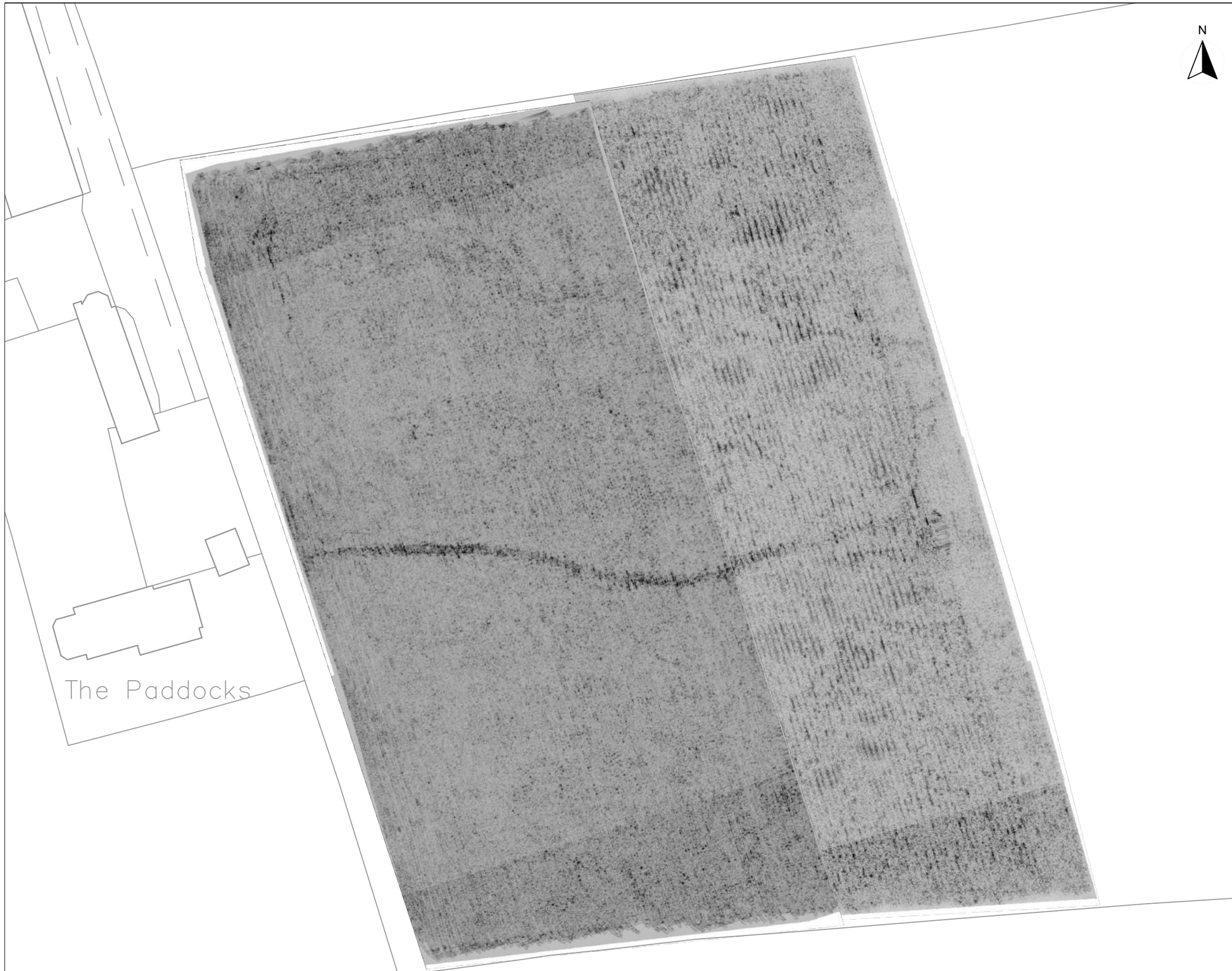
Title:
GPR Survey - Timeslice at 0.80m depth

