sumo
Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

GEOPHYSICAL SURVEY REPORT

17 – 19 Between Towns Road, Oxford

Client
Southampton City Council

Survey Report
16403

Date
November 2019

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GEOPHYSICAL SURVEY REPORT

Project name:
17 – 19 Between Towns Road, Oxford

SUMO Job reference:
16403

Client:
Southampton City Council

Survey date:
4th November 2019

Report date:
26th November 2019

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Richard Fleming

Field crew:
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1 SUMMARY OF RESULTS

A combined detailed magnetometer and ground penetrating radar (GPR) geophysical survey was conducted over an area of approximately 1300 m² in the back yards of the properties at 17 - 19 Between Towns Road, Oxford to search for evidence of archaeological features such as pottery kilns.

The magnetometer survey was dominated by areas of magnetic disturbance; however, a single possible kiln and waste pit have been located in the south of the site.

A number of high amplitude anomalies were identified by the GPR survey. These features are of uncertain origin, although they may be archaeology related features. The GPR survey also detected several linear features that could be associated with structural remains such as walls or foundations, although their origin is uncertain. Several possible services were also found by the GPR survey, mainly in southern part of the survey area.

2 INTRODUCTION

2.1 Background synopsis

SUMO Geophysics Ltd were commissioned to undertake a geophysical survey of the backyards of 17 and 19 Between Towns Road in Oxford. The survey objective was to search for evidence of archaeological features prior to development of the site.

2.2 Site details

NGR / Postcode	SP 544 041 / OX4 3LX
Location	The site is a backyard with car park at Nos. 17 - 19 Between Towns Road in Oxford
District	Oxford
Ward	Cowley
Geology	Solid: Beckley Sand Member - sandstone (BGS) Superficial: none recorded (BGS)
Soils (CU 2019)	Unsurveyed (U), mainly urban and industrial areas (CU)
Archaeology	There is potential to find possible pottery kilns within the survey area. A 15m long trial trench in the back yard of No 17 found only an undated sheep or goat burial and a few sherds of Roman pottery. In 1934 when the Cowley Conservative Club was built at No 19 a quantity of pottery, mainly 2nd century, was recovered including a distorted waster. Work to the rear of the Conservative Club in 1969 produced late Roman colour-coated wares. No 19 was subject to gradiometer and GPR surveys in 2011. The survey identified weak evidence of kilns in the central region of the survey area. Discrete, moderately high magnitude anomalies, possibly related to thermoremanent features, were identified in the gradiometer data. No corresponding features were evident in the GPR data. Three trenches were excavated in 2014-2015 of which only Trench 2, targeted specifically on key geophysical anomalies, contained features of Roman date, principally represented by a late Roman pit which had been heavily truncated by modern features. The small pottery

assemblage from this feature included a rare white ware flagon face mask. Trench 1 contained no features, while a small pit in Trench 3 was of post-medieval date. Irregular patches of stone in this area were probably a natural formation.

Survey Methods	Detailed Magnetometer and Ground Penetrating Radar (GPR)
Study Area	1300 m^2 split into two areas. The ground surface of the backyard of No 17 Between Towns Road in Oxford is tarmac with a trench that has not been resurfaced when reinstated. The surface of the backyard of No 19 comprises of concrete slabs without evidence of reinforcing.
Equipment	1. Bartington Grad 601-2 2. Mala Mira High Density Array Radar in conjunction with 400 MHz antenna

2.3 Aims and Objectives

The key objective of the survey was to search for evidence of archaeological features associated with the pottery kilns.

3 METHODS, PROCESSING & PRESENTATION

3.1 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).

3.2 Survey Methods

A detailed magnetic survey (magnetometry) was chosen as the most efficient and effective method of locating thermoremnant features such as kilns or areas of burning. Due to the urban nature of the site a Ground Penetrating Radar (GPR) was chosen to locate features of archaeological interest possibly that might be masked by the expected ferrous responses.

3.3 Survey Procedure

The Bartington Grad 601-2 operates with an inbuilt data logger. A base station was set up for the magnetometer survey in a quiet part of the site, for monitoring instrument drift. The magnetic data was collected over the same area as the electromagnetic data along 1 metre spaced, east-west oriented survey grid lines, with readings taken at 0.25 metre intervals. More information regarding the magnetic method is given in Appendix A and B.

The site was covered by a high density array using the Mala Mira system. A parallel grid of radar profiles spaced at 0.08 metre intervals was completed over the accessible parts of the site. More information regarding the GPR method is given in Appendix C.

3.4 Survey Techniques

3.4.1 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 and buried obstructions which might be expected at this site.

Bartington Grad 601-2	Traverse Interval 1.0m	Sample Interval 0.25m
Mala MIRA	Traverse Interval 0.08m	Sample Interval 0.05m

3.4.2 **Magnetic Survey Data**

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.

3.4.3 **Ground Penetrating Radar Data**

Each radargram has been studied and those anomalies thought to be significant were noted and classified as detailed below. Inevitably some simplification has been made to classify the diversity of responses found in radargrams. This abstraction is then employed as the primary source for producing the interpretation plot but is not itself reproduced in the report.

i. Strong and weak discrete reflector.