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
08



Timeslice at 1.00m depth

TIMESLICE PLOTS

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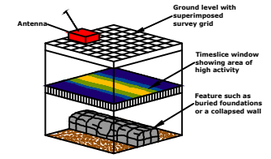

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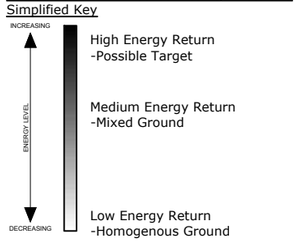
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

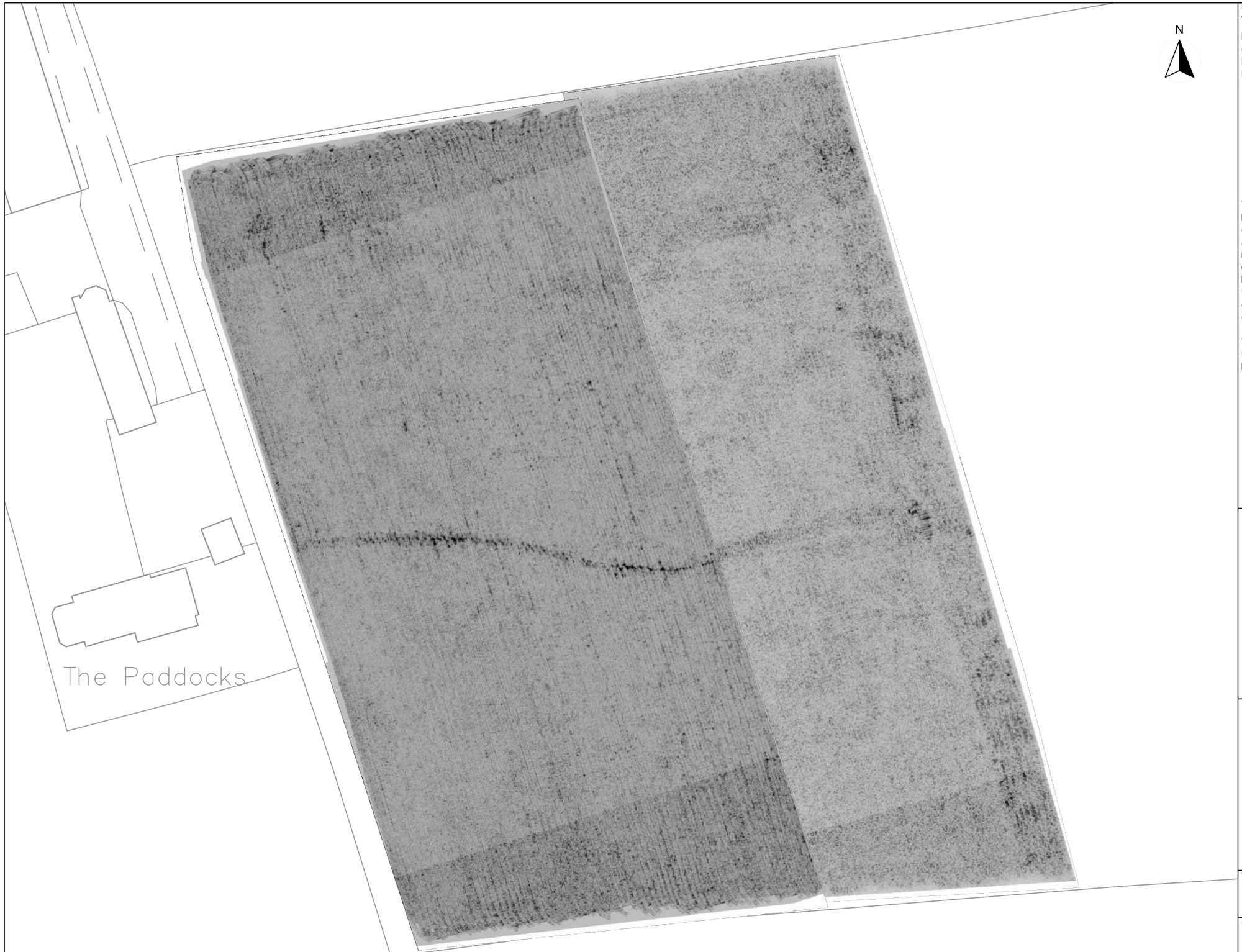
Title:
GPR Survey - Timeslice at 1.00m depth

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
09



Timeslice at 1.00m depth

TIMESLICE PLOTS

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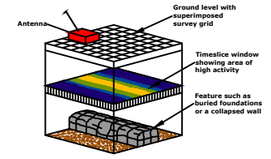

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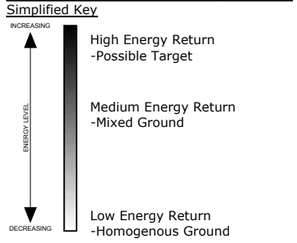
Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

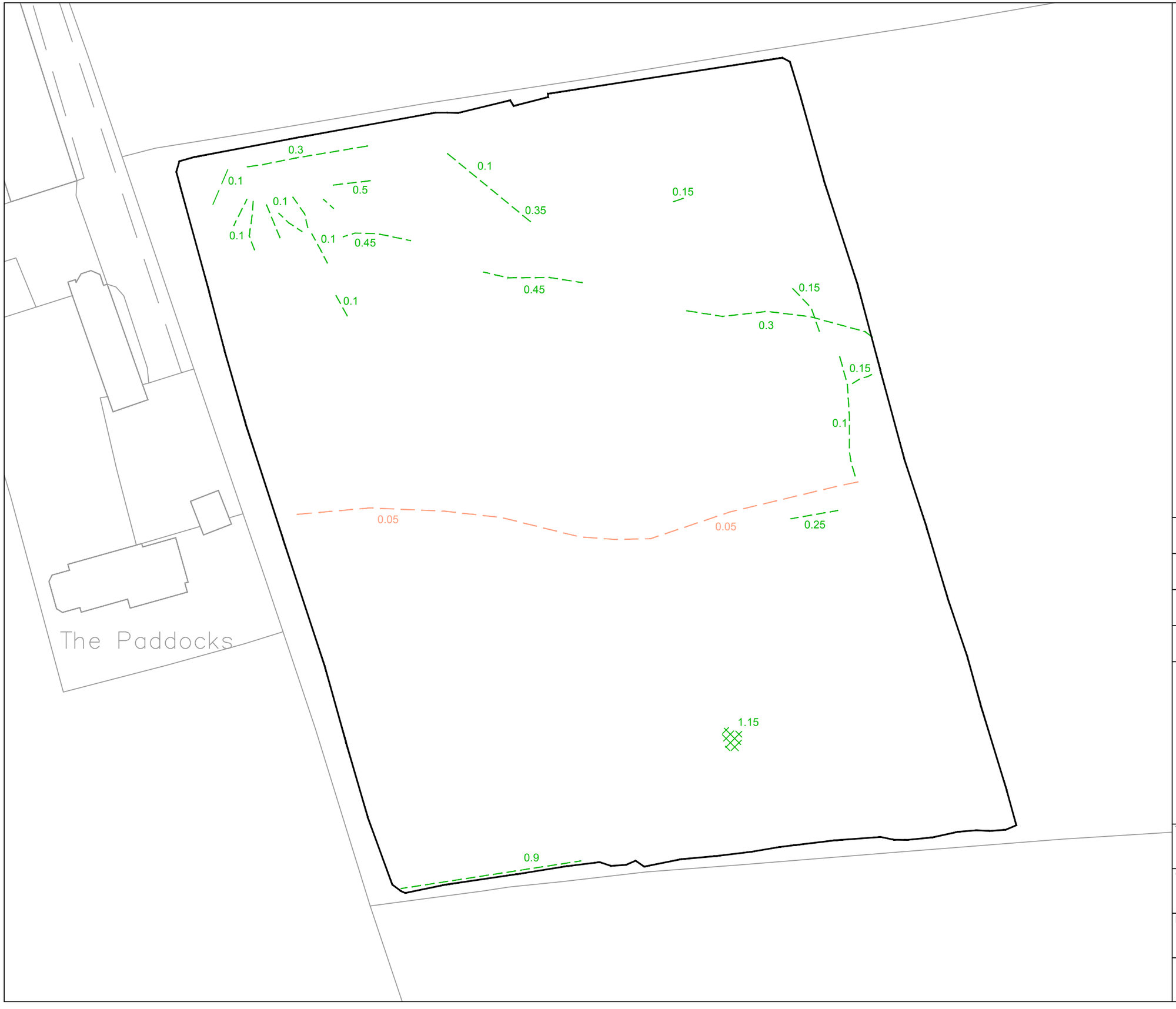
Title:
GPR Survey - Timeslice at 1.60m depth