These may be a mix of different types of reflectors but their limits can be clearly defined. Their inclusion as a separate category has been considered justified to emphasise anomalous returns which may be from archaeological targets and would not otherwise be highlighted in the analysis.

ii. Complex reflectors.

These would generally indicate a confused or complex structure to the subsurface. An occurrence of such returns, particularly where the natural soils or rocks are homogeneous, would suggest artificial disturbances. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface, which in turn may be associated with a marked change in material or moisture content.

iii. Point diffractions.

These may be formed by a discrete object such as a stone or a linear feature such as a small diameter pipeline being crossed by the radar traverse (see also the second sentence in iv. below).

iv. Convex reflectors and broad crested diffractions.

A convex reflector can be formed by a convex shaped buried interface such as a vault or very large diameter pipeline or culvert. A broad crested diffraction as opposed to a point diffraction can be formed by (for example) a large diameter pipe or a narrow wall generating a hybrid of a point diffraction and convex reflector where the central section is a reflection off the top of the target and the edges/sides forming diffractions.

v. Planar returns.

These may be formed by a floor or some other interface parallel with the surface. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface which in turn may be associated with a marked change in material or moisture content.

vi. Inclined events.

These may be a planar feature but not parallel with the survey surface. However, similar responses can be caused by extraneous reflections. For example, an “air-wave” caused by a strong reflection from an above ground object would produce a linear dipping anomaly and does not relate to any sub-surface feature. Normally this is not a problem as the antennae used are shielded, but under some circumstances these effects can become noticeable.

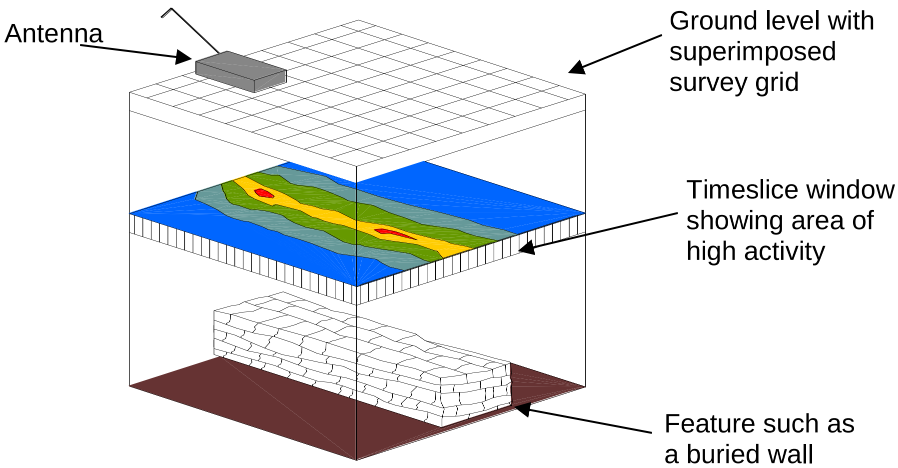
vii. Conductive surface.

The radiowave transmitted from the antenna has its waveform modulated by the ground surface. If this ground surface or layers close to the surface are particularly conductive a ‘ground coupled wavetrain’ is generated which can produce a complex wave pattern affecting part or all of the scan and so can obscure the weaker returns from targets lower down in the ground.

A category for “focused ringing” has been included as this type of anomaly can indicate the presence of an air void. This is created by the signal resonating within the void, but with a characteristic domed shape due to the “velocity pull-up effect”.

Timeslice plots

In addition to a manual abstraction from the radargrams, a computer analysis was also 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 a range. The 3D file can be sampled 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. Based on an average velocity, calculations have been made to show the equivalent depth into the ground.

The weaker reflections in the time slice windows are shown as dark colours namely blues and greens. The stronger reflections are represented by brighter colours such as light green, yellow, orange and red.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as foundations or surfaces within the soil matrix.

4 RESULTS

The results of the magnetometer survey are presented in Figure 4 and the results of the GPR survey are presented in Figure 13. Combined interpretation is presented in Figure 14.

4.1 Magnetometer

4.1.1 *Possible Kilns*

Clays used to make pots, tiles and/or bricks contain iron minerals which, when heated above a specific temperature known as The Curie Point, first become demagnetised and then permanently locked in to the Earth's magnetic field as they cool down. This is the effect known as thermoremanence and results in strong magnetic anomalies. These often have two peaks when viewed as XY traces – one peak for each sidewall of a kiln. An example of this can be seen in Figure A below.

The results from the area in the southwest demonstrate these characteristics, indicating a possible kiln which was also located in the previous geophysical survey conducted over this site (R.Smalley, Stratascan, 2015)

Figure 1 Simplified trace plot showing response caused by a thermoremanent feature such as kilns.

4.1.2 ***Possible waster pit.***

A magnetic spike has been identified in the south of the site which is possibly associated with a waster pit. The true origin of this features is difficult to determine from geophysical data alone and could be associated with a piece of modern debris.

4.1.3 ***Magnetic Disturbance***

The data is dominated by the presence of magnetic disturbance caused by the large amount of ferrous materials located within the survey area. This disturbance is likely to mask any subtle features of an archaeological origin that may be located within the site.