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
10



KEY

	Uncertain Origin (linear / discrete)
	Modern path
0.35	Depth to the top of the feature (in m)

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Plan Interpretation

Client:
Martin J Cook

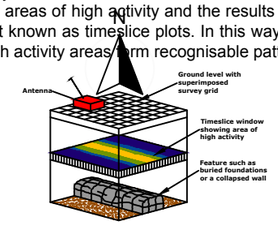
Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
0 metres 30
1:600 @ A3

Fig No:
11

TIMESLICE PLOTS

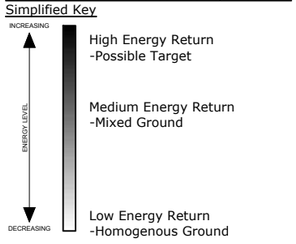
In addition to a manual abstraction from the radargrams, a computer analysis was carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.



The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Calculations, based on an average velocity, have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
2017 Google Earth Image and GPR Timeslice showing modern path

Client:
Martin J Cook

Project:
01069 - Willersey Road, Badsey, Worcestershire

Scale:
NOT TO SCALE

Fig No:
12

Appendix A - Technical Information: Magnetometer Survey Method, Processing and Presentation

Standards & Guidance

This report and all fieldwork have been conducted in accordance with the latest guidance documents issued by Historic England (EH 2008) (then English Heritage), the Chartered Institute for Archaeologists (CIfA 2014) and the European Archaeological Council (EAC 2016).

Grid Positioning

For hand held gradiometers the location of the survey grids has been plotted together with the referencing information. Grids were set out using a Trimble R8 Real Time Kinematic (RTK) VRS Now GNSS GPS system.

An RTK GPS (Real-time Kinematic Global Positioning System) can locate a point on the ground to a far greater accuracy than a standard GPS unit. A standard GPS suffers from errors created by satellite orbit errors, clock errors and atmospheric interference, resulting in an accuracy of 5m-10m. An RTK system uses a single base station receiver and a number of mobile units. The base station re-broadcasts the phase of the carrier it measured, and the mobile units compare their own phase measurements with those they received from the base station. This results in an accuracy of around 0.01m.

Technique	Instrument	Traverse Interval	Sample Interval
Magnetometer	Bartington Grad 601-2	1m	0.25m

Instrumentation: Bartington *Grad* 601-2

Bartington instruments operate in a gradiometer configuration which comprises fluxgate sensors mounted vertically, set 1.0m apart. The fluxgate gradiometer suppresses any diurnal or regional effects. The instruments are carried, or cart mounted, with the bottom sensor approximately 0.1-0.3m from the ground surface. At each survey station, the difference in the magnetic field between the two fluxgates is measured in nanoTesla (nT). The sensitivity of the instrument can be adjusted; for most archaeological surveys the most sensitive range (0.1nT) is used. Generally, features up to 1m deep may be detected by this method, though strongly magnetic objects may be visible at greater depths. The Bartington instrument can collect two lines of data per traverse with gradiometer units mounted laterally with a separation of 1.0m. The readings are logged consecutively into the data logger which in turn is daily down-loaded into a portable computer whilst on site. At the end of each site survey, data is transferred to the office for processing and presentation.