4.2 **GPR**

Most ground conditions contain electrically contrasting layers which produce reflection events on the GPR profiles. Features such as soil or fill boundaries provide the background signals around unusual features. Processing and interpretation procedures are designed to separate reflections into various target categories and then map the different reflection types on to a plan diagram. This process involves an areal interpretation of all the profiles.

The confidence levels placed on a plan interpretation depend on the survey grid spacing. A target such as a former pottery kiln must be intersected by at least one radar profile to be detected. Ideally, the profile spacing should allow any target to be intersected by several profiles. It is not usually possible to get total survey coverage of a site, so survey line spacing is selected to provide a good indication of site conditions and allow for available access.

The GPR survey did not detect any obvious evidence of archaeological features such as pottery kilns in the survey area, although four significant categories of reflection targets were identified:

- i) Irregular high amplitude anomaly
- ii) Linear anomaly
- iii) Possible service
- iv) Reinstated trench

4.2.1 **Irregular high amplitude anomaly**

A number of irregular high amplitude anomalies with diffuse borders were identified from the from the background signals. These anomalies could be associated with archaeological features, although their true origin remains uncertain and they may simply correspond to areas of more recent disturbed ground.

4.2.2 **Linear anomaly**

The MIRA time slices have revealed a number of moderate high amplitude linear anomalies with discrete boundaries, and of variable length and orientation. The linear anomalies are of uncertain origin. These may correspond to linear constructional features such as wall foundations, ditches or tracks for example, although the age and origin of is uncertain.

4.2.3 **Possible service**

A number of linear moderate high amplitude anomalies identified within the Mala data has been interpreted to be a buried service due to their proximity to the manhole covers. The linear feature in northern half of the site is believed to be a service located beneath a visible service trench.

4.2.4 **Reinstated trench**

Three trenches have been dug out in the backyard of No 19 Between Towns Road in Oxford during archaeological works in 2014-2015. Another 15 metres long trench appears in No 17 backyard. It has been reinstated but not resurfaced.

5 DATA APPRAISAL & CONFIDENCE ASSESSMENT

5.1 Historic England guidelines (EH 2008) Table 4 states that the typical magnetic response on sandstone is generally poor but can vary. The results from this survey are severely affected by magnetic disturbance. The site was covered with tarmac which will obscure any weak archaeological features. Strong magnetic responses from nearby building, cars, etc. will obscure all archaeological features.

5.2 The GPR data across the area show a moderate contrast between strong complex and discrete responses and that of the background response, suggesting that the underlying geology is conducive to GPR survey. The survey achieved a maximum depth of approximately 1.0m bgl. Anomalies of potential interest have been detected indicating that the survey has been effective.

6 CONCLUSIONS

6.1 ***Magnetometry***

Ferrous responses are found along the western and southern boundaries of the site due to adjacent boundary fences and metal mesh fencing around trees and other plants. The widespread nature of this ferrous disturbance will have masked any archaeology that may be visible in the data. The areas free of ferrous disturbance did show evidence of a possible kiln in the south west of the site. A magnetic spike has also been identified. This feature may be related to a piece of modern debris, alternatively, this may be caused by a possible pit / waster associated with kilns.

6.2 *GPR*

The GPR survey identified two significant categories of anomalies that may be related to archaeological features or be of more recent origin. A number of irregular high amplitude anomalies with diffuse boundaries have been identified. These anomalies appear to be vaguely clustered around the western corner of the southern end of the site, and also close to the north-east boundary.

A series of discrete linear anomalies of variable length and orientations were found grouped in a zone near the northern corner of the southern half of the site.

7 REFERENCES

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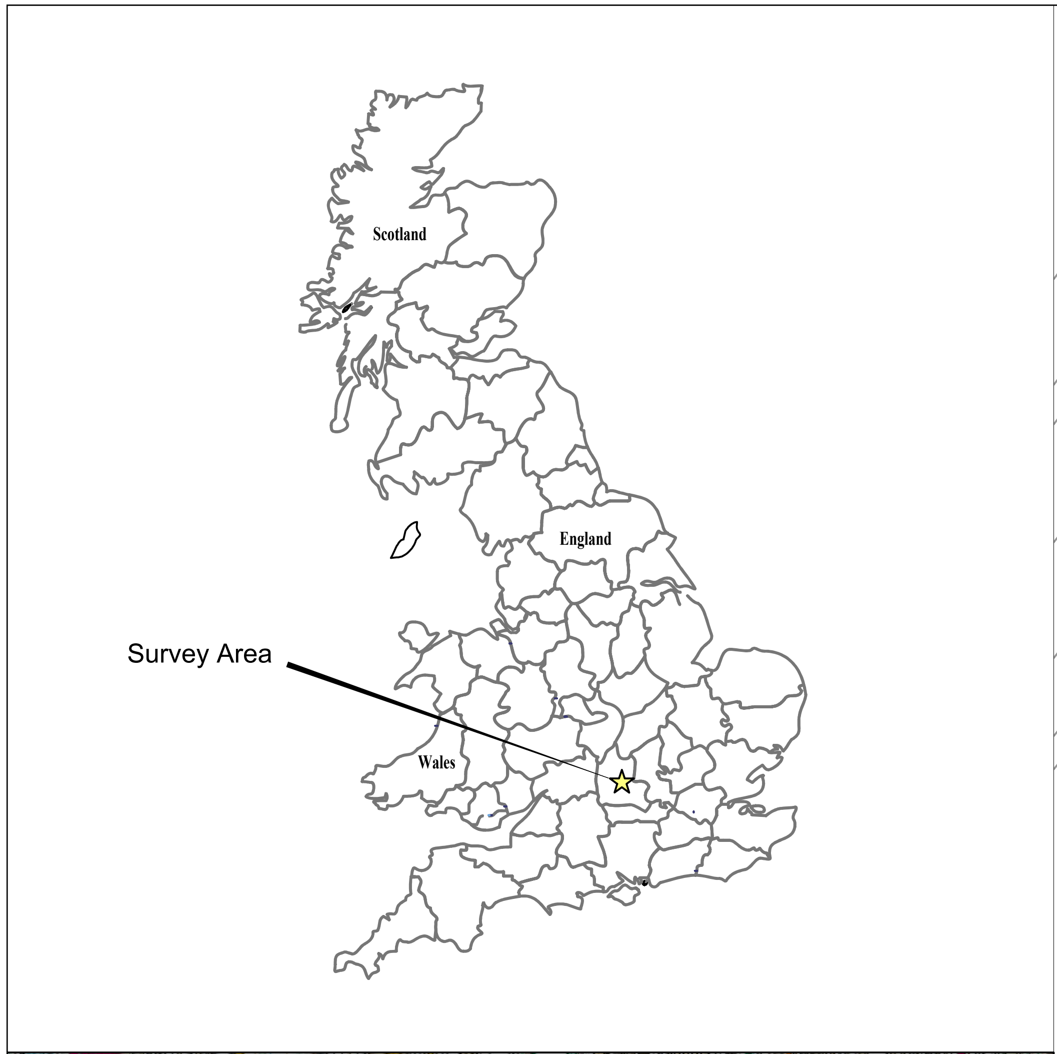

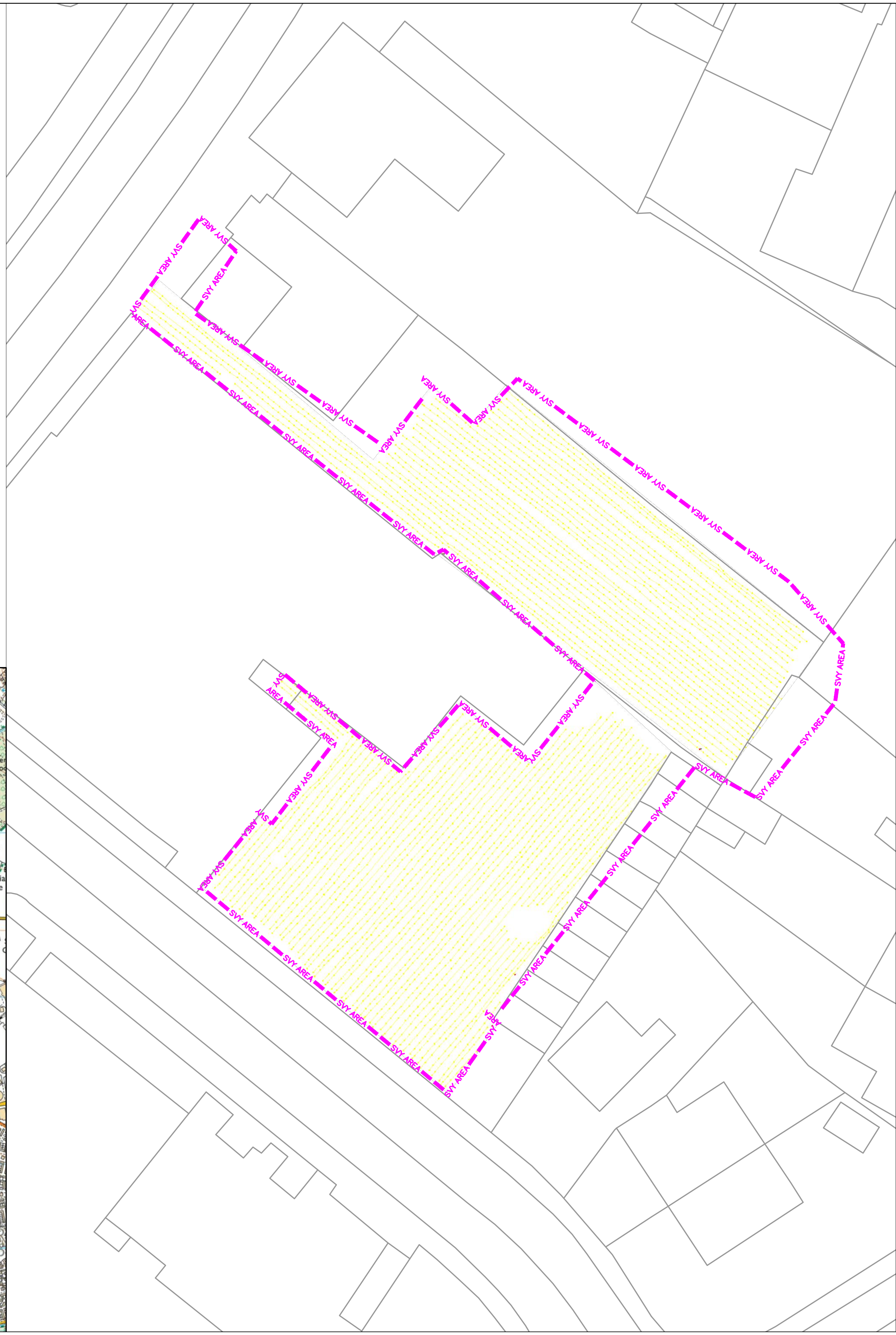

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KEY

Survey Areas

N

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
Site Location

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 20
1:400 @ A3

Fig No: 01

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

N

Sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
Magnetometer Survey - Minimally processed data