Data Processing

Zero Mean Traverse	This process sets the background mean of each traverse within each grid to zero. The operation removes striping effects and edge discontinuities over the whole of the data set.
Step Correction (De-stagger)	When gradiometer data are collected in 'zig-zag' fashion, stepping errors can sometimes arise. These occur because of a slight difference in the speed of walking on the forward and reverse traverses. The result is a staggered effect in the data, which is particularly noticeable on linear anomalies. This process corrects these errors.

Display

Greyscale/ Colourscale Plot	This format divides a given range of readings into a set number of classes. Each class is represented by a specific shade of grey, the intensity increasing with value. All values above the given range are allocated the same shade (maximum intensity); similarly, all values below the given range are represented by the minimum intensity shade. Similar plots can be produced in colour, either using a wide range of colours or by selecting two or three colours to represent positive and negative values. The assigned range (plotting levels) can be adjusted to emphasise different anomalies in the data-set.

Presentation of results and interpretation

The presentation of the results includes a ‘minimally processed data’ and a ‘processed data’ greyscale plot. Magnetic anomalies are identified, interpreted and plotted onto the ‘Interpretation’ drawings.

When interpreting the results, several factors are taken into consideration, including the nature of archaeological features being investigated and the local conditions at the site (geology, pedology, topography etc.). Anomalies are categorised by their potential origin. Where responses can be related to other existing evidence, the anomalies will be given specific categories, such as: Abbey Wall or Roman Road. Where the interpretation is based largely on the geophysical data, levels of confidence are implied, for example: Probable, or Possible Archaeology. The former is used for a confident interpretation, based on anomaly definition and/or other corroborative data such as cropmarks. Poor anomaly definition, a lack of clear patterns to the responses and an absence of other supporting data reduces confidence, hence the classification Possible.

Interpretation Categories

In certain circumstances (usually when there is corroborative evidence from desk-based or excavation data) very specific interpretations can be assigned to magnetic anomalies (for example, *Roman Road, Wall,* etc.) and where appropriate, such interpretations will be applied. The list below outlines the generic categories commonly used in the interpretation of the results.