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale:	Fig No:
0 metres 25 1:500 @ A3	02

Survey date	Drawn by	Checked by
November 2019	SDH	PPB

N

sumo Survey

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

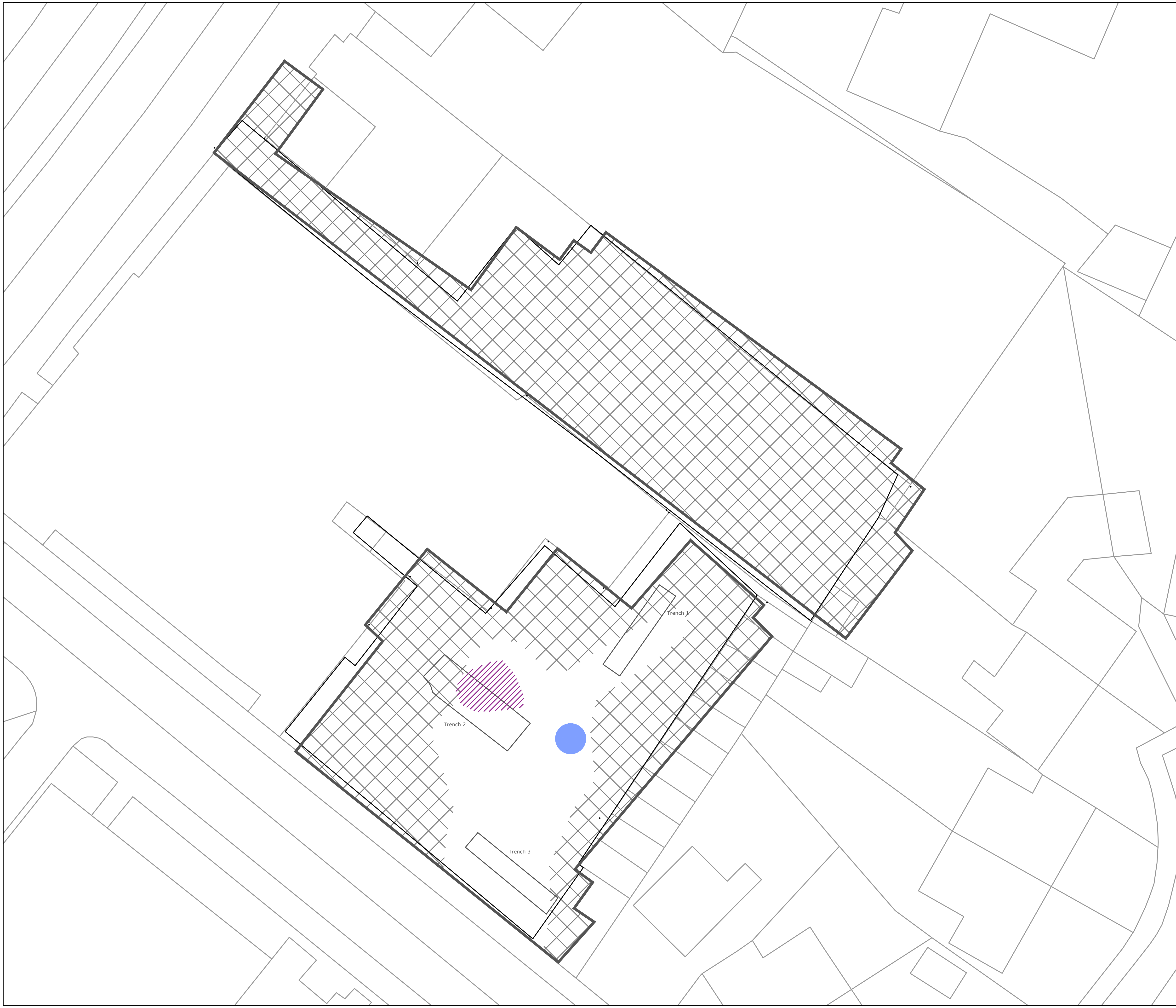
Title:
Magnetometer Survey - Processed data

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 25 1:500 @ A3	Fig No: 03

Survey date	Drawn by	Checked by
November 2019	SDH	PPB



KEY

	Probable archaeology (potential kilns)
	Possible archaeology (potential waster pits) (discrete / area of enhanced response)
	Ferrous

sumo Survey GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: Magnetometer Survey - Interpretation

Client: Southampton City Council

Project: 16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 15
1:300 @ A3

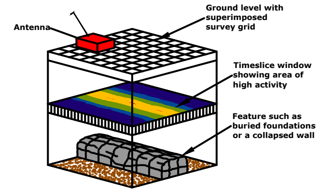
Fig No: 04

Survey date	Drawn by	Checked by
November 2019	SDH	PPB

Timeslice at 0.10m 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.



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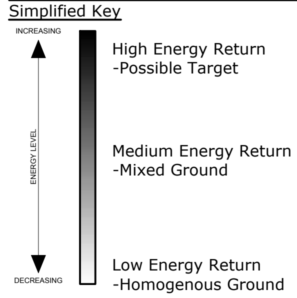
The weaker reflections in the time slice windows are shown as light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:	GPR Survey - Timeslice at 0.10m
Client:	Southampton City Council
Project:	16403 - 17-19 Between Towns Road, Oxford
Scale: 0 metres 15, 1:300 @ A3	Fig No: 05

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

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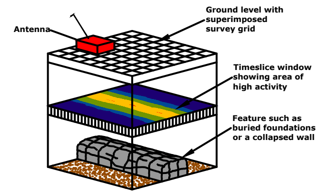

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING

ENERGY LEVEL

DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.20m

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale:
0 metres 15
1:300 @ A3

Fig No:
06

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

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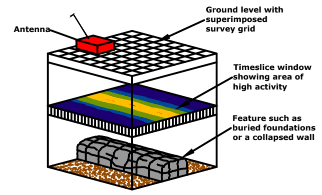

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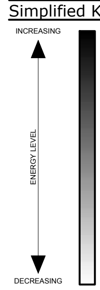

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.30m

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale:
0 metres 15
1:300 @ A3

Fig No:
07

Survey date	Drawn by	Checked by
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TIMESLICE PLOTS

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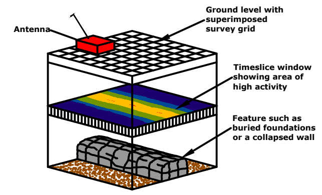

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING

ENERGY LEVEL

DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.40m

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale:
0 metres 15
1:300 @ A3

Fig No:
08

Survey date	Drawn by	Checked by
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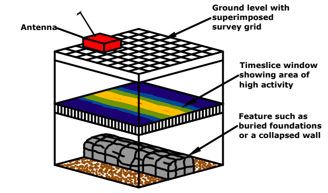

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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING
ENERGY LEVEL
DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.50m

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

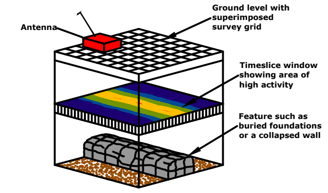
Scale:
0 metres 15
1:300 @ A3

Fig No:
09

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

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 light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING
ENERGY LEVEL
DECREASING

High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

SUMO Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.60m

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 15
1:300 @ A3

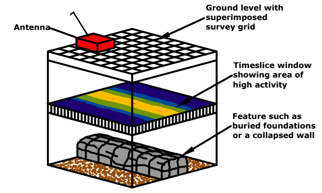
Fig No: 10

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

Timeslice at 0.70m 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.

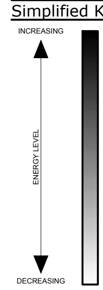


The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within range. The data was then modelled to produce activity plots at various depths. As the radar is actually measuring the time for each of the reflections found, these are 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 light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key



High Energy Return
-Possible Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Timeslice at 0.70m

Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

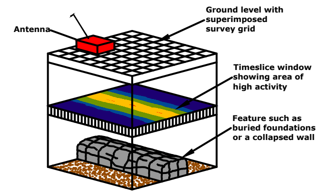
Scale:
0 metres 15
1:300 @ A3

Fig No:
11

Survey date	Drawn by	Checked by
November 2019	MUK	PPB

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 light grey. The stronger reflections are represented by dark grey and black.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING — ENERGY LEVEL — DECREASING

High Energy Return -Possible Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Timeslice at 0.80m