Archaeology / Probable Archaeology	This term is used when the form, nature and pattern of the responses are clearly or very probably archaeological and /or if corroborative evidence is available. These anomalies, whilst considered anthropogenic, could be of any age.
Possible Archaeology	These anomalies exhibit either weak signal strength and / or poor definition, or form incomplete archaeological patterns, thereby reducing the level of confidence in the interpretation. Although the archaeological interpretation is favoured, they may be the result of variable soil depth, plough damage or even aliasing as a result of data collection orientation.
Industrial / Burnt-Fired	Strong magnetic anomalies that, due to their shape and form or the context in which they are found, suggest the presence of kilns, ovens, corn dryers, metal-working areas or hearths. It should be noted that in many instances modern ferrous material can produce similar magnetic anomalies.
Former Field Boundary (probable & possible)	Anomalies that correspond to former boundaries indicated on historic mapping, or which are clearly a continuation of existing land divisions. Possible denotes less confidence where the anomaly may not be shown on historic mapping but nevertheless the anomaly displays all the characteristics of a field boundary.
Ridge & Furrow	Parallel linear anomalies whose broad spacing suggests ridge and furrow cultivation. In some cases, the response may be the result of more recent agricultural activity.
Agriculture (ploughing)	Parallel linear anomalies or trends with a narrower spacing, sometimes aligned with existing boundaries, indicating more recent cultivation regimes.
Land Drain	Weakly magnetic linear anomalies, quite often appearing in series forming parallel and herringbone patterns. Smaller drains may lead and empty into larger diameter pipes, which in turn usually lead to local streams and ponds. These are indicative of clay fired land drains.
Natural	These responses form clear patterns in geographical zones where natural variations are known to produce significant magnetic distortions.
Magnetic Disturbance	Broad zones of strong dipolar anomalies, commonly found in places where modern ferrous or fired materials (e.g. brick rubble) are present.
Service	Magnetically strong anomalies, usually forming linear features are indicative of ferrous pipes/cables. Sometimes other materials (e.g. pvc) or the fill of the trench can cause weaker magnetic responses which can be identified from their uniform linearity.
Ferrous	This type of response is associated with ferrous material and may result from small items in the topsoil, larger buried objects such as pipes, or above ground features such as fence lines or pylons. Ferrous responses are usually regarded as modern. Individual burnt stones, fired bricks or igneous rocks can produce responses similar to ferrous material.
Uncertain Origin	Anomalies which stand out from the background magnetic variation, yet whose form and lack of patterning gives little clue as to their origin. Often the characteristics and distribution of the responses straddle the categories of *Possible Archaeology* / *Natural* or (in the case of linear responses) *Possible Archaeology* / *Agriculture*; occasionally they are simply of an unusual form.

Where appropriate some anomalies will be further classified according to their form (positive or negative) and relative strength and coherence (trend: weak and poorly defined).

Appendix B - Technical Information: Magnetic Theory

Detailed magnetic survey can be used to effectively define areas of past human activity by mapping spatial variation and contrast in the magnetic properties of soil, subsoil and bedrock. Although the changes in the magnetic field resulting from differing features in the soil are usually weak, changes as small as 0.1 nanoTeslas (nT) in an overall field strength of 48,000 (nT), can be accurately detected.

Weakly magnetic iron minerals are always present within the soil and areas of enhancement relate to increases in *magnetic susceptibility* and permanently magnetised *thermoremanent* material.

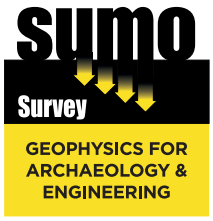
Magnetic susceptibility relates to the induced magnetism of a material when in the presence of a magnetic field. This magnetism can be considered as effectively permanent as it exists within the Earth's magnetic field. Magnetic susceptibility can become enhanced due to burning and complex biological or fermentation processes.

Thermoremanence is a permanent magnetism acquired by iron minerals that, after heating to a specific temperature known as the Curie Point, are effectively demagnetised followed by re-magnetisation by the Earth's magnetic field on cooling. Thermoremanent archaeological features can include hearths and kilns; material such as brick and tile may be magnetised through the same process.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil creates a relative contrast against the much lower levels of magnetism within the subsoil into which the feature is cut. Systematic mapping of magnetic anomalies will produce linear and discrete areas of enhancement allowing assessment and characterisation of subsurface features. Material such as subsoil and non-magnetic bedrock used to create former earthworks and walls may be mapped as areas of lower enhancement compared to surrounding soils.

Magnetic survey is carried out using a fluxgate gradiometer which is a passive instrument consisting of two sensors mounted vertically 1m apart. The instrument is carried about 30cm above the ground surface and the top sensor measures the Earth's magnetic field whilst the lower sensor measures the same field but is also more affected by any localised buried feature. The difference between the two sensors will relate to the strength of a magnetic field created by this feature, if no field is present the difference will be close to zero as the magnetic field measured by both sensors will be the same.

Factors affecting the magnetic survey may include soil type, local geology, previous human activity and disturbance from modern services.



- Archaeological
- Geophysical
- Laser Scanning
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Registered Office Unit 8 Hayward Business Centre, New Lane, Havant, Hampshire, PO9 2NL