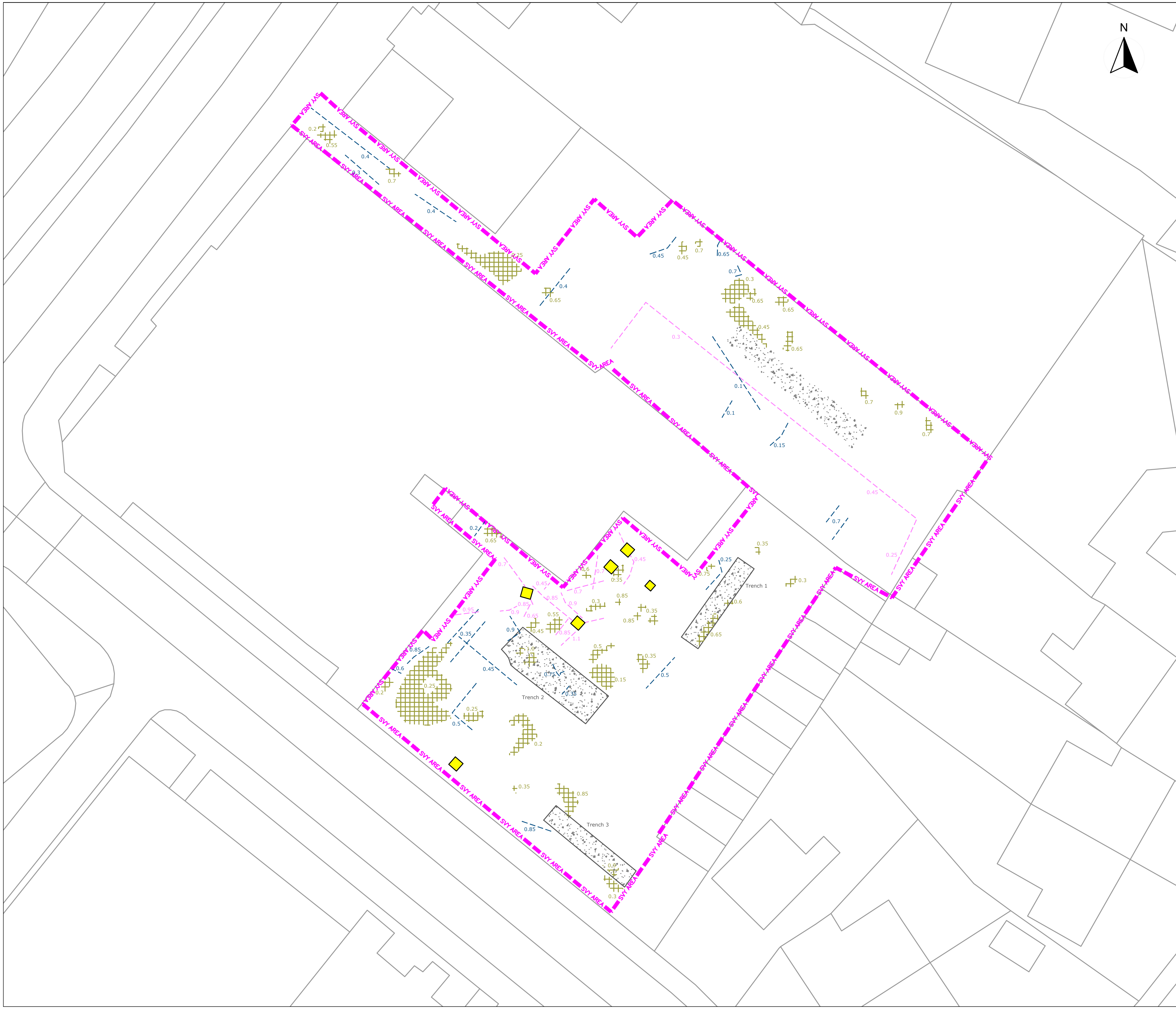
Client: Southampton City Council

Project: 16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 15 — 1:300 @ A3

Fig No: 12

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical survey, any ground works should be undertaken with extreme caution.

KEY

	Irregular high amplitude anomaly
	Linear anomaly
	Possible service
	Reinstated trench
	Manhole
0.60	Depth to the top of the feature (in m)

Sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Interpretation

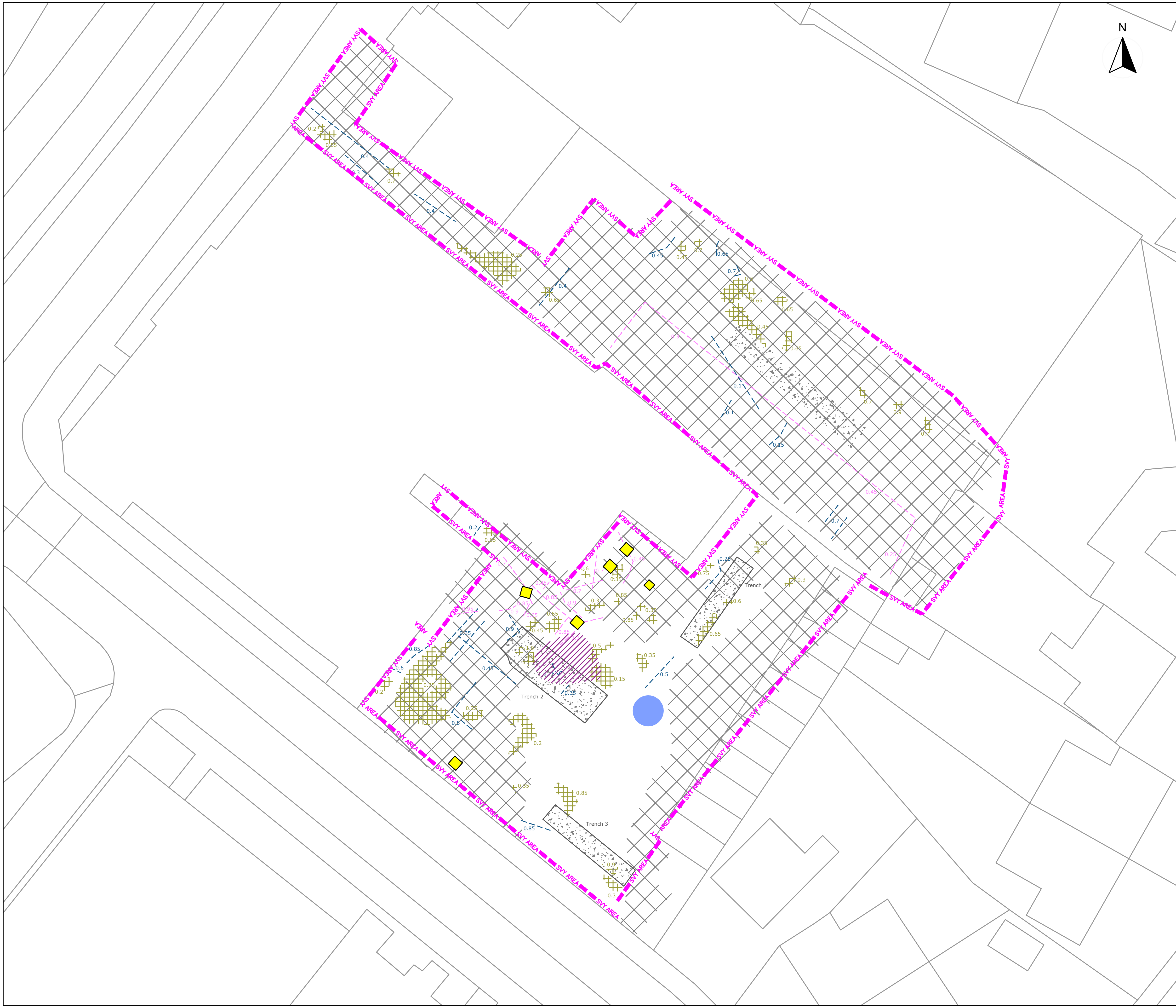
Client:
Southampton City Council

Project:
16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 15
1:300 @ A3

Fig No:
13

Survey date	Drawn by	Checked by
November 2019	MUK	PPB



The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical survey, any ground works should be undertaken with extreme caution.

KEY

	Probable archaeology (potential kilns)
	Possible archaeology (potential waster pits) (discrete / area of enhanced response)
	Ferrous
	Irregular high amplitude anomaly
	Linear anomaly
	Possible service
	Reinstated trench
	Manhole
0.60	Depth to the top of the feature (in m)

Sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: Combined GPR and Magnetometer Interpretation

Client: Southampton City Council

Project: 16403 - 17-19 Between Towns Road, Oxford

Scale: 0 metres 15
1:300 @ A3

Fig No: 14

Survey date	Drawn by	Checked by
November 2019	MUK, SDH	PPB

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.

Appendix C - Technical Information: Ground Penetrating Radar (GPR)

Grid locations

The location of the survey traverses has been plotted in Figure 1.

Survey equipment and configuration

Two of the main advantages of radar are its ability to give information of depth as well as work through a variety of surfaces, even in cluttered environments which normally prevent other geophysical techniques being used.

A short pulse of energy is emitted into the ground and echoes are returned from the interfaces between different materials in the ground. The amplitude of these returns depends on the change in velocity of the radar wave as it crosses these interfaces. A measure of these velocities is given by the dielectric constant of that material. The travel times are recorded for each return on the radargram and an approximate conversion made to depth by calculating or assuming an average dielectric constant (see below).

Drier materials such as sand, gravel and rocks, i.e. materials which are less conductive (or more resistant), will permit the survey of deeper sections than wetter materials such as clays which are more conductive (or less resistant). Penetration can be increased by using longer wavelengths (lower frequencies) but at the expense of resolution.

As the antennae emit a "cone" shaped pulse of energy an offset target showing a perpendicular face to the radar wave will be "seen" before the antenna passes over it. A resultant characteristic diffraction pattern is thus built up in the shape of a hyperbola. A classic target generating such a diffraction is a pipeline when the antenna is travelling across the line of the pipe. However, it should be pointed out that if the interface between the target and its surrounds does not result in a marked change in velocity then only a weak hyperbola will be seen, if at all.

The Ground Penetrating Impulse Radars used was GSSI Dual Frequency system manufactured by GSSI. This system collects data using 300MHz and 800MHz simultaneously.

Sampling interval

Readings were taken at 0.05m intervals. All survey traverse positioning was carried out using a Trimble S6 Robotic Total Station.

Depth of scan and resolution

The average velocity of the radar pulse is calculated to be 0.12m/nsec which is typical for the type of sub-soils on the site. The Dual Frequency 800MHz has a range setting of 20.95nsec this equates to a maximum depth of scan of 1.30m but it must be remembered that this figure could vary by ± 10% or more. The 300MHz has a range setting of 41.9nsec equating to a maximum depth of scan of 3.00m.
A further point worth making is that very shallow features are lost in the strong surface response experienced with this technique.

Under ideal circumstances the minimum size of a vertical feature seen by a 200MHz (relatively low frequency) antenna in a damp soil would be 0.1m (i.e. this antenna has a wavelength in damp soil of about 0.4m and the vertical resolution is one quarter of this wavelength). It is interesting to compare this with the 400MHz antenna, which has a wavelength in the same material of 0.2m giving a theoretical resolution of 0.05m. A 900MHz antenna would give 0.09m and 0.02m respectively.

Data capture

Data is displayed on a monitor as well as being recorded onto an internal hard disk. The data is later downloaded into a computer for processing.

- Archaeological
- Geophysical
- Laser Scanning
- Measured Building
- Topographic
- Utility Mapping